



10. FLOOD

10.1 HAZARD PROFILE

10.1.1 HAZARD DESCRIPTION

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

Overview

Flooding is defined as the inundation of water onto areas that are typically dry. This phenomenon can occur due to several factors, including intense rainfall, coastal waves, or the failure of dams. Even a slight accumulation of water can lead to significant damage, while more severe flooding may submerge homes up to their rooftops. Flooding can develop rapidly within minutes, or it may take place over an extended period, lasting days, weeks, or even longer. On O‘ahu flooding is often exacerbated due to the mountainous terrain of the island which increases flash flooding. A flash flood occurs due to intense or excessive rainfall over a brief duration, typically less than six hours. These floods are often marked by rapid and powerful torrents that can traverse riverbeds, urban areas, or mountainous canyons. Flash floods can also occur absent rainfall, such as in instances of dam failures, or following a sudden release of water caused by debris (NOAA n.d.).

Flood Causes and Types

Various types of flooding may occur within the City. For the purposes of this LHMP, the following categories of flooding are addressed within this hazard profile:

- **Riverine and flash flooding**—This type of flooding occurs when water levels exceed the banks of a river, which can result from several factors, including heavy rainfall from tropical systems making landfall or prolonged thunderstorms in the same region (NOAA n.d.). Riverine flooding can turn into a flash flood if the river is at or above flood stage and if the soil is saturated (FEMA 2019). Areas recently impacted by wildfires are more susceptible to flash floods and debris flows during rainstorms. Additionally, downstream areas are at increased risk due to the loss of vegetation that normally helps absorb rainfall. When heavy rain occurs, the absence of vegetation and soil stability can lead to rapid runoff, causing streams and drainageways to flood sooner and with greater intensity than usual. Intense rainfall in these regions can mobilize sediments, resulting in more severe and destructive debris flows. (NOAA n.d.).
- **Coastal flooding**—This type of flooding is the inundation of land areas adjacent to the coastline. It is primarily caused by higher-than-average high tides and is exacerbated by heavy rainfall and onshore winds (i.e., winds blowing from the ocean towards the land) (NOAA n.d.). King tides are a form of coastal flooding that are caused by the alignment of the gravitational forces of the moon and the sun. King tides



happen when the moon is closest to the earth and when the earth is closest to the sun, resulting in the strongest gravitational pull on the earth's oceans. These combined gravitational pulls cause ocean levels to rise higher than usual (UH n.d.). Since king tides are driven by gravitational forces, they can occur on sunny days without the presence of rainfall that typically contributes to other types of flooding. King Tides in the Hawaiian Islands tend to occur during the summer (July and August) and winter (December and January) months in conjunction with new moons and full moons (UH n.d.). King tides combined with long-term global sea level rise, plus an additional high water level anomaly, resulted in the highest observed tide at the Honolulu station, near Keehi Lagoon Small Boat Harbor, on August 21, 2017 (Yoon 2021).

- **Storm surge**—An unusual increase in water levels in coastal regions, surpassing the typical astronomical tide. Storm surge can be caused by a storm's strong winds pushing onshore. Storm surge poses significant risks, as it can lead to extensive flooding in coastal areas. Particularly when storm surge coincides with the normal high tide, it can result in water levels rising by 20 feet or more in certain instances. Along the coastline, storm surge often represents the most significant threat to lives and property during a hurricane (NOAA n.d.). Additional information on storm surge is available in Chapter 13 Hurricane.
- **Inland flooding**—This type of flooding can occur due to moderate precipitation accumulating over several days, intense rainfall occurring over a short duration, or a river overflowing as a result of a debris jam, overgrowth of vegetation, inadequate stream capacity, or sedimentation. Unlike coastal flooding, which is influenced by tides and storm surges, inland flooding is primarily driven by precipitation and the inability of the ground to absorb or channel the excess water.

Flood events can be intensified by other natural hazards, including sea level rise, hurricanes, and tsunamis. Further details on sea level rise can be found in Chapter 6, information on hurricanes is available in Chapter 13, and details regarding tsunamis are provided in Chapter 17.

Potential Impacts

Flooding can result in loss of life and injuries, as well as extensive damage and property loss. While flooding can be inherently destructive, flood events can also trigger additional hazards such as riverbank erosion, landslides, and releases of hazardous materials. In the headwaters of rivers with steep gradients, floodwaters may pass rapidly, leading to scouring of riverbanks. This erosion can increase the vulnerability of nearby properties and structures. Saturation of soils on steep slopes during flooding can cause slope failure, resulting in landslides. Additionally, floodwaters may cause rupture of storage tanks containing hazardous materials, leading to potential spills. Other secondary consequences of flooding include the following:

- Flooded buildings may have gas and electrical service disrupted if the service panel, generator, meter, or other equipment are not elevated above the flood protection level.
- Oversaturated soils may cause utility poles to tip over or fall completely, interrupting the power grid for a potentially large area, especially if the transformer is impacted.
- Transportation systems may be disrupted, resulting in shortages of food and supplies.



- Location of river and stream channels may change as the result of flooding. New channels develop, leaving the old channels dry.
- Sediment deposited by flooding may destroy farmland (although silt deposited by floodwaters could also help to increase agricultural productivity).
- Jobs may be lost due to the disruption of services, destruction of business, etc. (although jobs may be gained in the construction industry to help rebuild or repair flood damage).
- Insurance rates may increase.

10.1.2 LOCATION

This section describes mapped hazard areas and areas of greater vulnerability based on their physical location.

O'ahu's topographic, climatological, meteorological, and land use features create an environment conducive to flooding. The island's mountainous terrain contributes to where flooding is prevalent. The windward (eastern) side of the mountain ranges receive high rainfall due to rising air cooling and releasing moisture as precipitation. The leeward (western) side of the mountains experience significantly less rainfall due to these areas being shielded from prevailing winds.

Areas that are more likely to have an increased risk of flooding include:

- Low-lying coastal areas
- Areas with poor drainage
- Developed areas with excess amounts of impermeable surfaces
- Locations that are projected to be impacted by sea level rise

The City has proactively designated areas across the island that are susceptible to flooding based on historical data. These maps are used to provide supplemental planning information for FEMA's regulatory maps. The maps were prepared by the Honolulu Land Information System for DPP. These identified zones reflect locations with a documented history of flooding; however, it is important to recognize that the potential for flooding may exist outside of these mapped areas. Detailed maps of the identified flood-prone regions are provided in the Appendix H. These areas are primarily in coastal regions and the valleys of mountains.

Floodplains

A floodplain is flat land adjacent to a river or stream that is subject to periodic inundation. A floodplain is designated when floodwater exceeds the capacity of the main channel, or water escapes the channel through bank erosion. A floodplain is made up of different sections (FEMA 2019) (US DHS 2019):

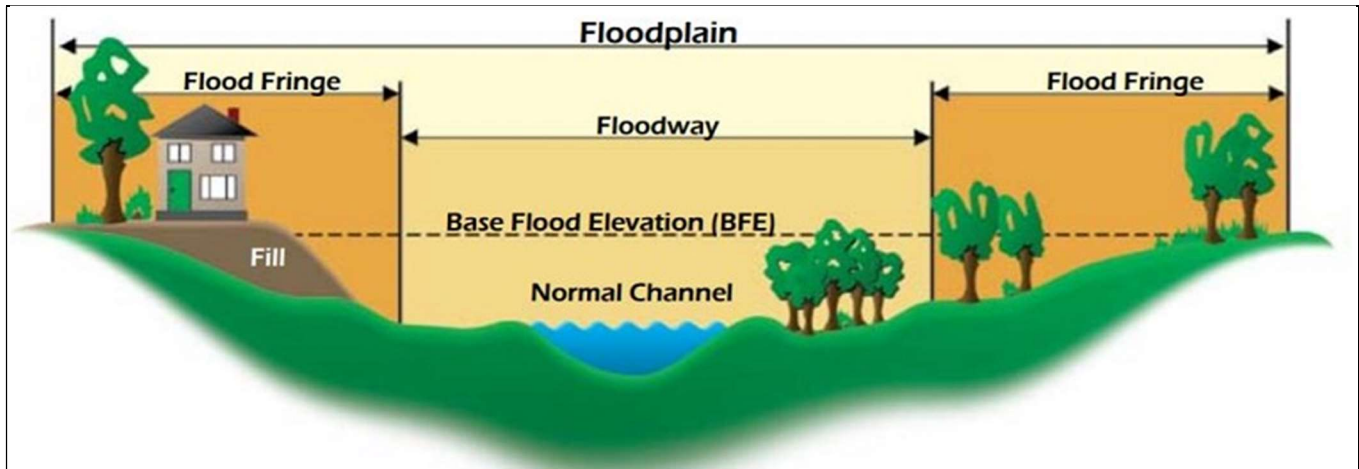
- **Flood Fringe**—the area within the floodplain but outside the floodway; this area extends from the outer banks of a floodway to the river valley, where the elevation begins to rise.



- **Floodway**—the channel of a river or other waterway and the adjacent land areas that are under water or reserved to carry and discharge the overflow of water caused by flooding.
- **Base Flood Elevation (BFE)**—the value that indicates the height of flood waters during a base flood; the BFE dictates the lowest level at which a living space can be built without being impacted by floods.

Refer to Figure 10-1 for a visual example of a floodplain.

Figure 10-1. Characteristics of a Floodplain



Source: FEMA 2022

Floodplains serve multiple functions. They moderate flooding, maintain water quality, recharge groundwater, reduce erosion, redistribute sediment, and support fish and wildlife habitat. The boundaries of floodplains are altered as a result of changes in land use, the impervious surface, placement of obstructing structures in floodways, changes in precipitation and runoff patterns, improvements in technology for measuring topographic features, and utilization of different hydrologic modeling techniques.

Floodplain mapping is based on riverine and coastal flooding conditions. Future flooding conditions (from factors such as sea level rise and changes in rainfall) are not included in FEMA’s development of floodplain mapping. As such, floodplain maps may underestimate flood risk in many areas. As a result, the public may also underestimate risk.

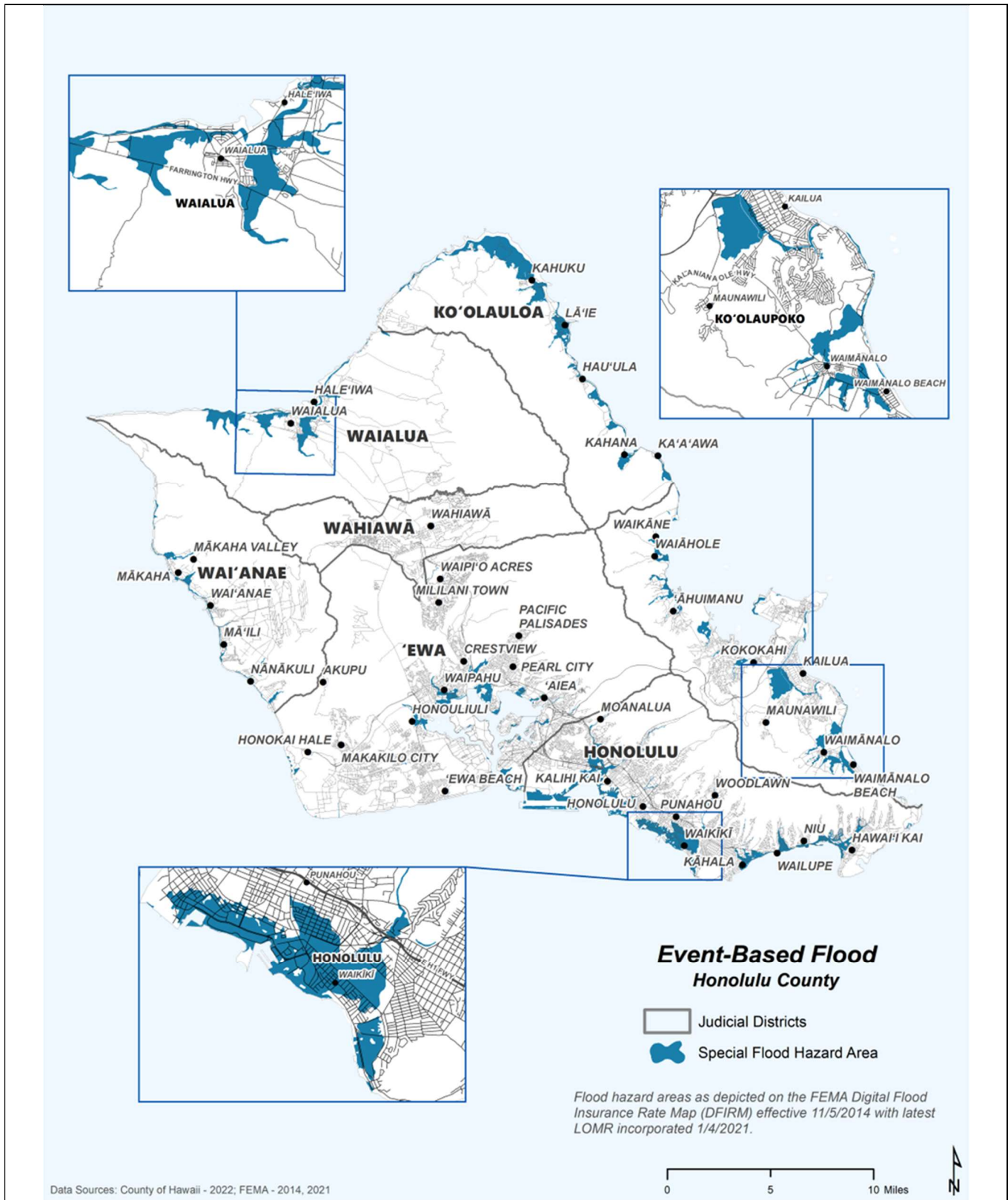
To assist with identifying areas prone to flooding, FEMA develops Flood Insurance Rate Maps (FIRMs) and establishes a boundary for the special flood hazard area (SFHA). The SFHA is the areas that will be inundated by the “100-year” flood, or a flood that has a 1-percent chance in any given year of being equaled or exceeded. Figure 10-2 shows the SFHA for the City. DLNR also host FIRMs digitally on its Flood Hazard Assessment Tool website (fhat.hawaii.gov/). In this area, the National Flood Insurance Program’s (NFIP) floodplain management regulations are enforced, and the purchase of flood insurance is mandatory (FEMA 2020).



The FIRM serves as the regulatory basis in which the City's flood damage prevention ordinance is enforced. The flood damage prevention ordinance requires that development in the City's SFHAs identified on the FIRM meets certain standards to reduce damage from flooding, such as being elevated above the base flood elevation. A major FIRM update is on the horizon for the City. Officials from FEMA and the City have worked together to provide updated information that accurately reflects the current flood risk as flood hazards are dynamic and frequently change due to various factors, including weather patterns, erosion, and community development (FEMA 2025).



Figure 10-2.Special Flood Hazard Areas in the City





10.1.3 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.

On average, the state of Hawai'i experiences approximately 11 flood events annually, predominantly during the wet season from October to May, although these incidents can occur at any time throughout the year. The severity of any flood depends upon the type, cause, duration, and existing conditions (i.e., drainage design and pathways for water to exit). Flooding from severe rain events coupled with high tide flooding increases the severity of chronic coastal flooding.

Monitoring and Warning

The National Weather Service (NWS) uses radar to display precipitation on a map, showing intense rainfall locations and estimating duration. Forecasters can track storm cell development and movement, aiding flash flood assessment.

Rain gauges provide precise rainfall measurements at specific points, and real-time data is crucial for flash flood detection. Comparing radar estimates with rain gauge values improves accuracy. The Hawai'i Statewide GIS Program's interactive map shows 293 rainfall gauges on O'ahu. (Hawaii Statewide GIS Program 2024).

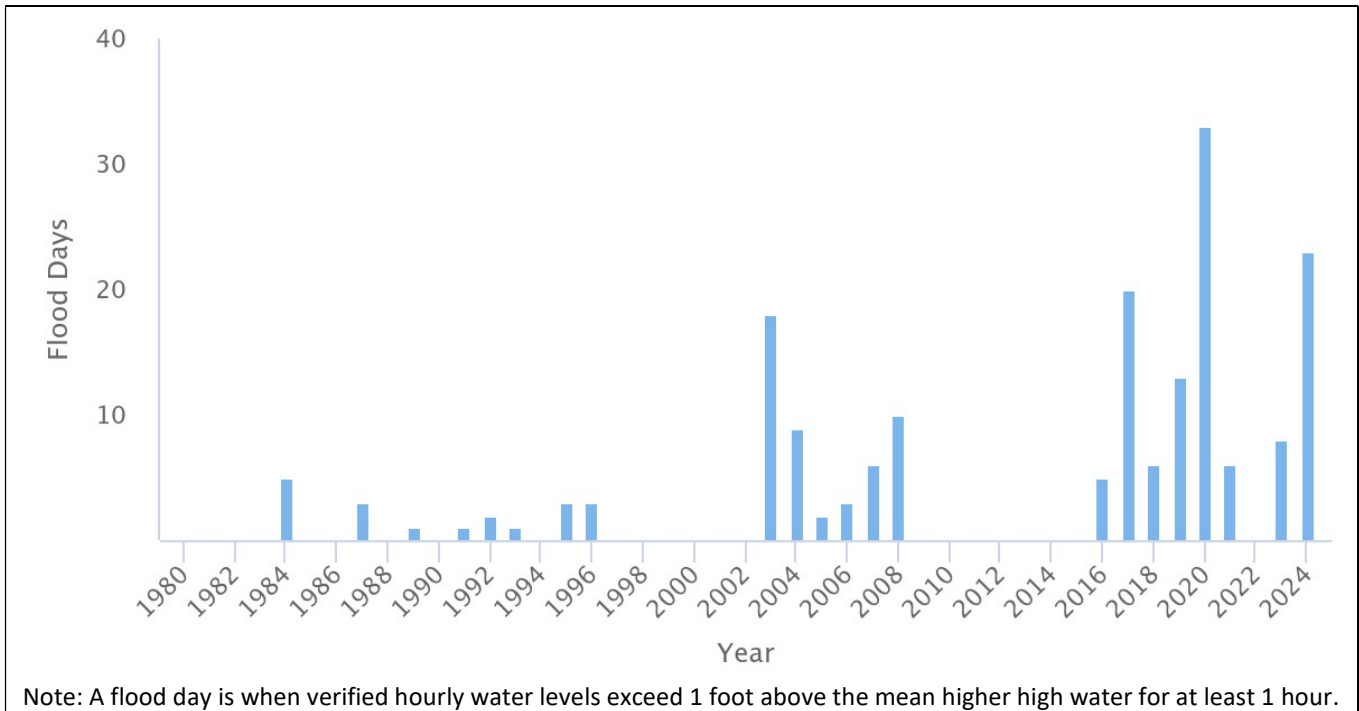
To enhance the ability to provide warnings of impending hazardous conditions, the University of Hawai'i at Mānoa, in partnership with DLNR, is installing an advanced network of approximately 100 weather monitoring stations across the state. This initiative will establish the Hawai'i Mesonet, a statewide advanced weather and climate monitoring network. Data collected through the Mesonet is publicly available and stored in the Hawai'i Climate Data Portal (University of Hawai'i n.d.). There are 10 weather monitoring stations installed on O'ahu.

Coastal flooding is measured on O'ahu with three NWS tidal stations that monitor observed water levels and forecast water levels over the next 48 hours. The tidal stations are in Pearl Harbor, Honolulu Harbor, and Kaneohe Bay. NWS stations recorded an increasing number of flood occurrences since data collection began in 1980, see Figure 10-3 and Figure 10-4.

NWS forecasters issue flood products to provide warning of potential flood activity. Lead time of flood activity can range from several days to very little notice. The following products are used by NWS to communicate current flood risk. A description of these products is provided in Table 10-1.

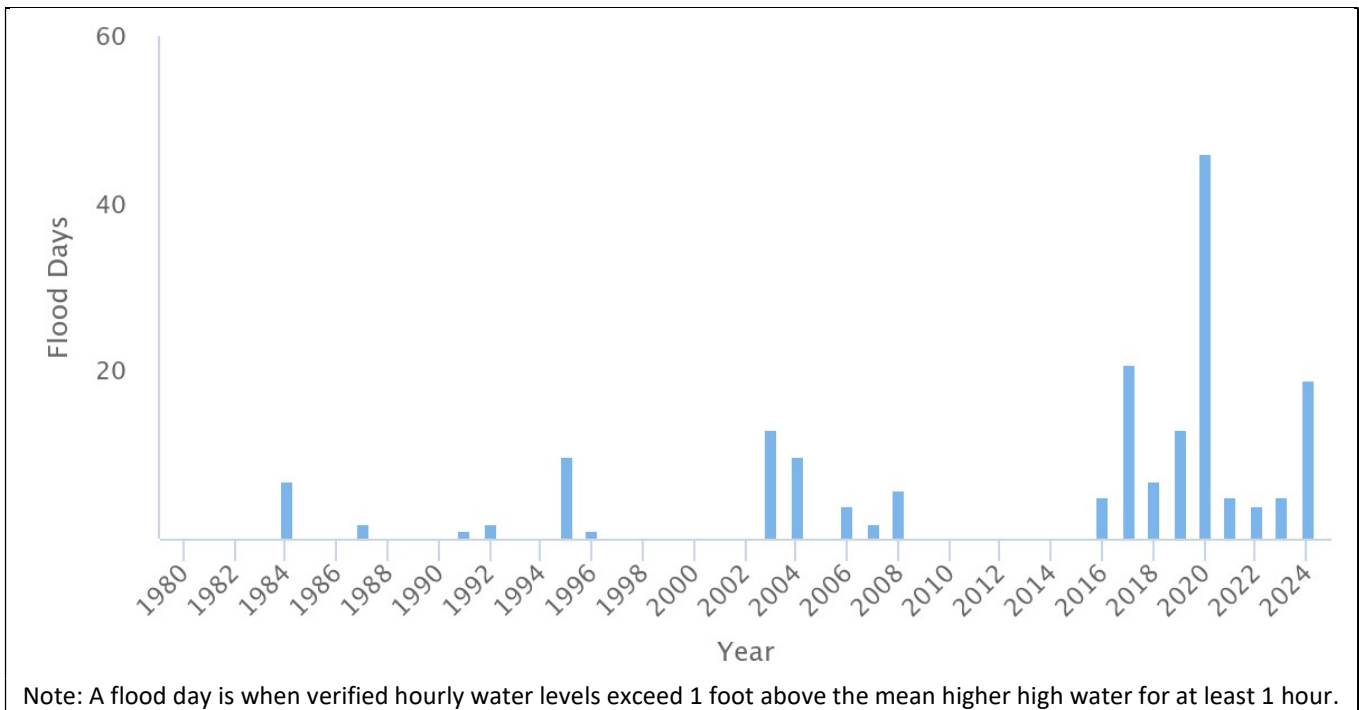


Figure 10-3. Kaneohe Bay Station Annual Flood Days, 1980-2024



Source: (NOAA n.d.)

Figure 10-4. Honolulu Station Annual Flood Days, 1980-2024



Source: (NOAA n.d.)



Table 10-1 NWS Flood Products

Product	Description	Lead Time	Scale
Hydrologic Outlook	Possibility of a significant heavy rain event with the potential to produce widespread flooding. Event must be big enough to affect at least 2 counties for at least 2 days	2 to 4 days before the onset of heavy rainfall.	May be issued island-wide to statewide.
Flood Watch	There is the potential for flash flooding due to heavy rainfall, but there is still uncertainty about event occurrence and severity.	0 to 2 days	May be issued island-wide to statewide.
Flood Advisory	Nuisance flooding is occurring or imminent. May be upgraded to a Flood Warning if flooding worsens and poses a threat to life and property.	None	May be issued island-wide or for a specific sub-area or areas.
Flash Flood Warning—Base	Flooding is occurring or will develop quickly. Used most of the time when flash flood impact damage is possible.	0 to 2 hours	May be issued island-wide or for a specific sub-area or areas.
Flash Flood Warning—Considerable	Used rarely, when there are indications flooding capable of unusual severity or impact is imminent or ongoing and urgent action is needed to protect lives and property.	0 to 2 hours	May be issued island-wide or for a specific sub-area or areas.
Flash Flood Warning—catastrophic	Used exceedingly rarely, when a threat to life and catastrophic damage is occurring or is imminent, and floodwaters have risen or will rise to levels rarely if ever seen. Rain events of this size can cause catastrophic flooding and affect areas that do not usually flood.	0 to 2 hours	May be issued island-wide or for a specific sub-area or areas.

Source: (NOAA n.d.)

NFIP and Repetitive Loss

The National Flood Insurance Program (NFIP) is a federal program managed by FEMA that provides flood insurance to property owners, renters, and businesses in participating communities. Established by the U.S. Congress in 1968, the NFIP aims to reduce the economic impact of flooding by providing affordable insurance, promoting sound floodplain management practices, and encouraging communities to adopt and enforce floodplain management regulations that mitigate flood risks. Key features of the NFIP include flood insurance coverage, floodplain management, and flood hazard mapping.

The City participates in the NFIP, which provides flood insurance to property owners, renters, and businesses to assist with recovering faster and a flood event. The NFIP makes flood insurance available to communities who adopt and enforce the minimum regulations established by the NFIP. Participation in the NFIP not only makes



federal flood insurance available within the participating community, but it also affords the community opportunities to pursue federal disaster assistance and mitigation funding opportunities.

At the time of the preparation of this plan, the City is in good standing with NFIP requirements. Communities participating in the NFIP may adopt regulations that are more stringent than those contained in 44 CFR 60.3, but not less stringent. Table 10-2 lists flood insurance statistics for the City.

Table 10-2. Flood Insurance Statistics for the City

Date of Entry	04/01/2022
# of Policies in Force	41,303
Total Current Annual Premium	\$22,594,779.00
Claims since 1978	2,792
Value of Claims since 1978	\$57,780,726.27
Average Payment per Claim	\$20,695.10

Source: FEMA Region 9, 2025

COMMUNITY RATING SYSTEM

The Community Rating System (CRS) is a voluntary incentive program that provides flood insurance premium discounts for communities that exceed the minimum regulations of the NFIP. The program encourages communities to address three goals to reduce flood risk. Those goals include the following:

- Reduce and avoid flood damage to insurable property
- Strengthen and support the insurance aspects of the National Flood Insurance Program
- Foster comprehensive floodplain management

The City is a Class 8 community, meaning a 10 percent discount is provided to NFIP policy holders. There are currently 6,616 policies in force with a total of \$22,594,779 in annual premiums.

REPETITIVE AND SEVERE REPETITIVE LOSS AREAS

To assist with identifying areas of frequent flooding, the NFIP identifies properties as repetitive loss (RL) and severe repetitive loss (SRL). The NFIP defines RL properties as structures that meet one of the following qualifiers (FEMA 2022):

- Two or more claims of more than \$1,000 paid by NFIP within any rolling 10-year period, since 1978.
- Two or more claims (building payments only) that, on average, equal or exceed 25 percent of the market value of the property.

The NFIP defines SRL properties as structures that meet one of the following qualifiers (FEMA 2022):



- Received four or more separate claim payments of more than \$5,000 each (including building and contents payments).
- Received two or more separate claim payments (building payments only) where the total of the payments exceeded the current value of the property.

A repetitive loss area is a portion (or portions) of a community that includes buildings on FEMA’s list of repetitive losses and any nearby properties that are subject to the same or similar flooding conditions (FEMA 2015). For the LHMP update, FEMA provided a list of properties with NFIP policies, past claims, and multiple claims. Table 10-3 summarizes repetitive loss statistics for the City; this information is current as of January 28, 2025.

Table 10-3. Repetitive Loss Statistics

Total Claims	Total Payments (Building + Contents)	Number of NFIP Repetitive Loss (RL) Properties
370	\$14,535,617.94	132

Source: FEMA Region 9, 2025

FEMA provided a list of RL statistics specifying the type of structure. Table 10-4 summarizes the NFIP RL statistics by structure type for the City.

Table 10-4. Number of Repetitive Loss Properties by Structure Type

Loss Type	Structure Type			
	Single Family	Other Residential	Commercial	Other Non-Residential
Repetitive Loss	99	14	6	13
Severe Repetitive Loss	7	1	0	4

Source: FEMA Region 9, 2025

10.1.4 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

Table 10-5 shows recent events for O’ahu.



Table 10-5. Flood Events in the City (2020 to 2025)

Event Date	Disaster Declaration/ Proclamation			Description
	Federal	State	Mayoral	
March 15-18, 2020	N/A	N/A	N/A	An upper low, known as a kona low in Hawaii, and concomitant trough developed west of the islands and brought heavy showers, thunderstorms, and flash flooding to the area.
January 25, 2021	N/A	N/A	N/A	Strong high pressure far northeast of the islands and an upper trough to the southwest caused low level moisture to flow over the state from the southeast. Instability from the trough brought heavy showers, isolated thunderstorms, and flash flooding, mainly over the Big Island and O’ahu.
March 10-15, 2021	DR-4604 HI-00062 (SBA)	Emergency Proclamation Related to Heavy Rains and Flooding	Mayor’s Declaration of Emergency for Heavy Rains and Flooding	Heavy showers and isolated thunderstorms caused flash flooding in some instances. Major flooding problems occurred over windward portions of O’ahu and the North Shore, especially around Haleiwa and Waialua, where an evacuation order was issued. Damages occurred to public and private property, including roads and bridges washed out. Nine homes were destroyed, 44 suffered major damage, and 55 suffered minor damage. Low level moisture continued to pool over the area, and the result was more heavy precipitation and periods of flash flooding.
December 5, 2021 to December 10, 2021	DR-4639 HI-00067 (SBA)	Emergency Proclamation Related to Heavy Rains and Flooding	Mayor’s Declaration of Emergency for Heavy Rains and Flooding	A surface front and a deep upper low, known locally as a kona low, produced heavy and sustained showers and thunderstorms as tropical moisture was pulled north over State. The downpours also led to instances of flash flooding.
January 1, 2022	N/A	N/A	N/A	A surface trough moving from the southeast and south, and an upper low far west of the islands produced heavy showers and thunderstorms over portions of the state. Rainfall was particularly intense over parts of O’ahu, which led to flash flooding.
February 20, 2023	N/A	N/A	N/A	An extended period of enhanced rainfall with embedded locally heavy rainfall rates overwhelmed a few local roads on the Pearl City Peninsula.
April 2-3, 2023	N/A	N/A	N/A	Rainfall was sufficient to flood and close roads in urban Honolulu.
April 29, 2023	N/A	N/A	N/A	Flooding impacts due to locally heavy rainfall were reported across portions of O’ahu.



Event Date	Disaster Declaration/ Proclamation			Description
	Federal	State	Mayoral	
December 20-21, 2023	N/A	N/A	N/A	Abundant low-level moisture and atmospheric instability led to periods of heavy rainfall with flooding over portions of the islands.
January 8-9, 2024	N/A	N/A	N/A	A strong cold front impacted the Hawaiian Islands and brought periods of heavy rain and gusty winds. This resulted in flooding over portions of the islands as well as wind damage.
May 12, 2024 to May 22, 2024	N/A	Emergency Proclamation Related to Kona Low Weather Event	N/A	A kona low storm pulled deep tropical moisture over the state from the south for several days which led to periods of heavy rainfall and flash flooding. Impacts included flooded roads and landslides.
January 30-31, 2025	N/A	N/A	Mayor’s Declaration of Emergency Relating to Low-Pressure Weather Event	Severe weather and potential flooding from a “Low Pressure” weather event brought strong southerly winds and heavy sustained rain fall creating the threat of flash flooding in the City. NWS issued a flash flood warning covering the entire island of O’ahu.

Source: (FEMA 2024) (Hawaii 2025) (NOAA 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) and activate certain federal assistance programs based on factors related to the magnitude of the hazard threat or impacts. Table 10-5 indicates recent events that received federal emergency (EM) or disaster (DR) declarations.

State and Local Emergency Proclamation

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 10-5 indicates recent events for which state or local emergency proclamations were issued.



10.1.5 PROBABILITY OF FUTURE OCCURRENCES

Information on previous flood occurrences in the City was used to calculate the probability of future occurrence of such events. Table 10-6 lists the number of events from various sources over the 28-year period from 1996 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 occurrence for flood in the City is considered “frequent.”

Table 10-6. Probability of Future Flood Events in the City

Hazard Type	Number of Occurrences Between 1996 and 2024	% Chance of Occurring in Any Given Year
Flood	179	100%

Source: (NOAA 2024)

Note: The time period presented in this table is the most complete period of record for the various data sources reviewed. 100% probability indicates that it is statistically likely for an event to occur every year. It does not indicate that the occurrence of an event is a certainty in any given year.

10.2 VULNERABILITY AND IMPACT ASSESSMENT

To understand risk, a community must evaluate what assets are exposed and vulnerable in the identified hazard area. In places where flood hazard data was not available, sea level rise analysis was included. The following text evaluates and estimates the potential impact of the flood hazard on the City.

10.2.1 LIFE, HEALTH, AND SAFETY

Heavy rainfall events and flooding pose immediate life-threatening risks, primarily through drowning, the leading cause of death during floods. Fast-moving floodwaters can sweep away people, vehicles, and debris, causing fatalities and physical injuries such as fractures, lacerations, and head trauma. These types of hazard events can trap individuals in their homes, vehicles, or other structures, making rescue efforts difficult and endangering lives. People in isolated or rural areas may face greater risks due to delayed rescue and limited access to emergency services.

Floodwater often becomes contaminated with sewage, chemicals, and pathogens, increasing the risk of waterborne diseases such as leptospirosis, hepatitis A, cholera, and gastroenteritis (CDC 2024). These diseases can spread rapidly in flood-affected areas, particularly in communities with limited access to clean water, sanitation, and healthcare services. Standing water created by flooding can serve as breeding ground for mosquitoes and other vectors that transmit diseases such as dengue fever. See Chapter 12 for additional information on health risks. These diseases can spread rapidly in the aftermath of a flood, particularly in warm, tropical climates like Hawai'i. Flooding can disrupt industrial sites, sewage systems, and chemical storage facilities, releasing hazardous substances into the environment. Exposure to these chemicals can cause



respiratory issues, skin irritation, poisoning, and long-term health problems such as cancer or neurological disorders.

Flooding can displace residents, forcing them to evacuate to shelters or other temporary accommodations. Displacement increases vulnerability to other hazards, such as exposure to the elements, inadequate shelter, lack of access to medical care, and overcrowding, which can exacerbate health risks.

Floodwater can also cause electrical malfunctions, increasing the risk of electrocution for both residents and emergency responders. It can also damage electrical circuits and fuel tanks, leading to explosions or fires. This is particularly dangerous when firefighting capabilities are compromised due to blocked roads or damaged equipment.

Table 10-7 displays the number of households and individuals that could seek shelter during a worst-case flood event. It is recommended that this data is used to plan for regional scale impacts based on the impact estimates provided for each regional planning area.

Table 10-7. Honolulu Projected Displacements from Proposed Regulatory 1% Annual Chance Flood

Regional Planning Area	1% Annual Chance Proposed Regulatory Flood Impacts on People			
	Total Population (2020 Decennial)	Displaced Population	Persons Seeking Short-Term Sheltering	Persons Seeking Short-Term Sheltering (%)
Central O’ahu	135,107	3,767	681	0.50%
East Honolulu	50,922	4,731	281	0.55%
‘Ewa	127,456	516	175	0.14%
Ko’olau Loa	21,899	8,680	500	2.28%
Ko’olau Poko	121,275	5,225	789	0.65%
North Shore	18,872	5,358	659	3.49%
Primary Urban Core	489,012	56,567	7,199	1.47%
Wai’anae	51,965	5,708	1,539	2.96%

Source: Tetra Tech, Inc. (Tetra Tech) was awarded Contract No. CT-DPP-2400165 on December 22, 2023. The purpose of this contract is to perform a Federal Emergency Management Agency (FEMA) Hazus v.4.2 or later Flood Level 2 Analysis of riverine and coastal flooding to better understand flood risks across the City. Community Resilience Consulting, LLC (CRC), Tetra Tech’s subcontractor, conducted a Hazus GIS-based flood risk assessment modeling incorporating City-provided inventory and hazard data as well as publicly available data. The flood hazard analysis quantifies flood exposure to buildings across O’ahu and estimates economic and social costs of different potential flood event scenarios.

Socially Vulnerable Population

Kūpuna and people with disabilities face greater challenges in evacuating and accessing emergency services. They may have mobility issues, rely on medical equipment, or need assistance with daily activities, making them



more susceptible to injury, illness, and death. Children are particularly vulnerable to the physical and psychological impacts of flooding. They may have difficulty recognizing danger, are more susceptible to waterborne diseases, and can suffer long-term psychological effects such as anxiety, trauma, and post-traumatic stress disorder (PTSD).

People with limited financial resources may lack access to transportation, emergency supplies, or adequate shelter, making it more difficult for them to evacuate, prepare, or recover from a flood. Homeless individuals are particularly vulnerable, as they may have no safe place to go and limited access to health care or social services. People with Low English Proficiency may not understand urgent evacuation notices, putting them at greater risk of injury during a flooding event. Unhoused individuals are particularly vulnerable as many individuals reside in locations vulnerable to flood impacts, such as on the beaches, and more recently, along stream beds. These locations may experience flood impacts with little warning time. Living in these locations increase demands on the City's resources during flood events as the populations in these areas have required rescue from flood waters.

10.2.2 ECONOMY AND GENERAL BUILDING STOCK

Flood damage to businesses is difficult to estimate. Businesses that are disrupted by floods often have to be closed. They lose their inventories, customers cannot reach them, and employees are often focused on protecting or cleaning up their flooded homes. Business can be disrupted regardless of the business being located in the floodplain when customers and clients cannot reach their location. As with flooded roads, public expenditures on flood fighting, fire department calls, clean-up and repairs to damaged public property affect all residents of the City, not just those in the floodplain.

A Hazus analysis was conducted to understand the potential impact of floods on the island's building stock. Table 10-8 displays the residential, commercial, and other building stock (including industrial, government, religion, agricultural, and education structures) losses that could occur in the 1% annual chance flood hazard area. A flood could cause more than \$5.5 billion in damages to the island's building stock.

Another planning consideration for floods is the amount of debris that could be created and require clean-up by recovery crews. Table 10-9 displays the debris amounts and types that could be generated during a 1% annual chance flood.



Table 10-8. Honolulu Building Stock in Proposed Regulatory 1% Annual Chance Flood

Regional Planning Area	1% Annual Chance Proposed Regulatory Flood Impacts on Buildings						
	Number of Buildings Exposed	Total Replacement Cost Value (RCV)	Estimated Loss for All Occupancies	Percent of Total	Estimated Loss for Residential Properties	Estimated Loss for Commercial Properties	Estimated Loss for All Other Occupancies
Central O’ahu	4,172	\$529,904,773	\$68,747,835	13.0%	\$39,032,824	\$20,163,494	\$9,551,517
East Honolulu	1,482	\$2,480,192,150	\$249,721,115	10.1%	\$215,489,420	\$11,457,223	\$22,774,472
’Ewa	892	\$171,837,747	\$6,513,662	3.8%	\$3,573,411	\$1,992,752	\$947,499
Ko’olau Loa	429	\$2,404,350,226	\$328,476,056	13.7%	\$266,759,741	\$20,363,792	\$41,352,523
Ko’olau Poko	3,230	\$1,026,743,558	\$115,281,351	11.2%	\$87,799,828	\$9,869,177	\$17,612,346
North Shore	1,072	\$1,183,517,924	\$268,955,679	22.7%	\$248,415,521	\$4,683,188	\$15,856,970
Primary Urban Core	6,621	\$47,820,067,210	\$4,432,976,564	9.3%	\$1,425,066,705	\$2,621,789,471	\$386,120,388
Wai’anae	746	\$1,082,607,370	\$79,461,093	7.3%	\$62,520,517	\$3,278,436	\$13,662,140

Source: Tetra Tech, Inc. (Tetra Tech) was awarded Contract No. CT-DPP-2400165 on December 22, 2023. The purpose of this contract is to perform a Federal Emergency Management Agency (FEMA) Hazus v.4.2 or later Flood Level 2 Analysis of riverine and coastal flooding to better understand flood risks across the City. Community Resilience Consulting, LLC (CRC), Tetra Tech’s subcontractor, conducted a Hazus GIS-based flood risk assessment modeling incorporating City-provided inventory and hazard data as well as publicly available data. The flood hazard analysis quantifies flood exposure to buildings across O’ahu and estimates economic and social costs of different potential flood event scenarios.



Table 10-9. Honolulu Estimated Debris Generated in Proposed Regulatory 1% Annual Chance Flood

Regional Planning Area	Estimated Debris Created During the 1-Percent Annual Chance Proposed Regulatory Flood Event			
	Total (tons)	Finish (tons)	Structure (tons)	Foundation (tons)
Central O’ahu	2,997	1,814	685	498
East Honolulu	1,099	593	305	201
‘Ewa	396	300	56	40
Ko’olau Loa	14,958	10,447	1,507	1,004
Ko’olau Poko	5,979	2,982	1,603	1,394
North Shore	12,414	7,774	2,635	2,005
Primary Urban Core	38,814	33,011	3,216	2,587
Wai’anae	4,141	3,167	605	369

Source: Tetra Tech, Inc. (Tetra Tech) was awarded Contract No. CT-DPP-2400165 on December 22, 2023. The purpose of this contract is to perform a Federal Emergency Management Agency (FEMA) Hazus v.4.2 or later Flood Level 2 Analysis of riverine and coastal flooding to better understand flood risks across the City. Community Resilience Consulting, LLC (CRC), Tetra Tech’s subcontractor, conducted a Hazus GIS-based flood risk assessment modeling incorporating City-provided inventory and hazard data as well as publicly available data. The flood hazard analysis quantifies flood exposure to buildings across O’ahu and estimates economic and social costs of different potential flood event scenarios.



10.2.3 COMMUNITY LIFELINES AND OTHER CRITICAL FACILITIES

Flooding can weaken building foundations, bridges, roads, and other infrastructure, increasing the risk of structural collapse. Potential flood impacts on community lifelines and other critical facilities are numerous:

- All community lifelines have facilities located in flood zones, making them vulnerable to flood impacts and potential service disruptions.
- Energy Lifeline—Oversaturated soils from periods of heavy rain and flooding may cause utility poles to tip over or fall, interrupting the power grid for a potentially large area, especially if a transformer is impacted.
- Water Systems Lifeline—Excess water makes it more difficult for water treatment plants to treat the water efficiently and effectively.
- Transportation Lifeline—Geographic isolation can be caused by bridges being washed out or roads being blocked by floods or debris in communities with limited transportation routes.

10.2.4 NATURAL, HISTORIC, AND CULTURAL RESOURCES

Natural Resources

The loss of natural resources resulting from increasing flood occurrences is difficult to quantify in dollar amounts; however, their loss would deeply impact the state. Flooding can change the landscape of beaches and many of O‘ahu’s iconic beaches are located where freshwater meets the ocean, such as Waimea Bay, Kailua Beach, and Waikiki.

Additionally, flooding has the potential to impact facilities that could release wastewater or hazardous materials and waste to nearshore waters and coastal habitats. Many Native Hawaiian cultural resources could be damaged by flooding.

Historic and Cultural Resources

Historic places and institutions are vulnerable to impacts from flooding. Historic buildings face structural damage during flood events. Historic structures often are not built to modern building code requirements, including design flood elevation and construction standards. Historic resources and structures were often built close to waterways, increasing their flood risk.

Cultural institutions, parks and open spaces, community facilities, and religious institutions are all vulnerable to impacts from flooding. Venues such as museums face structural damage during flood events, with additional risk of damage to important cultural artifacts housed within them. Parks, recreation, and community space closures due to flood events can disrupt residents’ lives and hinder access to community services. Parks and recreational areas are often located near waterways. Although these facilities often experience flooding, they are positioned with flooding in mind, as many parks are considered as open space to disallow development.



10.2.5 FUTURE CHANGES THAT MAY AFFECT RISK

Understanding future changes that affect vulnerability can assist in planning for future development and ensure establishment of appropriate mitigation, planning, and preparedness measures. The following sections examine potential conditions that may affect hazard vulnerability.

Potential or Planned Development

Non-urban zoned lands throughout the state are being urbanized rapidly. From 2000 to 2030, housing density is projected to substantially increase on approximately 8% (65,000 acres) of Hawaii's private forest land (USDA 2014). On O'ahu, the directed growth policy of the City encourages growth to occur beyond the primary urban center (Honolulu 2021).

The Revised Ordinances of Honolulu (ROH) is the set of local laws passed by the City Council regulating activity within the City. The ROH Chapter 26 Shoreline Setbacks was amended in 2023 to list reduced coastal hazards and increased community resilience as the primary concerns of city policymakers. In addition, the amendment increased the shoreline setback from 40 feet to 60 feet beginning July 1, 2024 and established a 3-foot minimum above base flood elevation requirement for new structures within a special flood hazard area (Honolulu 2023).

ROH Chapter 17 Electrical Code establishes regulations for electrical work within flood hazard areas and development adjacent to drainage facilities. Regulations state that all important electrical equipment, like power service connections, meters, switchgear, control centers, transformers, and lighting panels, must be placed above the base flood elevation or inside waterproof enclosures or barriers. All regular lighting circuits in areas below the base flood level should be powered from a main power panel located above this level or protected by a waterproof box or barrier. Likewise, all emergency lighting circuits in these areas must be powered from a separate panel, also located above the base flood level or within a waterproof box or barrier.

ROH Chapter 21A Flood Hazard Areas establishes regulations for developments in flood hazard areas. Regulations state that land use permits must be reviewed for compliance with the flood hazard areas ordinance, additional building height is allowed if required to elevate the structure above the base flood elevation, and dwelling units on lots located in a floodway are limited to two. Transit oriented development plans are required to consider the impact of flood hazards and sea level rise on planned developments.

Projected Changes in Population

O'ahu's population is expected to rise by around 50,000 people by the year 2050. Population increases are unlikely to have an impact on the incidence of flooding; however, populations living and working near the floodplain can expect to see structures, roads, and ecosystems impacted by floods. Table 10-10 outlines O'ahu's population projections through 2050.



Table 10-10. City Population Projections

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

Source: (DBEDT 2023)

Climate Change

Climate change is expected to significantly increase the severity and intensity of floods affecting O‘ahu. By 2100, sea levels in Honolulu are projected to rise between 3.81 and 5.84 feet compared to 2000 levels, with a possible 7.91 feet rise in a high-emission scenario (City and County of Honolulu Climate Change Commission 2022). This sea level rise poses a severe threat to O‘ahu’s densely populated coastal areas, including Waikiki and downtown Honolulu, potentially leading to permanent inundation of low-lying areas and increased vulnerability to storm surges.

Rising sea levels are expected to exacerbate, or introduce, many impacts in coastal regions, including:

- Groundwater inundation
- Storm-drain backflow
- Seasonal wave run-up
- Storm surges associated with tropical cyclones
- Chronic coastal erosion leading to land loss
- Extreme tidal flooding
- Intense rainfall
- Compound events (e.g., heavy rainfall coinciding with high tides)

The Honolulu Climate Change Commission anticipates that the most significant short-term flooding will result from tropical cyclone storm surges and compound flooding events (City and County of Honolulu Climate Change Commission 2022). These scenarios could severely impact O‘ahu’s critical infrastructure, including its transportation networks, energy systems, and water supply.

Projected changes in total rainfall for Hawai‘i are not consistent across recent studies; with some studies showing a decrease in daily rainfall intensity while other studies indicate that consecutive wet and dry days are both increasing statewide. Rainfall is projected to decrease from November to April and increase 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



Although projections of future rainfall are uncertain, streams and rivers on the Hawaiian Islands have experienced a reduction in flow over the last century, making them more prone to flash floods (EPA 2016).

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.