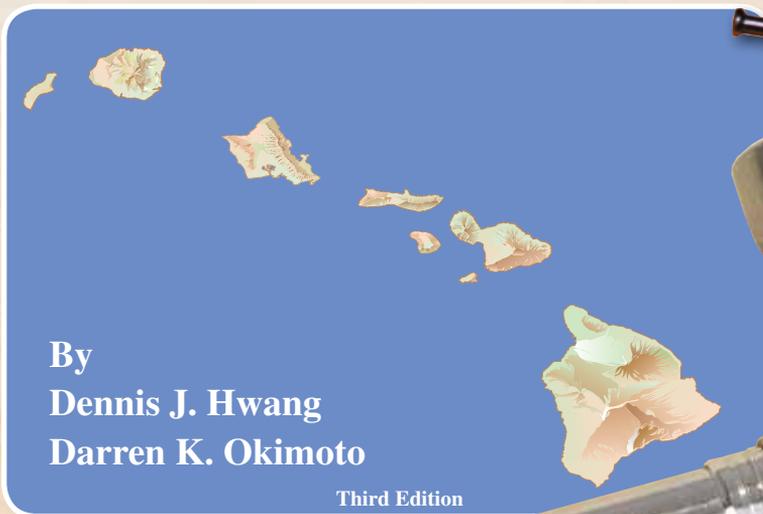


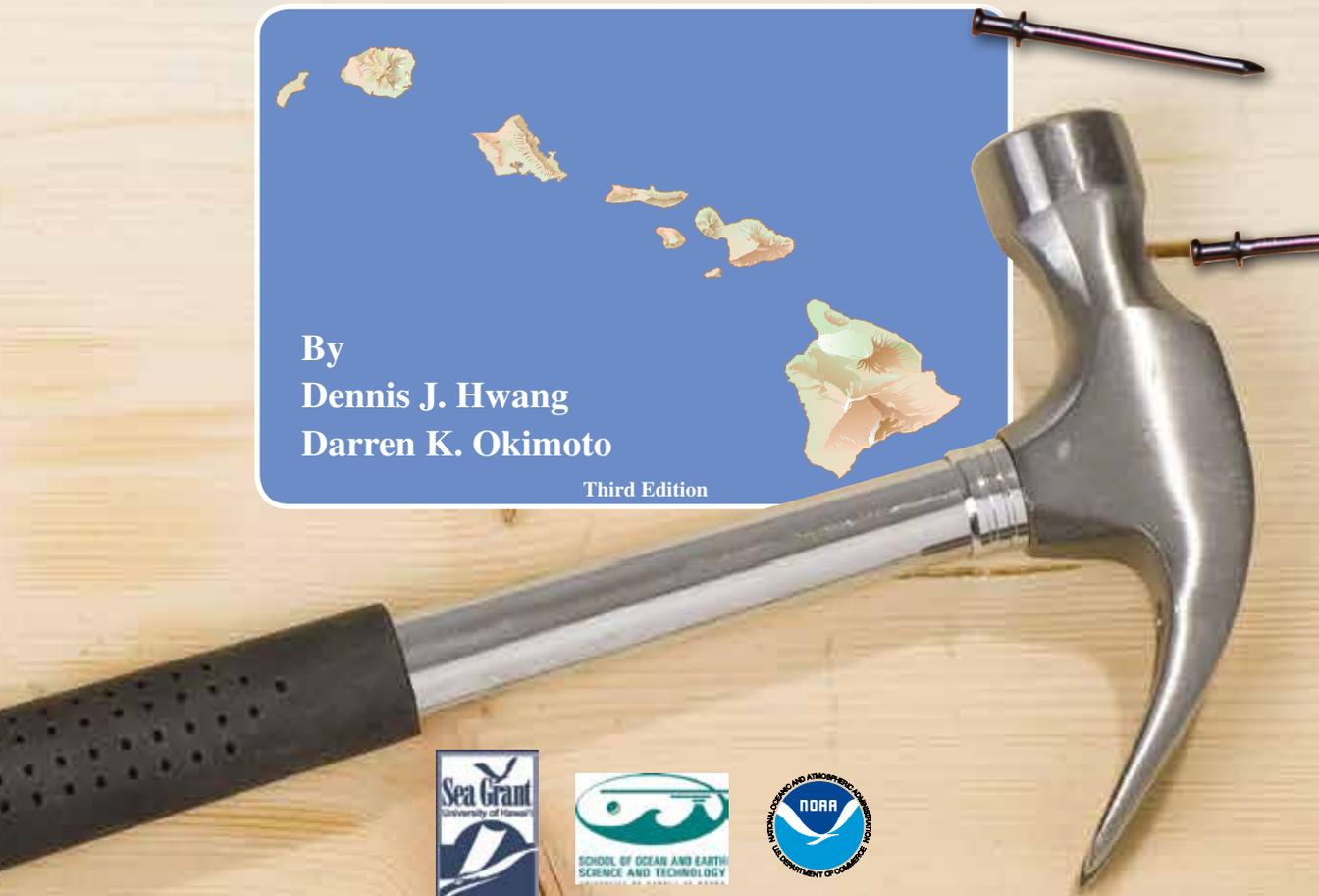
University of Hawai'i Sea Grant College Program

HOMEOWNER'S HANDBOOK TO PREPARE FOR NATURAL HAZARDS



By
Dennis J. Hwang
Darren K. Okimoto

Third Edition

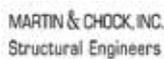


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It is our hope that the information contained within the handbook, which is in part a compilation from numerous publications associated with natural hazards and hazard mitigation, will be widely used and adopted by stakeholders in Hawai'i and the region.

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Part 1

Introduction

Your home is your castle. It protects you and your family, as well as your worldly possessions, from the elements. For many, the home is also your major investment. Yet natural hazards such as tsunamis, hurricanes, floods, or high wind events can threaten your home, both inhabitants and contents. When a natural hazard occurs, the results can be devastating.

This handbook was created to help you prepare for a natural hazard so that risks to family and property may be reduced. While it is never possible to eliminate all damage from a natural hazard, you as a homeowner can take action and implement many small and cost-effective steps that could significantly lower your risk. Mother Nature can be intense. Your family and home deserve the protection that only you can provide.

This handbook is divided into four parts. This introduction presents the purpose and layout of the handbook, and includes a discussion of common myths that may have prevented you from taking action in the past. A summary of the content of this handbook is also provided in the form of 10 action items. Part 2 provides basic information on tsunamis, hurricanes, earthquakes, and flooding that will allow you to make an educated decision about the steps to take to protect your family and property. Part 3 discusses in detail how to protect yourself and your family. Included in this section are the stock of essential emergency supplies, evacuation kit, evacuation planning, evacuation procedures, and important information that the civil defense and emergency management agencies want you to know even before a warning siren goes off. Part 4 covers how you can protect your property. Many examples are provided.

This handbook is available for free as a downloadable pdf file at the University of Hawai‘i Sea Grant College Program website: <http://seagrantsoest.hawaii.edu/homeowners-handbook-prepare-natural-hazards>

This handbook will be updated on an as-needed basis as new information becomes available and feedback from the public is obtained. You can also contact your state or county civil defense and emergency management

agencies by phone at the addresses and numbers provided in appendices. In addition, many of the sponsors and participants of this handbook may have updated information on their own websites.

1.1 Common Myths and Reasons to Prepare

You may be among the many homeowners in Hawai‘i who have not fully prepared for a natural hazard because of complacency caused by several myths. The most commonly quoted myths are discussed below and are discussed in order to remove some of the major barriers to taking action and to encourage people to prepare.

1) “A natural hazard can’t happen to me.” Scientists agree that it is not a matter of IF the next tsunami or hurricane will occur, but WHEN. From 1819 to 1975, Hawai‘i experienced at least 26 damaging tsunamis, or about one every six years.¹ Since 1975, we have not had a damaging tsunami until the recent tsunamis associated with the Chile earthquake in 2010 and the Japan earthquake in 2011. Still, the damage in Hawai‘i from these tsunamis was relatively minor compared to historical events. This long period of inactivity from 1975 to 2010-2011 is unlikely to continue. For hurricanes, the National Weather Service expects an event to impact the islands about once every 15 years. Indeed, our state has been fortunate in the last few decades, and there is a good chance you will experience a major event in your lifetime. Hurricanes Genevieve, Iselle and Julio all near Hawai‘i during August of 2014 are an important reminder that the islands are very vulnerable to hurricanes and tropical storms.

2) “If a hazard occurs, it won’t be that bad.” When a tsunami or hurricane occurs, the damage can be devastating. When Hurricane Iniki struck Kaua‘i in 1992, more than 41 percent of the island’s 15,200 homes were damaged or destroyed (1,100 were destroyed; about 1,000 suffered severe damage; 4,200 suffered moderate to minor damage).² More than 7,000 residents were left homeless.³ Damage could have been much worse if Iniki had struck the islands of Maui, Hawai‘i, or O‘ahu, which have approximately two to eight times more residential properties.⁴ It is also conceivable that a single hurricane can strike more than one island.





3) **“I survived Hurricane Iniki so I am sufficiently prepared.”** Many people outside of Kaua‘i have the impression that they survived Hurricane Iniki, and therefore they do not need to prepare any more than they did in 1992. As will be shown, only Kaua‘i received the full force of the winds, rain, and high surf from Hurricane Iniki.



4) **“Hurricanes only hit Kaua‘i so those on the other islands don’t need to prepare.”** It is a myth that only Kaua‘i will be hit by a hurricane. While the most recent hurricanes hit Kaua‘i—‘Iwa (1982) and Iniki (1992)—other hurricanes or cyclonic storms have hit the other islands at various points in history. For example, Nina damaged O‘ahu in 1957, and, according to the National Weather Service, a major hurricane hit Maui and Hawai‘i in 1871. Also, there have been many close misses, both historically and recently. Most scientists agree that all the islands are at nearly equal risk from a hurricane.



5) **“I don’t live near the coast, so I am safe.”** In fact, the vast majority of damage or destruction on Kaua‘i by Iniki was caused by the powerful winds of the hurricane.⁵ Therefore, all homeowners should prepare, not just those along the coast.



6) **“Installing hurricane clips doesn’t guarantee there will be no damage after a hurricane, so I won’t bother.”** Even though someone may wear a seat belt, shoulder belt, and have an airbag, there is no guarantee that a person won’t be injured in a major auto accident. Yet most people recognize the importance of these safety devices in reducing risk and use them. Likewise, the measures discussed in this handbook could significantly reduce risk, although there are no guarantees there will be no damage.

7) **“If a natural hazard occurs, the government will come to the rescue.”** After the October 15, 2006, earthquake, many homeowners on the island of Hawai‘i found that the government will not repair their damaged houses or even provide adequate compensation for property damage. It is up to you to plan properly, strengthen your house, and have the appropriate financial protections in place, such as

insurance, if it is available. After a natural hazard, the government may also be overwhelmed by the number of people in need.

8) “My house in Hawai‘i County survived the October 15, 2006, earthquake, so I do not need to retrofit for earthquakes.” The ground shaking on all the islands during the October 15, 2006 event was significantly lower than the force exerted by an earthquake that would cause damage to homes built to the current building code specifications. If and when such an earthquake occurs, the resulting damage to homes will be much greater. Homeowners in Hawai‘i County should consider retrofits that provide a continuous load path connection, which will help protect homes against both hurricanes and earthquakes. Additional simple measures are also possible.

9) “Earthquakes only affect Hawai‘i County, so I don’t need to worry.” Although earthquakes affecting the island of Hawai‘i are more frequent and likely to be larger, there is still a significant seismic hazard for Maui County and the island of O‘ahu. Fortunately, many of the measures to protect a home against a hurricane in Maui County and O‘ahu can also protect against an earthquake. Residents of Hawai‘i County may need additional measures.

10) “Even if a hazard occurs, there is nothing I can do.” Fortunately, there are many small steps you can take to significantly reduce the risk of damage to life and property. The number of options available to homeowners has never been greater. While it is not possible to eliminate all risk or damage, many reasonable steps as described in this handbook to plan and prepare can make a major difference and determines whether your house survives and receives only minor or no damage. Thus, the information in this handbook covers two major parts for preparation: (i) protecting yourself and your family, and (ii) protecting your property.

11) “Strengthening my house is too expensive and not worth the effort.” Here are various cost-effective ways to strengthen your house:

- Adding hurricane clips or window coverings offers significant protection alone and runs on the order of a few thousand dollars.





Strengthening a roof structure (trusses and rafters) with bracing can be done at a minimal cost.

- While strengthening an existing roof can be expensive, consider doing so when you are ready to replace it with a new roof as the additional cost is far more reasonable. Many homeowners who install solar photovoltaic panels reroof beforehand and this is a good time to strengthen the roof (See Appendices D and E).
- Upgrading the house foundation can be expensive but may be well worth it, especially if your house is your major investment.

Many of these upgrades can be offset with insurance premium discounts. Ultimately, the time and money spent to prepare your house in order to minimize damage from a natural hazard are just a tiny fraction of what you might have to expend if major damages to your house occur as a result of a failure to take preventative measures.

By preparing and strengthening your house, you may be able to wait out the hazard, as when a hurricane nears, rather than evacuate to a shelter. Evacuation to a shelter should be the last resort. There will be minimal supplies, the simplest of sanitary facilities, a bare floor, and little space (10 square feet per person - 5 feet by 2 feet). You will have to bring your own supplies including bedding, medication, food, and water. By remaining at home during a hazard, you will be in far more comfortable conditions and have the ability to take better care of family members, including the elderly, those with special needs, and pets. Whether you can indeed shelter in place will depend on numerous factors including your original house design, the retrofits you install, the strength of the hazard event, and if you are in any high risk flood zones. Nevertheless, by strengthening your house you protect your neighbors as well as yourself. A house that falls apart during a hurricane will create debris that can damage adjacent properties.

1.2 Ten Things You Can Do to Prepare

As covered in later parts of this handbook, here are 10 things you can do to prepare that will provide greater protection to your family and your property.

- 1) Gather your emergency supplies now.** The good news is many items you need are probably in your home already (see Part 3). Check and restock each month so that the supplies are complete, not outdated, or used. Expiration dates, which are hard to read because of small print, can be made more visible on the packaging with an indelible ink pen such as a Sharpie. Avoid rushing to a store during an emergency to gather your supplies. There will be long lines and empty shelves – you will only add to the crowd and confusion. During the approach of Hurricane/Tropical Storm Iselle in 2014, many stores were out of water, gas and other supplies two or three days before expected landfall.
- 2) Compile your evacuation kit.** If your evacuation plans include using a public shelter for a hurricane, you will need an evacuation kit that contains water, food, clothing, medications, personal hygiene products, and other items for five to seven days. The kit should already be assembled and checked before hurricane season (see Part 3). If the kit will be used during evacuation for other hazards such as a tsunami, three days may suffice.
- 3) Create an evacuation plan for both a tsunami and a hurricane. They are different.**

For a hurricane, your plan may include sheltering in your house if it is: (i) sufficiently strong (i.e., built with a strong connectors, see #6), (ii) outside the evacuation zone (see your phone book yellow pages), and (iii) outside any high-risk flood zone (see Figures 2-13 and 2-14 to determine your flood zone). If you can't use your house, use a suitable alternative structure (a friend or relative's house) or **a shelter that is officially open (listen to local radio and television)** (see Part 3).

For a tsunami, evacuate to high ground outside the evacuation zone if necessary. The evacuation zone is identified in your phone book





(currently in the yellow pages as of 2011, but in the past it was in the white pages). Only evacuate the evacuation zone if: (i) there is an earthquake strong enough so that you cannot stand, or (ii) there is appreciable earthquake shaking **and** the siren sounds a few minutes later, or (iii) you are instructed by local radio and television to evacuate. **If there is no shaking, the siren means to turn on local radio and TV.** Once you have evacuated, the wait may be many hours (see Part 3).



Discuss and practice drills of your evacuation plan with your family each year.



4) Know your property and take appropriate action. Look at where you are located. If the land floods, consider flood insurance. If trees overhang your house, consider trimming or cutting the branches overhead which may damage your house in a storm. If the property is near a ridge, it may be especially susceptible to wind damage during a storm or hurricane. By identifying the characteristics of your house you can help determine the most effective measures to strengthen the structure (see Part 4).



5) Know your house and take appropriate action. When was your house built? Does it have connectors to tie the roof to the wall or the wall to the foundation? When will you need to re-roof? Look at your blueprints. They may be available from your homebuilder, your local building department, or your architect (see Part 4).

6) Strengthen your house. A house built after the early to mid-1990s should have hurricane clips to tie the roof to the wall and strong connectors from the wall to the foundation (see Table 4-1, column 3). If your house was built before then, you can still retrofit at a reasonable cost. All households should consider the many options now available to protect your windows, garage, and doors. You can also strengthen your roof when it is time to re-roof. The steps a homeowner can take will vary with each house, but for the majority of homeowners, there are a few steps that can make a significant difference (see Part 4 and Appendices D and E).

7) Insurance. Don't gamble with your house. Obtain adequate insurance for a hurricane, flood insurance if you are in a flood-prone

area, and earthquake insurance if you are at risk and it is available (see Part 4 and Appendices D and E).

8) Take advantage of potential discounts for your hurricane insurance premiums. Coverage may vary among insurance companies, so call your insurance agent to find out about discounts that may be available. Significant discounts in your hurricane insurance may be provided for reducing the risk to your house with window protection, roof-to-wall tie-downs (hurricane clips), and wall-to-foundation tie-downs (see Part 4).

9) Finance creatively. Consider efforts to strengthen your house your most important home improvement project. Most projects are not that expensive. For the more costly ones, a small home improvement loan and potential discounts from hurricane insurance premiums make these projects within reach. It is a great investment to strengthen your house and provide more protection to your family (see Part 4).

10) Seek the assistance of a qualified, licensed architect, structural engineer, or contractor. This handbook covers work that you may be able to do yourself. If you cannot do the work, seek qualified assistance through trusted references from friends and family, the Structural Engineers Association, your county civil defense and emergency management agencies, or the contractors associations for your island. Even if you do the work yourself, it is always best to seek professional advice for initial guidance since every house is a little different (see Part 4).



Part 2

Natural Hazards: An Overview for Homeowners

In Hawai‘i, many different types of natural hazards can occur, such as flooding, fire, rock falls, landslides, earthquakes, coastal erosion, bluff erosion, sea-level rise, subsidence, volcanism, and high waves. This handbook concentrates on tsunamis and hurricanes, the most potentially devastating hazards in terms of loss of life and property damage. In addition, information is provided for earthquake and flood hazards.

Preparing for the larger hazard events (hurricanes, tsunamis, earthquakes, and flooding) will offer protection from the smaller, more frequent events. There is much more information on these hazards than can be provided in this handbook. Included here is only basic information that may play a role in how you as a homeowner can prepare for these hazards.

2.1 Tsunami Hazards in Hawai‘i

A tsunami is a series of traveling ocean waves generated primarily by earthquakes occurring below or near the ocean floor. Not all underwater earthquakes will create a tsunami. If the motion of the seafloor is more vertical than horizontal, a tsunami is more likely to be generated. Underwater volcanic eruptions and landslides can also generate tsunamis.⁶

In the open ocean, the tsunami travels at great speed (about 500 miles per hour) and has a wave height of only one foot or less. As the tsunami approaches shallow coastal waters, the waves slow down and the water piles up to form a wall that can be more than 30 feet high.

A tsunami has great destructive power. Given the proper coastal configuration, water from a tsunami can penetrate several thousand feet inland (see Figure 2-1).⁷ This destructive power demands great respect. It is necessary for all residents, particularly those along the coast, to plan properly for tsunamis.





Figure 2-1. Inundation from the 1946 tsunami in Hilo reached several thousand feet inland. This photo depicts the tremendous power of a tsunami. Taken from the Hilo Tribune-Herald. Photo courtesy of Pacific Tsunami Museum—Andrew Spaulding Collection.

There were 26 damaging tsunamis around the islands between 1819 and 1975, or about one every six years.⁸ Since 1975, there had not been a major damaging tsunami until the Japan earthquake of March 11, 2011 which caused catastrophic devastation in Japan and over 30 million dollars in property damage around the state (see Figure 2-2).⁹ The long period of tsunami inactivity from 1975 until 2010 and 2011 was unusual when compared to the historical record. Thus, it is important to prepare for the tsunami hazard, which could be more frequent in the future.

In Hawai‘i, our major risk from a tsunami comes from earthquakes that occur both far away and locally. Since a tsunami travels at 500 miles per hour, it may take some time for the wave to reach various coastal areas. Travel times may vary from 15 hours for an earthquake off South America (Chile earthquakes of 1960 and 2010), 7.5 hours for one off Japan (Japan earthquake of 2011) to 4.5 hours for one off Alaska (Aleutian earthquake of 1946) (see Figure 2-3). For a local earthquake, travel times may vary from 40 minutes or less for an earthquake off Hawai‘i County to reach Kaua‘i, to five minutes or less for an earthquake off Hawai‘i County to impact its own coastline (see Table 2-1).





Figure 2-2. The tsunami generated from the March 11, 2011 earthquake off Japan damaged many residences in Kealakekua Bay on the island of Hawai'i. The house on this empty lot was swept into the bay.

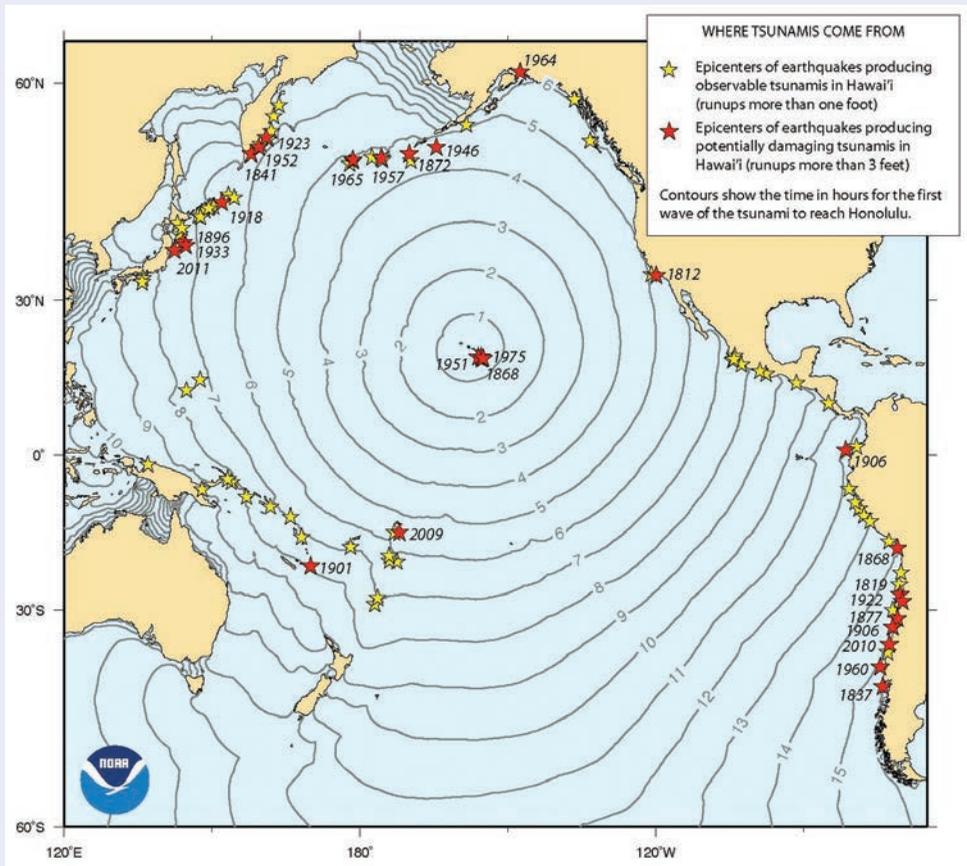


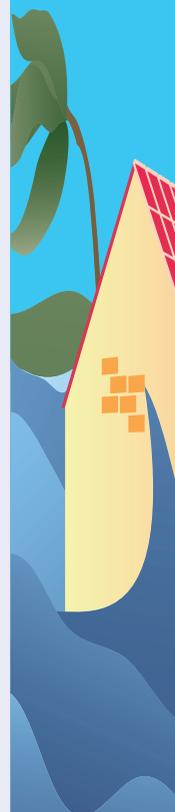
Figure 2-3. Travel times to Hawai'i in hours from various earthquake locations around the Pacific Rim. Note travel times for the 1946 earthquake near Alaska (4.5 hours), the 1960 and 2010 earthquakes off Chile (15 hours), and the 2011 earthquake off Japan (7.5 hours). Locally generated tsunamis caused by earthquakes in 1868, 1951, and 1975 are also marked. Compiled by Gerard Fryer of the Pacific Tsunami Warning Center.

Table 2-1. Travel Times from Various Potential Sources of a Tsunami

Some Possible Sources	Destination	Tsunami Travel Time
South America (example, 1960 and 2010 Chile earthquakes)	State of Hawai'i	15 hours
Japan (example, 2011 Japan earthquake)	State of Hawai'i	7.5 hours
Alaska (example, 1946 Aleutian earthquake)	State of Hawai'i	4.5 hours
Local Earthquake Hawai'i County	Kaua'i	40 minutes
Local Earthquake Hawai'i County	O'ahu	25 minutes
Local Earthquake Hawai'i County	Maui	15 minutes
Local Earthquake Hawai'i County	Hawai'i County	5 minutes or less

Our response will differ if there is a distant tsunami or a locally generated one. According to the Pacific Tsunami Warning Center, it will take about three minutes to analyze an earthquake, determine if a potentially damaging tsunami has been generated, and sound the siren.¹⁰ However, from the above, we learned that if there is a local earthquake near Hawai'i County, a wave may reach the coastline there in five minutes or less. If you feel an earthquake strong enough that interferes with your ability to stand upright, a local tsunami may have been generated and it is necessary to evacuate inland to high ground immediately. Do not take the time to check your phone book or listen to the radio. The wave may come before the sirens can sound and before a radio message to evacuate can be issued (see Part 3.3).

Once a tsunami reaches our coastline, it may take many hours for the series or train of waves to pass the islands.



2.2 Hurricane Hazards in Hawai'i

Tropical cyclones consist of tropical depressions, tropical storms, and hurricanes. Before a system becomes a hurricane in tropical waters near Hawai'i, it starts out as a tropical depression, develops into a tropical storm, and intensifies into a hurricane. A hurricane is an intense tropical weather system with a well-defined circulation pattern and maximum sustained winds of 74 miles per hour or more. In contrast, a tropical storm, which is also an organized weather system with well-defined circulation, has maximum sustained winds between 39 and 73 miles per hour. A tropical depression is a low-level circulation system of persistent clouds and thunderstorm with maximum sustained winds of 38 miles per hour or less. While far less powerful than hurricanes, tropical storms and tropical depressions can cause substantial damage. After a hurricane weakens and dissipates in tropical waters, it reverts to a tropical storm and eventually a tropical depression.

Hurricane strength is often given in categories using the Saffir-Simpson Hurricane Scale, which rates hurricanes from 1 to 5 based on the intensity of the sustained winds. During a hurricane, there is a triple threat of damage from high winds, very high surf, and flooding associated with heavy rains. Table 2-2 shows expected wind-related damages from the different hurricane categories.

One misperception around the state is that a hurricane will only strike Kaua'i and, therefore, residents of the other islands do not need to prepare. This is based on the impacts to Kaua'i from Hurricanes Dot (1959), 'Iwa (1982), and Iniki (1992). However, in 1957 damage occurred on O'ahu from Hurricane Nina. Also, the National Weather Service has records that indicate a major cyclonic system (or hurricane) struck the islands of Hawai'i and Maui in 1871.

Looking at the tracks of a few recent hurricane systems clearly illustrates the need for all islands to prepare. Figure 2-4 shows the round about path Hurricane Iniki took in 1992 that missed the islands of Hawai'i, Maui, and O'ahu, but struck Kaua'i directly. If Iniki had turned north only six hours earlier, the more populated areas of the state could have been severely impacted and, conceivably, more than one island could have been struck.

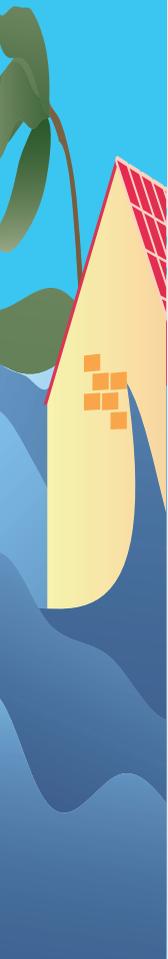


Figure 2-5 shows a satellite image of Hurricane Iniki with the outline of the Hawaiian Islands superimposed. The major damaging winds and rain associated with the spiral bands and eye are concentrated over Kaua‘i and away from the more populated areas. Typical wind damage is shown in Figure 2-6 and measures to prevent this are covered in Part 4.

In 2000, Hurricane Daniel reached Category 3 status with winds of 125 mph. It was heading toward Hawai‘i before veering away and passing to the east as a tropical storm (Figure 2-7). Daniel did produce heavy surf along the north shores of the islands. As a tropical storm, a direct hit on O‘ahu could have caused considerable damage, as demonstrated when Iselle hit Hawai‘i County in 2014.

Hurricanes that formed in the Central Pacific and while moving towards Maui, Hawai‘i and O‘ahu, either weakened or passed to the east or west were Iniki (1992), both Daniels (2000 and 2006), Flossie (2007) and Felicia (2009). The 2014 hurricane season served as a reminder of the risk of hurricanes to all the islands with the appearances of Genevieve, Iselle, and Julio in August, and Ana in October (Figures 2-8, 2-9, and 2-10).

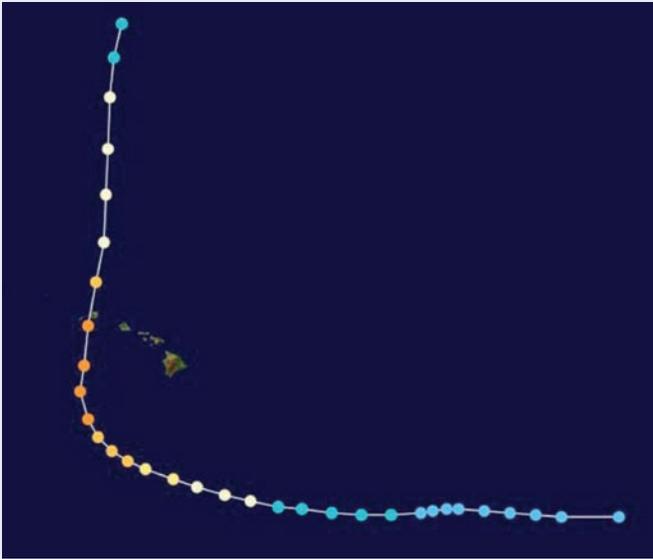


Figure 2-4. Track of Hurricane Iniki in 1992 and its evolution from a tropical depression and tropical storm (blue and aqua colors) to a major Category 4 hurricane (orange). Iniki suddenly curved due to a low pressure system to the north. Note, hurricanes avoid high pressure and move toward low pressure. From NOAA National Weather Service, Honolulu.



Table 2-2. Expectations of Wind-Related Damage in Hawai‘i for Different Hurricane Categories (1 to 5)¹¹

No.	Wind mph	Damage
1	74–95	No real damage to sturdy buildings. Damage to poorly constructed older homes or those with corrugated metal. Some tree damage such as palm fronds torn from the crowns. Examples: ‘Iwa (Kaua‘i, 1982), Dot (Kaua‘i, 1959), Nina (Kaua‘i, O‘ahu, 1957).
2	96–110	Some damage to building roofs, doors, and windows. Considerable damage to poorly constructed or termite-infested homes. Trees blown down, especially those that are shallow rooted.
3	111–130	Some structural damage to well-built small residences. Extensive damage to termite-infested buildings. Large trees blown down. Up to 50 percent of palm fronds bent or blown off. Some large trees, such as monkey pod and breadfruit, blown down, especially if the ground is wet. Example: Iniki (Kaua‘i, 1992).
4	131–155	Extensive damage to non-concrete roofs. Complete failure of many roof structures, windows, and doors, especially unprotected, non-reinforced ones; many well-built wooden and metal structures severely damaged or destroyed. Considerable glass failures due to flying debris and explosive pressure forces created by extreme wind gusts. Complete disintegration of structures of lighter material. Up to 75 percent of palm fronds blown off. Many large trees blown down. Major erosion of beach area.
5	> 156	Total failure of non-concrete-reinforced roofs. Extensive or total destruction of non-concrete residences. Some structural damage to concrete buildings from debris such as cars or appliances. Many well-constructed storm shutters ripped off from structures. Many large trees blown down. Flooding and major damage to lower floors near the shoreline. Example: No record in Hawai‘i, Andrew (Florida, 1992).

From NOAA National Weather Service, Honolulu, after Lander & Guard. These guidelines are projections and should be treated as approximations of wind damage. Damage in some cases may result from lesser winds than indicated. Local topography (surface configuration of an area) may also strengthen or weaken the winds. Wind speed is based on the average speed of sustained winds over a one-minute period. See the cited reference for the complete guideline.

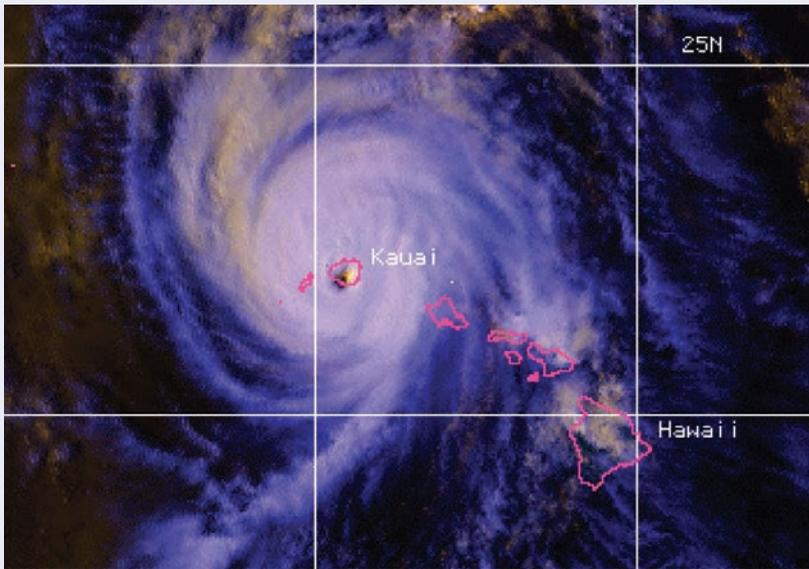


Figure 2-5. NOAA satellite image of Hurricane Iniki, September 11, 1992. The band of strong winds and rain surrounding the eye of the hurricane missed the majority of Hawai'i's populated areas. Iniki passed west of these areas.



Figure 2-6. A common site on Kauai after Hurricane Iniki. Many roofs were blown off due to a lack of proper connection. Photo courtesy of Department of Commerce and Consumer Affairs Insurance Division.

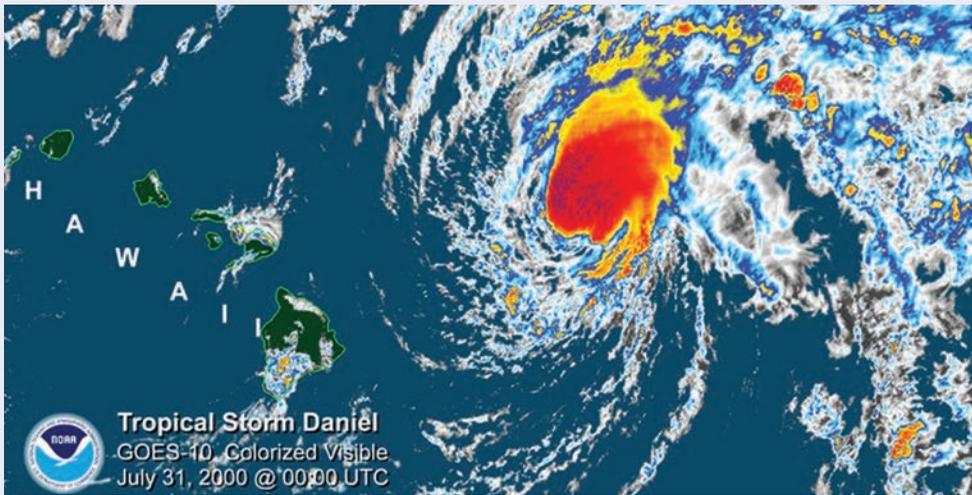


Figure 2-7. Tropical Storm Daniel, 2000. The spiral bands associated with the heavy winds and rain from former Hurricane Daniel passed to the east of the Hawaiian Islands. The major impact was high surf along the northern shorelines. Photo courtesy of NOAA.

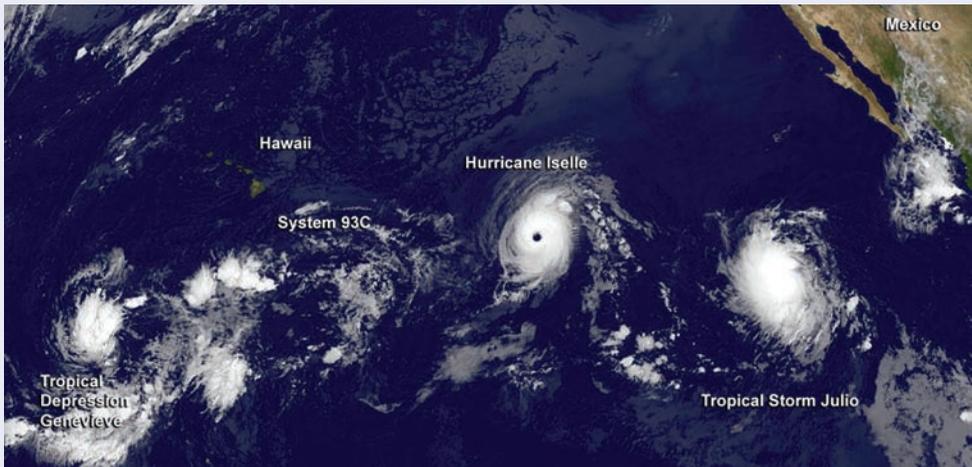


Figure 2-8. In August of 2014, Hurricanes Genevieve, Iselle, and Julio threatened Hawai‘i. Genevieve passed to the south of Hawai‘i before becoming a full blown hurricane. Iselle reached Category 4 strength before weakening and hitting the Puna area of Hawai‘i County as a tropical storm. Julio strengthened but veered north, taking a path similar to Daniel in 2000. Julio was still a powerful Category 2 storm when it passed to the east of O‘ahu and Maui. Hawai‘i was fortunate, but these systems demonstrate the significant hurricane risk in Hawai‘i and the need for all islands to prepare. Image courtesy of GOES satellite NOAA.

Tropical cyclones go through a life cycle, as they are born and strengthen until they weaken and die (e.g., tropical depression > tropical storm > hurricane > tropical storm > tropical depression). As a depression, there is significant risk of rain and flooding damage. For a tropical storm, damage

can be from the rain and flooding as well as strong winds and storm surge or wave inundation. This was demonstrated by the damage to Hawai‘i County from Iselle. A hurricane also has the triple threat of rain or flooding, wind damage, and coastal inundation, but on a much greater scale.

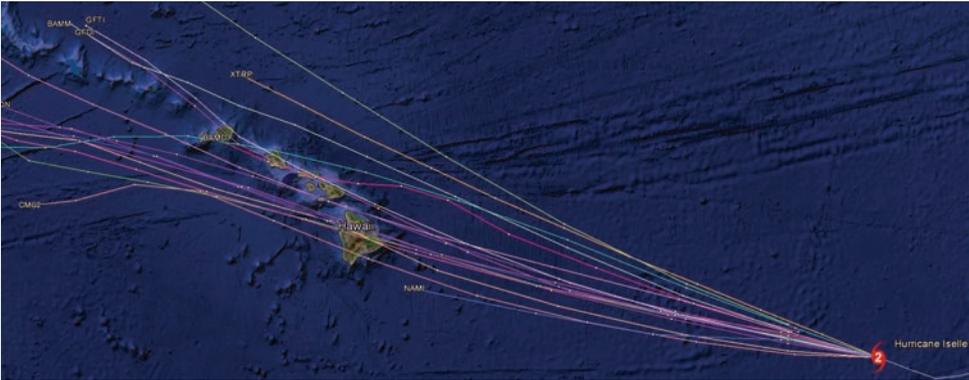


Figure 2-9. Two and half days before Iselle hit Hawai‘i County as a tropical storm, many computer models projected it just as likely to strike Maui or O‘ahu. Thus it is a myth to believe these islands are not susceptible. Iselle caused significant damage to homes from the high winds (roof damage and fallen trees) as well as wave inundation for homes along the coast. A similar strike on O‘ahu would have been much worse because of the greater population density. Image courtesy of NOAA.

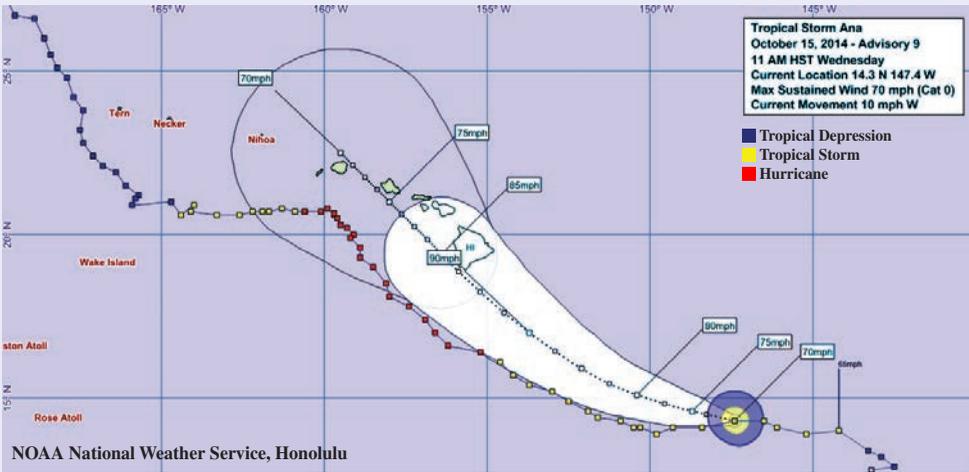


Figure 2-10. About two days before a potential landfall from Ana, hurricane winds were expected to impact the islands, with especially damaging winds from the right-front quadrant for all islands except Kaua‘i. High pressure to the east moved Ana to the west (track shown by colored boxes, see also Figure 2-4). Even with Ana over 100 miles away, rainfall was up to 5 inches on Kaua‘i, 11 inches on O‘ahu, 14 inches on Maui, and 13 inches for Hawai‘i. Rainfall and flooding varied greatly by location. Had there been no high pressure system, or one further to the east, Ana would most likely have followed the predicted earlier track with greater rainfall (up to 25 inches as indicated by offshore monitors) and significant damaging winds for west Hawai‘i, Maui, O‘ahu, and Kaua‘i.

2.3 Earthquake Hazards in Hawai'i

All the islands are at nearly equal risk for hurricanes and tsunamis. For earthquakes, however, the risk does differ from one island to the next. The greatest concentration of earthquake activity is found near the island of Hawai'i, although there have been significant earthquake events near Maui (1938) and Lāna'i (1871) (Figure 2-11). These earthquakes, including the one off Hawai'i on October 15, 2006, are deeper earthquakes caused by bending of the earth in response to the developing load of the island mass. However, more numerous are the shallower earthquakes resulting from the intrusion of magma around the active volcanoes and the buildup and then release of stress along ruptures and fault surfaces.¹²

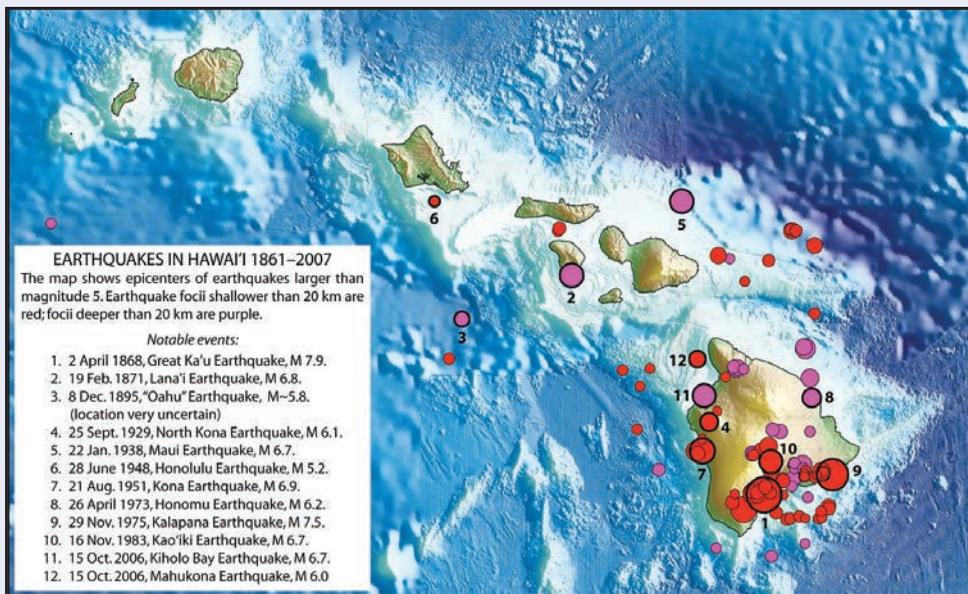


Figure 2-11. Distribution of earthquakes in the Hawaiian Islands from 1861 to 2007. The larger dots are associated with the larger earthquakes. The most frequent and larger events are associated with the southeast coast of the island of Hawai'i. The location of the two October 15, 2006, earthquakes are marked with dots 11 and 12. Compiled by Gerard Fryer of the Pacific Tsunami Warning Center.

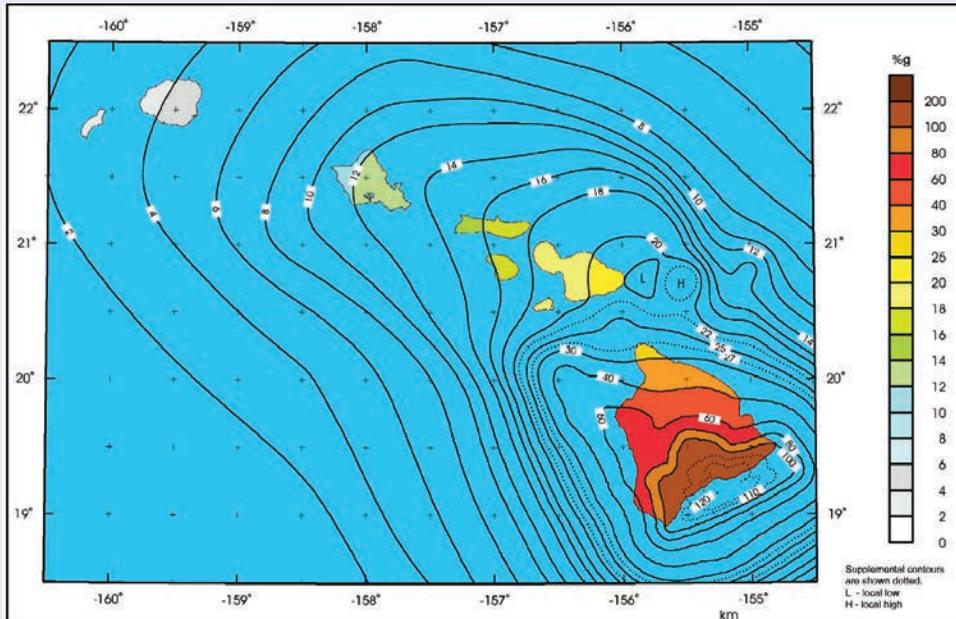


Figure 2-12. Scientists have developed maps that relate the probability of earthquake strength for different areas based on the distribution of earthquakes in a given region. The map indicates that for a given period of time the strongest earthquake shakings will occur along the southeast portion of Hawai'i County while the weakest ones will be felt near Kaua'i. In scientific terms, the graph represents the peak horizontal acceleration expressed as a percent of gravity for events with a 10 percent probability of exceedance every 50 years. From U.S. Department of the Interior—U.S. Geological Survey.

Figures 2-11 and 2-12 indicate that homeowners in Hawai'i County should be the most concerned about earthquakes, earthquake insurance, and strengthening their homes for ground motion, much less so for Kaua'i homeowners who would be the least impacted by this type of hazard.

Also based on these figures, the most likely source for a local tsunami generated by a local earthquake is from Hawai'i (remember that for a distant tsunami, all islands are at equal risk). Because residents of the island of Hawai'i are likely to be closest to the source when there is a local earthquake, they will have the least amount of warning time, if any. Thus, it is especially important for those residents to know that if they feel shaking strong enough so that they lose their balance and cannot stand, they should move to higher ground outside of the evacuation zone as quickly as possible. Residents should also be aware of nature's own warning signals to evacuate (see Part 3). It will be relatively rare or unlikely that shaking will be strong enough so that you cannot maintain your stance if you are on O'ahu and Kaua'i.

2.4 Flood Hazards in Hawai'i

Flooding in Hawai'i is probably the most common, if not the most intense, natural hazard in the state. Flooding can be caused by a hurricane, tropical storm, tropical depression, or any other weather system that produces heavy rain. Flooding can build up gradually over a period of days, or suddenly in a few minutes (commonly known as a flash flood). In addition, coastal flooding and wave inundation can be produced by a tsunami, hurricane, or high-surf event with waves generated by local storms or even storms thousands of miles from Hawai'i.

Flooding can be associated with living near a body of water such as an ocean, stream, river, or reservoir. To determine whether you are in a high-risk flood area, look at the Federal Emergency Management Agency's (FEMA) Flood Insurance Rate Maps (FIRM). These maps show what areas are susceptible to flooding and high velocity wave action (for those near coastal areas) from a one percent annual chance event (a.k.a. 100-year flood). As of October 1, 2009, the FIRM is only available in digital format through FEMA's Map Service Center at www.msc.fema.gov. The State of Hawai'i Department of Land and Natural Resources (DLNR) maintains a map viewer tool that displays the current effective Digital Flood Insurance Rate Maps (DFIRM) for Hawai'i (see Figure 2-13).

Flood Zones are geographic areas that FEMA has defined according to varying levels of flood risk. These zones are depicted on a community's FIRM and each zone reflects the severity or type of flooding in the area. Generally, these zones can be identified as one of three risk classifications (see Figure 2-14).

Even if you are not in a high risk flood zone, you may be at risk from flooding. According to FEMA, nearly 25 percent of flood insurance claims come from low-to-moderate risk areas.

A good way to determine the risk of flooding for your house is to observe and study your property. Even inland properties may be susceptible to flooding if there is poor localized drainage. If your property floods during small rain events, then the problem will be greater during a storm

or hurricane. You can protect yourself by improving the local drainage, making your house resistant to floods, and purchasing flood insurance. You do not need to be in a high risk flood zone to obtain flood insurance.

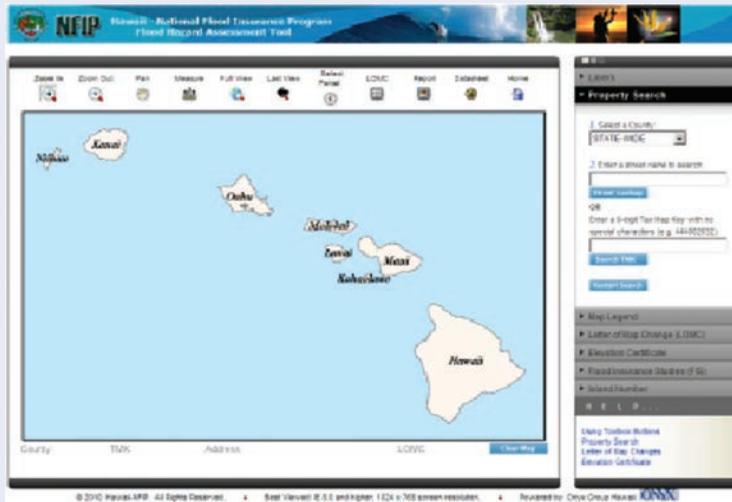


Figure 2-13. The Hawai'i Flood Hazard Assessment Tool (<http://gis.hawaiiinfp.org/fhat>) allows users to search for specific properties by site address or Tax Map Key (TMK) and determine their flood zone. A report can be generated for each property which indicates the level of flood risk as explained in Figure 2-14.

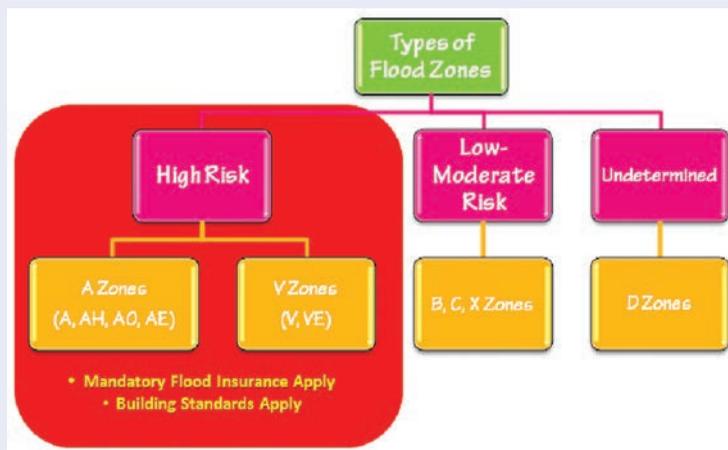


Figure 2-14. High Risk Flood Zones are in the Special Flood Hazard Area (subject to inundation by the one percent annual chance flood or 100-year flood). They consist of flooding (A zones) and high velocity wave action (V zones) near the coast. In addition, there are areas of Low-Moderate risk (B, C, X zones) and areas where the risk is undetermined (D zones). Even in these zones, the homeowner should consider flood insurance if there are localized flooding or drainage conditions on their property as indicated by past weather or storm events.

Part 3

Protecting Yourself and Your Family

This part of the handbook covers the topic of protecting yourself and your family from natural hazards. In particular, it is important that your household has a stock of emergency supplies, an evacuation kit, and evacuation plans for both a tsunami and hurricane since each poses a different kind of threat. You should discuss the evacuation plan and practice what to do with your family once a year or whenever there is a major change (for example, when a member of the family goes to a new school or is working in a different location).

3.1

Emergency Supplies

A stock of emergency supplies will be helpful during a major event like a hurricane or tropical storm, as well as for a minor event like a simple power outage. The importance of these supplies was demonstrated during the October 15, 2006, earthquake, which knocked out power throughout much of the state.

You should gather emergency supplies as soon as possible and check them monthly to ensure that they are complete, unused, and fresh (clearly mark expiration dates with an indelible ink marker and check expiration dates). Old food and water should be used or discarded and replaced with fresh supplies. Do not keep expired supplies. Your supplies should include at least the following:

- Portable radio, flashlight, and extra batteries (flashlights with light emitting diodes or LEDs can last many times longer on the same set of batteries versus those with conventional incandescent bulbs)**
- First-aid kit**
- List and supply of special medications (prescriptions and others)**
- Seven day supply of nonperishable foods**

- Hibachi with charcoal, camping stove with fuel, or barbeque grill with propane.** (Do not use these items indoors or in an area with no ventilation. Follow all manufacturer instructions.)
- Manual can opener**
- Matches or lighter**
- Disposable plates and kitchen utensils**
- Seven day supply of water.** A reasonable estimate is one gallon per person per day for drinking, cooking, and personal hygiene needs. It is important to have available good water containers for any water-interruption situations. Four- to six-gallon water containers are readily available in stores. Amazon also sells plastic “WaterBOB” containers that sit in a bath tub and can be used to store up to 100 gallons of potable water. You can also store water for toilet use (in unlined bathtubs, rubbish containers, washing machines, water heater, etc.).
- Extra pet food** (if you have a pet)

Additional items you may want to add:

- Portable toilet or porta potty**
- Spare cash** (ATM machines may not have power)
- Waterproof plastic sheeting or blue tarp, with string or rope**
- Cell phone and a hardwire single line phone.** Cell phone networks may be overloaded during times of natural hazards. Cordless phones with a base station will not work without electricity. If you need to rely on cordless phones, get an alternate source of power. Otherwise, have an old-fashioned corded phone. Use your phone only in an emergency during a natural hazard.
- Alternate power supplies.** During an emergency or power outage, you may need to rely on alternative sources of power (e.g., generators, inverters, power stations, and battery chargers). See Part 4.10 for a description of alternative power sources that may supplement your emergency supplies.

Note: if you plan to take shelter in your home, be sure that it is outside any flood zone and is a strong dwelling (see Part 4). Consider having more than seven days of supplies, as a major storm or hurricane can disrupt the supply line of goods to Hawai‘i. If you have space, stock up for a two-week period before there is a threat from a storm or hurricane. Gather your supplies over a period of time rather than rushing out during an emergency when shortages are likely.



3.2 Evacuation Kit

The evacuation kit differs from your stock of emergency supplies since the kit is what you will take if you need to leave your house in an emergency. Your evacuation kit should be prepared as soon as possible and can be checked before the beginning of hurricane season, which runs June 1 to November 30. The components of the kit should be stored in one place, perhaps in a duffel bag or backpack, so that it is ready to go at a moment's notice. The kit is primarily for evacuation during a hurricane, although it could be used for other situations (including tsunami evacuation, lava flow, wildfire, police situation, etc.).

The following evacuation kit was compiled with the input of all county civil defense and emergency management agencies:¹³

- One gallon potable water per day per person**

Personal items—carry-on bag with:

- Family needs, such as two-week supply of daily prescription medications, a three-day supply of nonperishable food and any special dietary foods, can opener, infant formula, and diapers**

- Prescription eyewear and personal hygiene items such as waterless cleaner, toothbrush/toothpaste, toilet paper roll**
- List of any required medications, special medical information, medical care directives, health insurance card, personal identification, and other important documents**
- First-aid kit**
- Flashlights, batteries, and spare bulbs, and portable radio with spare batteries**
- Change of clothes, towels**
- Pillows, blankets, and folding mattresses/air mattresses**

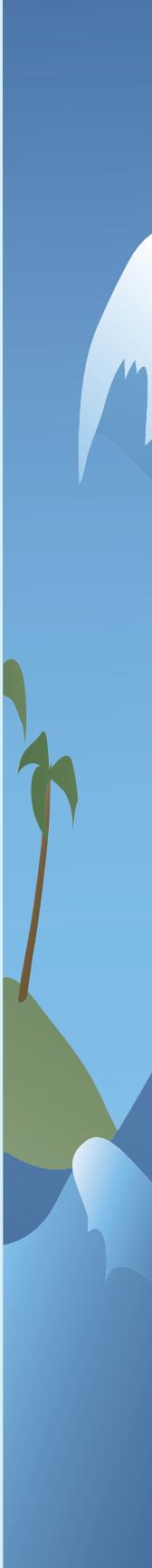
The American Red Cross recommends that the evacuation kit contain supplies for seven days. If the supply chain to Hawai‘i is disrupted (e.g., damage to airports or warehouses), you will be better off than others who do not have adequate supplies. After Hurricane Iniki, people were not able to move out of the shelters and back into their homes for two weeks, as their roofs had to be temporarily fitted with plastic sheets or tarps.

There is a fine line between bringing too many supplies that overload the limited shelter space of 10 square feet per person and not bringing enough. However, if you go to a shelter, keep in mind that there will be limited space, so bring only what is recommended unless you are instructed otherwise by your civil defense or emergency management agencies.

3.3 Evacuation Planning

In Hawai‘i, it is important for families to plan for both a tsunami and a hurricane. When you put your evacuation plan together, here are some things to consider:

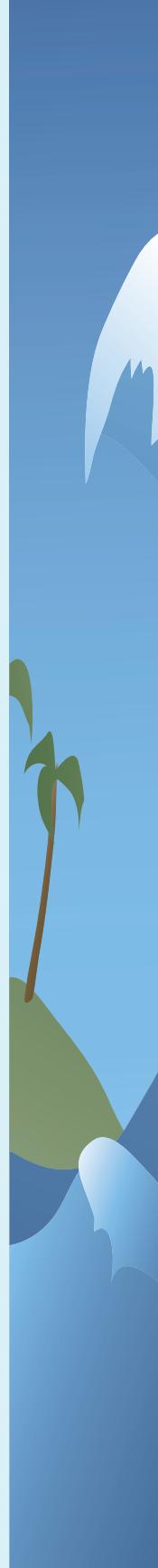
- Stay alert, stay calm, and be informed (tuning in to local radio and television is important). Create an evacuation plan and review it with your family every year.



- 
- Evacuation procedures for a hurricane will differ from those of a tsunami. You must plan for both. In a hurricane, you must protect yourself from strong winds, torrential rain, and coastal inundation. In a tsunami, you must protect yourself from coastal inundation only.
 - Your telephone directory Yellow Pages contain tsunami evacuation maps. If you live along the coastline, use the tsunami evacuation maps as a guide to determine the minimum safe distance to evacuate inland from a tsunami. You can also use the State of Hawai'i Tsunami Evacuation Zone Mapping Tool at: <http://www.scd.hawaii.gov/> or use the Useful Links section in the back of this book to go to the Civil Defense or Emergency Management Agency websites for your county. For a hurricane, you may have to evacuate if you are in a low lying flood zone or if the wind is too strong for your house. To determine if you are in a flood zone go to: <http://gis.hawaiiinfip.org/fhat/>. High Risk Flood Zones are covered in Figure 2-14.
 - You should plan for a tsunami even if you live inland because members of your family may be driving through or working in the evacuation zone. **The important thing is to know where you need to evacuate if you are at home, work, school, or in your car.**
 - **Always use the most recent phone book to view the tsunami evacuation maps (specifically, the yellow pages). The tsunami evacuation maps may be updated at any time, so do not depend on outdated versions.**
 - **Listen to your local radio and television stations carefully as there may be additional or modified directions based on the best available information at that time. Mother Nature is unpredictable and a team of scientists will always be monitoring unusual conditions for public safety.**
 - “Local” means radio and television broadcasts specific to the island you are on. Television is important but may contain information that is more applicable to one island than another, since the broadcasts are usually statewide.
 - Your evacuation plan should consider yourself, the members of your family, those with special health needs for whom you take responsibility

(like the disabled or elderly), and your pets. Practice evacuation procedures with your family through yearly drills.

- In an evacuation or emergency situation, all able-bodied persons (men, women, and children) should be able to take care of themselves if they act calmly and with proper direction. This is why it is important to practice your plan regularly.
- Parents should confirm with their child's school the evacuation plans that are in place, specifically, where the students will be held and for how long during each type of natural hazard. You should not have to drive to school to pick up your children.
- As part of your evacuation plan, consider how family members will communicate if they become separated. Each family member should have a list of telephone and cellular phone numbers of everyone in the family and phone numbers of a few contacts outside of the family.
- If needed, develop a plan to help those who cannot help themselves, such as the disabled or those with limited mobility. If people with special health needs are with a care-provider, confirm that the care-provider has an evacuation plan. Otherwise, you, your family, your friends or relatives, or someone nearby who is designated can take responsibility for that person(s). Hurricane evacuation shelters designated to serve as special needs shelters are listed in Appendix A and the most recent version can be found at <http://www.scd.hawaii.gov>. Special health needs evacuees must either be capable of taking care of themselves or be accompanied by a care-provider.
- Develop a plan for your pets. Go to the Hawai'i Emergency Management Agency (formerly State Civil Defense) website <http://www.scd.hawaii.gov> to determine if there is a pet-friendly shelter near you. Pets entering such shelters should be caged and the owners need to provide water and food for their pets. For a tsunami, take your pet with you. You will not be evacuating to a hurricane evacuation shelter, but rather to anywhere that is high ground outside of the evacuation zone.
- **In general, stay off the roads.** Only drive if it is absolutely essential. Your evacuation plan for tsunamis should emphasize reaching an area by walking. The police may close many roads during an emergency, so





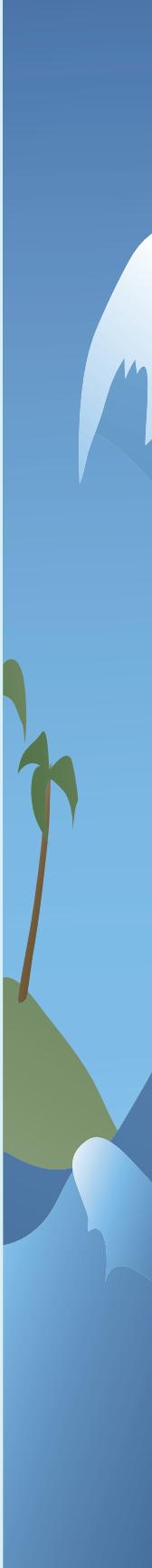
people can exit a freeway, but not necessarily get on it. On O‘ahu, buses will try to alter their normal routes and shuttle people to higher ground at no cost.

- It is important to note that hurricane evacuation shelters, such as those listed in Appendix A are for hurricane evacuation. These shelters are not planned for tsunami and flood evacuation during the hazard event. Later, if there is tsunami inundation or flood damage, some of these sites may be opened up as temporary shelters. Monitor official radio and television broadcasts for an updated list of refuge areas or shelters that may be open for a specific event. Do not count on all shelters to be open.
- There are a limited number of hurricane evacuation shelters and spaces that offer protection from wind, rain, and coastal waters. Since there is a shortage of shelters, there may be a possibility you cannot get in, even if you wanted to. Therefore, plan to use a shelter only as a last resort. A better alternative is to strengthen your house. If there are limitations in your house, go to a friend’s or relative’s house that is strongly built.
- Become familiar with the closest shelter or shelters in case you have to evacuate to one (see Appendix A). **Check for updates to the list of shelters on the Hawai‘i Emergency Management Agency website** [http:// www.scd.hawaii.gov](http://www.scd.hawaii.gov).
- If you are outside an evacuation zone (see yellow pages) or high-risk flood zone (see Figures 2-13 and 2-14) and in a strong house, use your house as a shelter. You will be better off sheltering at your house than going to a hurricane evacuation shelter. A strong house is built with connectors that tie the roof to the wall (hurricane clips) and the wall to the foundation (this is known as the continuous load path connection; see Part 4). Generally, houses built after 1993 on Kaua‘i, after 1994 on Hawai‘i, and after 1995 for O‘ahu and Maui fall into this category (see Table 4-1, column 3). In addition, the house should have coverings for the window that protect against wind pressure and impact.
- If you use your house as a hurricane shelter, you may be better able to store food and water and take care of your loved ones, including those with special health needs, the elderly, and your pets. This is why it is important to strengthen your house with hurricane clips and window coverings if they are not already in.

- For tsunami evacuation, listen to your local radio. Generally, anywhere away from the coast and outside the evacuation zone on high ground is suitable for tsunami evacuation. If in doubt, go farther inland to be safe. Shelters may eventually be set up for those whose homes are uninhabitable or inaccessible.
- Plan and prepare to be at your tsunami evacuation point for several hours.
- For a tsunami, you will have less warning time to evacuate or prepare than for a hurricane. For a tsunami you may be notified up to a maximum of 15 hours for a very distant tsunami to as little as three minutes if the source is local. Because there is potential for very little warning time for a local tsunami, special procedures are required for this scenario (see Table 3-3 for Nature’s Own Warning [NOW] evacuation signals). For a hurricane there will be an indication of potential danger most likely days in advance. General statewide evacuation on a distant tsunami will begin three hours prior to estimated wave arrival.
- Know the difference between a tsunami watch and tsunami warning versus a hurricane watch and hurricane warning. Do not confuse the two. When each is triggered, there are different actions you and your family should take. Also note that the Pacific Tsunami Warning Center and/or the civil defense and emergency management agencies may issue what is called an **Urgent Local Tsunami Warning** in the case of a local earthquake and tsunami.

3.3.1 Key Definitions

Tsunami Advisory. A tsunami is expected, but will not be large enough to cause significant land flooding. Evacuation of the coast is not necessary, but the beach and coastal waters may be hazardous because of unusual waves and strong currents. Sirens will not sound, but beaches will be closed. The advisory will be continued until wave action falls below danger levels, which may take several hours.





Tsunami Watch. Issued if there is the potential for a damaging tsunami but the existence of a tsunami has not yet been confirmed. A tsunami watch will always be upgraded to a tsunami warning or a tsunami advisory or will be canceled. If it is upgraded to a warning or advisory, that upgrade will occur with a target of at least three hours before the tsunami arrives. If you learn that a tsunami watch has been issued, tune to local television or radio for further information and prepare to evacuate in case the watch is upgraded to a warning.

Tsunami Warning. A damaging tsunami is expected and people should evacuate from the tsunami zones. When a warning is issued, sirens will sound and the warning will be broadcast by local media. Normally a warning is issued at least three hours before the tsunami arrives; the tsunami arrival time is part of the warning and will be repeated by the media. The warning continues until wave heights have dropped below hazard levels, which may be more than 12 hours. After a damaging tsunami, the warning will be downgraded to an advisory before it is cancelled.

Urgent Local Tsunami Warning. Issued when there has been a major earthquake in the Hawaiian Islands and a damaging tsunami is likely within minutes to tens of minutes. If you feel ground shaking which is so severe that you have difficulty standing, take the shaking as a natural tsunami warning and move inland immediately; do not wait for the sirens to sound. If you feel shaking, even if it is not very severe, and the sirens sound within a minute or two, immediately leave the coastal area, preferably on foot. Tune to local television or radio once you are out of the evacuation zone.

Hurricane Watch. Hurricane conditions (sustained winds of 74 mph or higher) are possible in the specified area of the watch, but the watch is called 48 hours before the possible arrival of the tropical storm winds (sustained winds of 39 to 73 mph). During a watch, prepare your home and review your plan for evacuation in case a hurricane warning is issued. As discussed earlier in this section, preliminary preparations should begin even before a watch has been issued.

Hurricane Warning. Hurricane conditions (sustained winds of 74 mph or higher) are expected in the specified area of the warning, but the warning

is called 36 hours before the expected arrival of the tropical storm winds (sustained winds of 39 to 73 mph). Complete hurricane preparations and leave the threatened area if directed by officials.

Flash Flood or Flood Watch. Issued when flash flooding or flooding is possible within the designated watch area. Be prepared to move to higher ground; listen to the NOAA weather radio station, local radio stations, or check your local television for information.

Flash Flood or Flood Warning. Issued when flash flooding or flooding has been reported or is imminent. Take necessary precautions at once. If advised to evacuate to higher ground, do so immediately.

3.3.2 Emergency Alert System

The Emergency Alert System (EAS) is the official source of natural hazard information and instruction in the state. This information can originate from county, state, or federal agencies. For example, the EAS network could disseminate warnings and/or instructions from the governor's office during threats or emergencies affecting one or more counties within the state. The statewide network may also be activated by the National Weather Service Forecast Office to disseminate weather- or tsunami-related watches or warnings.

If a siren sounds, turn on your radio. Some radios with the NOAA weather radio band turn on automatically when an emergency broadcast through the EAS is announced. This could be useful for homeowners along the coast. The NOAA weather radio station broadcasts round-the-clock weather and surf conditions, and also participates in the EAS system.

All local radio stations have voluntarily agreed to participate in the EAS system. Additional information may also be available on local and cable television. There are also primary radio stations around Hawai'i that have a wide circulation and specialized equipment including decoders and back up generators for use during emergency situations (see Table 3-1).

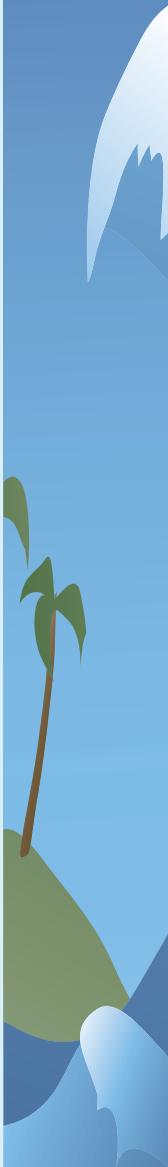


Table 3-1. Primary Radio Stations Participating in the EAS Network*

County	Local Primary	Phone Number
O‘ahu	1 KSSK-AM 590 khz	Office: 550-9200 / Request: 296-5959
	2 KRTR-FM 96.3 mhz	Office: 275-1000 / Request: 296-9696
Kaua‘i	KQNG-FM 93.5 mhz	Office: 245-9527 / Request: 246-9399
Maui	KMVI-AM 550 khz	Office: 877-5566 / Request: 877-1417
Hawai‘i (Hilo)	KWXX-FM 94.7 mhz	Office: 935-5461 / Request: 296-5999
Hawai‘i (Hilo)	KBIG-FM 97.9 mhz	Office: 961-0651 / Request: 296-5244
Hawai‘i (Kona)	KWXX-FM 101.5 mhz	Office: 935-5461 / Request: 296-5999
Hawai‘i (Kona)	KBIG-FM 106.1 mhz	Office: 961-0651 / Request: 296-5244

*All phone numbers are area code 808.

3.4 Evacuation Procedures for a Tsunami

The recent tsunamis in Hawai‘i generated by the February 27, 2010 earthquake in Chile and the March 11, 2011 earthquake in Japan showed that emergency management agencies and residents are generally well prepared to evacuate when there is ample warning time (15 hours for Chile and 7.5 hours for Japan). This section covers the planning and evacuation concepts utilized during those events and also addresses some more challenging evacuation issues, such as: (i) an earthquake from Alaska with only 4.5 hours before the ocean-crossing tsunami impacts our state, and (ii) the threat of a locally generated tsunami.

- **Respect the power of a tsunami.** A ten-foot tsunami wave will inundate much further inland than a ten-foot wind-generated wave. From a distance, the tsunami wave may not look much higher than a normal wind wave, but it will just keep coming. The tsunami may inundate an area thousands of feet inland.
- A tsunami wave can wrap around the island. Thus, all coastal sectors may be at risk from the wave and not just the side that the tsunami is approaching from. For example, even though a tsunami may be generated by an earthquake near Alaska, north of the islands, residents on the south side of the islands can still be at risk because of wraparound.

- Tsunamis come in a series of waves, each of which may be 15 to more than 30 minutes apart. The first wave is not always the largest, but may be the second, third, or fourth. There may be as many as ten or more waves in the tsunami train. Do not believe that just because an area survived the first wave, it is safe from subsequent waves. Many people have drowned from making this assumption.
- **When a siren sounds indicating an alert, listen to the local radio first for information and follow the instructions carefully.** You may have to scan the radio band. **The siren is your notice to tune to local media such as radio, but it does not necessarily signify a need to evacuate.** Local television is also important but may contain information that is more applicable to one island than another, since broadcasts may be statewide.
- Your county civil defense or emergency management agency, through local radio and television, will give you instructions on when to evacuate. When instructions are issued, move outside of the evacuation zone (see your phone book, yellow pages as of 2011) and to high ground immediately.
- **Avoid driving unless it is essential.** By driving, you may contribute to potential gridlock that places other people and emergency responders in jeopardy. Remember that many roads will be blocked off. Plan to walk to your evacuation area.
- **If your house is outside the evacuation zone, stay there and stay off the road.** You will be more comfortable and will not add to traffic.
- **If your house is inside the evacuation zone, then you must leave.** You will need to evacuate even if your house is elevated on piers and columns and built according to standards for the National Flood Insurance Program.
- **Do not drive to school to pick up your children.** Most schools are outside the tsunami evacuation zone. Those very few public schools in the evacuation zone are required to have emergency plans and have carried out extensive drills to evacuate to higher ground. Trust the teachers to look after their students. The schools will hold onto your children until the all-clear signal is given. This may take several hours.



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- **If you are at work and outside the evacuation zone, stay there.**
 - **On O‘ahu and Maui only:** For concrete- and steel-reinforced buildings with six stories or more, evacuation may be by vertical evacuation (i.e., moving to the building’s third floor or above). This guidance is about to change, so listen to civil defense and emergency management officials for any vertical evacuation situation. **For all other islands, vertical evacuation is a last resort. Moving to high ground outside the evacuation zone is safer than moving to high ground within the evacuation zone.**
 - **For Hawai‘i and Kaua‘i Counties: Vertical evacuation is not recommended. It may be a last resort for a local tsunami in the case when there is little time, but it is better to move inland to high ground.**
 - **Return to your property only when the all-clear signal has been given.** Be prepared to wait several hours. It may take a distant tsunami 4 to 15 hours to reach Hawai‘i and 6 to 8 hours more for the train of waves to pass the state.

Table 3-2 summarizes many of these evacuation scenarios. General guidelines are provided for whether you are at home, work, school, or in your car. Your county civil defense or emergency management agencies may modify these directions during unfolding of the event.

For a locally generated tsunami, there may not be enough time for you to receive a warning to evacuate by siren and television or radio. Therefore, utilize NOW Evacuation Signals based on unusual characteristics of the earthquake, surrounding sounds and observations. For example, if you feel an earthquake strong enough so that you have difficulty in standing, evacuate immediately. See the rest of the NOW signals in Table 3-3.

Table 3-2. Tsunami Evacuation Scenario - General Guidelines

Source & Time	If you are at home	If you are at work	If you are at school	If you are in your car
Local Tsunami Arrival in less than 5 minutes to 40 minutes	If inside the evacuation zone, walk out to evacuate if: (i) siren and (ii) severe ground shaking (strong or long), (iii) earthquake and rumbling noise, (iv) earthquake and siren, (v) water recedes, or (vi) wall of water. If outside the evacuation zone, remain at home.	If inside the evacuation zone, walk out to evacuate if: (i) siren and (ii) severe ground shaking (strong or long), (iii) earthquake and rumbling noise, (iv) earthquake and siren, (v) water recedes, or (vi) wall of water. If outside the evacuation zone, remain at work.	If inside the evacuation zone, walk out to evacuate. Evacuate if: (i) siren and (ii) severe ground shaking (strong or long), (iii) earthquake and rumbling noise, (iv) earthquake and siren, (v) water recedes, or (vi) wall of water. If outside evacuation zone, remain at school.	If there is: (i) siren and instructions to evacuate, (ii) severe ground shaking (strong or long), (iii) earthquake and rumbling noise, (iv) earthquake and siren, (v) water recedes, or (vi) wall of water, then: (a) drive out of an evacuation zone (head mauka); (b) once out, park in nearest parking lot or along the curb or a clear side street and stay there; (c) don't block traffic or abandon your car in the middle of the road. If necessary, pull to the side and walk.
Alaska Arrival 4-5 hours away	If inside the evacuation zone, evacuate when given instructions by the radio broadcast. If outside the evacuation zone, remain at home.	If inside the evacuation zone, evacuate when given instructions by the radio broadcast. If outside the evacuation zone, remain at work.	If inside the evacuation zone, evacuate when given instructions by the radio broadcast. If outside the evacuation zone, remain at school.	Listen to local radio for instructions. In general: (i) drive out of an evacuation zone (head mauka); (ii) once out, park in nearest parking lot or along the curb or a clear side street and stay there; (iii) don't block traffic or abandon your car in the middle of the road. If necessary, pull to the side and walk.
Chile Arrival 15 hours away	If inside the evacuation zone, evacuate when given instructions by the radio broadcast. If outside the evacuation zone, stay at home.	If inside the evacuation zone, listen to local radio as to when you should evacuate. If outside the evacuation zone, listen to local radio to determine if you should stay or when to leave.	If inside the evacuation zone, listen to local radio as to when you should evacuate. If outside the evacuation zone, listen to local radio to determine if you should stay or when to leave.	Listen to local radio for instructions. In general: (i) drive out of an evacuation zone (head mauka); (ii) once out, park in nearest parking lot or along the curb or a clear side street and stay there; (iii) don't block traffic or abandon your car in the middle of the road. If necessary, pull to the side and walk.



Table 3-3 Nature's Own Warning (NOW) Evacuation Signals for Low Lying Coastal Areas*

Nature's Own Warning	Immediate Response	Comment
Feel strong earthquake - have difficulty standing	<p>Protect yourself. If in a building, drop to hands and knees to protect yourself from falling, Cover your head and neck under sturdy table, desk or with arms and hands, hold on to shelter.</p> <p>Evacuate tsunami evacuation zone after shaking stops.</p>	Any strong shaking, as measured by difficulty in standing, requires you to protect yourself, then evacuate. This is top priority. If in doubt if the shaking is strong or not, evacuate.
Feel weak earthquake	<p>Become Alert - Start counting the duration of shaking in seconds. Don't turn your back on the ocean, observe the water and listen for sounds. Prepare to evacuate.</p>	Feeling an earthquake is likely the first sign you receive related to a locally-generated tsunami. Yet not all earthquakes generate tsunamis. People in the County of Hawai'i generally feel 2-3 earthquakes per year. Since 1901, there have been 6 locally generated tsunamis. ¹⁴
Feel earthquake for more than 20 seconds	<p>Evacuate tsunami evacuation zone</p>	As soon as you feel weak shaking, pay attention to the duration by counting to 20 seconds. Pay attention to the ocean for unusual water changes or sounds.
Feel earthquake and rumbling noise from ocean - like thunder, truck noise or a jet airliner	<p>Evacuate tsunami evacuation zone</p>	Sound is often an early warning of imminent danger. ¹⁵ If there is no earthquake, the noise could be real thunder, a truck, or jet.
Feel earthquake and siren	<p>Evacuate tsunami evacuation zone</p>	If no earthquake is felt, the siren is your signal to turn on local TV and radio for further instructions and refer to the civil defense information in the front of your phone book.
Unusual disappearance of water; exposed reef	<p>Evacuate tsunami evacuation zone</p>	A later signal – ocean doesn't always recede. May provide enough evacuation time. Better to evacuate if have earlier signals.
Unusual wall of water	<p>Evacuate tsunami evacuation zone</p>	A later signal – wall of water doesn't always appear first. Even less time to evacuate.

*Based on discussions with James Kauahikaua & Paul Okabo - USGS – Hawaiian Volcano Observatory; Daniel Walker, Senior Seismologist UH Mānoa, Retired & Tsunami Advisor to the Department of Emergency Management for the City and County of Honolulu; Charles McCreery and Gerard Fryer - Pacific Tsunami Warning Center, NOAA; George Curtis - University of Hawai'i & Hawai'i County Tsunami Advisor; and Walter Dudley, University of Hawai'i at Hilo.

To summarize tsunami evacuation: evacuate only if you are in a tsunami evacuation zone (consult the front of your phone book) and one of following happen: **(i)** the siren sounds **and** local radio or television instruct you to evacuate; **or (ii)** you experience one or more of the **Evacuation NOW Signals**:

- (a) strong earthquake – difficulty in standing
- (b) long earthquake – shaking over 20 seconds
- (c) feel earthquake and hear rumbling noise
- (d) feel earthquake and hear siren a few minutes after
- (e) water recedes from ocean, or
- (f) a wall of water approaches

Not all earthquakes will generate a tsunami, so it is important to know the **Evacuation NOW Signals**.

3.5 Preparations Before a Hurricane

The following are some precautions that should be taken well before a hurricane arrives.¹⁶

- Wedge sliding glass doors with a brace or broom handle to prevent them from being lifted from their tracks or being ripped loose by wind vibrations.
- Unplug all unnecessary appliances. Shut off gas valves.
- Turn refrigerators and freezers to their coldest setting.
- If you are going to evacuate, shut off electricity and main switch, and gas and water at their main valves.
- Package your valuables such as jewelry, titles, deeds, insurance papers, licenses, stocks, bonds, inventory, etc., for safekeeping in waterproof containers. Take these with you if you are going to evacuate.
- Outside, turn down canvas awnings or roll them up and secure them with sturdy rope or twine.
- Check door locks to ensure doors will not blow away.



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- Check outdoor items that may blow away or be torn loose; secure these items or move items such as potted plants inside.
 - Store chemicals, fertilizers, or other toxic materials in a safe section or secure area of the premises.
 - Secure propane tanks. They should not be stored near sources of heat (like your water heater or other appliances).
 - Fill the gas tank of your car.
 - Deploy window protections well in advance of the arrival of any winds. For those that have already prepared plywood shutters, partial deployment could begin before there is any official hurricane warning. Closely monitor advisories and warnings to guide your deployment (see Part 4).
 - Ensure that you have a sufficient amount of cash in hand to purchase goods and items if needed following the hurricane, as banks and ATM machines may be inaccessible because of a lack of electricity.

3.6 Evacuation Procedures for a Hurricane

- Your emergency supplies and evacuation kit should already be in place before there is a hurricane watch or warning.
- In your evacuation plan, you should already have decided if you will stay in your house, go to a shelter, or go elsewhere (friend's or relative's house). You should stay in a place that is away from any flood or inundation zones, and that is able to withstand strong winds and rain.
- If you evacuate, you should already have made plans for your pet and prepared your house.
- If you plan to go to a shelter, you should already know the location of two or three shelters that are closest to your residence.
- As a general guideline,¹⁷ you should evacuate if you are:
 - Along low-lying coastal areas;

- Along low-lying areas subject to flooding (for example, near a stream or river);
 - In any evacuation zone (yellow pages) or High Risk Flood Zone as shown on FEMA's Insurance Rate Maps (Figures 2-13 and 2-14), even if your house is built for wave action and flooding. When Hurricane/Tropical Storm Iselle hit Hawai'i County in August of 2014, many residents in coastal Kapoho stayed in their elevated structures. Water-borne debris knocked over their access stairs and would have trapped them if the water was higher;
 - Along ridge lines exposed to strong winds;
 - Living in certain wood frame structures (e.g., single wall without a continuous load path design) or lightly-constructed building.
 - If in doubt go to an officially open hurricane evacuation shelter (Appendix A) or another house such as a friend's or relative's that has a continuous load path connection (Table 4-1 – column 3), is outside any FEMA flood zone (Figures 2-13 and 2-14), and is outside the evacuation zone (yellow pages).
- **Go to a hurricane evacuation shelter only if it is open. Listen to your local radio for shelters that are open to the public. Local television may also have this information, but the information may be specific to a particular island.**
 - Evacuate with your evacuation kit before danger arrives.
 - Not all parts of a school serve as hurricane evacuation shelter. Follow the directions of personnel who are staffing the shelter. If there are no personnel, the shelter is either not open or you are at the part of the facility that is not being used as a shelter.
 - When you get to a hurricane evacuation shelter, you will have a maximum space of 10 square feet. There will be a bare floor. You will have to provide your own bedding, food, water, and other essentials. Your evacuation kit should contain all of these important items.
 - Make the best of the situation and cooperate with the volunteers.



3.7 Evacuation Procedures for a Flood

The general rule if you are evacuating from a flood is to stay away from flood waters and head to higher ground. Stay away from moving water. Even six inches can make you fall or cause your car to stall. Two feet of moving water can move your car. If there is a flash flood and you are caught in your house, go to the second floor or the roof, if necessary.¹⁷

3.8 Evacuation Procedures for an Earthquake

You will not have any warning before an earthquake occurs, since it can occur anytime without advance notice. According to the U.S. Geological Survey, if you are in your house during an earthquake, you should stay there. The U.S. Geological Survey also recommends the following: “Get under a desk or table and hang on to it, or move into a hallway or get against an inside wall. **STAY CLEAR** of windows, fireplaces, and heavy furniture or appliances. **GET OUT** of the kitchen, which is a dangerous place (things can fall on you). **DO NOT** run downstairs or rush outside while a building is shaking or while there is danger of falling and hurting yourself or being hit by falling glass or debris.”¹⁸

If you are outside, get out in the open, away from anything that may fall on you. If you are in your car, stop gradually and pull your car out of the way of traffic. Do not park on or under a bridge or near power lines, trees, or signs. Stay in your car until the shaking stops. When you resume driving, watch out for obstacles that may have fallen on the road. If you are in a hilly area, watch for landslides and boulders.

3.9 Emergency Information and Contacts

For general emergency information, contact your state or local civil defense and emergency management agencies. Use them as a resource when you are planning and preparing your evacuation plan. Do not wait until an emergency when these agencies are responding to hundreds or even thousands of calls. For a list of emergency contacts and contact information, please see Appendix B.

Part 4

Protecting Your Property

Protecting your property and protecting your family go hand in hand, since your house may be able to provide shelter from most weather conditions and perhaps even severe conditions. By strengthening your house, you may be able to shelter in place during a hurricane. The amount of protection your house can provide is limited by a number of factors, some of which are listed below:

(1) The Severity of the Hazard Event. Protecting against a tropical storm or Category 1 hurricane will be much easier than against a major Category 4 or 5 hurricane (Table 2-2). For stronger storms, eliminating all damage is very difficult and the major goal is to significantly lessen the amount of damage. Fortunately, stronger storms are thought to occur less frequently. Also, many small improvements can make a difference.

(2) Your Location. Even though a hurricane may be a Category 1, you could experience much stronger wind. Being on a ridge, for example, amplifies the wind speed. Wind maps have been created for each island that show how topography affects wind speed.¹⁹ They are now part of the new State of Hawai‘i Building Code that was adopted on April 16, 2010.

(3) How Your House Was Built. Today, county building codes require new houses to have hurricane clips that tie the roof to the wall and other connectors that tie the wall to the foundation. This is known as a “continuous load path connection” (see Figure 4-1). Because of this requirement, houses today are generally much stronger than those built before this requirement was in effect (see Table 4-1).

(4) How Your House Was Maintained. Maintenance of your house is important. Painting the exterior every five years protects the wood and prevents rot, which can weaken the structure. Termites can also weaken a wood-framed house. If the wood in the house is rotten or has severe termite damage, it will be more difficult, or even impossible, to strengthen the house in a retrofit. So, it is important to maintain your house by periodic



painting and eliminating termites. Proper maintenance will extend the life of a house in more ways than one.

(5) What You Can Do to Strengthen Your House. Even if your house was not built with double walls or hurricane clips, there are many small steps and some major ones that can be taken to address how your house was initially built and further fortify it. Part 4 concentrates on many of the concepts and measures that can be implemented to strengthen your house, as well as programs in place that provide incentive to encourage you to act.

To guide us on the most cost effective ways to strengthen your house, we can learn from past events. When Hurricane Iniki struck Kaua‘i in 1992, over 41 percent of the island’s 15,200 homes were damaged or destroyed. An approximate breakdown is shown below:

- 1,100 homes totally destroyed
- 1,000 homes were damaged severely (more than 50 percent damage to structure)
- 4,200 homes were damaged moderately (15–50 percent damage to structure) or minimally (less than 15 percent damage to structure)²⁰

For many homeowners, even minor damage of 15 percent or less can be an extreme hardship. After Iniki, FEMA conducted an assessment of building performance and came up with the following statements:

*“Incomplete design and construction for load transfer and improper connections, especially between roof and walls, were found to be the most important factors causing structural failure of buildings due to uplift wind forces.”²¹ This statement relates to **Concept 1: Creating the Continuous Load Path Connection and tying your roof to the wall with hurricane clips to significantly reduce the risk of structural failure to your house.***

*“In many instances, loss of glazing (e.g., glass doors and windows), either from direct wind pressure or from debris impact, resulted in breach of the building envelope, subsequent internal pressures, and progressive structural failure.”²² This statement relates to **Concept***

2: Creating a Wind- and Rain-Resistant Envelope by protecting the openings around your house such as windows.

Had the impacted houses on Kaua‘i been properly designed and fitted with hurricane clips, wall-to-foundation connections, and window protection, perhaps hundreds of homes that were destroyed could have been saved, and thousands that suffered severe, moderate, or minor damage may have instead had moderate, minor, or no damage, respectively. Because the islands of Maui, Hawai‘i and O‘ahu have almost two to eight times the number of houses as Kaua‘i did before Iniki, the risk of catastrophic damage is much greater as is the need to retrofit.

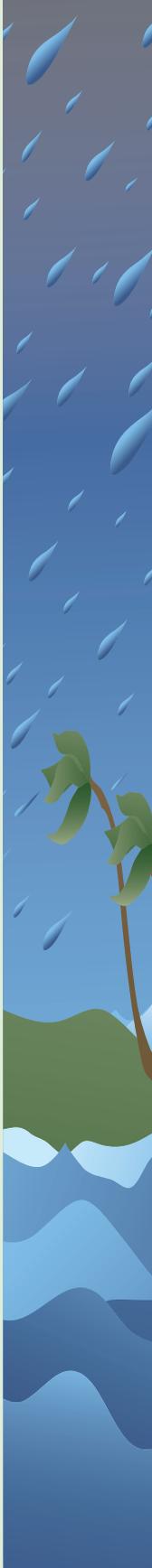
Since there is the potential to prevent significant property damage, a major portion of Part 4 covers: (i) Completing the Continuous Load Path Connection as much as possible, and (ii) Protecting the Wind-and Rain-Resistant Envelope around your house. The importance of these measures is stated in the FEMA Damage Assessment Report for Iniki and reflected in the discounts in hurricane insurance premiums provided by many companies for their implementation (see Section 4.7). Furthermore, new houses built under the Hawai‘i State Building Code, which was adopted on April 16, 2010, will eventually be required to have many of these measures. One goal of Part 4 is to explain to homeowners the many practical measures that can be put into their existing homes through retrofit to make them stronger.

You may be able to perform the work for many of these measures. However, if the work is beyond your capabilities, consider hiring a licensed contractor, structural engineer, and/or architect. Even if you do this work yourself, it is best to contact one or more of these professionals first to obtain guidance and details specific to your house.

4.1

Concept 1: Continuous Load Path Connection

The concept of continuous load path connection is illustrated on the next page. The load path provides a continuous connection between your roof and your house’s foundation and helps to keep the roof from blowing off during a hurricane.



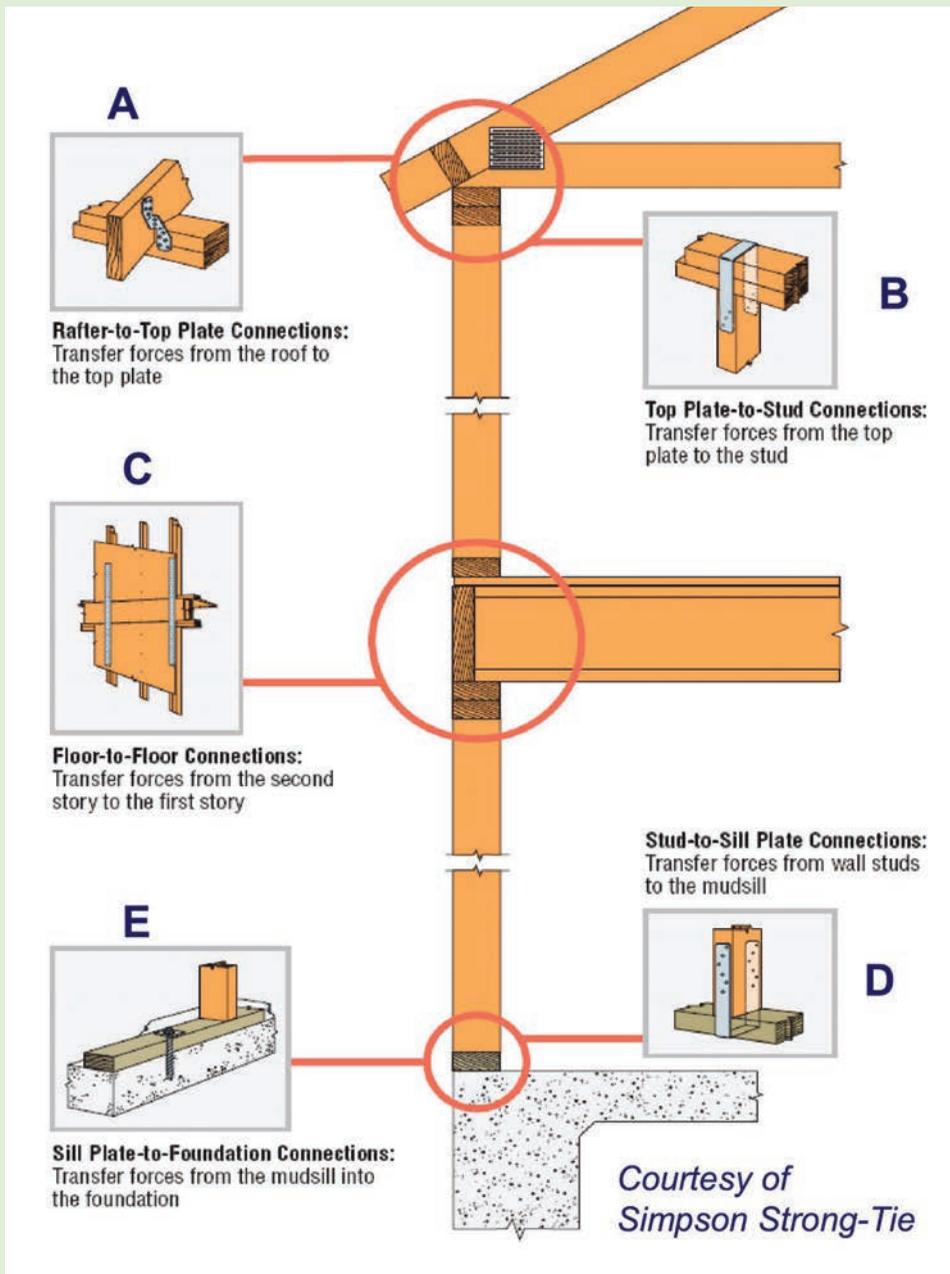


Figure 4-1. Continuous load path connection ties: (i) the roof to the wall, typically with hurricane clips (A) and plate ties (B); (ii) the wall of a higher story to the wall of a lower story with straps (C); and (iii) the wall to the foundation with plate ties (D) and anchors (E). For a single story house, the connections at C are not needed. These connections are in all new houses (see Table 4-1). Older homes usually will not have these features. In many cases, retrofit can easily be done for certain portions.

The continuous load path connection is analogous to a chain: both are only as strong as their weakest link. Historically, the weakest link has often been the roof-to-wall connection. Thus, the hurricane clip was created.

Naturally, all houses have some connection from the roof to the foundation, otherwise they would fall apart. However, only recently, in response to damage from Hurricanes ‘Iwa and Iniki, were much stronger connections required in the form of straps, anchors, and hurricane clips to protect against hurricane winds, as depicted in Figure 4-1.

According to the State Department of Commerce and Consumer Affairs Wind Resistive Devices (WRD) Technical Specification under the former Hawai‘i Loss Mitigation Grant Program (http://hawaii.gov/dcca/ins/consumer/consumer_information/hrt), your house is likely to have the following hurricane protection based on the given benchmark dates:

Table 4-1. Key Dates for Homeowners to Know Regarding the Hurricane Protection

County	Date likely to have hurricane clips	Date likely to have complete load path, including hurricane clips
Kaua‘i	Plans dated 1989 or later; built after 1990	Plans dated 1992 or later; built 1993 or after
O‘ahu	Plans dated 1987 or later; built after 1988	Plans dated 1994 or later; built 1995 or after
Maui	Plans dated 1989 or later; built 1990 or after	Plans dated 1994 or later; built 1995 or after
Hawai‘i	Plans dated 1993 or later; built 1994 or after	Plans dated 1993 or later; built 1994 or after

The dates in column 3 reflect when the requirements for the Uniform Building Code Appendix for Conventional Light-Frame Construction in High Wind were adopted by the various counties. If your house construction falls in the transition period, check with your architect, home builder, or developer to determine if this Appendix was adopted for your





house. It is important to know if your house has: (i) no hurricane clips; (ii) hurricane clips only (column 2); or (iii) hurricane clips along with the complete load path connection (column 3).

New houses have the complete load path connection. For older houses, it is possible to retrofit to add components of the connection (see Figures 4-2 through 4-6). Each house is different but, in general, it will be easier and less expensive to put in hurricane clips than to do the foundation connection. Check with a licensed architect, structural engineer, or contractor to determine what is feasible for your house. In some cases, if you are willing to spend the time and have proper direction from a licensed structural engineer or architect, you may be able to properly install the hurricane clips yourself. See the step-by-step guide for installing the Simpson Strong-Tie Hawaiian Plantation Tie (HPT) clip in the next section.

It is preferable to do both the roof-to-wall connection and the wall-to-foundation connection. However, if the wall-to-foundation connection is too difficult or expensive because of the way your house was built, installing only the roof-to-wall connection is better than doing nothing. Remember, the weakest link for many homes is the roof-to-wall connection and thus the hurricane clip will make that weakest link significantly stronger.

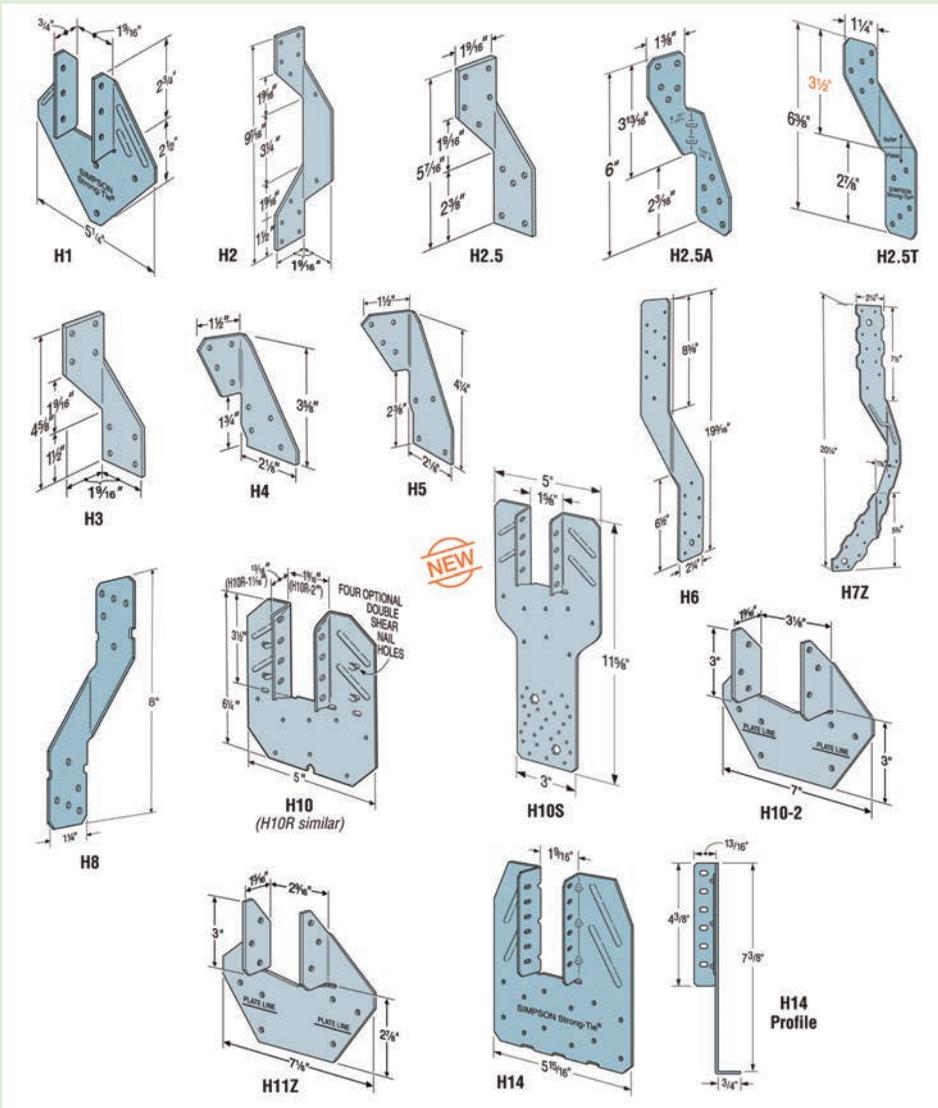


Figure 4-2. There are many different types of hurricane clips. Your licensed architect, structural engineer, or contractor can tell you what is suitable for your house and for the amount of protection you want. The H2.5 and H3 were popular models in Hawai'i but today even stronger clips are being used such as the H10. Figure courtesy of Simpson Strong-Tie.



Figure 4-3. This is the popular H2.5 hurricane clip installed during new construction of houses. Five nails are hammered into the lower beam (or top plate) and five more need to be used for the roof (truss-rafter) connection. A hurricane clip is required for each truss-rafter. Upon completion of this structure, the hurricane clip will be hidden from view. This particular clip costs 30 cents. For less than one dollar in material cost, stronger ones can be installed for both new and retrofit applications.

Figure 4-4. This is an example of retrofitting an existing house, originally built without hurricane clips. The popular H3 clip is used here; four nails attach the clip to the roof (truss-rafter) and four more nails attach to the wall or top plate below. For a retrofit, the clips are exposed on the outside of the house, therefore, both the clip and fasteners should be corrosion resistant and painted to blend with the exterior of the house. With the correct clip and nails you could perform the work or, if you prefer, hire a licensed contractor.²³



Figure 4-5. In this retrofit example, a hurricane clip attaches the roof structure to a horizontal ridge beam, which is in turn attached to the vertical post with a metal strap. This is an attempt to tie the load from the roof to the foundation, or create the complete load path connection. Note that these clips and straps are in the process of being painted. Photo courtesy of Hurricane Protection Services.



Figure 4-6. In some retrofit examples, it is possible to tie a portion of the house to the foundation. Here, a metal strap connects the vertical post to the foundation, which attempts to finish the continuous load path connection from the roof to the foundation. Photo courtesy of Hurricane Protection Services.

As we have seen, it is possible in many older houses to strengthen certain portions of the structure by attempting to complete the continuous load path connection. In particular, the “weakest link” in most houses, the roof-to-wall connection, can be fortified with hurricane clips. You can install the hurricane clips after consultation with a licensed structural engineer or architect, or you can hire a licensed contractor who has experience in this area of work. Other portions of this work, unrelated to the hurricane clips, will most often require the work of a licensed contractor. There are financial incentives offered by some insurance carriers (see Part 4.7), to perform this work. You must follow certain guidelines to be eligible.

You should consult with a licensed structural engineer or architect if your house is being retrofitted, even if you perform some of this work yourself. The structural engineer can go over the cost and benefits of installing the following:

1. Roof-to-wall connections (see also Section 4.1.1);
2. Wall-to-foundation connections (see also Section 4.1.2);
3. Stronger connectors than those required in the current building code; or
4. Using connectors to transfer the load path around windows and doors. The more connections that tie the roof to the foundation the better, but the connections around windows and doors are sometimes incomplete (see FEMA documents - Home Builder’s Guide to Coastal Construction P-499 and Local Officials Guide for Coastal Construction P-762).





4.1.1 Guide to Installing the Hawaiian Plantation Tie Hurricane Clip

The two most important things you can do to strengthen your house are (1) to add hurricane clips; and (2) protect the openings of your house, such as windows (see Section 4.2). This is indicated by the FEMA Building Performance Assessment Team Report after Hurricane Iniki. This message is reinforced by most hurricane insurance companies. Many offer discounts for installing hurricane clips and providing window protection (discounts may also be available for strengthening the wall-to-foundation connection, but this is often more complicated and secondary in importance). The evolution of the building codes reaffirm the need for hurricane clips and window protection, as over the years, the codes have changed to require these items. For example, hurricane clips were required in 1988 to 1994 - depending on the island after Hurricane 'Iwa. The continuous load path connection with hurricane clips was required in 1993 to 1995 - depending on the island after Hurricane Iniki. The continuous load path connection with hurricane clips and window protection (or a safe room) will be required within two years of the adoption of the Hawai'i State Building Code in April of 2010 and its implementing rules.

For houses without hurricane clips, it is encouraged to add them to prevent the roof from blowing off (see Figure 2-6). Every house in Hawai'i should have them as it has never been easier to do. With the introduction of the HPT clip, it is now possible for many single-wall houses with tongue and groove redwood framing or houses with angled or protruding blocking between the trusses or rafters to be fitted with the hurricane clip from the roof to the wall. You can hire a licensed contractor to do the work – estimates on O'ahu and Maui are about \$2,000 for a small single-wall house. For some insurance companies, you may also get a \$200 yearly discount on your hurricane insurance premium.

You can also do the work yourself. The following is a step-by-step guide for an easy installation. Also, a more difficult installation example is given.

Simple Installation Example:

- 1) Consult a licensed architect or structural engineer to confirm the specifications for your house. The guidelines provided in this book are for general installations, but your house may differ.
- 2) Only perform this work if you are capable of doing it. It is not difficult, but labor will be required. It will be more efficient and enjoyable to have two people do the work. It is a fun and worthwhile family project. Time and cost estimates in this book are provided, but proceed at a comfortable and steady pace, with progress made each week. It is not something that can be done when a hurricane watch is called.
- 3) Always think safety. Eye protection with goggles and hearing protection with ear plugs or ear muffs are highly recommended. Ladders should be sturdy and in good condition. Safety and OSHA instructions on the ladder should be read before use and followed.
- 4) Good equipment will make the job more efficient and enjoyable. You do not need professional construction grade tools, but modern tools for the homeowner at the hardware store will suffice.
- 5) Review Figure 4-1(A) for the particular section of the house to be targeted – the roof-to-wall connection. See Figures 4-7 and 4-8 for the specifications on the installation of the clip as well as the roof-rafter, wall connection terminology.
- 6) The HPT clip has a galvanized coating and costs under \$1 each. The stainless steel version is for maximum corrosion resistance and should be used for those living near the coastline. More information on the specifications for each of these clips is provided on the website <http://www.strongtie.com/ftp/fliers/F-HPT09.pdf>.
- 7) Some homeowners do not paint the clips and install them in their original condition (see Figure 4-7). Others paint them to match the color of the rafter, which can be done by first covering with a primer for galvanized metal, or spray Plasti-Dip. This is followed by painting the clip which provides corrosion protection and is more esthetically pleasing.



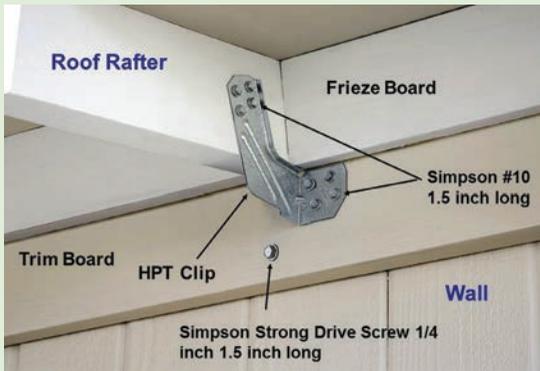


Figure 4-7. The Simpson HPT clip connects the roof rafter to the wall. Because the frieze board protrudes and is at an angle to the wall, the simpler-to-install H3 clip cannot be used (see Figure 4-4). Note the edge of the individual tongue and groove boards for this single wall house. The #10 and ¼ inch screws are screwed into the same board as the HPT clip.

Figure 4-8. For the simple installation in Figure 4-7, a right angle impact driver (A) is used to install the manufacturer's specified connections. Eight Simpson #10 wood screws with 1.5 inch length (B) are used for the top tab (roof connection) and the bottom tab (wall connection). In addition, one ¼ inch Simpson screw with 1.5 inch length (C) provides connection from the trim board to the wall. The HPT clip (D) is shown in its original state, and also primed and painted for the use with black rafters.



When installed as such, the clips provide 400 lbs. of uplift protection per rafter. Thus, even the roof of very old single wall houses can be tied down to the requirements of the building codes in effect at the time of the printing of this book. Although new building codes in 2012 and later will require even higher standards, this is nevertheless significant additional protection for the homeowner. For most single wall houses, two people can do the simple installation in two or three Saturdays with a material cost of under \$300, excluding power tool costs. For those that do not have the time, companies performing this work may be able to do the work for about \$2,000. Costs may vary per island and the size of the house.

Example of a More Difficult Installation:

There may be a few instances where the trim board is missing, or is not of sufficient size to support HPT connection to the wall of the house (see Figure 4-9). In this case, any trim or molding will need to be removed and replaced with at least a 1 inch x 3 inch trim board, or preferably a 1 inch x 4 inch trim board.

1. See examples 1-7 above.
2. The molding under the frieze board can be easily removed with the wood blade from a multi-tool and a nail-trim remover (see Figure 4-10).

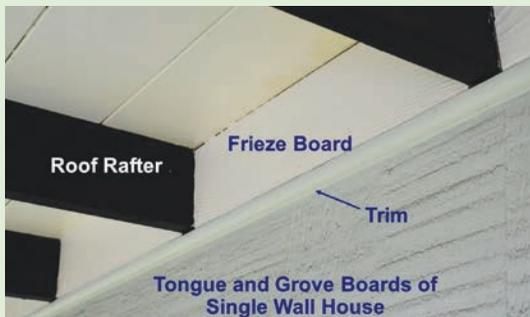


Figure 4-9. In this more difficult installation, the molding needs to be removed and replaced with a trim board so that the 1.5 inch screws don't penetrate through the wall of the single wall house, which is typically $\frac{3}{4}$ to $1\frac{1}{8}$ inch thick.

Figure 4-10. In the case where the molding needs to be removed, this can be easily done with a multi-tool (E) and a nail-trim remover (F).



Figure 4-11. The old trim has been pulled. The new trim is 1 inch x 4 inch exterior wood, treated for termites, painted with primer and two coats of paint that color match the wall. Color matching can be done by taking a small sample to your local hardware store.



Figure 4-12. With the proper trim, the HPT clips can be installed as shown in Figures 4-7 and 4-8. Every rafter is connected to the wall in an esthetically pleasing manner. Adding trim is not hard to do, but will double the installation time. Two people working on this project can complete the job in 3-4 days.

Summary: Almost every single wall house in the state can be strengthened with hurricane clips to prevent your roof from blowing off (see Figure 2-6). The simplest installation is to add the H3 clip in the case where the trim board and frieze board do not interfere (see Figure 4-4). If the H3 clip is used, nails instead of screws are used and an auto hammer or palm nailer would speed installation over the use of a hammer. Where there is protrusion of the frieze board, the HPT clip can be installed in most cases with little preparation (see Figures 4-7 and 4-8). In the rare case where the trim board is not of sufficient size, it should be replaced before installation (see Figures 4-9 to 4-12). While this installation is a little more time consuming it is still straight forward and a worthwhile family project. A licensed contractor can also do the work and estimates on O‘ahu and Maui were about \$2,000 in 2011.

4.1.2 Wall-to-Foundation Connection

Adding the H3 or HPT hurricane clip to tie the roof to the walls provides significant protection. The homeowner can then attempt to complete the continuous load path connection on single-wall houses by tying the wall to the foundation. Historically, this retrofit has been difficult due to the costs and extent of work. Recent reports, however, indicate the homeowner can more easily perform retrofit of the wall-to-foundation connection and provide significant, although not complete protection.

The reader is referred to the State of Hawai‘i Department of Commerce and Consumer Affairs, Loss Mitigation Grant Program - Wind Resistive Devices (WRD) Technical Specification at (http://hawaii.gov/dcca/ins/consumer/consumer_information/hrt) for a design that ties the wall to the foundation and provides protection from both the vertical forces of the wind trying to lift off the roof and the lateral forces of the wind pushing against the walls of the house. This design is for a single-story, single-wall house that uses a post and beam with an elevated first floor.

Additional information on strengthening foundation connections in the earthquake context is found in the report entitled *Structural Seismic Retrofits For Hawai'i Single Family Residences with Post and Pier Foundations*, prepared for the FEMA Hazard Mitigation Grant Program and found at http://www.hilo.hawaii.edu/~nathazexpert/expertsystem/report_forPost_andPierRetrofits-Volume1.pdf. While the major emphasis for an earthquake is horizontal or lateral loads from shaking of the ground, often a retrofit for lateral loads, such as anchorage of the foundation posts, will also be effective in resisting vertical uplift loads caused by hurricane strength winds.²⁴ Once anchorage to the foundation posts is performed, the weight of the house itself will provide some vertical uplift protection. The key is to keep the foundation posts properly anchored with the easier to do seismic retrofit. A licensed professional structural engineer should be consulted to provide the costs and benefits of utilizing either the hurricane retrofit design for wall-to-foundation connection in the WRD technical specification or the seismic retrofit designs for wall-to-foundation connection in the post and pier report. In some cases, the homeowner may be able to do the easier seismic retrofit and still provide more lateral and vertical protection from hurricane winds than if the retrofit was not performed at all. Additional information on the seismic retrofit is found in an online tutorial that guides the user through the retrofit process with a step-by-step questionnaire at: http://www.hilo.hawaii.edu/~nathazexpert/expertsystem/flash_path_fix.php. The tutorial then provides design plans based on the answers provided by the homeowner.²⁵

Summary: The foundation on single-wall houses can be significantly strengthened with a seismic retrofit design that provides protection from the horizontal forces of hurricane winds, and some protection from the vertical forces. Homeowners can also do a more extensive hurricane retrofit which provides protection from the horizontal forces and greater protection from the vertical forces. At the very least, the seismic retrofit should be considered for single-wall, single-level houses and is especially beneficial for houses on the islands of Maui and Hawai'i. It may turn out that the seismic retrofit is cost efficient for houses on O'ahu and Kaua'i because of the significant additional, but not complete, protection provided against hurricane winds. With the addition of the hurricane clip in Section 4.1.1 and the wall-to-foundation improvements in this section, many existing houses can be significantly strengthened by completing as much as reasonably possible the continuous load path connection. This leads us to the second most important item homeowners can do to strengthen their house: protecting the openings of their house (see next section).



4.2 Concept 2: Creating the Wind- and Rain-Resistant Envelope

During a hurricane, it is very important to protect the envelope of your house from wind and rain. Windows can serve to protect that envelope, unless they shatter, which is almost certain to happen if they are unprotected. Taping your windows will not protect that envelope. A broken window during a hurricane can be devastating in several ways: besides the incoming hurricane-force wind and torrential rain in your living room, there is shattered glass and debris from outside flying in. It can make walking in your own house hazardous. Even more importantly, there is the problem with internal pressurization of your house (see Figure 4-13).

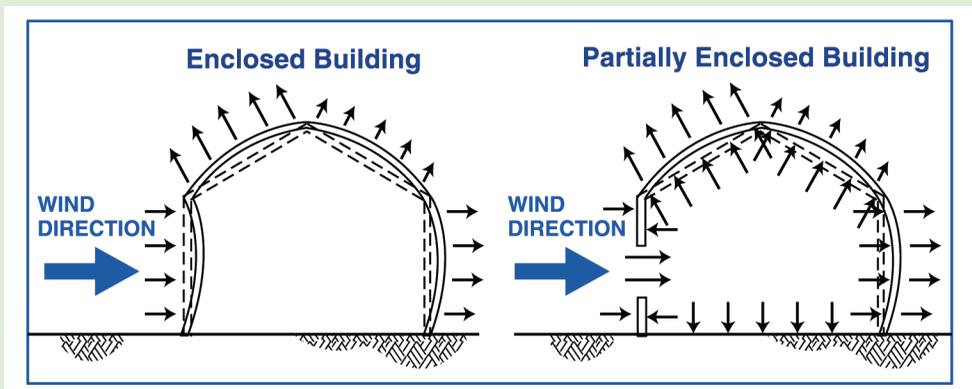


Figure 4-13. This figure illustrates the importance of protecting your windows. The diagram on the left shows a structure with the wind- and rain-resistant envelope intact. Pressure on the walls and roof comes from the outside only. In the diagram on the right, the structure's wind- and rain-resistant envelope has been breached due to a broken window. Now, pressure on the walls and roof comes from the outside and inside. The total amount of pressure increases significantly and can lead to the roof flying off and complete structural failure. Diagram from FEMA's Coastal Construction Manual (2000).

Some reports indicate that a window breach can potentially double the uplift forces on your roof and can significantly increase the chances that your roof will lift off.²⁶ This is why FEMA indicated in their assessment report that breach of the building envelope and subsequent internal pressurization led to progressive structural failure for many houses.

4.3 Window Coverings

Since protecting the wind- and rain-resistant envelope of your house is so important, much information is provided here on window coverings. At this point, it is necessary to go over the various options. All cost estimates provided are based on local estimates for installation, as well as estimates nationwide as of May 2011. Pricing may vary between vendors and may change over time. Check with the manufacturer that the coverings to be installed are tested and approved to meet industry standards for hurricane impact. Always use only licensed contractors and reputable dealers.

4.3.1 Roll-down Shutters

Roll-down shutters permanently attach to a building and are housed above the window.

Figure 4-14. During an emergency, roll-down shutters are quickly lowered as necessary. The shutter is held in place by guide tracks along the sides of the window and secured at the base by a latch on the guide track. For home use, the shutters can be deployed electrically or manually.



Figure 4-15. Roll-down shutters can provide significant protection against hurricane winds. The NOAA National Weather Service facility is protected with these shutters; here, the shutters are fully deployed over the two middle windows, and partially deployed at the sides. The shutters are made from heavy duty aluminum slats.

4.3.2 Bahama Shutters

Bahama shutters consist of a one-piece louvered unit that is attached above the window and propped open to provide shade. As with any permanently installed shutter system, permission may be required from your homeowner's association before you can proceed with installation. The cost of installation for Bahama shutters may range from \$30 to \$40 per square foot.

Figure 4-16. As a storm approaches, the Bahama shutter is pushed down against the wall and anchored with stainless steel bolts through the frame into anchor sleeves in the wall. Photo courtesy of Hurricane Secure.



4.3.3 Colonial Shutters

For many homes in Hawai'i, colonial shutters have many of the advantages of Bahama shutters (quick deployment, aluminum panels), while being more esthetically pleasing.

Figure 4-17. Colonial shutters are typically made of aluminum or fiberglass. During a storm, the panels are closed and secured along the vertical center of the window. During good weather, the panels open along hinges on the side of the window and rest flat against the wall in a decorative manner. Photo courtesy of Hurricane Secure.



4.3.4 Accordion Shutters

Accordion shutters are similar to roll-down shutters in that the shutter unit is housed along the edge of the window. For roll-downs, however, the shutter is housed on the top of the window, while for accordion shutters, it is stored on either side (see Figure 4-18).



Figure 4-18. For deployment during a storm, the panels unfold accordion-style and extend toward the center of the window along pre-installed tracks. Photo courtesy of the Department of Emergency Management, City and County of Honolulu.

4.3.5 Storm Panels

Storm panels were originally made of aluminum or steel, but now come in clear plastic also. The panels are corrugated and overlap for extra strength. Although the panels require storage when not in use, they usually stack together so the amount of space required is minimal. The clear plastic panels are an especially attractive option for homeowners in Hawai‘i since they allow light to go through while providing strong protection from flying debris from a hurricane. They are a good option for the first floor of houses or wherever there is easy access. The panels are relatively inexpensive at \$12-\$14 per square foot.

Figure 4-19. Although installation varies, this example shows panels that slip into a track above the window. The bottoms of the panels are secured by bolts that are permanently attached to the window. Photo courtesy of Hurricane Secure.



Figure 4-20. New versions of the hurricane storm panel come in clear plastic which allows light to be transmitted through the window. Some residents on the Gulf Coast leave these panels up during hurricane season. The tracks are permanently attached to the window and panels attach with the wing nuts. Photo courtesy of Hurricane Secure.



4.3.6 Impact-Resistant Glass Systems

Many hardware and home improvement stores offer the option of purchasing windows with impact-resistant glass as a replacement for existing windows. These windows come in a variety of styles, options, and costs, and are laminated to increase the impact strength of the glass.

Figure 4-21. This attractive window can be fitted with energy-efficient glass, impact-resistant glass, or both. The impact resistant glass consists of a laminate or film sandwiched between two glass panes. The frames are reinforced and the hinges have extra fasteners to withstand high wind events. During a wind event, debris may crack the glass, but the laminate will hold the window pane together in the frame and prevent breaching of the wind- and rain-resistant envelope. After the storm, the glass will need to be replaced.



4.3.7 Laminates

Just as laminates are used to create impact-resistant glass on new windows (see Part 4.3.6, Figure 4-21), they can also be placed over and used to protect existing windows (see Figure 4-22). For laminates, the amount of protection is a function of the thickness of the film, the type of glass being protected (safety glass versus plate glass), the existing frame in which the window is set, and the attachment of the frame to the house structure.



Figure 4-22. Laminated film comes in various thicknesses and strengths. Here the film is applied to an existing window before it is fastened to the frame with silicone structural sealant.

Under the former State of Hawai'i Loss Mitigation Grant Program, laminates qualified for the grant if details were shown how the window attached to the frame and walls, and data was provided showing that the assembly met hurricane impact standards. For some insurance companies, laminates may qualify you for a discount on your hurricane insurance premium. While laminates may provide more protection than unprotected windows, they are not a substitute for shutters, or even impact resistant glass, which is designed around specially strengthened frames.

4.3.8 Hurricane Mesh, Screen, or Fabric

In many cases, it may be difficult to protect your windows because they cover a large area or have an unusual configuration (for example, if they extend out past the wall). In this case, one option would be to use a hurricane screen, mesh, or fabric.

Figure 4-23. Hurricane screen, mesh, or fabric consists of woven polypropylene or a resin coated ballistic nylon. The screen can cover large areas and provide protection to windows with unusual configurations. Light can pass through the fabric so that the area inside is not totally dark. Photo courtesy of the Department of Emergency Management, City and County of Honolulu.

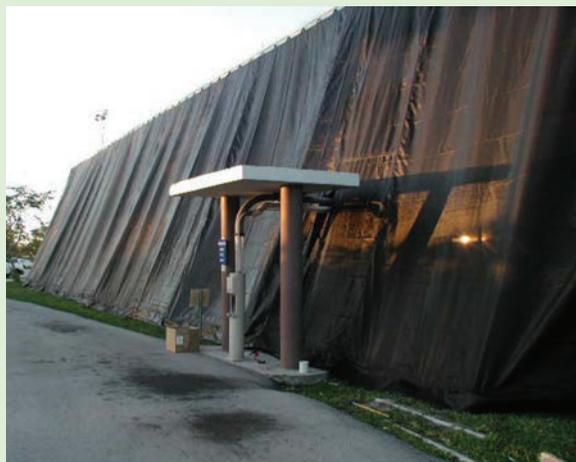


Figure 4-24. Installing hurricane fabric for the large patio windows. The fabric can deflect wind-borne debris. In addition, if properly placed, the fabric can deflect high winds, thereby minimizing uplift of overhangs. The fabric is lightweight and can be put up quickly and taken down by one person. During normal conditions the fabric is rolled up and stored in a bag for easy storage. Photo courtesy of Hurricane Secure.



4.3.9 Plastic Honeycomb Panels

A relatively recent and positive development in providing the consumer with more options for window protection is the introduction of plastic honeycomb panels made of polypropylene (see Figure 4-25). These panels are installed like plywood and have many of the good properties of regular plywood, with few of the disadvantages. The panels are white and translucent.

Figure 4-25. Plastic honeycomb panels have many times the strength of regular plywood and will not warp or rot. It is easy to cut and drill into, and, most importantly, it is light when compared to regular plywood. The major disadvantage is the lack of availability of this material in local hardware stores.



The honeycomb panels also come in a clear plastic version that lets light through. This is an attractive option to other protective systems, which can significantly darken a house when they are in use. However, these panels are more expensive than the opaque version.

4.3.10 Plywood Shutters

One of the most important options for window protection is regular plywood. Plywood is available at almost every hardware store and offers good protection if properly installed. Furthermore, the material cost is the least expensive of any of the other options discussed.

The disadvantages of plywood are that it can rot or warp if stored in a wet or warm area. In addition, plywood shutters are relatively heavy. You will need two people who can lift 30–40 pounds to help with the preparation and deployment of these shutters. Plan accordingly, as it will not help if the people you are counting on to assist you are not available during the deployment. Because of their weight, it would be difficult, or even dangerous, to install plywood shutters if a ladder is needed. Thus, plywood shutters are good for easily accessible windows on the first floor, or windows that can be easily reached by a terrace or patio on upper floors.

Table 4-2 lists the advantages and disadvantages of each type of window covering. In many cases it may be preferable to mix and match the options. For example, use plywood shutters for easily accessible windows, storm panels, or another type of system for windows with medium accessibility, and roll-down shutters or laminates for windows that are difficult to reach. This will allow all windows to be covered at reduced costs.

Table 4-2. Pros and Cons of Various Types of Window Protection

Type of Protection	Pros	Cons	Cost for 3 ft. x 4 ft. window
Impact Resistant Glass	Attractive and energy efficient. Provides security protection. Storm resistant. Many options for styles and costs.	Costs vary widely and can be high. Replaces existing window. While building envelope is protected, cracked glass will likely require replacement.	Wide range in costs - \$360 to \$600 or more
Roll-down Shutters	Easiest to deploy. Good protection.	Most expensive of permanent shutter systems. Needs manual backup for power outages or an emergency power source. May need homeowner association approval.	\$360 to \$600
Bahama Shutters	Easily deployed. Good protection. Provides shade.	Esthetics. May need homeowner association approval. Blocks light.	\$360 to \$480





Type of Protection	Pros	Cons	Cost for 3 ft. x 4 ft. window
Colonial Shutters	Easily deployed. Good protection. Esthetically pleasing.	May need homeowner association approval. Requires room along side of window for shutter to swing out.	\$300 to \$420
Accordion Shutters	Easily deployed. Good protection.	Esthetics. May need homeowner association approval.	\$300 to \$360
Laminates	Storm, security, and UV protection. Energy efficient. Always on. Allows light in. Ideal for hard-to-reach windows.	Other systems are stronger. Need to lock laminate to frame. Frame must be strong. Window may need replacement after storm.	\$180 to \$204
Plastic Honeycomb	Strong system. Lightweight. Reasonable cost. Won't warp or rot.	Storage of panels. Time to create and deploy. While cost is reasonable, still most expensive of deployable systems. Materials difficult to obtain.	\$144 to \$170
Storm Panels	Strong. Removable. Relatively inexpensive permanent shutter system. Good protection for the costs.	Requires adequate space to store panels.	\$144 to \$168
Hurricane Mesh	Covers large areas and windows with unusual configurations. Allows light in. Lightweight.	Need proper supporting locations to fasten geotextile or mesh. Need accessible roofline.	\$144
Plywood	Materials readily available. Easy to install on lower levels.	Not as strong as some other shutter systems (for example, roll-downs, or storm panels). Difficult to install on upper levels.	\$25 to \$35 for materials only

4.4 Installing Plywood Shutters

Because financial cost is a barrier to some homeowners obtaining window protection, plywood shutters are a very attractive option. Yet these shutters take time to create and deploy. Some suggestions summarized here could reduce installation time and make this option even more attractive. There is scattered information on installing plywood shutters; there is more to it than just buying plywood. Some of the tips provided in this section can also apply to the installation of plastic honeycomb panels.

4.4.1 Obtaining Assistance

Although you can install plywood shutters yourself to save on cost, you should still seek the advice of a licensed architect or structural engineer before you start. Professionals can guide you on specific details for your house's windows. The samples provided in this section may pertain to general applications, but remember that each window can be a little different. In addition, this section does not cover difficult applications such as installation for circular or triangular windows. Under the former State of Hawai'i Loss Mitigation Grant Program, grants were possible for window coverings, but drawings for the windows were required by a licensed architect or engineer. Some insurance companies that offer discounts on hurricane insurance premiums for window coverings do not require the drawings.

4.4.2 Material to Use

For plywood shutters, the National Institute for Business and Home Safety and the former State of Hawai'i Loss Mitigation Grant Program recommend that you use at least $\frac{5}{8}$ inch plywood.²⁷ Buy thinner plywood if you cannot handle the weight and your alternative is to do nothing. Thinner plywood is not as strong as $\frac{5}{8}$ inch thick plywood and did not perform as well during destructive Hurricane Andrew in Florida in 1992. Some insurance companies may allow use of thinner $\frac{1}{2}$ inch plywood to obtain a discount in hurricane insurance premiums. Nominal $\frac{1}{2}$ inch or $\frac{7}{16}$ inch is



allowed under the new Hawai‘i State Building Code, which was adopted in April of 2010.

You may want to consider thicker widths such as $\frac{3}{4}$ inch, since it is stronger than $\frac{5}{8}$ inch. The major concern with the thicker plywood is the added weight and difficulty in handling. For most people, $\frac{5}{8}$ inch exterior grade plywood is a good compromise between strength and practicality during installation. Since the new Hawai‘i State Building Code allows a minimum thickness $\frac{7}{16}$ inch plywood for new houses, it is also recommended for existing houses, although $\frac{5}{8}$ inch is the preference because it is stronger.

Your plywood should be treated to prevent termite damage when it is stored. In the past, harmful chemicals were used to treat plywood, but since the mid 1990s, plywood has been treated with borate, which is user-friendly and requires no special handling precautions. Thus, there is no downside to handling the treated wood currently on the market.

If you buy your plywood during the hurricane off-season, there will be plentiful supply and the stores may even cut the wood for little-to-no extra charge. If you wait until a storm is approaching, there will be long lines, limited or no supply, and possibly no cutting service.

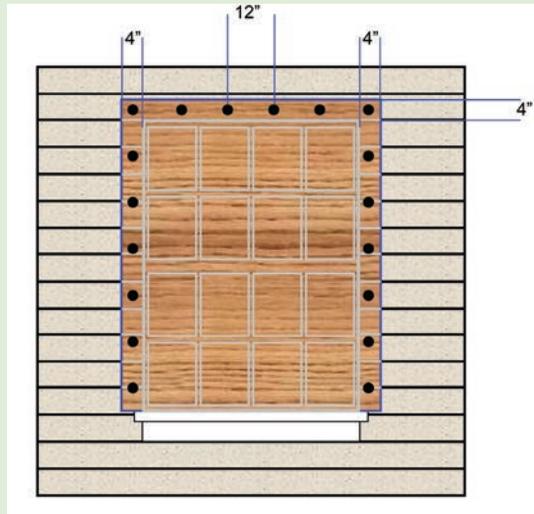
For the installation, you will need a hammer, duplex or double-headed nails, a circular saw, jigsaw, power drill with the proper bits, straight edge, tape measure, and the correct fasteners.



4.4.3 Measuring Your Windows and Cutting the Plywood

When you measure your windows, it is important to have a sufficient overlap of 4 inches on each side of the window.

Figure 4-26. In general, a plywood shutter should have 4 inches of overlap on each side of the window. Thus, if a window is 46 inches wide, the shutter should be 54 inches wide. Figure courtesy of Department of Emergency Management, City and County of Honolulu.



The overlap of the windows is essential because you will be putting the fasteners that attach the plywood: (i) away from the edge of the window; (ii) away from the edge of the plywood; and (iii) directly into the wall studs that surround the window rather than in the siding of the house (see Figure 4-27).



Figure 4-27. For this double-wall house under construction, two 2 by 4's frame the window. When attaching the plywood to the window, the fasteners should go into the 2 by 4's, not the siding. It is always useful to know how your house was built. Take pictures during construction (if possible), review your blueprints, drill small test holes if you have to, or ask your architect or home builder for the details on your window.

Figure 4-28. In this picture of a plastic honeycomb panel installation, the translucent panel reveals the location of the window to be protected (dark area). The panel overlaps the edges of the window by 4 inches and the fasteners are in the underlying studs around the window that are part of the structure of the building. A wood plywood installation would be similar. See FEMA *Protect Your Property From High Winds* (2011), <http://www.fema.gov/library/viewRecord.do?id=3263>



Plywood comes in 4 feet by 8 feet sheets (48 inches by 96 inches). If you need a covering that is 54 inches by 54 inches, you will need to join together two sheets of plywood. The point where two panels meet is called a joint. These joints should be supported and can be connected by 2 by 4's (see Part 4.4.8).

It may take up to two days to measure the windows, buy the plywood, cut it to the proper dimensions, label the panels, and designate where all the fasteners are to be attached. This would be extremely difficult to do when there is an incoming storm. **These preparations need to be done in advance.**



Figure 4-29. After the plywood is cut for each window, each piece should be labeled so that the panels for one window are not mixed with those for another. It would also save time to indicate on the panels, well before any threat of a storm, where the fasteners will be attached.

4.4.4 Fasteners and Attaching the Panels

There are many different ways to attach plywood panels to the window frame. Some literature suggests using nails in an emergency. However, nails would not be as strong as screws and also are very difficult to remove after they are attached. The fasteners shown below are consistent with the Wind Resistant Devices Technical Specification under the former State of Hawai‘i Loss Mitigation Grant Program available at: http://www.scd.hawaii.gov/HazMitPlan/chapter_6_appF.pdf. It is also more stringent than that required under the new Hawai‘i State Building Code, which follows the 2006 International Building Code. Based on the specifications, the following can be utilized for wood-frame houses:

- A) #8 wood screws with 2-inch embedment placed 16 inches apart for panel spans under 4 feet; 9 inches apart for panels between 4 feet and 6 feet; and 6 inches apart for panels between 6 feet and 8 feet; **or you can use**
- B) #10 wood screws with 2-inch embedment placed 16 inches apart for panel spans under 4 feet; 12 inches apart for panels between 4 feet to 6 feet; and 9 inches apart for panels between 6 feet and 8 feet; **or you can use**
- C) ¼ inch lag screw with 2-inch embedment placed 16 inches apart for all panel spans up to 8 feet.

Figure 4-30 shows what the #8 wood screws (A), #10 wood screws (B), and ¼ inch lag screws (C) look like. The duplex or two-headed nail (D) is also shown; this is used to quickly attach the panel to the frame before using one of the wood screws. Thus, D would be used with either A, B, or C. The screws discussed in A, B, or C are self driving and should require no pre-drilling. They can be attached quickly. All should be readily available at a hardware or home improvement store.

Figure 4-30. Key Materials for Fastening Plywood Panels

- A. #8—3-inch wood driving screw. Allows 2-inch embedment.
- B. #10—3-inch wood driving screw. Allows 2-inch embedment.
- C. ¼ Lag Screw—in this case, a 3-inch Simpson self-driving screw. Allows 2-inch embedment. Not all lag screws are self-drilling.
- D. Duplex or two-headed 2-inch nail.



4.4.5 Deployment

If the plywood is: (i) precut, (ii) prelabeled, and (iii) premarked with the location of all fasteners, then deploying and installing them can be relatively quick. First, align the panel, and then hammer a duplex nail into each top corner of the panel to hold it onto the frame. With the panel held by the two duplex nails, your hands are now free to drill the self-driving screws into the appropriate premarked location for the remainder of the panel. The duplex nail can easily be removed later, as they are designed for easy insertion and removal. The duplex nails are only used to hold the panel in place while the wood screws are drilled into place. They are not to be used to fasten the panel itself.

It is very important that you test the deployment and fasteners well before a storm. This will allow you to catch and remedy any unforeseen difficulties. For example:

- 1) Do the screws drive in easily without pre-drilling? If not, consider pre-drilling, which is relatively quick. It is possible for one person to pre-drill with a bit and another to drive in the screws.
- 2) Do the screws strip? Obtain high quality wood screws and, if necessary, pre-drill. Buying good screws will reduce the time of installation.
- 3) Does your hand drill have enough torque, or does it run out of power easily? Consider an 18-volt drill instead of a 12- or 14-volt one. Have extra charged batteries and an extra charger. Also consider using corded power equipment.

Many of these questions can be answered by sales assistants at your hardware or home improvement store.

4.4.6 Other Methods of Installation

It is also possible to permanently attach the fasteners to the frame of the house (see Figures 4-31 and 4-32). This has the advantage that the panels can be more quickly deployed and redeployed without drilling more holes. Attaching the fasteners permanently takes more installation time and many of the materials are not readily available. This method is useful if the panels need to be taken up and down frequently (for example, those in Florida). In Hawai'i, the frequency to deploy would not be as great and thus the method in Part 4.4.5 is acceptable as long as all the panels are fully ready to go well before a storm.



Figure 4-31. Many panels have permanent fastenings attached to the house. (i) After attaching the panel to the frame with two duplex nails (A), (ii) holes are drilled with the bit (B) into the panel and wood frame, (iii) then a spade wood boring bit (C) cuts wider holes into the panel and frame, (iv) and a lag screw anchor with female receptor (D) is screwed into the wood frame, (v) and the panel is attached with washer and wing nut (E).

Figure 4-32. Another method of attachment uses brass grommets (upper left) that are screwed into the wood frame. A wide head screw attaches the panels. Lower screw and washer wing nut are used to hold the two top corners. This is the method used in Figure 4-28.



Permanently installing the fasteners is more complicated, and either a licensed contractor or you can do this. You will, however, need some guidance from a licensed architect or engineer. One of the difficulties in permanently installing fasteners is obtaining the materials. You can look online for hurricane shutter kits with hanger bolts, or seek assistance from a licensed contractor experienced in this area.

4.4.7 Masonry Construction

Under the Wind Resistive Devices Technical Specification at http://www.scd.hawaii.gov/HazMitPlan/chapter_6_appF.pdf, if the screws in section 4.4.5 (#8, #10 or ¼ lag screw) are used for masonry or masonry/stucco, they must be attached using vibration-resistant anchors with a minimum withdrawal of 500 pounds. The Simpson Strong-Tie self-driving screws are not suitable for masonry; tap cons or Simpson Strong-Tie titen screws can be used instead.

4.4.8 Larger Windows

Occasionally, more than one sheet of plywood may be needed to cover a larger window or surface, like a sliding glass door. Other times, you may have two scraps of plywood that can be used to cover one window. If two sheets are joined, the Wind Resistive Devices Technical Specification requires that they be supported. Certain hurricane insurance companies allow unsupported joints if they are less than 4 feet in length. Supporting all joints is stronger and can be done with a 2 by 4. In no case should panels be joined that results in a span of greater than 8 feet. The fastening specifications provided by the former Loss Mitigation Grant Program, the International Building Code and International Residential Code apply to spans up to a maximum of 8 feet.

Figure 4-33. If the joint between the plywood is short, for example, 4 feet to 5 feet in length, a 2 by 4 (really 1 ½ inches by 3 ½ inches) can be used with the **wide end on the outside against the plywood**. Both ends of the 2 by 4 are then attached with screws through the plywood and into the window frame. This will require two 4 or 4 ½ inch lag screws, which may require pre-drilling or similar Simpson Strong-Tie self driving screws (SDS).



Figure 4-34. For larger windows, such as this sliding glass door, two 2 by 4's face outside and are oriented with the **narrow end against the plywood**. The fastening screws attach from the plywood into the 2 by 4 (see Figure 4-35).



Figure 4-35. During assembly of the shutters in Figure 4-34, the two panels to be joined sit atop the 2 by 4's. The outline of the 2 by 4's and all screw locations are marked on the panel. Panels should be cut, labeled, and marked as to all fastening locations before hurricane season. The panels can be quickly attached with wood screws drilled from the plywood panel into the 2 by 4. The panel is then raised with the end near the window being the pivot point. The panel is then attached to the structural framing of the window as shown in Figure 4-34.

For more information on hurricane shutter design using plywood, please refer to: <http://www.apawood.org>

The methods discussed in this handbook are not the only ways to attach panels. The larger your window, the more plywood will flex under hurricane conditions. Thus, you should leave a 4-inch space between the plywood and the window. If there is not enough space, the window may crack, although the plywood would stay in place and continue to serve as a wind and rain resistant envelope. One way to get around this is to build 2 by 4 trim around the window frame and add stiffeners. This may take considerable time and very few window protection installers or homeowners do this. However, if you prefer to do this, refer to the above website.

If there is a hurricane strong enough to flex the plywood panel, then replacing your windows after a hurricane would be a relatively minor task if that is all the damage incurred. Note that during a hurricane, impact-resistant glass and laminated glass would be expected to break, even though the building envelope would stay intact if the glass attachment



to the frame and the frame are strong enough. Thus these systems offer protection to the building envelope, although you must accept that the glass may need replacement after a hurricane (see Table 4-2).

Finally, whenever sliding glass doors or other entry areas are protected, it is necessary to make sure that there are always two storm-protected doors that will be operable for access and exiting at any time.

4.4.9 Storing Plywood Panels

Storage space may be one concern you have about using deployable plywood or plastic honeycomb panels. It is possible to store the panels in your garage if they are organized neatly and stacked together (see Figure 4-36).

Figure 4-36. Once the panels are created, they can be stored in the garage and take up minimal space if stacked neatly along the side of the garage, with the smallest pieces closest to the wall. Panels should be checked each year for any warping or rotting and replaced as needed.



4.4.10 Timing Deployment with a Hurricane Watch or Warning

You should consider getting the panels ready even before a hurricane watch. There's a fine line between installing all the panels and fasteners too early only to have the hurricane veer away, and installing them too late when the wind makes it impossible to deploy. If there is a serious threat of a hurricane but no watch or warning yet, do any minor assembly such as joining two panels (as in Figures 4-34 and 4-35) in advance. Then you can quickly mount the panels to the window if the threat increases.

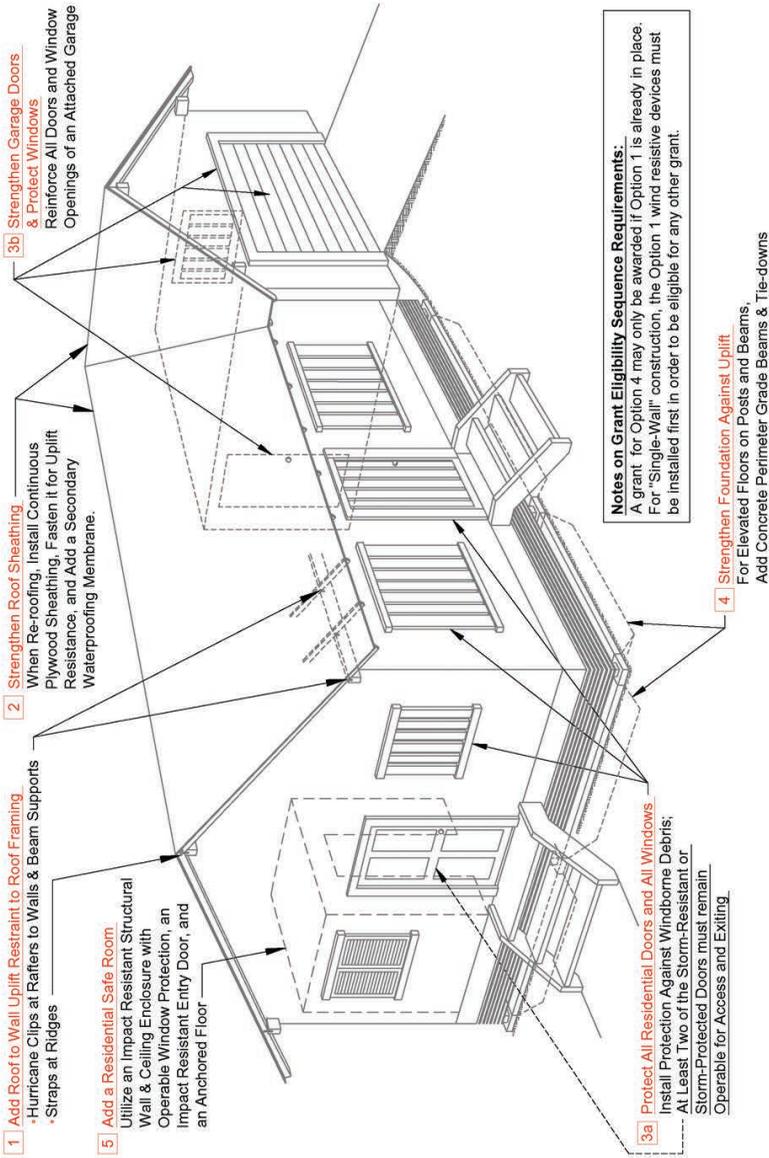
If there is a hurricane watch, do the most difficult installations first. Begin deploying the panels, but not all the fasteners. For example, if you use a #8 screw on a 7 foot panel, the fasteners should be 6 inches apart (see Part 4.4.4). Perhaps attach the four corners and the screws 18 inches apart. Leave one or two windows needed for access or light uncovered but ready to be protected. If the probability of a strike decreases and the hurricane turns away, there will be two-thirds fewer screws to remove and holes to patch with wood putty. If the probability of a strike increases, cover the remaining windows and add the remaining screws so that they are all spaced 6 inches apart. **The goal would be that if a hurricane warning is announced, you could complete full installation to your house in one–two hours simply by installing one or two more window panels and all the remaining screws. It is important to note that all fasteners need to be installed for the shutter to provide the full level of protection during a hurricane.**

This is a general guideline and will vary for each household depending on the situation. For example, you will need more time if you are protecting fifteen windows instead of five. Another consideration is how much help you will have and the number of other tasks you need to do to prepare your house and family. If you are deploying many windows, or have little help, consider beginning deployment a day or two before a hurricane watch. In some cases, there may be homeowners that deploy their panels, and still plan to evacuate to a stronger structure. In this case, time must be allotted to complete deployment and evacuate to your planned location. Planning is key and it is better to have too much time than too little.

4.5 Wind Resistive Devices Technical Specification

Under the former State of Hawai‘i Loss Mitigation Grant Program, grants that covered 35 percent of the cost for properly installed wind resistive devices (WRD) were provided. The program ended on June 30, 2008 but the technical specification implementing the program is still valid and will be referred to as WRD technical specification, available at http://www.scd.hawaii.gov/HazMitPlan/chapter_6_appF.pdf. It will be discussed in Section 4.5 along





OVERVIEW OF THE FIVE OPTIONS OF WIND RESISTIVE DEVICES ELIGIBLE FOR THE STATE LOSS MITIGATION GRANT PROGRAM

Figure 4-37. Options to Strengthen Your House under the Wind Resistive Devices Technical Specification under the former State of Hawai'i Loss Mitigation Grant Program.

with additional FEMA documents providing more guidance to strengthen your home.

Some options in the WRD to strengthen your house include: (i) roof-to-wall connections (for example, hurricane clips), (ii) roof protection, (iii) garage door and window coverings, (iv) foundation upgrades, and (v) a safe room. Figure 4-37 displays the various types of protection that are covered in the technical specification.

4.5.1 Option 1: Roof-to-Wall Connection

Concepts regarding the roof-to-wall connection were covered in Parts 4.1 to 4.1.1. In addition to hurricane clips, the rafters at gable end eaves should be strapped down. Exterior beams supported by corner columns also require strap down. For houses with post and beam roof construction, fasteners should be for roof rafter to roof beams, top of post to horizontal ridge beam, and post to beam connections located at the exterior wall (see Figure 4-5).

You should seek a licensed architect, structural engineer, or contractor to select the proper connectors and nails for your house. You can then do either all or part of this work yourself, or hire a licensed contractor.

4.5.2 Option 2: Roofing

The wind from a hurricane attacks any weaknesses in the roof. Once a weakness is exposed, adjacent areas can be more easily damaged and peeled away. Thus, strengthening the roof is important and it should be considered for new construction and when a roof is replaced after its expected life.

The roofing option involves installing a continuous structural sheathing (for example, plywood where it is missing or damaged; see technical specification at http://www.scd.hawaii.gov/HazMitPlan/chapter_6_appF.pdf). Additional fasteners and a secondary waterproof membrane are required. You should seek a licensed roofing contractor to do this work. See also two FEMA reports: *Home Builder's Guide to Coastal Construction* (publication number FEMA P-499, 2010) (fact sheets 7.1 through 7.6 on roofing) and



Wind Retrofit Guide for Residential Buildings (publication number FEMA P-804, 2010). If reroofing is unlikely to take place in the near future, existing older roofs can still be strengthened with spray polyurethane foam (see Figure 4-38).

As a side note, there are small things you can do to strengthen the roof even if it is relatively new. For example, if you climb in your attic and see nails that are supposed to attach the plywood sheathing to the truss have missed the truss, then you have found what could be a structural weakness. The joint can be strengthened with a wood epoxy or spray polyurethane foam.

Figure 4-38. Spray polyurethane foam is used to add strength between the rafters and the plywood sheathing. This method can be used to strengthen existing roofs, and may negate the need to replace older roofs. It can also be used where fasteners are missing or at the corners of hip style roofs or the ends of gable end roofs, which are especially susceptible to wind forces. See FEMA publication numbers P-499 and P-804.



4.5.3 Option 3: Exterior Opening Protection

Option 3 covers work to protect your windows, doors, and garage. This is to maintain the wind- and rain-resistant envelope of your house. Exterior window protections were covered in Parts 4.3 and 4.4.

Option 3 also covers work to strengthen your garage, which includes the garage door, garage windows, and the entry door. The garage door is a significant weakness during a hurricane due to its large area and the stress it is subject to. Garage door options include: (i) replacement with a stronger door, (ii) horizontal bracing, (iii) vertical bracing, or (iv) other types of a bracing kit. For many garage doors the vertical bracing is a popular and reasonably priced option (see Figure 4-39).

Figure 4-39. Vertical braces such as these can be deployed during high wind events to strengthen the garage door. The braces are secured from the header over the garage door to the fasteners installed in the concrete floor. Deployment and breakdown are about 10 minutes each. The windows have been covered with a laminate film.



More information on the design of new garage doors or retrofitting existing ones can be obtained in FEMA's *Home Builder's Guide to Coastal Construction* (publication number FEMA P-499, 2010), fact sheet 6.2. <http://www.fema.gov/library/viewRecord.do?id=2138>; FEMA's *Local Officials Guide for Coastal Construction* (publication number P-762, 2009), Chapter 10 at <http://www.fema.gov/library/viewRecord.do?id=3647> and the report *Protecting Your Property from High Winds* (2011) at <http://www.fema.gov/library/viewRecord.do?id=3263>. A garage door should meet the design wind speed requirements for the area or be retrofitted to withstand the design wind speed. However, because of structural limitations in the original door, this may not always be possible.

Under Option 3, double entry doors should have slide bolts at the top header and bottom threshold of the inactive door, a deadbolt with at least 1-inch throw length between each door, and three hinges for each door. This requirement is similar to other guidelines for single entry doors, which call for at least three hinges and a bolt long enough that goes into the 2 by 4 framing of the door.²⁸ Whenever entry doors are fortified, at least two of them must be operable for access and exiting at any time.

4.5.4 Option 4: Foundation Uplift Strengthening Restraint

The former grant program required improvements for Option 1 to be in place first. This is in recognition that the roof-to-wall connection is the most critical component for strengthening and completing the continuous load path connection. Once the “weakest link” was taken care of with hurricane clips, the foundation connection can be addressed. The



continuous load path connection was previously covered in this book in Section 4.1, hurricane clips in Section 4.1.1, and wall-to-foundation connections in Section 4.1.2.

4.5.5 Option 5: Safe Room

A safe room is a room designed to withstand winds from the strongest of hurricanes (Categories 3-5). In the WRD Technical Specification, guidance is provided for the design of the room, including ventilation, exiting, occupancy and communication requirements. Additional information can be found in the following documents: ***Taking Shelter From the Storm: Building a Safe Room for Your Home or Small Business*** (publication number FEMA 320 CD, 2008) - <http://www.fema.gov/library/viewRecord.do?id=1536>; ***Design and Construction Guidance for Community Safe Rooms*** Second Edition, (publication number FEMA 361, 2008) - <http://www.fema.gov/library/viewRecord.do?id=1657>; and at the Federal Alliance for Safe Homes, Inc. website <http://www.flash.org> and the safe room website <http://www.highwindsaferooms.org/>.

4.6 The Safe Room: Tax Credits and Cost

On Kaua‘i, residents who build a safe room can get a credit on their property taxes. A house with a safe room gets a \$40,000 safe room exemption in addition to the \$40,000 primary residential tax exemption. For a \$250,000 house on Kaua‘i with a safe room, property taxes are based on a value of \$170,000. This would save you about \$200 per year in property taxes.

For Maui, a quote was received to build a 10 by 10 foot safe room within an existing structure for \$300 per square foot, or \$30,000. Quotes on Kaua‘i to build a safe room for an existing house with a kit range from \$6,000 to \$8,000. The kit could also be used for new houses. For additional information on building a safe room, see the sources listed in Section 4.5.5.

It is much less expensive to build a safe room at the time a new house is built. Estimates received on Kaua‘i ranged from \$2,000 to \$4,000. FEMA notes that while construction costs vary nationwide, the cost to build a safe room inside a new house (which can also double as a master closet,

bathroom, or utility room) ranges from \$7,000 to \$13,500 per Table II-3 in FEMA's *Taking Shelter From the Storm: Building a Safe Room For Your Home or Small Business*, Third Edition (publication number FEMA 320, 2008). In the future, developers may offer the safe room as an option for new home buyers. When the new Hawai'i State Building Code comes into effect for the different counties, new houses will be required to have window coverings or a safe room.

If you are building or buying a new home, ask your architect, developer, home builder, or licensed contractor to provide a low cost estimate to build a safe room in a master closet or other suitable room. A guideline for cost could be the lower end of the estimate provided by FEMA of \$7,000 to \$13,500. The additional cost can then be wrapped into the original home mortgage. With the adoption of the new Hawai'i State Building Code in April 4, 2010, based on the International Building Code, counties will have two years to comply. In the new building code are specifications for a residential safe room which are similar to those in the WRD technical specification. New houses built under this code will need a residential safe room or be required to have window coverings.

Safe rooms should not be built in a high risk flood zone (see Figure 2-12), where there is a threat of moving water. The 100-year flood zone needs to be avoided (V, A zones) and ideally the 500-year floodplain (B, C, X zones). During a hurricane or other high flood event, these areas need to be evacuated because of the water, no matter how fortified the room is against the wind.

In addition, under the new building code, safe rooms should not be built in areas subject to dam failure inundation as determined by the State of Hawai'i Department of Land and Natural Resources.

4.7 Insurance Discounts for Installation of Hurricane Protection

Some, though not all, insurance companies offer substantial discounts in hurricane insurance premiums as an incentive for you to strengthen your house. The discounts are available for:



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1. Roof-to-wall connection (hurricane clips) (typically 10 percent off)
 2. Wall-to-foundation connections (typically 10–12 percent off)
 3. Window coverings (15–18 percent off for single-family houses and 18 percent off for condominiums)

Check with your insurance agent as to the availability of the discounts and the specific requirements needed to obtain them. Each company is different. Conceivably, if all three strengthening measures are performed, as much as 35 percent could be saved on your hurricane insurance premiums. To obtain the insurance discounts you normally must submit a letter from the contractor verifying that the work has been completed. If you build plywood shutters, you must submit pictures to substantiate the work. If your house is already built with the continuous load path connection or has hurricane clips, your premium may already be adjusted based on the date of construction (see Table 4-1).

Consider work to strengthen your home as a home improvement that adds value and longevity to your house while protecting your family and offering peace of mind. With a home improvement or home equity loan to pay for the work, you may be able to get: (i) discounts on hurricane insurance premiums, (ii) a lower interest rate because your house is used as collateral, and (iii) a tax deduction on the interest (check with your accountant or financial institution).

4.8 Protecting Your Property with Insurance

There are two ways to protect your property from natural hazards. The proactive way is to strengthen your house to address the individual hazard. If, however, there is still damage, insurance can provide resources to aid recovery.

Hurricane insurance is important for all residents of Hawai‘i and is a requirement for bank loans. Flood insurance is important for those in a high risk flood zone (Figure 2-14), or if you are subject to periodic flooding, even if you are outside a high risk flood zone. Earthquake insurance is particularly important for those on the island of Hawai‘i and,

to a lesser extent, Maui, yet earthquake insurance may not be available or can be very expensive.

4.8.1 Hurricane Insurance

To protect your property from the winds of a hurricane, you need hurricane insurance. A regular homeowner's policy will not cover hurricanes. Coverage is typically provided in terms of replacement costs, or the cost to rebuild your house. The homeowner typically selects a deductible, for example 1–2 percent of the cost to rebuild.

In Hawai'i, some homeowners do not have hurricane insurance, particularly those without a mortgage. Also, older homes (built before 1959), or those in poor condition may have difficulty in qualifying for hurricane insurance. If insurance is available, it is very expensive and provided by only a few out-of-state companies. Nevertheless the market for insurance is changing, so continue to check. For homes without hurricane insurance, it is even more important to strengthen the house or there could be a major loss during a hurricane. Ideally, you would have both a strong house and insurance.

Hurricane insurance policies vary for each company. Check with your agent and policy for the following:

- Does the policy have an inflation guard that increases each year as the cost to rebuild goes up? Construction costs have steadily increased and may increase even more so after a natural disaster.
- After a hurricane, there can be widespread damage and very few contractors or supplies available to perform repairs. After Hurricane Iniki, it took up to two years for homeowners to repair their homes because of the heavy demand. This surge can result in an increase in cost to rebuild. Some homeowners have chosen to increase their insurance coverage by 30–40 percent to account for an expected spike in future construction costs after a hurricane.
- Additions or improvements to your house made since your initial policy purchase may not be covered, so it is important to have a periodic appraisal so that your coverage is adequate.



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- Check with your insurance agent. Not all companies provide discounts for hurricane protective devices. These discounts over time can pay for the cost of certain retrofit upgrades.
 - Understand your policy. Many policies cover only hurricanes and not lesser events such as a tropical storm or a tropical depression.
 - Make sure you have coverage for: (i) your main structure, (ii) detached structures, (iii) the contents in your house, and (iv) expenses for loss of use (such as hotel stays). Only the first item is required by the banks, so you may not have sufficient coverage for the remaining items.

4.8.2 Flood Insurance

To obtain coverage from flooding, you need flood insurance. Your homeowner's insurance will not cover floods. Your hurricane insurance generally will not cover floods unless wind damage from a hurricane leads to rainfall intrusion and subsequent water entering the house. However, check your policy to be certain.

Flood insurance will cover inundation or flooding for homes near a river, stream, or along the coastline. In addition mudflows (defined as movement of the land by viscous water saturated soil) are covered, but landslides are not (for example, movement of the land by earthquakes). Coastal flooding and flooding from high surf, hurricane, and tsunami inundation are covered.

Consider flood insurance if you are at risk of flooding. Insurance can be obtained even if you are not in a high risk flood zone (see Part 2.4). You may need flood insurance if you live near the coastline, a river, a stream system, any other body of water, or you just have poor localized drainage.

Contact your insurance agent to see if he or she offers federally-backed National Flood Insurance. The following website provides a listing of agents issuing flood insurance for your community: <http://www.floodsmart.gov/floodsmart/>. For low risk areas, the cost of insurance is minimal compared to the protection it can provide.

4.8.3 Earthquake Insurance

To obtain protection from earthquakes, you will need earthquake insurance. Homeowner's policies do not cover earthquakes. Earthquake insurance is especially important for residents on the island of Hawai'i (see Figures 2-11 and 2-12). However, because of the great risk on this particular island, coverage is either very difficult to get, with only a few carriers providing it, or very expensive. Earthquake insurance is commonly offered with high deductibles.

If earthquake insurance cannot be provided, it is even more important that you take steps to strengthen your house and protect the contents from ground shaking. Note that if your house is built to modern standards with a hurricane protection system (i.e., continuous load path connection), this may offer some protection from earthquake shaking.

Thus, strengthening your house for a hurricane also offers protection from an earthquake. This provides additional incentive for homeowners to act, particularly if you live in a high-risk area and cannot obtain earthquake insurance.

4.9 Electrical Issues for Your House

An important publication for you to have is the *Information Handbook for Emergency Preparedness*, distributed by Hawaiian Electric Company (HECO), Maui Electric Company, and Hawai'i Electric Light Company.

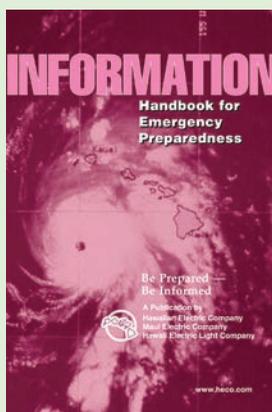


Figure 4-40. The HECO handbook covers many of the topics dealing with electrical safety and power outages. Printed copies can be obtained at the customer service departments for each company. For an electronic version, go to <http://www.heco.com/portal/site/heco>. Click the tab for Safety and Emergency and then the Handbook for Emergency Preparedness link.



The HECO handbook provides useful information on turning off the power to your house in case of an emergency through the main breaker switch, circuit breaker panel, or fuse box. The handbook also describes ground fault circuit interrupters (GFCI) and their role in protecting people from severe or fatal shock. GFCI's are commonly found in kitchens, bathrooms, laundry rooms, or other places where water and electricity are close together. If you don't have them, consider having them installed by a licensed electrician. For coastal properties, any light switches, wiring, and receptacles that are below the design flood elevation should be protected with ground fault protected electrical breakers (*Home Builders Guide to Coastal Construction*, publication number FEMA P-499, 2010 - Fact Sheet 8.3).

The handbook also describes indoor and outdoor electrical safety tips that are applicable during both normal times and emergencies. During a hurricane there could be many downed power lines and associated power outages. The HECO handbook provides tips for negotiating downed power lines as well as a reminder to call 911 if you spot one or if you see someone being shocked. Many tips are provided for dealing with power outages, which is especially important to know during and after a hurricane. For instance, after Hurricane Iniki only 20 percent of the power had been restored on the island of Kaua'i after one month.

4.10 Alternate Power Sources

The following information is meant to supplement the HECO handbook's section on power outages. Before discussing alternate power sources during an emergency, one general suggestion is to make your house as energy efficient as possible as you replace equipment and appliances in your house after they have outlived their normal life. For example, if the lights, a television, or refrigerator need replacing, consider products with the Environmental Protection Agency's (EPA) Energy Star label. These products may cost slightly more, but over their lifetime the energy savings will far outweigh the small initial cost increase.



Figures 4-41. Items with the EPA's Energy Star label use much less energy than standard models. Items include washing machines, dishwashers, refrigerators, freezers, air conditioning units, and light bulbs.

Energy efficient equipment will be especially useful during an emergency, when you may be on alternative forms of power with limited supply. For example, a regular 100-watt lamp running off an emergency power station (essentially built around a car battery) may run for two hours. That same emergency station can run a fuel efficient 23-watt compact fluorescent light almost 8–9 hours with the same light output. Today, even more energy efficient LED lighting using light emitting diodes have now become feasible and bright enough for home use. As another example, a refrigerator with the EPA's Energy Star label can run on a fuel-efficient generator for 16 hours on one gallon of gas. Since most refrigerators do not need to run continuously, it may be possible to run the efficient refrigerator on one gallon of gas for one or two days.

4.10.1 Generators

Some households may require uninterrupted power because of the critical needs of some family members. For example, the elderly, disabled, or sick may require a respirator, dialysis machine, or other medical equipment. Some medicine such as insulin, which is stored over a month, may need to be refrigerated. For many families, the most important major power requirement is to run a refrigerator or freezer. If your family cannot get by without the refrigerator, or there are other critical power needs for medical or other purposes, then you may want to consider a portable generator.

This handbook does not recommend any particular generator or brand. However, if you are considering a generator, look first at your power needs and then at cost, reliability, quietness, and fuel efficiency, among other





factors. You may want to read reviews of generators that are published for the consumer. Some of the factors to consider include:

1. **Power needs.** Size the generator so that it runs the equipment you need or want to run in an emergency. It will make a difference if you just run the refrigerator, versus the refrigerator, lights, and other equipment. Some equipment such as a refrigerator may require 500 watts to run but 1500 watts to start up. Each piece of equipment is different. You can get general guidelines from the manufacturers in the form of charts and tables for equipment power needs. A more accurate estimate, however, is to call your manufacturer or buy an amp meter that measures running and start up wattage or amperage.²⁹ You can also get good advice on sizing a generator from the dealer where you buy the unit.
2. **Fuel efficiency.** During an emergency there will be limited fuel supplies. The amount of power you need and the fuel efficiency of the generator will determine if you need one or two gallons per day instead of five or six.
3. **Quietness.** Generators are usually noisy, but some are quieter than others. If you need to run a generator, your family and neighbors will appreciate if the generator is quiet.

Never run a generator indoors or in your garage because of the buildup of carbon monoxide gas, which cannot be detected by smell. Good ventilation is required. Operate your generator outside and away from open windows. Do not hook up a generator to your house power supply without a licensed electrician. Most people use extension cords to connect to the appliances and the cord should be of sufficient gauge to carry the power load.

A general guideline for running your refrigerator with a generator is to keep the refrigerator and freezer at the coldest setting. Refrigerators may only need to run a few hours a day to preserve food. Using a refrigerator thermometer, you should aim to maintain 40 degrees in the refrigerator compartment and 0 degrees in the freezer.³⁰ Open the refrigerator door as little as possible. If in doubt as to the safety of the food, do not eat it. In general, eat food in the refrigerator first, then the freezer, and, last, your nonperishable supplies in your emergency supplies stock (see Part 3.1).

If you have questions regarding food safety, call the State of Hawai'i Department of Health at (808) 586-4725.

4.10.2 Power Stations

Power stations are found in many hardware stores and may have a radio, flashlight, air compressor, battery jump starter, AC outlet, or DC outlet built around a modified car battery. These units can come in handy during a power outage, since they can form part of your stock of emergency supplies and also provide limited emergency power. For example, many people discovered their wireless phones did not work during the power outages associated with the October 15, 2006, earthquake. If your cordless phone does not work because the base of the unit has no power, a power station could supply electricity so that calls could be made (an alternative is to use a corded phone). It should be noted that after an emergency, there may be many reasons the phone does not work that are beyond your control, such as heavy traffic or loss of function with the phone system.

4.10.3 Inverters

Inverters take the 12-volt DC power from your car battery and convert it to 115-volt AC power that can run household appliances. This can be very important if you need to run power tools in an emergency and the power is out. The inverter will drain your car battery, but look for inverters that have a low battery shutdown feature to prevent total battery drain. You should not run an inverter with the car running unless the manufacturer provides specific instructions with safety guidelines. In addition, the car should not be run indoors or in a garage, but rather in a well-ventilated area if the manufacturer approves of such procedures.

4.10.4 Battery Chargers

Your car battery can be an important source of DC and AC power with an inverter. To keep the car battery charged, you should consider a battery charger as part of your emergency supplies. The charger only works when there is household power, or backup power through a generator, but it can recharge your car battery if it is needed. New units are small and portable



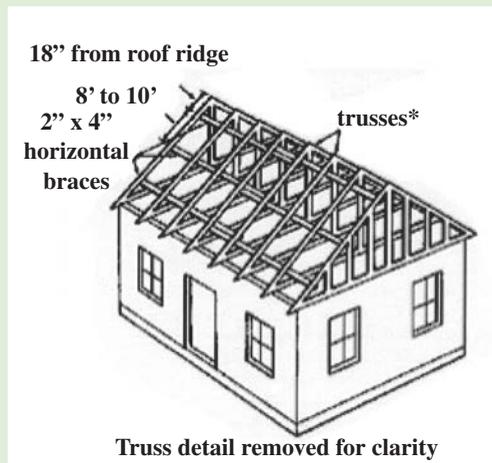
and provide a quick charge to a dead battery in only a few minutes and a total charge in a few hours.

4.11 Other Measures to Protect Your Property

Some additional measures you can take to protect your property during a hurricane include cutting or trimming trees that overhang your house, and also bracing the trusses and rafters in your attic if your house has a gable end.

4.11.1 Truss Bracing

It is possible to significantly strengthen your roof by providing lateral and diagonal bracing to the trusses. This is particularly important for houses with gable end roofs. This bracing can be done simply with 2 by 4's; it is also possible to buy prefabricated metal braces at a home improvement store.



In Figure 4-42, the trusses are built with a peak at the ridge line of the house. The trusses at the end of the house form an A-shaped pattern known as a gable end. During a hurricane, the gable end is subject to great forces from the wind and is likely to tip over, collapsing the other trusses in a domino fashion.

For lateral bracing, 2 by 4's are attached to the trusses that run the length of the roof. The 2 by 4's overlap over two trusses. Braces should be 18 inches from the center ridge and the base. They should be about 8 feet to 10 feet apart from each other. You or a professional can do this work. You should use two 3-inch, 14-gauge wood screws or two 16d (16 penny nails are used for each truss).³¹

Figure 4-43. In this application of lateral bracing, the 2 by 4's are 18 inches from the ridge and connect to horizontal members that attach the opposing trusses. Not all roofs will have the horizontal members. The 2 by 4's are connected with two #14 3-inch screws (A) and overlap over two trusses (A and B). The end is connected to the gable end with an angle or L bracket (C).



Another important type of bracing for your gable end involves making diagonal braces (see Figure 4-44). Diagonal braces provide additional support against collapse of the gable end. (See FEMA's *Protect Your Property From High Winds* (2011), <http://www.fema.gov/library/viewRecord.do?id=3263>).

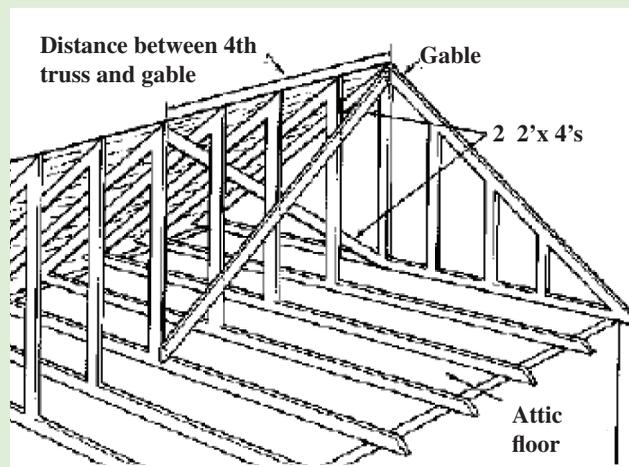


Figure 4-44. Diagonal braces form an X pattern from the top center of the gable end to the bottom center of the fourth truss and from the bottom center of the gable end to the top center of the fourth truss. The same screws as for lateral bracing are used.

In certain instances when large lumber is not practical to install in the attic, additional designs for gable end bracing can be found in *Wind Retrofit Guide for Residential Building* (publication number P-804, 2010; Figures 4-15 and 4-16) *Home Builder's Guide to Coastal Construction* (FEMA P-762, 2009) (see Fact Sheet 9.2).

Hip-style roofs do not need as much bracing, as they are aerodynamically superior and they have the bracing built into the design of the structure. While gable end roofs have a flat end that is A-shaped, hip-style roofs have all four sides of the roof sloping towards the center of the roof.

4.11.2 Tree Trimming

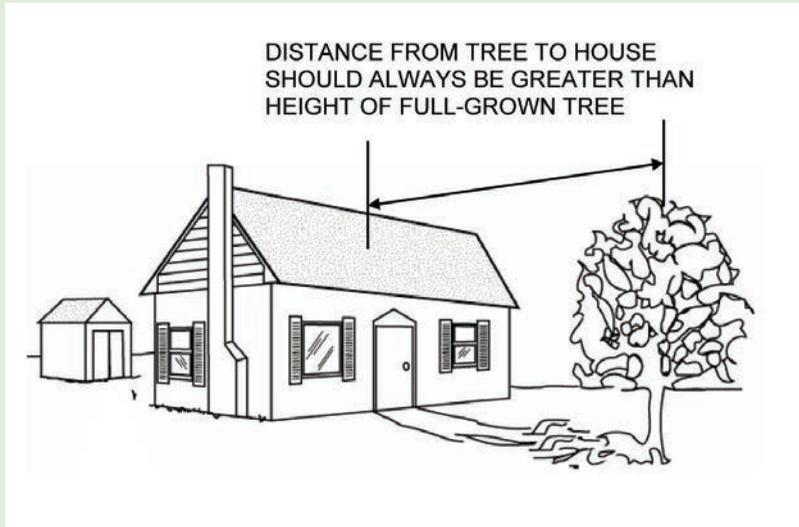


Figure 4-45. FEMA recommends that the distance between a tree and your house should always be greater than the height of the full-grown tree. This is to prevent trees from falling on the roof.³²

Considerable damage to your house can be done if tree limbs or branches fall onto or impact your house. If it is not possible to remove a tree, at least trim it so that air can flow through. If the branches and vines are so thick that the air cannot flow through, the tree will act like an umbrella and catch the wind before it topples over. Generally, you should hire a licensed tree trimmer to perform this work.

When Iselle hit Hawai‘i County as a weakened tropical storm on August 7-8, 2014 (Figure 2-8), many houses were damaged by Albizia trees, which topple over easily in less than hurricane strength winds. These trees are located in other counties and their potential to damage nearby houses, infrastructure, and power lines should be evaluated.

4.12 Earthquake Retrofit

The need to retrofit houses to address earthquakes is greatest for Hawai'i County and becomes less urgent with each island to the northwest (see Figures 2-9 and 2-10). The reader is referred to the report *Structural Seismic Retrofits For Hawai'i Single Family Residences With Post and Pier Foundations* Volume 1 (2009) Prepared for the FEMA Hazard Mitigation Grant Program (Ian Robertson and Gary Chock, 2009). In this report, three simple retrofit designs are provided to strengthen post and pier foundations, which are common throughout the islands.

As discussed in Part 4.8.3, retrofitting your house so that it has a continuous load path connection will reduce the risk of damage from both a hurricane and earthquake. The major concern during an earthquake are the horizontal forces from the earth shaking. The major concern during a hurricane is the horizontal forces of wind pushing against the structure, and the vertical uplift forces from roofs that act like airplane wings in the strong wind. The retrofit designs provided in the post and pier report can address the horizontal forces of hurricanes and earthquakes, and significantly reduce the risk of damage from uplift forces with a hurricane. They are simple enough so that using the report and an online tutorial at http://www.hilo.hawaii.edu/~nathazexpert/expertsystem/flash_path_fix.php, homeowners with some construction experience can do the retrofit themselves.

Ideally, for complete uplift protection between the walls and foundation, the horizontal and vertical loads should be transferred from the foundation blocks to the ground, as shown in the WRD technical supplement. This is a more complicated and expensive retrofit that will require the assistance of a structural engineer. Additional resources for consideration include the *Homebuilders Guide to Earthquake Resistant Design and Construction* (publication number FEMA P-232, 2006) at <http://www.fema.gov/library/viewRecord.do?id=2103> and *A Step-by-Step Guide to Retrofit Your Home for Earthquakes* (2007) at <http://www.strongtie.com/literature/f-plans.html>.

In summary, significant earthquake protection can be provided with the simplified retrofits in the post and pier report. Significant hurricane protection can be provided with the simple retrofits in the post and pier





report, along with the addition of hurricane clips (see Sections 4.1 and 4.1.1) and window coverings (see Section 4.2).

In addition to protecting your house from earthquakes, consider protecting the contents in your house. See FEMA's *Protect Your Property from an Earthquake* (2008) at <http://www.fema.gov/library/viewRecord.do?id=3260>. Section 4.12 of the report covers: anchoring large equipment, bookcases, file cabinets, propane tanks and gas cylinders; bolting sill plates to the foundation; bracing cripple walls; securing drawers, cabinets, picture frames, mirrors, computers and appliances; and using flexible connections for gas and water lines.

4.13 Flood Retrofit

Some excellent sources of information for protecting your property from flooding are found in FEMA's *Coastal Construction Manual: Principles and Practices of Planning, Siting, Designing, Constructing, and Maintaining Residential Buildings in Coastal Areas*, Third Edition, (publication number FEMA 55CD, 2011), <http://www.fema.gov/residential-coastal-construction> and also *Home Builder's Guide to Coastal Construction* (publication number FEMA P-499, 2010), <http://www.fema.gov/library/viewRecord.do?id=2138>.

You should also familiarize yourself with the FEMA report *Protect Your Property from Flooding*, found at:

<http://www.fema.gov/library/viewRecord.do?id=3262>.

This report covers:

- (1) Raising electrical system components;
- (2) Anchoring fuel tanks;
- (3) Installing sewer back flow valves; and
- (4) Building with flood resistant materials.

In addition, *Homeowner's Guide to Retrofitting*, Second Edition, (publication number P-312, 2009), <http://www.fema.gov/library/viewRecord.do?id=1420> covers:

- (1) Elevating your home, which is an expensive but effective option;
- (2) Wet flood proofing a building;

- (3) Relocation and other methods; and
- (4) Protecting service equipment.

In many cases flooding on a property can be caused by poor drainage. If this is the case, it may be of great benefit to address the drainage issue with the professional advice of a licensed civil engineer.

4.14 Licensed Contractors

Selecting a contractor to do your work is very important. This handbook does not recommend or endorse any particular company. It is up to you to select the companies and verify their record. Make sure the contractor is licensed, insured, and has not received complaints. You should always ask for a list of referrals. You can check the contractor's record at the State of Hawai'i Department of Commerce and Consumer Affairs, Regulated Industries Complaints Office. The number is (808) 587-3222.

The City and County of Honolulu Department of Emergency Management has a list of contractors performing work in the area of hurricane protection. This compilation is not a recommendation or endorsement of any particular company, but a listing of what company is performing work in this area so that you can follow up with further investigation. The number at the department is (808) 723-8960.

You can also look in your yellow pages using the key word "hurricane" for locating contractors who perform work in this area. When selecting a company, it is still necessary to do the proper due diligence and check their qualifications (see above).

Hiring a licensed contractor is very important. After Hurricane Iniki, many families lost savings and insurance funds as a wave of unlicensed contractors flooded the impacted area in search of work. A good resource to find a licensed contractor is the particular organization on each island that deals with contractors. These organizations can provide direction and are listed below:

Contractors Association of Kaua'i: (808) 246-2662

Maui Contractors Association: (808) 871-5733





Hawai‘i Island Contractors Association: (808) 935-1316

General Contractors Association of Hawai‘i: (808) 833-1681

Before you have extensive work performed, you should see a licensed architect or structural engineer, depending on the particular work that needs to be done. Even if you perform the work yourself, a licensed professional should be consulted for initial guidance, since every house is slightly different.

Useful Links

This page contains links to websites where you can get more information on planning for a natural hazard.

American Red Cross—Hawai‘i State Chapter
<http://www.hawaiiiredcross.org/>

Department of Emergency Management, City and County of Honolulu
<http://www.oahuDEM.org>

Electrical Safety Foundation
<http://www.esfi.org>

Federal Alliance for Safe Homes
<http://www.flash.org>

FEMA Building Code Resources
<http://www.fema.gov/building-code-resources>

FEMA Building Codes Toolkit
<https://www.fema.gov/media-library/assets/documents/30423>

FEMA Building Science Branch
<http://www.fema.gov/building-science>

FEMA Building Science Toolkit CD
<http://www.fema.gov/media-library/assets/documents/92819>

FEMA Coastal Construction Manual: Principles and Practices of Planning, Siting, Designing, Constructing, and Maintaining Residential Buildings in Coastal Areas
<http://www.fema.gov/residential-coastal-construction>

FEMA Home Builder’s Guide to Coastal Construction Technical Fact Sheet Series
<http://www.fema.gov/library/viewRecord.do?id=2138>

FEMA Local Officials Guide for Coastal Construction
<http://www.fema.gov/library/viewRecord.do?id=3647>

FEMA Recommended Residential Construction for Coastal Areas: Building on Strong and Safe Foundations
<http://www.fema.gov/library/viewRecord.do?id=1853>





Hawai‘i Flood Hazard Assessment Tool
<http://gis.hawaiinfip.org/fhat>

Hawai‘i County Civil Defense
<http://www.scd.hawaii.gov>

Hawai‘i Emergency Management Agency (formerly State Civil Defense)
<http://www.scd.hawaii.gov/>

Hawaiian Electric Company, Inc.
<http://www.heco.com>

Insurance Institute for Business and Home Safety
<http://www.disastersafety.org>

Kaua‘i County Civil Defense
<http://www.kauai.gov/civildefense>

Maui County Civil Defense
<http://www.mauicounty.gov/departments/CivilDefense/>

National Weather Service Honolulu
<http://www.prh.noaa.gov/hnl/>

Official Site for the National Flood Insurance Program
<http://www.floodsmart.gov>

NOAA Pacific Services Center
<http://www.csc.noaa.gov/psc/>

NOAA Weather Radio
<http://www.weather.gov/nwr/>

Pacific Disaster Center
<http://www.pdc.org>

Pacific Tsunami Warning Center
<http://www.prh.noaa.gov/ptwc/>

State of Hawai‘i, Coordinating Office for the National Flood Insurance Program
<http://www.hidlnr.org/eng/nfip/>

University of Hawai‘i Sea Grant College Program
<http://seagrant.soest.hawaii.edu>

Appendix A

Hurricane Evacuation Shelters

Updated June, 2013

During an emergency or threat of disaster, civil defense and emergency management information will be broadcast over local radio and TV stations. When an evacuation is necessary these broadcasts may include information about the location of hurricane evacuation shelters in affected areas. More information, including the location of shelters designated for people with special health needs, and facilities for household pets may be broadcast, as well as when volunteers will be available to open shelters and direct evacuees to the appropriate areas.

Since hurricane evacuation shelters do not stock supplies, please bring your evacuation kit (see Section 3.2).

Please review this statewide list of hurricane evacuation shelters and note the two or three closest to your house. The shelters are listed by county.

Hurricane evacuation shelters may not be open during evacuations for a Tsunami Warning. Your local civil defense or emergency management agency will provide locations of tsunami evacuation centers or assembly areas through local media.

For more information on evacuation and shelter information contact your local civil defense or emergency management agency (see Appendix B).

O‘ahu

North Shore (Ka‘ena Point–Kahuku)

Waialua High and Intermediate [S/P]

Leeward Coast

(Mākuā–Waipahu and Vicinity)

August Ahrens Elementary

Barbers Point Elementary

Campbell High [S/P]

‘Ewa Beach Elementary

‘Ewa Elementary [S]

Holomua Elementary

Honowai Elementary [S]

‘Ilima Intermediate [S/P]

Ka‘imiloa Elementary

Kaleiopu‘u Elementary

Kamaile Elementary

Kanoelani Elementary

Kapolei Elementary [S]

Kapolei High [S]

Leihoku Elementary

Mākaha Elementary

Makakilo Elementary

Mauka Lani Elementary [S]





Nānākuli Elementary
Nānākuli High & Intermediate [S/P]
Pōhākea Elementary
Wai‘anae Elementary
Waipahu Elementary [S/P]
Waipahu High [S/P]
Waipahu Intermediate [S]

Central O‘ahu (Wahiawā–Mililani and Vicinity)

Helemano Elementary [S]
‘Iliahi Elementary
Ka‘ala Elementary [S]
Kīpapa Elementary [S]
Leilehua High [S/P]
Mililani High [S/P]
Mililani ‘Ike Elementary
Mililani Mauka Elementary
Mililani Waena Elementary [S]
Mililani Middle [S/P]
Mililani-Uka Elementary [S]
Wahiawā Elementary [S]
Wahiawā Middle [S]

Pearl City–Salt Lake and Vicinity

‘Aiea Elementary [S]
‘Aiea Intermediate [S]
‘Aiea High [S/P]
Āliamanu Elementary [S]
Āliamanu Middle [S]
Hālawa District Park
Highlands Intermediate [S/P]
Lehua Elementary [S]
Makalapa Elementary [S]
Manana Elementary [S]
Moanalua Elementary [S]
Moanalua Middle [S/P]
Moanalua High [S/P]
Momilani Elementary

Nimitz Elementary
Palisades Elementary [S]
Pearl City District Park
Pearl City Elementary
Pearl City High [S/P]
Pearl City Highlands Elementary [S]
Pearl Harbor Elementary
Pearl Harbor Kai Elementary
Pearlridge Elementary [S]
Radford High [S/P]
Red Hill Elementary [S]
Salt Lake Elementary [S]
Waiau Elementary
Waimalu Elementary [S]
Webling Elementary

Salt Lake–Punchbowl and Vicinity

Central Middle [S]
Dole Middle [S]
Farrington High
Fern Elementary
Ka‘ahumanu Elementary
Ka‘ewai Elementary [S]
Ka‘iulani Elementary [S]
Kalākaua Middle [S/P]
Kalihi Elementary
Kalihi-Kai Elementary [S]
Kalihi-Uka Elementary [S]
Kalihi Valley District Park
Kalihi-Waena Elementary [S]
Kapālama Elementary [S]
Kauluwela Elementary
Kawānanakoa Middle [S/P]
Lanakila District Park
Lanakila Elementary [S]
Likelike Elementary
Linapuni Elementary [S]
Ma‘ema‘e Elementary [S]
Nu‘uanu Elementary

Pauoa Elementary
Pu‘uhale Elementary [S]
Roosevelt High [S/P]
Royal Elementary [S]
Stevenson Middle [S/P]

Punchbowl–Wai‘alae and Vicinity

Ali‘iōlani Elementary [S]
‘Ānuenue Elementary
Hawai‘i Convention Center [S]
Hōkūlani Elementary [S]
Jarrett Middle [S/P]
Ka‘ahumanu Elementary
Kaimukī High [S/P]
Kaimukī Middle [S/P]
Kūhiō Elementary
Liholiho Elementary [S]
Lincoln Elementary
Lunalilo Elementary
Mānoa Elementary [S]
McKinley High [S]
Neal Blaisdell Center [S]
Noelani Elementary [S]
Pālolo Elementary [S]
Wai‘alae Elementary [S]
Waikīkī Elementary
Washington Middle [S/P]
Wilson Elementary [S]

‘Āina Haina–Hawai‘i Kai and Vicinity

‘Āina Haina Elementary [S]
Haha‘ione Elementary [S]
Kahala Elementary [S]
Kaiser High [S/P]
Kalani High [S/P]
Kamiloiki Elementary [S]
Koko Head Elementary [S]
Niu Valley Middle [S]

Windward Coast (Kahuku–Makapu‘u Point)

‘Āhuimanu Elementary [S]
Aikahi Elementary
Benjamin Parker Elementary
Brigham Young University of Hawai‘i [S]
Castle High [S/P]
Enchanted Lake Elementary [S]
He‘eia Elementary [S]
Kahalu‘u Elementary [S]
Kahuku High and Intermediate [S]
Kailua Elementary [S]
Kailua High [S/P]
Kailua Intermediate [S]
Kainalu Elementary
Kalāheo High [S/P]
Kāne‘ohe Elementary
Kapunahala Elementary
Keolu Elementary
King Intermediate [S/P]
Lanikai Elementary [S]
Maunawili Elementary [S]
Pope Elementary [S]
Pū‘ōhala Elementary
Waiāhole Elementary [S]
Waimānalo Elementary and Intermediate [S/P]

Maui

Hāna

Hāna High

Kahului/Wailuku/Waihe‘e

Baldwin High [S/P]
‘Īao Elementary [S]
Kahului Elementary [S]
Lihikai Elementary [S]
Maui High [S/P]
Maui Waena Intermediate [S/P]





University of Hawai‘i Maui College
Waihe‘e Elementary [S]
Wailuku Elementary [S]

Kīhei/Mākena

Kamali‘i Elementary [S]
Kīhei Elementary [S]
Lokelani Intermediate [S/P]

Lahaina (West Maui)

Lahaina Intermediate [S]
Lahainaluna High [S]
Princess Nahi‘ena‘ena Elementary [S]

Upcountry

Haiku Elementary
Kalama Intermediate [S/P]
King Kekaulike High [S/P]
Makawao Elementary [S]
Pa‘ia Elementary [S]
Pukalani Elementary [S]

Hawai‘i

North Kohala District

Kohala High and Elementary [S]
Kohala Intermediate [S]

South Kohala District

Waikoloa Elementary [S]
Waimea Elementary [S]
Waimea Middle
Waimea State Office Building

North Kona District

Hōlualoa Elementary
Kahakai Elementary [S]
Kealakehe Elementary [S]

Kealakehe High [S/P]
Kealakehe Intermediate [S]

South Kona District

Ho‘okena Elementary
Konawaena High [S/P]

Ka‘ū District

Ka‘ū High [S/P]
Pahala Elementary [S/P]

Hāmākua District

Honoka‘a High and Intermediate [S/P]
Kalaniana‘ole Elementary [S/P]

South Hilo District

E B de Silva Elementary
Hilo High [S/P]
Hilo Intermediate [S]
Kaumana Elementary [S]
Waiākea Elementary [S]
Waiākea High [S/P]
Waiākea Intermediate [S]
Waiākea Waena Elementary [S]

Puna District

Kea‘au Elementary
Kea‘au High [S/P]
Kea‘au Middle [S/P]
Keonepoko Elementary [S]
Mountain View Elementary [S]
Pāhoa Elementary [S]
Pāhoa High and Intermediate [S/P]

Kaua‘i

Central

Kamakahahei Middle [S]
Kaua‘i Community College
Kaua‘i High [S/P]
Kaua‘i Humane Society [pets only]
Kaua‘i War Memorial Convention Hall
King Kaumuali‘i Elementary [S]
Wilcox Elementary

Eastside

Kapa‘a Elementary School [S]
Kapa‘a High School [S/P]
Kapa‘a Middle School [S/P]

North

Kīlauea Elementary School
Kīlauea Neighborhood Center [S]

South

‘Ele‘ele Elementary School [S/P]
Kalāheo Elementary School [S/P]
Koloa Elementary School [S]

West

Waimea Canyon Elementary and
Middle [S/P]
Waimea High [S/P]

Moloka‘i

Kaunakakai Elementary
Kilohana Elementary
Kualapu‘u Elementary
Moloka‘i High [S]

Lāna‘i

Lāna‘i High [S]

When evacuating to a shelter don't forget your family's evacuation kit and be sure to make arrangements for your family pets.

Facilities designated to serve as special needs shelters provide limited support to persons with special health needs. Special health needs evacuees must either be capable of taking care of their own needs or be accompanied by a caregiver. Pet friendly shelters are co-located with some general population shelters. Household pets entering a pet friendly shelter must be caged for safety and owners should provide water and food for their pets.

Legend:

**S = Special Needs +
General Population**
**P = Pet Friendly +
General Population**
**S/P = Special Needs + Pet Friendly +
General Population**





Appendix B Emergency Contacts

Department of Emergency Management—City and County of Honolulu

650 South King Street
Honolulu, HI 96813
Ph: (808) 723-8960
Fax: (808) 524-3439
<http://www1.honolulu.gov/dem/>

Hawai‘i Civil Defense Agency

920 Ululani Street
Hilo, HI 96720
Ph: (808) 935-0031
Fax: (808) 935-6460
http://www.hawaii-county.com/directory/dir_defense.htm

Kaua‘i Civil Defense Agency

3990 Kā‘ana Street, Suite 100
Līhu‘e, HI 96766
Ph: (808) 241-1800
Fax: (808) 241-1860
<http://www.kauai.gov/civildefense>

Maui Civil Defense Agency

200 South High Street
Wailuku, HI 96793
Ph: (808) 270-7285
Fax: (808) 270-7275
<http://www.co.maui.hi.us/index.aspx?nid=70>

State of Hawai‘i Emergency Management Agency—(formerly State Civil Defense)

3949 Diamond Head Road
Honolulu, HI 96816-4495
Ph: (808) 733-4300
Fax: (808) 733-4287
<http://www.scd.hawaii.gov>
AskCivilDefense@scdhawaii.gov

Appendix C

Installation of Simpson Strong-Tie Storm Panel Screws

The Storm Panel Screws are currently available in Hawai‘i and meet the International Residential Code (2006, 2009, and 2012) for storm-panel attachment to wood and concrete structures. Once the screws are installed, storm panels can be easily attached or removed.¹

The following installation is suitable for plywood panels, as well as for other materials such as polypropylene (plastic honeycomb panels - Section 4.3.9). Follow the two-step process below.

Step 1. See Section 4.4 of this book on Installing Plywood Shutters. In general, panels are prepared before installation by following the 4 P's:

- 1) Precut the panels to the proper dimensions – generally four inches of overlap on either side of the window so that the fasteners penetrate the structural framing;
- 2) Pre-label the panel as to what window on the house it is for;
- 3) Premark the location of all fastener holes (Section 4.4.4); and
- 4) Pre-drill the fastener holes with a 1/8 inch bit. This makes drilling of the fastening screws easier. It will also allow the option of using #8, #10, or ¼ inch self-driving screws (Figure 4-30); or the ¼ inch Storm Panel Screws. Follow the suggested spacing in Section 4.4.4 and note that the Storm Panel Screws should be treated as a ¼ inch self-driving wood screw with 16-inch spacing.

Step 2. If the Storm Panel Screws are utilized:

- 1) In the location where the pre-drilled fastener holes are located – drill a wider hole with a 3/8 inch spade bit into the panel [see Figure 4-31(C)].
- 2) Mount the panel on the window with the duplex or double-headed nails [see Figure 4-30(D)], one on the upper right corner and one on the upper left corner. Pre-drilling of the duplex nail locations on the panel may facilitate installation.
- 3) With the panel now mounted on the window, drill the ¼ inch Storm Panel Screws into the center of the pre-drilled 3/8 inch hole and into the structural framing (Figure C-1). Drive the screw about 2 inches into the framing.

¹ See Sections 4.3.9 and 4.3.10 of the Homeowners Handbook for compatible panels as well as Fact Sheet in FEMA document 499 – “Home Builders Guide to Coastal Construction” at: (<http://www.fema.gov/media-library/assets/documents/6131?id=2138>). For more information on the Storm Panel Screws go to: (<http://www.strongtie.com/ftp/fliers/F-SPS12.pdf>).





Figure C-1. The top corners of the panel are temporarily held by a duplex nail, while the Storm Panel Screws are drilled into the center of the $\frac{3}{8}$ inch holes and properly aligned.

Repeat for all fastener locations being careful to center the screw.

- 4) Pull off the duplex nails from the top corners of the panel.
- 5) Pull off the panel.
- 6) Adjust screw penetrations so that the spacer between the top set of screw threads and the bottom set of screw threads is at the surface of the framing of the window (Figure C-2).

Figure C-2. The Storm Panel Screws are driven into the window framing so that the top set of screw threads are just above the surface of the framing. The white plastic caps are kept on during normal conditions. During an incoming event, the caps are pulled off; the panel is placed on the window and attached with wing nuts (Figure C-1).



- 7) Test installation by placing the panel back on the attached screws and fastening with the supplied wing nuts.
- 8) If suitable, pull off the panel and store for an emergency event. Place the wing nuts in a plastic bag and attach to the stored panel. Place the supplied plastic white caps over the permanently installed screws on your window framing.

The Storm Panel Screws cost about \$40 for a box of 25 screws, wing nuts, and white plastic caps. With 16-inch spacing and a 3 ft. by 4 ft. window, a box will be sufficient for three windows.

Appendix D

Asphalt Shingle Roofing and Ridge Vents

Reroofing provides an opportunity to strengthen one of the most important components of your house. Many people who install solar photovoltaic panels reroof their house beforehand so they don't have to reroof after their solar is on. This is because the average life of a new solar unit maybe over 25 years, while asphalt shingle roofs, especially those that are over 20 years old would be approaching the end of their expected life.

We first begin by noting that roofing practices in Hawai'i have improved over previous standards. If you follow these common practices in Hawai'i, your roof is likely to be significantly stronger than similar roofs 20 years ago.

- Bids should be obtained from three licensed roofing contractors.
- Shingles should be selected with an H rating and a shingle that has a minimum fastener pull-through resistance of 30 lbs. at 73 degrees Fahrenheit (see page 2 of Fact Sheet 7.3 in Footnote 3). Obtaining fastener pull through resistance may require checking with the manufacturer.²
- It is now common in Hawai'i to see roofs with a 130 mph warranty. This will require six nails per shingle, as well as starter shingles along the eaves of the roof. Previously, it was common to use four nails per shingle. Today, many contractors put in six nails per shingle, even if the 130 mph warranty is not sought, and this should be the standard practice.

However, even with these practices, roof damage can occur during a hurricane (see Figure D-1 for roof components nomenclature and areas susceptible to wind damage).

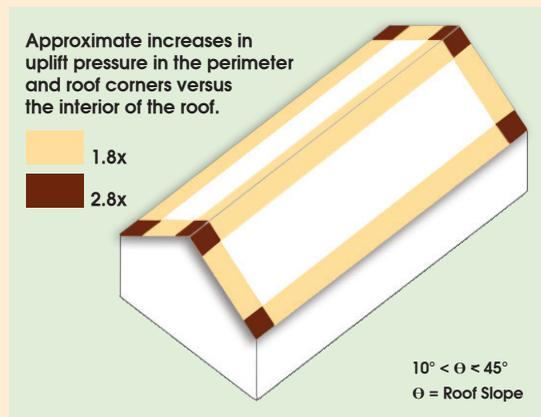


Figure D-1. During a hurricane, uplift wind pressure on the roof may be 2.8 times greater at the corners compared to the interior areas (shown in white). In addition, increased pressure is along the eaves (edge of roof parallel to the ground) and rakes (edge of roof running up to the ridge). The ridge is the intersection at the top of the roof of the two sloping surfaces and also has increased pressure. Examination of

past hurricane damage indicates that blow off of asphalt shingles along the corners, eaves and rakes is common, even when 6 nails are used. Adapted from ASCE 7-5, ASCE 7-10 and the FEMA Coastal Construction Manual.

² Interview with Thomas Smith, AIA, RRC, F.SEI of TlSmith Consulting Inc.



Figure D-2. When Iselle hit Hawai‘i County as a tropical storm, this coastal house experienced wave inundation and roof damage. Although not an asphalt shingle roof, the damage was initiated at the corners, as expected, where uplift pressures are greatest (Figure D-1). Furthermore, the winds were less than hurricane strength. Better building practices could include less overhangs, overlap of roofing panels and use of ring shank nails. See also the Wind Resistive Devices Technical Specifications referenced in this Appendix for better practices with various roof types.



Figure D-3. At less than hurricane strength winds, Tropical Storm Iselle initiated the peeling off of asphalt shingles along the rakes (edge) of this roof, as expected (Figure D-1). This problem would have been much worse with a hurricane, as forces on building structures do not double with the doubling of wind speed but quadruple. Progressive failure with

wind speed increase could include peeling off of all the shingles, then the sheathing and then the entire roof. This Appendix D covers some best practices to help prevent damage from high wind events.

It is possible to build stronger than the common practice currently in Hawai‘i. The following guidelines for asphalt shingle roofs come from many FEMA documents.³

This guideline is not commonly done for residential roofs in Hawai‘i, and it will add about 10-15 percent to the cost of reroofing. Still if you value a strong roof as the most important part of your house, then the installation could be well worth the cost in extra protection and peace of mind. Since this is an unusual installation

for Hawai‘i, the licensed roofer may not have much experience performing all the tasks and this could also increase cost of a bid.

After the roof deck is cleared and cleaned of the old asphalt shingles, the roof sheathing (generally $\frac{5}{8}$ inch plywood) is inspected for integrity. If the plywood is in good condition, a self-adhering modified bitumen layer complying with ASTM D 1970 is applied according to FEMA Technical Fact Sheet 7.2 (see Footnote 3 and Figure D-4). If the sheathing is Oriented Strand Board (“OSB”) instead of plywood, check with the OSB manufacturer to determine if a primer is needed before installing the self-adhering bitumen layer.



Figure D-4. A self-adhering, modified bitumen layer (black) is put over the roof sheathing ($\frac{5}{8}$ inch plywood for this house). This layer, as the name implies, adheres and seals around holes and cracks in the roof (e.g., joints or the intersection of two sheets of plywood which are potential leak points, as well as around nails that attach the shingles, or around screws that mount PV panels to the

roof rafters). If the shingles were to blow off, the layer helps maintain the waterproof barrier. When attaching this layer, the sheet should be sealed around existing roof penetrations such as plumbing vents with roof tape or asphalt roof cement.

Above the self-adhering modified bitumen layer is placed roofing felt, either ASTM D226 Type II (#30), or ASTM D226 Type I (#15), or ASTM D4869 Type II felt according to FEMA Technical Fact Sheet 7.2 (see Footnote 3 and Figure D-5).

With the bitumen layer and roofing felt in place, starter shingles are placed along the eaves following FEMA Technical Fact Sheet 7.3 (see Footnote 3). The shingles should not overhang the eave or rakes by more than a $\frac{1}{4}$ inch. Between the starter shingles and first course of shingles are placed 1 inch dabs of asphalt roof cement (Figure D-6). The dabs should be as close to the edge of the roof as possible, just far enough so that the cement does not ooze out.

³ Chapter 11 of the FEMA Coastal Construction Manual (2011) at: <http://www.fema.gov/media-library/assets/documents/3293?id=1671>; the FEMA Home Builder’s Guide to Coastal Construction (P-499, 2010 update) at: <http://www.fema.gov/media-library/assets/documents/6131?id=2138>; which also appears more specifically in FEMA’s Technical Fact Sheet No. 7.2 for Roof Underlayments: http://www.fema.gov/media-library-data/20130726-1537-20490-6674/fema499_7_2rev.pdf; and FEMA’s Technical Fact Sheet No. 7.3 for Asphalt Shingles: http://www.fema.gov/media-library-data/20130726-1536-20490-8282/fema499_7_3.pdf.





Figure D-5. Roofing felt (grey) is then tacked onto the self-adhering modified bitumen layer. The FEMA guideline calls for the #15 felt, which is supposedly cheaper. In this instance, the #30 felt is stronger and about the same price (considering more expensive materials, but cheaper installation cost). Check with your licensed contractor. The purpose of the felt is to prevent the bonding of the overlying asphalt shingles with the underlying bitumen layer.

If there is bonding, it would be difficult to remove the shingles at the end of their useful life. Bonding problems in the past have required complete removal of the plywood to remove the asphalt shingles.

Figure D-6. To address the increased wind pressure on the corners and edges of the roof from hurricane winds (see Figures D-1 to D-3), 1 inch dabs of asphalt roof cement are placed between the starter shingles (black) and first course of roof shingles (brown) for the eaves. With this technique, the especially vulnerable corners and edges of the house are protected with shingles that are attached with six nails and nine dabs of asphalt roof cement. For exact placement of the shingles and cement see Technical Fact Sheet 7.3 in Footnote 3. Refer to this Fact Sheet for the eaves, rakes, hips, or ridges of the roof. This method takes time, but is stronger at the vulnerable part of the house (see also Figure E-1).



The above guideline is for asphalt shingle roofs. For other types of roofs, refer to the Wind Resistive Devices Technical Specifications at: http://www.scd.hawaii.gov/HazMitPlan/chapter_6_appF.pdf and also Chapter 11 of the FEMA Coastal Construction Manual cited in Footnote 3. Any time there is a chance, or need to reroof, this is an opportunity to make your roof significantly stronger with possibly marginal cost and effort.

Related to roofing are ridge vents. This method of attic circulation can be very effective in removing heat from the attic through natural circulation and breezes. The hot air in an attic simply rises to the highest point and escapes through linear vents that are cut along the roof ridge (see Figure D-7). A cooler attic results in a cooler house, with

less energy used for cooling. A cooler attic and roof (also related to the reflectivity of the shingles utilized) puts less wear on the shingles and thus helps to extend life. Ridge vents also conceivably last longer than solar fans, which remove hot air from the attic with solar powered fans, but have an expected life of about ten years.

However, ridge vents could conceivably leak and could blow off if care is not taken during installation. If your existing roof does not have ridge vents and it is desired to install ridge vents as part of the reroofing, then a portion of the roof sheathing will need to be cut and removed in order to allow air to flow out of the attic.

The current common practice in Hawai'i has several safe guards. First, in installing the vent, cuts are made into the plywood along almost the entire ridge of the roof. Care is taken not to cut into the rafters but only remove the plywood sheathing. Thus the cuts should be no more than the thickness of the plywood, typically $\frac{5}{8}$ inch. Second, check that the ridge vents installed are approved by Miami-Dade County in Florida. Here the design wind speeds are significantly higher than Hawai'i, and thus certain wind testing has taken place.

Similar to the guidance for Asphalt Shingle Roofs, there are ways to make ridge vents stronger. The following guidelines are from Chapter 11 of the FEMA Coastal Construction Manual (Footnote 3). If a ridge board occurs under the roof, and if the sheathing on either side of the ridge is nailed into the ridge board, then in lieu of cutting a slot on either side of the ridge line, it is preferable to cut holes through the sheathing in order to maintain structural integrity of the roof diaphragm. This guideline is not commonly found in Hawai'i. Furthermore, it is more time consuming and thus there is a cost. While the typical time to cut a linear slot along either side of the roof ridge took maybe

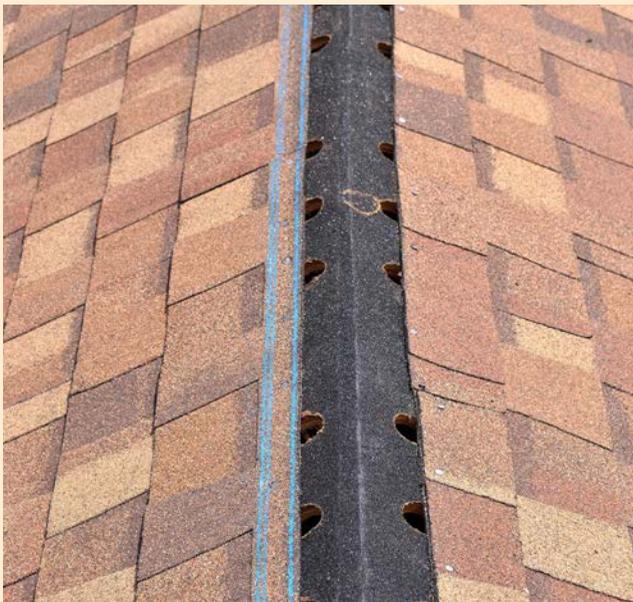


Figure D-7. Instead of a continuous cut on either side of the ridge line, 2 inch holes are spaced 6 inches apart on either side of the roof rafters. As a result, the majority of the structural strength in the plywood sheathing leading up to the ridge line remains intact. Refer to Chapter 11 of the FEMA Coastal Construction Manual for the correct spacing. The cut holes should be made with a hole cutter that creates plugs, rather than a grinder that would make wood chips that fall into the attic.



15 minutes, it took three hours for the contractors to cut the holes between the rafters as recommended in the FEMA Coastal Construction Manual (see Figure D-7). The trade-off in time and cost, however, is a stronger roof.

When the ridge vent is attached, it is possible to make that stronger also by adding extra fasteners (see Figure D-8). This is important because if the ridge vent blows off, a lot of water can enter the attic and leak inside the house.



Figure D-8. The installation of the vent over the roof ridge is made stronger than manufacturer's specifications by doubling the nailing pattern. Ring shank nails are placed in the specified holes and also in between. Asphalt roof cement and nails are then used to attach shingles over the ridge vent. The original specifications for the ridge vent, while strong, were fortified even more since this is a critical part of the roof that is vulnerable to leaks if the vent were to blow off.

Appendix E

Solar Photovoltaic

Between 2012 and 2013, there were approximately 500 to 2,450 solar residential permits issued each month on O‘ahu. This number varied, with the height of demand in October of 2012, and a later slow down due to the oversaturation of solar. In the year 2013, over 17,600 solar units were installed in the state (see (<http://www.civilbeat.com/voices/2013/07/09/19464-darkening-skies-over-hawaii-solar-industry/>); <http://westhawaii.com/news/local-news/solar-panel-installations-push-electric-utilities-brink>) and (<http://www.greentechmedia.com/articles/read/How-Much-Solar-Can-HECO-and-Oahus-Grid-Really-Handle>).

A significant number of houses are installing solar and many of them are also reroofing beforehand, with the potential to make roofs stronger under current practices, and even stronger as shown in Appendix D.

There are many measures that can be used to ensure the solar photovoltaic systems remain secure under high wind events.

- 1) By reference to Figures D-1 to D-3 and E-1, the wind pressure is greatest along the corners and edges of the house during a hurricane. Thus, if there is space, keep at least a 3-foot minimum buffer, and preferably a 6-foot buffer between the solar panels and the edge (eave and rakes) and ridge of the roof.⁴
- 2) If you reroof, make it strong. This is especially important for the ridges, eaves and rakes. Here the benefits of the additional asphalt roof cement come into play (Figure D-6). In addition, the self-adhering modified bitumen layer helps to seal any penetrations of the roof. This includes nails for the shingles or lag bolts fastening the solar PV to the roof rafters. There is often concern about adding extra fasteners to attach the solar, because of the additional penetrations on the roof and potential leaks. The self-adhering modified bitumen layer helps to reduce this problem, along with the use of proper flashing (metal barriers around roof elements to prevent leaks).
- 3) More efficient panels require less space per given power output. One advantage of a system that has a smaller footprint is that it is less likely to be hit by flying wind-borne debris during a hurricane, although during such an event, debris can be everywhere. Also, there is more flexibility to place the

⁴Your installer should be able to follow and provide documents on determining wind loads and roof zones to meet ASCE 7-05 or ASCE 7-10 standards and local building codes for the materials that are used on your roof. An example is provided for one type of solar mount commonly used which shows how the roof zones and mount spacing is determined (see <http://unirac.com/sites/default/files/ii227.pdf>). Note the size of the buffer zones will depend on the dimensions of your house (height and width) and the roof configuration. Check with the above document and your installer for the optimum buffer for your house.



panels on the sweet spot of your roof, away from edges (eaves, rakes, ridges and corners) with maximum sunlight exposure.

- 4) While most panels cannot resist damage from wind-borne debris during a hurricane, nevertheless, panels do have a certain amount of impact resistance from hail. Check the technical specifications of the panels for impact resistance which is usually given as a hail size diameter and speed (e.g., 1 inch at 52 mph).⁵
- 5) Regarding hurricane wind-borne debris, there is little you can do to make sure the panel is not damaged. There are two keys here: (a) increase your hurricane insurance to account for any panel damage. This should be done as standard practice for any significant home improvement susceptible to hurricane wind damage (Section 4.8.1); and (b) make sure the panel stays in place on the roof.
- 6) Related to 5(b), it is vital that the panel remain on your roof, even if it is damaged. This will help protect your house and your neighbors. Photos of hurricane damage for houses with solar panels often show correctly installed panels will help to keep the roof on, even if there is damage elsewhere (Figure E-1). This is because on most of the roof, plywood is attached to the rafters with nails, but where there are solar mounts, the plywood is attached with nails and lag bolts that penetrate the plywood and structural framing, namely the rafters.



Figure E-1. Florida house with solar panel hit by hurricane winds. Note the major damage along the rakes of the roof. As noted in Figures D-1 to D-3 and D-6, pressure is greatest along the edges and can lead to loss of shingles and eventually the roof decking (plywood sheathing). The solar panels remained on the roof, and helped to stabilize the

structure, most likely fortified by bolts attaching the panel system to the roof rafters – seen in this photo. Photo courtesy of One Block Off the Grid.

- 7) To ensure a strong installation of the solar panels, note the following:
 - a. Figure E-2 shows the materials commonly used to mount solar panels. This may differ by house type and contractor. Obtain a bid from three licensed solar contractors that include manufacturer’s information and testing on the

⁵ For More Information – see ASTM-E1038-10 – Standard Test Method for Determining Resistance of Photovoltaic Modules to Hail by Impact with Propelled Ice Balls.

materials to be used. While cost is an important factor, realize also that measures to make an installation stronger could add marginal cost.

- b. Lag bolts must go into the rafters of your roof, not the sheathing (usually $\frac{5}{8}$ inch plywood). Rafters are quite strong, and are typically 2 inches by 6 inches (really 1.5 inches by 5.5 inches). The contractor is likely to drill test holes with a small $\frac{1}{8}$ inch drill bit to make sure the rafter locations are exactly identified. Inspection inside the attic will reveal if the lag bolts have squarely hit the rafter. This should be checked by the contractor before the racking system is installed so that if a lag bolt did not fully engage a rafter, the brackets can be relocated and properly fastened. The target, for any bolt, is to hit the middle $\frac{1}{3}$ of the rafter. The lag bolt should go at least 2.5 inches into the rafter for the screw shown in Figure E-2. Besides pilot holes to identify the rafter, a larger pilot hole of $\frac{3}{4}$ of the diameter of the lag screw can be drilled into the rafter to prevent splitting of the wood.

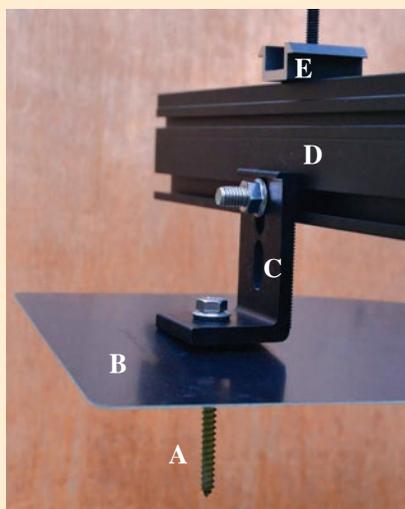


Figure E-2. Typical Solar Mounting System. (A) Lag Bolt – In this instance, $\frac{3}{8}$ inch diameter - 3.5 inch length [see paragraph 7(b)]; (B) Flashing is used to prevent leaks from the roof penetrations. The flashing has a rubber seal at the top and bottom of where the lag bolt is placed [see paragraph 7(d)]. (C) L bracket made by EcoFasten Solar. Items A, B, and C, consist of the portion of the system fastening the racking system to the roof. See Figure E-3. In addition, there is the (D) Unirac Mounting System which should have undergone wind testing and have approval by a Licensed Design Professional hired by the Contractor [see paragraph 7(c)]. As part of the racking system, there are (E) side clamps attaching the Solar PV panels (not shown) to the racking system.

- c. The key to keep your solar on is proper fastening of the racking system to the roof with lag bolts, and proper fastening of the solar panels to the racking system.⁶ Under the cited ASTM standard, the racking system should be approved by a Licensed Design Professional (LDP) who can approve structural designs in Hawai‘i. ASTM also calls for the LDP to review the structural design, the sizing method and the method of attachment for wind design loads under the applicable codes. Hawai‘i has adopted the State Building Code, which incorporates by reference the 2006 International Building Code. Ask your contractor for the letter from their LDP that certifies that the racking system and attachment methods meet the design wind forces and load combinations under the International Building Code. This can be readily provided.

⁶ ASTM E2766-13 – Standard Practice for Installation of Photovoltaic Arrays on Steep Slope Roofs.

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- d. The ASTM E2766-13 standard also provides guidelines for flashing the roof penetrations. Flashing materials should be sufficiently durable and compatible to last the life of the installation. A polycarbonate sealant can be used to seal the gap, or fill the hole, between the lag bolt penetration and flashing for asphalt shingle roofs. The flashing should be shingled into the roof so that it lies under the upper shingle and over the lower shingle. The flashing should be fastened to the upper shingle with fasteners or polycarbonate sealant. In addition to flashing, a self-adhering modified bitumen layer can add additional water proof protection (Figure D-4). As noted previously, this is an upgrade to standard roofing but could be well worth the cost for those homeowners who reroof.
- e. It is not the responsibility of the homeowner to determine uplift wind loads on the panels and the number of fasteners required to resist these loads. This is the role of the contractor, or if there is a need, their licensed structural engineer. Nevertheless, the homeowner can relieve the need for design demands by placing the panels on the interior of the roof, where wind pressures are less (see Figures D-1 to D-3, E-1, as well as Footnote 4). This should be the preferred location, given all other factors are equal (e.g., sun exposure, shadow effects, existing space, or location of existing vents). It may still be appropriate to build closer to the edge if there is a need, however in this case, extra fasteners or wider and/or longer lag bolts may be needed (see Figure E-3). Check with your contractor if there is a need and refer to the footnote below.⁷ Key factors to determine a need are the roof zone and the topography around your house.

⁷ Wind loads for seismic panels have been proposed by the Structural Engineers Association of Hawaii (SEAOH). See Guide to the Wind Design Provisions of the Hawaii State Building Code, by Gary Chock, available from Hawai'i Emergency Management Agency. Use for the interior roof zone: Force = 40 (Area of Panel)(Velocity Eff./105),² where Velocity Effective is from the wind maps <http://ags.hawaii.gov/bcc/building-code-rules/>. See also http://martinchock.com/_library/documents/papers/hawaiistatebuildingcodewindprovisions.pdf. The wind maps are readily available and easy to look up for your area by using the supplied index. As an example, a panel of 41 by 61 inches is 3.41 feet by 5.08 feet = or has a surface area of 17.32 square feet. For a large portion of Mānoa, O'ahu – Veffective is between the 110 and 120 contours, or by using interpolation 115 mph. The Force = 40(17.32) (115/105)² = 831 pounds (formula provides answer in pounds). Compare this with the ASTM E2766-13 recommendation for the mounting system to resist at least 30 psf. Given a panel of 17.32 sq.ft., the mounting system should resist at least 519.6 lbs. Thus the ASTM minimum is 519.6 lbs of uplift resistance, and the SEOH recommendation is 831 lbs. These are the wind loads for the 17.32 sq. ft. panel for certain parts of Mānoa. The loads will be higher further into the valley (see wind map). The loads also differ on where you place the panels on your roof. If the panels are located near the edge, and in particular the corners, see Figure D-1 and Footnote 4, the pressures are much greater (up to 2.8 times greater). Thus SEAOH recommends the following formula - Force = 100 (17.32)(115/105)². This gives a SEAOH recommended load to resist of 2,077 lbs. This is one of the reasons why it is better to locate panels away from the edges and corners of the house and in the interior of your roof, if possible, as noted above. If you must build at the edges, corners or ridges for some houses (see Footnote 4 for roof zones), consider an increased number of fasteners, or wider and/or longer lag bolts, given your geographical location. This may be especially important at a ridge or high wind area (see wind map for your location). Finally, your contractor should be able to provide testing data from the racking system they will use. The fasteners should have pull out tests which exceed the wind loads of at least 519.6 lbs, preferably 831 lbs, or 2,077 lbs per panel if you are near the corner of the roof for a typical house in Mānoa. This should factor in the pull out strength of the fasteners and the number of fasteners per panel. For the house in Figure E-3 using 3/8 diameter lag bolts and 2.5 inches of penetration, 750 lbs per fastener was used as a planning guideline with a safety factor included. For a useful reference relating uplift loads with lag bolt width and diameter, see <http://solarprofessional.com/articles/design-installation/pitched-roof-pv-mounting/page/0/5>.



Figure E-3. Fasteners used to attach the racking system and solar panels are shown. The fasteners represent parts A, B, and C in Figure E-2. Where it was necessary to go near the rakes or edge of the roof, or the corner near the ridge, extra fasteners were provided. Thus the change from every 4 ft., or every other rafter, to every 2 ft. only for the areas near the higher wind roof zones. Extra fasteners were \$85 each. Federal and State tax credits pay for a portion of the increased cost. Check with your contractor if extra fasteners are needed given

wind loads on your panels at your location (Footnote 7) and uplift resistance per-fastener. Another alternative to extra fasteners are wider and/or longer lag bolts into the roof rafters.

Note that many of the principles in this Appendix are for solar photovoltaic panels that are parallel to the roof surface. Panels that are not parallel represent an unusual, but still common, scenario (refer to the Guide to the Wind Design Provisions of the Hawai'i State Building Code cited in Footnote 7). In either case, a licensed professional (engineer or architect) should be consulted that is either hired by the homeowner, or is at least part of the contractor/installer's professional design team. Thus, when a licensed contractor or installer is hired, an important consideration is the expertise, reliability, and integrity of the design professionals in the company. In addition to providing this information on their design team, the company should be able to provide a full background on all equipment used, including wind-testing on the equipment and how loads were calculated, either from the manufacturer or the installation company.

The purpose of this Appendix is not to have homeowners design their own system, but to become more educated about best management practices and considerations for installation that they can intelligently discuss with their installer. With more educated homeowners, more secure and safer systems can be installed.





Appendix F

Working with the Community

For a community to be resilient (i.e., able to bounce back quickly from a hazard event) it is important that all individuals and organizations (the core of the community) prepare.

This book concentrates on helping individuals and families to prepare. Individuals who were planning to help in the community will be limited in their ability to assist if they or their families are not prepared. With an increased capacity to cope with different hazards because of preparation, groups of individuals and organizations should be more able to assist the community by volunteering. This book encourages such effort. Here are some tips:

- 1) Learn about community resilience and the steps you can take to prepare by requesting from the National Disaster Preparedness Training Center (<https://ndptc.hawaii.edu/>) free courses such as Coastal Community Resilience, Flood Risk Reduction and HURRIPLAN (see the full course catalog: <https://ndptc.hawaii.edu/training/catalog>). All NDPTC courses are FEMA certified and sponsored.
- 2) In addition to learning about best practices in the home through this book, there are many FEMA resources in the Useful Links section at page 98 and through the Building Sciences Division at: (<http://www.fema.gov/building-science>). A recent emphasis by FEMA has also been on working with the community – See “A Whole Community Approach to Emergency Management: Principles, Themes and Pathways for Action” at: <https://www.fema.gov/media-library/assets/documents/23781>. Many of the resources in paragraphs 1. and 2. emphasize actions individuals can do to empower organizations and the community.
- 3) Whether you want to lead disaster resilience efforts in your community or just help, a great way to get involved is to participate in the Hawaii Hazards Awareness & Resilience Program (HHARP). The goal of HHARP is to enhance community resilience to multiple hazards through a facilitated education and outreach program that promotes hazard understanding and awareness, and offers tools and information resources to guide mitigation, preparedness, response and recovery. Led by the Hawai‘i Emergency Management Agency (formerly State Civil Defense), and developed in partnership with the Pacific Disaster Center, the program helps communities prepare and become self-reliant by improving their ability to care for their own needs and reduce the impacts of natural hazards. Free HHARP resource kits are available to help communities organize, plan, and prepare for hazard events in their neighborhoods.

Contact the Hawai'i Emergency Management Agency at (808) 733-4300 extension 561 to find out how your community can get involved.

- 4) If you are physically able, you can be of great benefit by joining a Community Emergency Response Team (CERT) for your county. CERT members get free training in first aid, search and rescue, light rescue, and disaster response. As a result, they help the police or fire departments during times of need. To learn more about the programs go to: <http://www.hawaiiicounty.gov/civil-defense-cert> for Hawai'i County; <https://www.citizencorps.fema.gov/cc/showCert.do?id=47955> for Maui; <https://www.citizencorps.fema.gov/cc/showCert.do?id=44073> for O'ahu; and <http://www.kauai.gov/Government/Departments/FireDepartment/CommunityEmergencyResponseTeam/tabid/325/Default.aspx> for Kaua'i.
- 5) Another way you can help your community during time of disaster is to become trained in the humanitarian mission of the American Red Cross. Beginning training includes shelter operations, residential damage assessment, and providing emergency assistance. All disaster training is free. For more information, refer to: www.redcross.org/hawaii.
- 6) Get to know your neighbors. Contrary to popular belief, the most likely assistance you will get after a natural hazard that turns into a disaster is not from the local, state, or federal government. It is likely to be from your neighbors or local community members. This is because the government may be overwhelmed in responding to life threatening emergencies or maintaining critical infrastructure. Your community will be better able to cope with a disaster when you work with your neighbors and local government agencies as a team.
- 7) All citizens should sign up for emergency alert announcements for their county at their own civil defense or emergency management agency (see Appendix B). By signing up, you can get free watches, warning and advisories on your computer mobile phone or personal electronic devices. Through these announcements, you can be alerted to advisories, watches, and warnings for the different hazards, learn about tips for preparation, and even be informed of educational opportunities such as workshops or fairs.



Endnotes

¹ C.H. Fletcher, E.E. Grossman, B.M. Richmond, and A.E. Gibbs, *Atlas of Natural Hazards in the Hawaiian Coastal Zone*. (U.S. Department of the Interior, U.S. Geological Survey, University of Hawai‘i, State of Hawai‘i Office of Planning, National Oceanic and Atmospheric Administration, 2002) 182.

² Based on data from the former Office of Emergency Permitting, Kaua‘i County. This is based on the reconstruction and building permit database.

³ Figures from the Federal Emergency Management Agency (FEMA). *Honolulu Star Bulletin* 8 September 2002.

⁴ Based on the number of single family homes on each island. From the *Hazard Mitigation Study for the Hawai‘i Hurricane Relief Fund* 7 December 2001. See also Center for Development Studies, Social Science Research Institute, University of Hawai‘i. 1993. *Hawai‘i Coastal Hazard Mitigation Planning Project*.

⁵ Report by U.S. Army Corps of Engineers, Pacific Ocean Division, “Hurricane Iniki—Coastal Inundation, September 11, 1992.”

⁶ UNESCO-IOC, *Tsunami, The Great Waves*. IOC Brochure 2006-2. (Paris, UNESCO, 2006.)

⁷ During the 1946 tsunami, the water also inundated several thousand feet inland at Kahuku on the north shore of O‘ahu. On December 26, 2004, a

tsunami generated from a magnitude 9.3 earthquake in the Indian Ocean resulted in the deaths of over 200,000 citizens in over eleven countries. In Indonesia, the tsunami inundated an area several miles inland. The December 26, 2004, tsunami in the Indian Ocean is thought by many scientists to be a very rare event (time interval between a return event is greater than once every two hundred years) and outside the realm of local historical experience.

⁸ See note 1.

⁹ Data from Hawai‘i Emergency Management Agency (formerly State Civil Defense) on March 24, 2011. The tsunami generated by the February 27, 2010 earthquake in Chile did not cause significant damage in the State, although small tsunami waves did reach the islands.

¹⁰ It used to take about 30 minutes, but advances in science and increased monitoring have cut the time needed to analyze potentially damaging earthquakes.

¹¹ To see the entire guideline, go to http://www.typhoon2000.ph/tropical_SS.htm

¹² Interview with Gary Chock of Martin and Chock.

¹³ This kit was developed pursuant to Hawai‘i Special Session 2005—Act 5. It appears in “Report of Recommended Statewide Public Hurricane Shelter Criteria, Hurricane Shelter Criteria Committee, State Civil Defense.”

¹⁴ See the poster – Tsunamis in Hawai‘i – Daniel Walker.

¹⁵ W.C. Dudley, R. Whitney, J. Faasisila, S. Fonolua, A. Jowitt, M. Chan-Kau, Learning from the victims: New physical and social science information about tsunamis from victims of the September 29, 2010 event in Samoa and American Samoa, Earth-Science In Press.

¹⁶ Adapted from the Hawai‘i County Civil Defense Guide on Hurricane Preparedness. Also from “Information—Handbook for Emergency Preparedness,” by Hawaiian Electric Company, Maui Electric Company, and Hawai‘i Electric Light Company.

¹⁷ See “Information Handbook for Emergency Preparedness,” published by Hawaiian Electric Company, Maui Electric Company, and Hawai‘i Electric Light Company; http://www.uhh.hawaii.edu/~nat_haz/hurricanes/evacuating.php; <http://www.prh.noaa.gov/cphc/pages/pr3.php>; and <http://www.prh.noaa.gov/cphc/pages/pr5.php>

¹⁸ <http://earthquake.usgs.gov/learning/faq.php?categoryID=14&faqID=80>

¹⁹ These maps were created at the offices of Martin & Chock.

²⁰ See note 2.

²¹ From “Building Performance: Hurricane Iniki in Hawai‘i—Observations, Recommendations, and Technical Guidance” from the FEMA Federal Insurance Administration, in cooperation with the State of Hawai‘i Civil Defense and Kaua‘i County. January 1993.

²² See above.

²³ The former State of Hawai‘i Loss Mitigation Grant Program recognized that installing hurricane clips was something that a homeowner could do as a “do it yourself project.” However, a licensed structural engineer or architect should be consulted to provide initial guidance on the correct clip and fasteners for your home. Each house is a little different.

²⁴ Robertson and G. Chock, Structural Seismic Retrofits For Hawai‘i Single Family Residences with Post and Pier Foundations, Volume 1, Results of Study, Structural Analysis, and Retrofit Strategies. Federal Emergency Management Agency Grant Program – DR-1664-HI.

²⁵ The Retrofit Expert System was prepared under a collaborative project with the Center for the Study of Active Volcanoes and the University of Hawai‘i at Hilo Department of Computer Sciences with support from Hawai‘i State Civil Defense.

²⁶ Institute for Business & Home Safety. 1998. *Is Your Home Protected from Hurricane Disaster?—A Homeowner’s Guide to Retrofit*; see also <http://www.mothenature.com>

²⁷ State of Hawai‘i Department of Commerce and Consumer Affairs, Loss Mitigation Grant Program, Wind Resistive Devices Technical Specifications, and Institute for Business & Home Safety. “Keep Water and Wind Out.” <http://www.ibhs.org/publications/view.asp?cat=78&id=555>. More recent IBHS publications at: http://www.disastersafety.org/commercial_maintenance/windows-wind-and-windborne-debris-how-to-protect-your-business-from-hurricanes/





and http://www.disastersafety.org/wp-content/uploads/hurricane_shutter-matrix.pdf note that two layers of 3/8 inch plywood can have the same effect or strength as one layer of 3/4 inch material. This would alleviate the concern with weight of the panels and create a strong system. The trade off is the significant extra time in preparing and installing two panels for each window.

²⁸ See National Weather Service Central Pacific Hurricane Center site at: http://www.prh.noaa.gov/cphc/HAW/entry_doors.php

²⁹ Watts are equal to the voltage (usually 110 to 120) times the amps. Amp meters can measure in watts or amps and provide information on the running and startup power needs in digital readout.

³⁰ Tip from Florida Power and Light on running your refrigerator with a generator. http://www.fpl.com/storm/generator_safety.shtml

³¹ From “Against the Wind—Protecting Your Home From Hurricane Wind Damage,” by American Red Cross, FEMA, Home Depot, National Institute of Home Builders, and Georgia Emergency Management Agency.

³² From “Protect Your Property from High Winds,” by FEMA <http://www.fema.gov/media-library/assets/documents/13270>

Notes

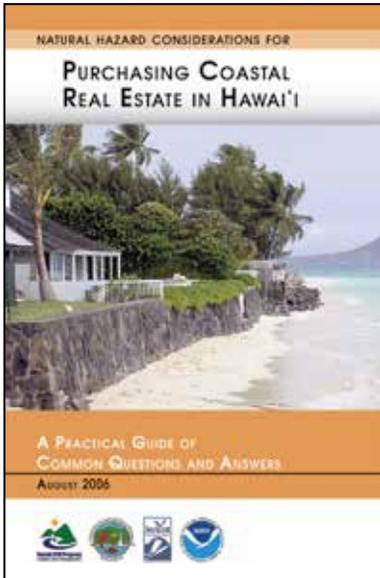


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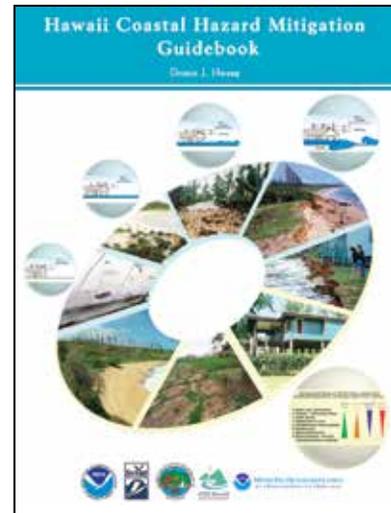


***Purchasing Coastal Real Estate in Hawai'i:
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Hawai'i Coastal Hazard Mitigation Guidebook

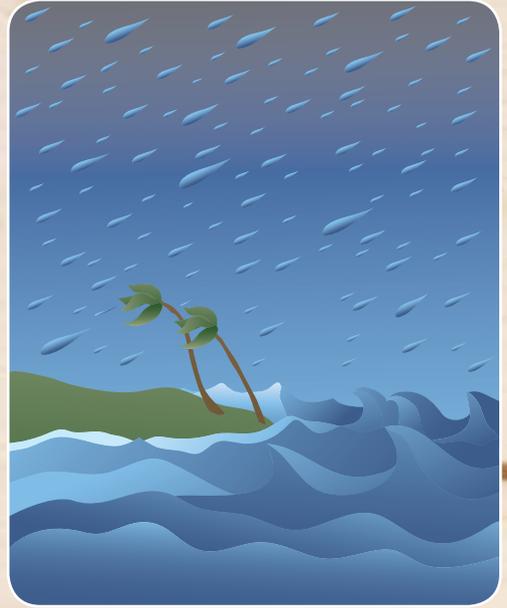
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