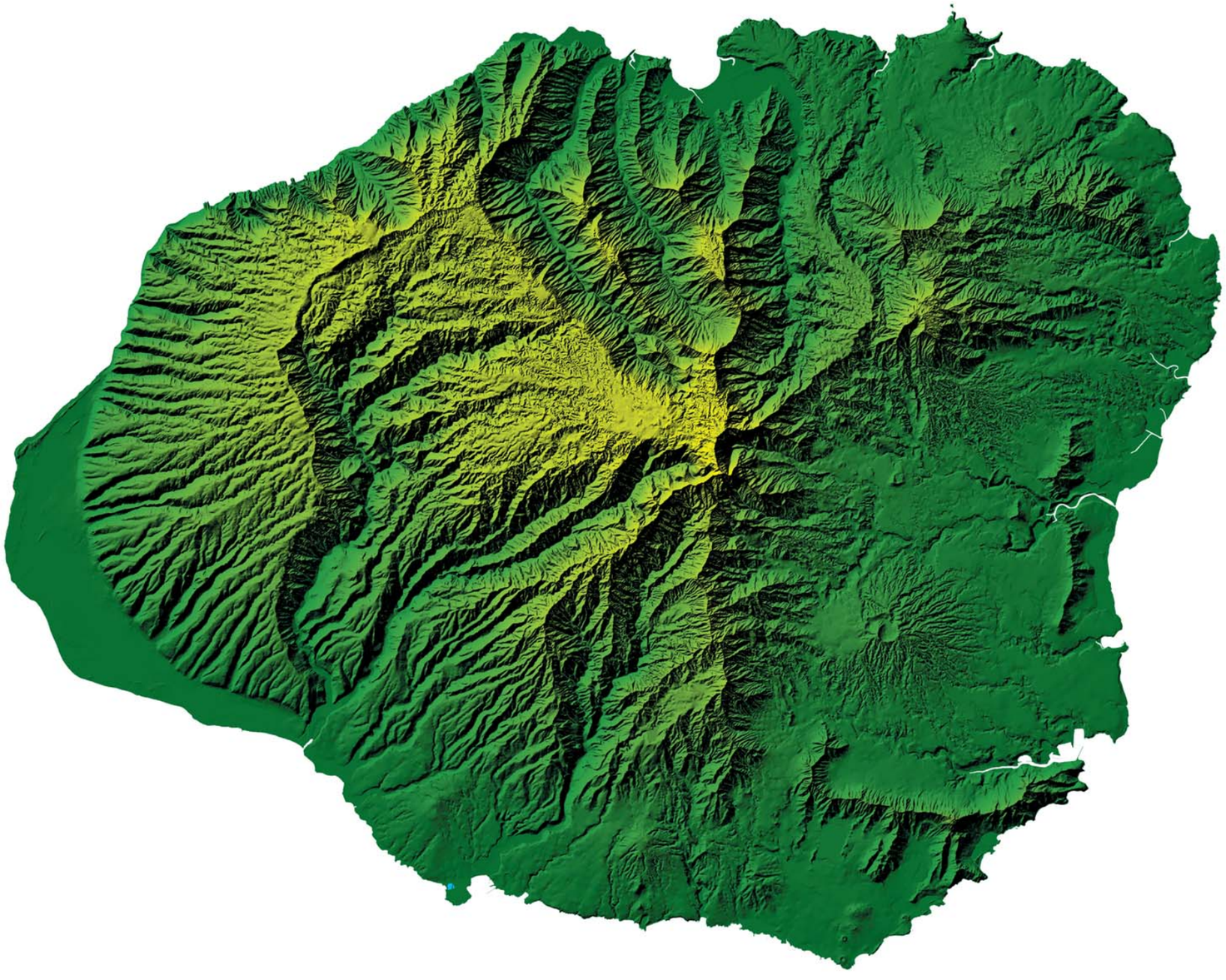
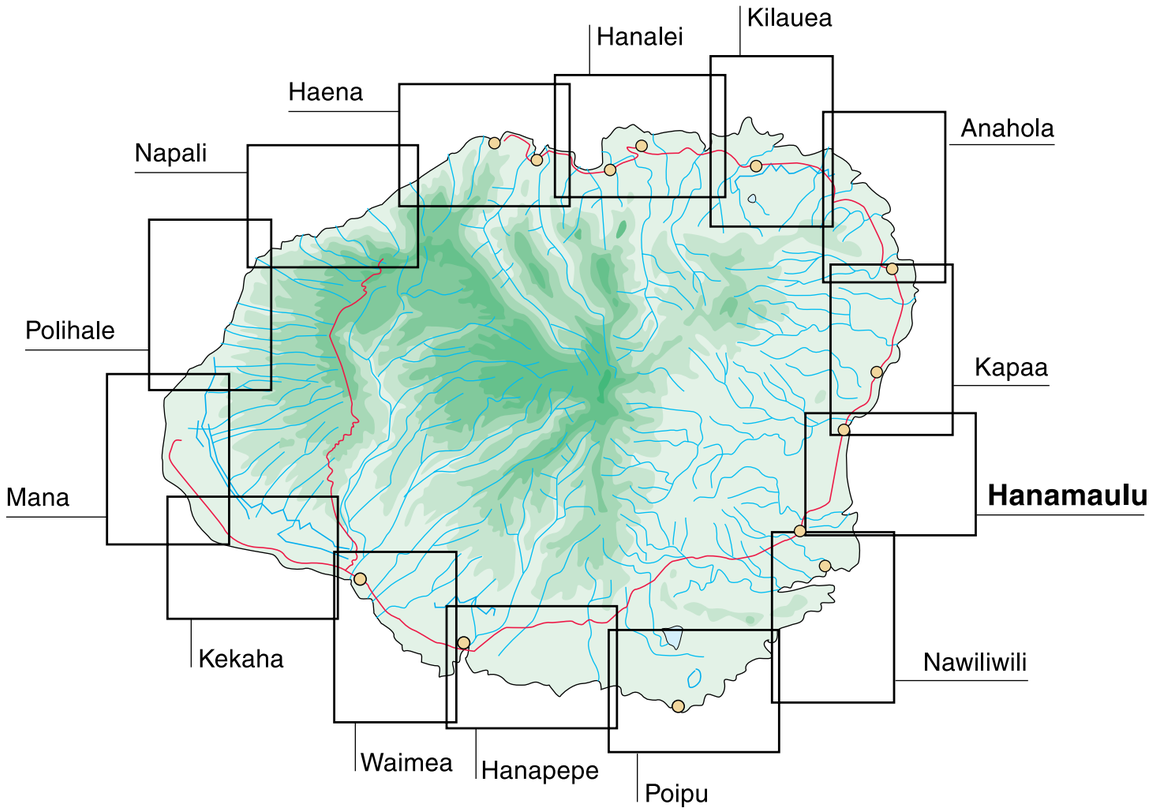
Kauai

The Garden Isle of Kauai is the oldest and most eroded of the main Hawaiian Islands. Mount Waialeale, located in the middle of the island, is one of the wettest places on Earth. As a result, stream erosion and flooding are common, carving deep valleys and canyons and transporting abundant sediment to the coast. Flooding is especially prominent in the coastal zone, where the steep slopes of the central mountains meet the low-lying coastal plains.



Kauai

Index to Technical Hazard Maps



Tsunamis

A tsunami is a series of great waves most commonly caused by violent movement of the sea floor. It is characterized by high speed (up to 590 mph), long wave length (up to 120 mi), long period between successive crests (varying from 5 min to a few hours, generally 10 to 60 min), and low height in the open ocean. However, on the coast, a tsunami can flood inland 100's of feet or more and cause much damage and loss of life. Their impact is governed by the magnitude of seafloor displacement related to faulting, landslides, and/or volcanism. Other important factors influencing tsunami behavior are the distance over which they travel, the depth, topography, and morphology of the offshore region, and the aspect, slope, geology, and morphology of the shoreline they inundate. Their behavior is chaotic and relatively unpredictable. As a result, their expression at the shoreline can be considerably different within very short distances. This has been observed throughout Hawaii. The only general rule is that runup heights tend to be greatest near headlands, where the offshore bathymetry is steeper, enabling greater wave energy to reach the shore. Along gently sloping coasts, runup heights are reduced as wave energy is dissipated upon shoaling. Even so, inundation can be significant and is usually greatest along low-lying coastal plains. This is because tsunami waves have extremely long wavelengths. As they pass, the water level can rise for several minutes and/or tens of minutes, pushing far inland.

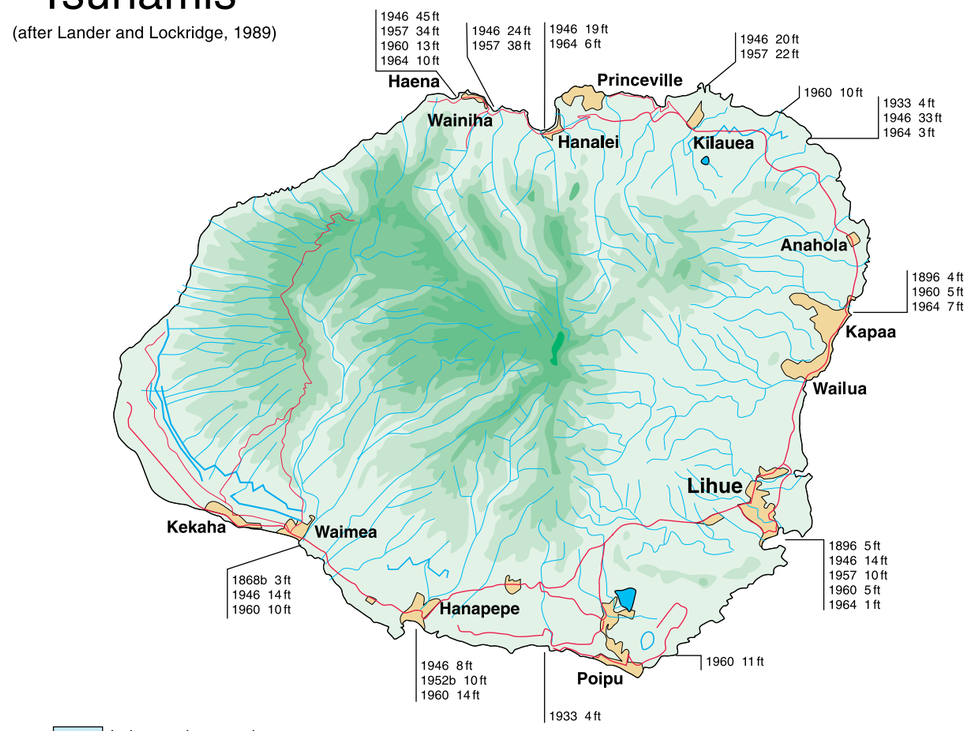
An important historical example that demonstrates the variability of tsunami impact at the shoreline occurred during the 1946 tsunami on the north shore of Kauai. Despite the same north-facing exposure at Haena and Hanalei, a runup height of 45 ft was recorded at Haena, while only a few miles away in Hanalei Bay, runup was 19 ft. In some cases, the runup height has been nearly equal on opposite sides of the island, suggesting that shoreline orientation (facing the tsunami source) is not always an important control. For example, during the 1960 tsunami, generated by an earthquake in Chile far to the southeast, a runup of 13 ft was recorded at Haena, only 1 ft lower than the maximum of 14 ft for the entire island reported at Hanapepe. Despite these variations, each side of Kauai has observed tsunami runups of over 10 ft with significant damaging effects.

The recorded history of Hawaiian tsunamis shows that 26 large tsunamis have made landfall within the islands and 8 have had significant damaging effects on Kauai. The last of these damaging tsunamis occurred in 1964, yet before this time (since 1868), a damaging tsunami reached Kauai on average once every 12 yr. It is important to note that the frequency of tsunami occurrence is chaotic or unpredictable and particular periods of time may be characterized by significantly different tsunami activity than others. For example, between 1868 and 1933, only three major tsunamis impacted Kauai's shores with an average reccurrence interval of 22 yr. However, during the more active period between 1946 and 1964 five tsunamis had damaging impacts to Kauai at an average frequency of 3.5 yr. Regardless of which time period we analyze, an important observation of the data is that since 1964, Kauai has not experienced a damaging tsunami. One might conclude that a damaging tsunami is long overdue to hit Kauai. Interestingly it has been precisely in this time that tremendous coastal development has occurred, raising the risk of damage from future tsunamis.

Kauai

Tsunamis

(after Lander and Lockridge, 1989)



Large tsunamis* (>1m, 3.3 ft) with reported damage in the Hawaiian Islands

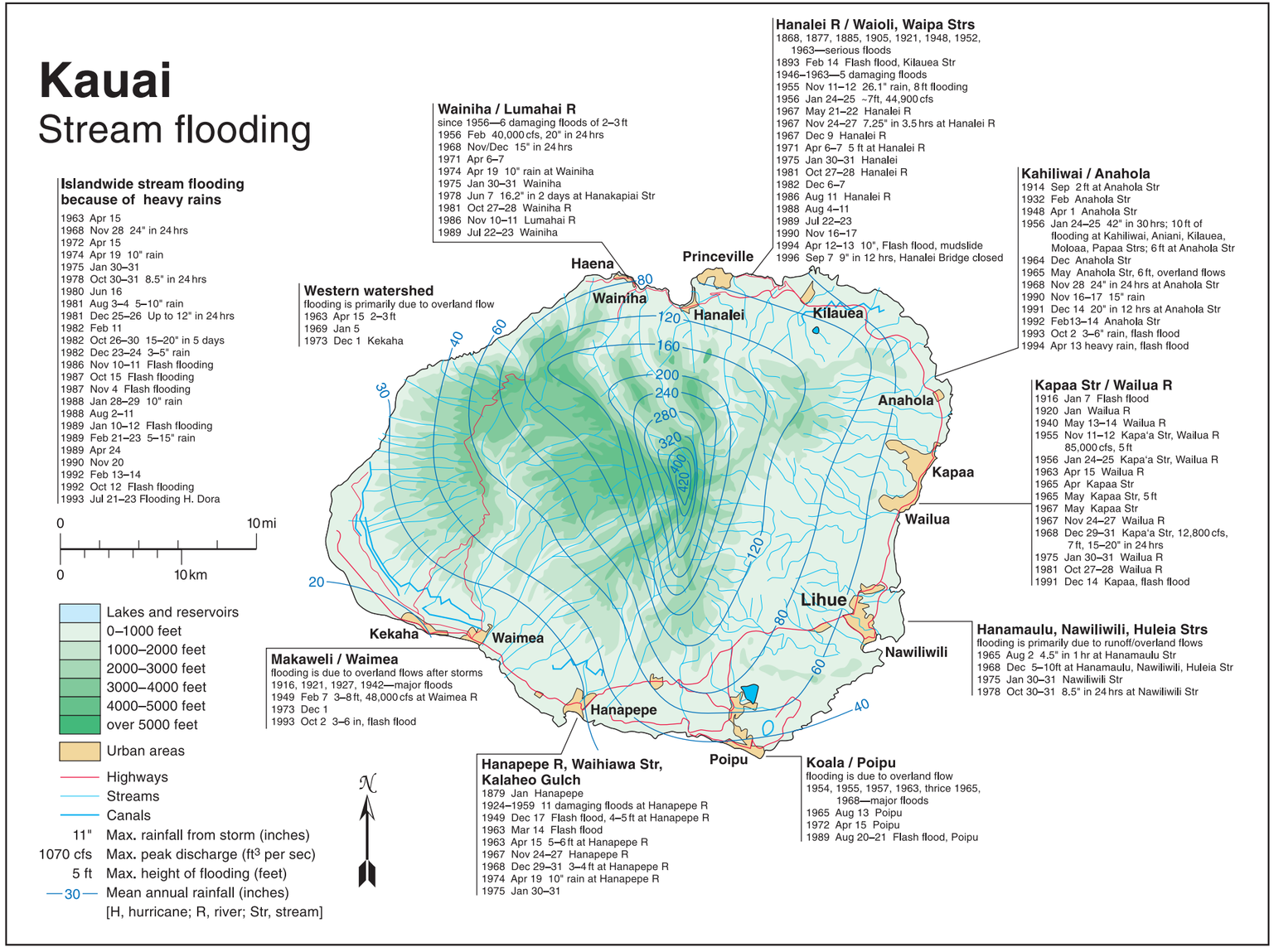
Year	Date	Area of origin	Magnitude**
1819	Apr 12	N Central Chile	M= 2.0
1835	Feb 20	Southern Chile	M = 4.0
1837	Nov 7	Southern Chile	M = 3.0
1841	May 17	Kamchatka	M = 2.0
1868a	Apr 3	SE Hawaii	M = 4.1
1868b	Aug 13	Northern Chile	M = 4.3
1868c	Oct 2	South Pacific	
1869	Jul 24	South Pacific	
1877	May 10	Northern Chile	M = 4.0
1878	Jan 20	Aleutian Is (?)	
1896	Jun 15	Japan	M = 4.0
1901	Aug 9	Tonga	
1906a	Jan 31	Colombia/Ecuador	M = 1.0
1906b	Aug 17	Central Chile	M = 2.0
1918	Sep 7	Kurils	M = 3.6
1919	Oct 2	Hawaii (H = 14 ft)	
1922	Nov 11	N Central Chile	M = 3.0
1923	Feb 3	Kamchatka	M = 3.0
1933	Mar 2	Japan	M = 3.0
1946	Apr 1	Eastern Aleutian Is	M = 5.0
1952a	Mar 17	Hawaii (H = 10 ft)	
1952b	Nov 4	Kamchatka	M = 4.0
1957	Mar 9	Central Aleutian Is	M = 3.5
1960	May 22	Chile	M = 4.5
1964	Mar 28	Gulf of Alaska	M = 4.5
1975	Nov 29	Big Island/Hawaii (H = 47 ft)	

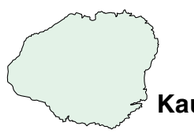
*Reliability of ≥ 3 (of 4)(Lander and Lockridge, 1989), runup > 1m (3.3 ft), and reported damage.

** Tsunami magnitude is defined by $M = \log_2 H$ as revised by Iida and others (1967), where H is the maximum runup height or amplitude on a coastline near the generating area.

Other tsunamis have occurred, such as that of Oct 1994, however, because of their low (<1 m) runup, insignificant damage, and/or uncertainty surrounding their timing and magnitude as noted in Lander and Lockridge (1989), they were not included here.

Kauai
Stream flooding





Kauai

Stream flooding

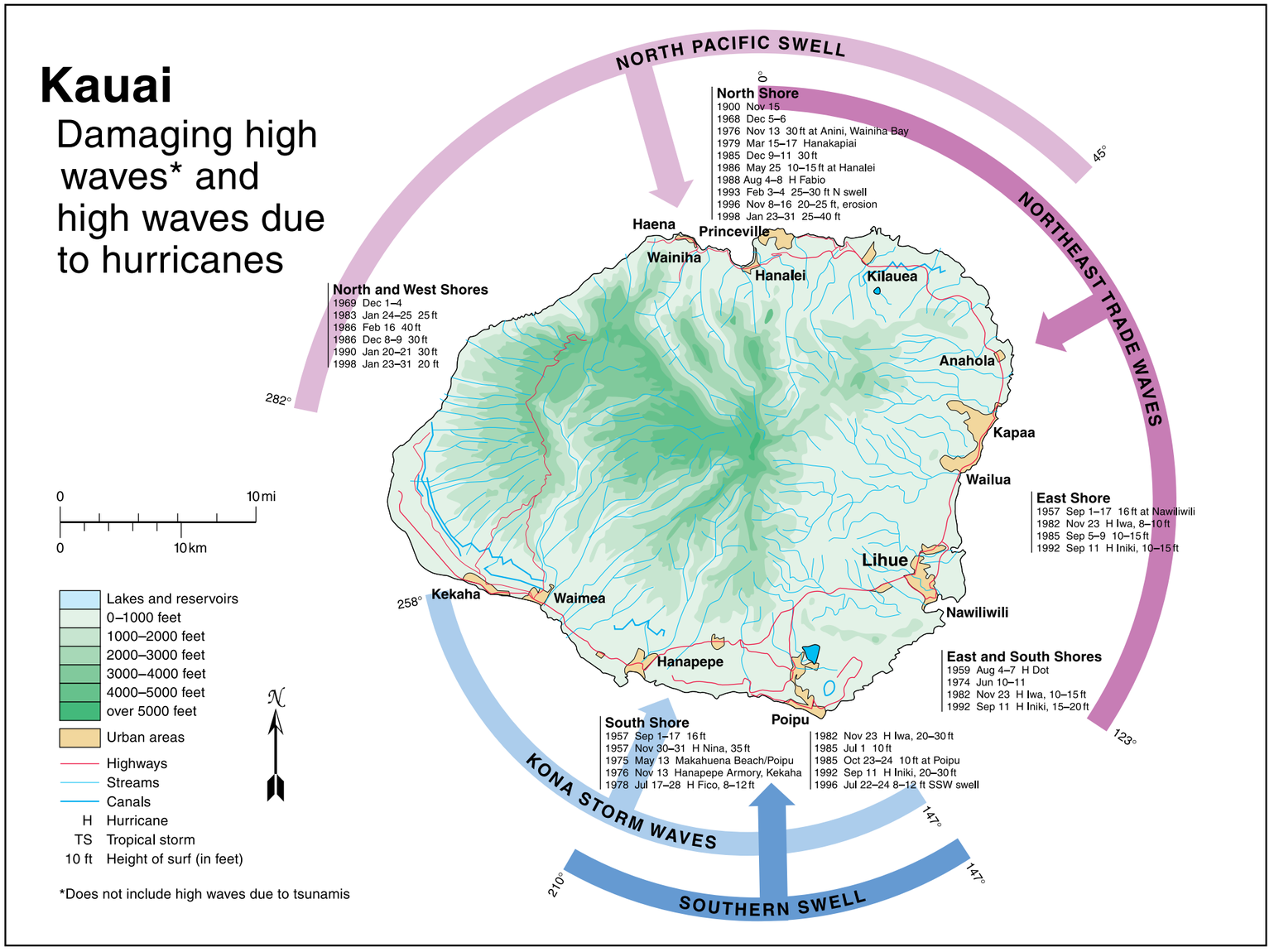
Stream flooding on Kauai is characterized by numerous flash floods as well as prolonged flooding associated with slowly passing rainstorms that saturate the soils. Kauai, famous as one of the wettest places on Earth, receives between 20 and 80 in of annual rainfall along the coast and more than 400 in at the higher elevation of Mt. Waealeale. Because of the abrupt transition from steep mountain topography to narrow, low-lying coastal plains, high precipitation often results in extremely high runoff on the mountain sides and channel overflow in the gently sloping streams at the coast. During prolonged rainfall, precipitation often exceeds absorption into the soil, which also transpires into high runoff and occasional mud slides. There is a long history of settlement in and near active stream valleys on Kauai, primarily for the agricultural benefit of naturally irrigating taro and other wetland crops. However, with the increase in development of homes, resorts, and public infrastructure along low-lying stream lands during the past two decades, flooding is not considered as beneficial today as it once was. As a result, many floodprone regions are now being artificially channelized to the detriment of wetland and floodplain ecosystems.

Flash floods resulting from a storm on December 14, 1991, that dropped over 20 in of rain in 12 hr over Anahola caused five deaths, intense flooding, bank failures, erosion, and slides totaling more than $5 million in property damages. During recent recorded history, such events are not uncommon. On January 24-25 1956, 42 in of rain fell in 30 hr on the northeast side of Kauai leading to 10 ft of floodwaters in the streams between Kilauea and Anahola. The Hanalei River, which most directly drains the wettest region of Mt. Waialeale, overflows its banks at the coast nearly every year. Some years are considerably more damaging than others, for example, November 1955, January 1956, April 1994, and September 1996. In September of 1996 for instance, 9 in of rain were recorded in 12 hr along the coast, and an uncertain amount fell in the uplands. This event led to flooding of Hanalei town and temporary closure of the Hanalei Bridge, the residents' sole access to the rest of the island. In the western portion of Kauai, the flooding hazard is primarily due to overland flows, especially after storms. Waimea River, for example, has a long record of flooding dating back to 1916 and includes numerous occasions when its channels overflowed after storm-fed precipitation in Waimea Canyon above. The challenge to mitigating the hazard due to stream flooding is in large part one of obtaining adequate warning in the case of flash floods and in improved planning of developments in areas of known flood history.

High waves

Each year the Hawaiian Islands receive high waves originating from distant regions in the Pacific Ocean as well as passing storms in close proximity to Hawaiian shores. The north shore of Kauai, like the north shores of all of the islands, is subject to extraordinary wave heights each winter ranging between 20 and 40 ft due to north and northwest swell. The south shore on average sees waves of 4 to 8 ft each summer from south and southwest swell. High waves in Hawaii are also generated by approaching storms, including tropical storms and hurricanes in summer and fall, as well as winter Kona storms. Strong trade wind events also stir up high waves that influence the east-facing shorelines. High waves can be damaging to life and coastal property and, when they coincide with high tides and/or storm surges, can inundate far inland. Nearly each year in Hawaii, high waves are reported to overwash and flood coastal lands and erode beaches and coastal property. The behavior of surface waves at the shoreline is determined by a large number of factors including swell height, period and direction, nearshore bathymetry and morphology, and shoreline aspect and slope. The interaction of these factors makes it difficult to accurately predict the hazard outcome at individual shorelines. Because of Hawaii's isolation in the central North Pacific Ocean, and the lack of inhabited islands north of Kauai, the magnitude and threat of high waves from north swell is often only recognized as the waves crash upon Kauai's shores. New technologies, including offshore wave sensors, are helping to provide adequate warning to approaching high waves with damaging potential.

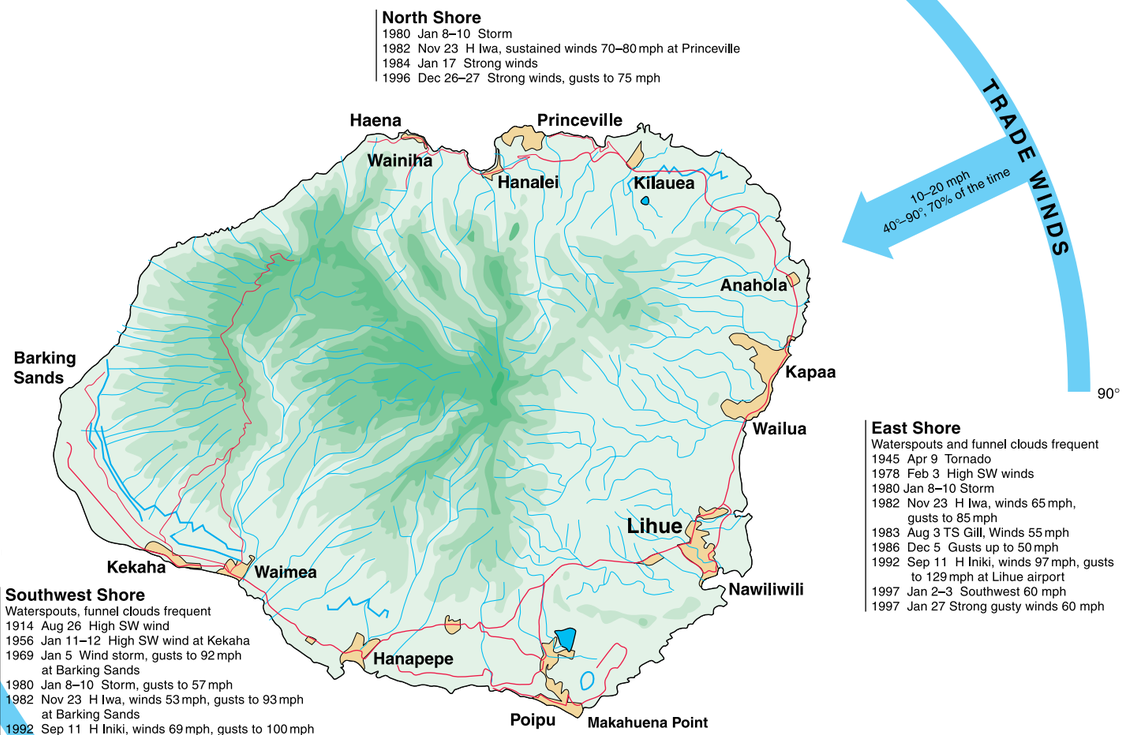
The historical record of high wave events on Kauai spans the 1900s but the majority of observations have been made only since the late 1950s. The largest wave events occurred on the north shore due to strong storms in the north Pacific, like those in December 1985, February 1993, November 1996, and January 1998. The events, like most north swell, had high wave amplitudes in addition to long wave periods and transferred enormous energy across the nearshore and onto the shoreline. They were associated with beach erosion and overwash of coastal property and, in the case of the November 1996 event, 20-25 ft waves and a high tide swept a rental home off of its foundation. The west shore on average sees waves of 15-20 ft each year, but occasionally waves as large as 40 ft, like in February 1986, reach west Kauai. South and southwest swell, while typically of lower height, generally have longer period, and the energy they transmit can be sufficient to impact the shoreline. Wave heights of 8-12 ft occasionally reach the south and southwest shore from distant storms in the Southern Hemisphere and overwash the low-lying regions. Passing hurricanes, however, have generated the highest wave heights along the south- and east-facing shores and may coincide with a high tide and typically generate a strong storm surge. Waves ranging from 20-30 ft were associated with Hurricane Nina (35 ft) in November 1957, Hurricane Iwa in November 1982, and Hurricane Iniki in September 1992 along the south coast near Poipu. Runup of ~29 ft above sea level was recorded near Poipu during Hurricane Iniki, which left a debris line more than 800 ft inland of the shoreline and landward of the coastal road. Waves as high as 15 and 20 ft were reported along Kauai's east shores during Hurricanes Iwa and Iniki.



*Does not include high waves due to tsunamis

Kauai
Strong winds

Islandwide strong winds
1949 Jan 15–17 Waimea
1950 Jan 11 High wind
1950 Aug 14 H Hiki, winds of 68 mph
1957 Sep 1–17 H Della, winds of 52 mph
1957 Nov 30–Dec 1 H Nina, winds of 92 mph
1959 Aug 4–7 H Dot, 138 mph
1967 Nov 2–11 Strong winds to 100 mph
1967 Nov 24–27 Gusts to 85 mph
1967 Dec 16–18 Strong, gusty, southerly winds
1968 Nov 28 Gale winds, 63 mph
1971 Jan 5 High winds
1971 Jan 8–18 TS Sarah, 61–66 mph
1975 Jan 30–31 Strong winds
1980 Jan 8–11 Storm
1982 Feb 11 Strong wind
1982 Aug 16 H Kristy
1982 Nov 23 H Iwa
1982 Dec 18–19 Strong winds
1983 Aug 3 TS Gil, 55 mph winds
1983 Dec 24–26 High winds
1984 Mar 1–2 Strong winds, gusts 30–40 mph
1984 Dec 24–25 Kona storm
1986 Feb 21 Strong winds, 50 mph
1987 Dec 11–19 Kona storm
1989 Mar 1–4 Storm
1991 Jan 27 Storm
1992 Sep 11 H Iniki, winds 130 mph, gusts to 160 mph
1993 Mar 14 Strong, gusty winds 50–70 mph
1993 Dec 4–6 Strong trade winds 60–80 mph
1997 Jan 27–28 Strong, gusty winds 60 mph



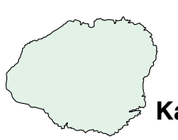
North Shore
1980 Jan 8–10 Storm
1982 Nov 23 H Iwa, sustained winds 70–80 mph at Princeville
1984 Jan 17 Strong winds
1996 Dec 26–27 Strong winds, gusts to 75 mph

Southwest Shore
Waterspouts, funnel clouds frequent
1914 Aug 26 High SW wind
1956 Jan 11–12 High SW wind at Kekaha
1969 Jan 5 Wind storm, gusts to 92 mph at Barking Sands
1980 Jan 8–10 Storm, gusts to 57 mph
1982 Nov 23 H Iwa, winds 53 mph, gusts to 93 mph at Barking Sands
1992 Sep 11 H Iniki, winds 69 mph, gusts to 100 mph at Barking Sands
1997 Jan 28 Thunderstorm, gusts to 75 mph

South Shore
Waterspouts common
1967 Nov 2–11 Strong winds, 100 mph
1967 Dec 17 Windstorm/tornado
1971 Dec 18 Waterspout/tornado
1971 Dec 31 Waterspout/tornado
1980 Dec 8–10 Storm, 62 mph at Lihue airport
1982 Nov 23 H Iwa, winds 63 mph, gusts to 85 mph at Lihue airport
1992 Sep 11 H Iniki, winds 81 mph, gusts to 143 mph at Makahuena Point
1997 Jan 28 Thunderstorm, gusts to 53 mph

East Shore
Waterspouts and funnel clouds frequent
1945 Apr 9 Tornado
1978 Feb 3 High SW winds
1980 Jan 8–10 Storm
1982 Nov 23 H Iwa, winds 65 mph, gusts to 85 mph
1983 Aug 3 TS Gill, Winds 55 mph
1986 Dec 5 Gusts up to 50 mph
1992 Sep 11 H Iniki, winds 97 mph, gusts to 129 mph at Lihue airport
1997 Jan 2–3 Southwest 60 mph
1997 Jan 27 Strong gusty winds 60 mph

Lakes and reservoirs
0–1000 feet
1000–2000 feet
2000–3000 feet
3000–4000 feet
4000–5000 feet
over 5000 feet
Urban areas
Highways
Streams
Canals
H Hurricane
TS Tropical storm
50 mph Max. winds (miles per hour)



Kauai

Strong winds

Strong winds on Kauai are associated with exceptionally strong trade wind events, winter Kona storms, and passing tropical storms and hurricanes. Trade winds dominate on average 70% of the year with easterly and northeasterly winds ranging between 10 and 20 mph. However, occasionally the subtropical high pressure cell to the north of Hawaii intensifies such that the trade winds strengthen to between 25-40 mph for several days. Strong winds associated with Kona storms generally occur in the winter and originate out of the south and southwest as areas of low pressure pass the islands. Kona winds can reach great velocities. The highest winds are typically associated with passing tropical storms and hurricanes and have been reported at over 100 mph. All of these winds can accelerate as they descend from the mountains to the coastal plains. In many instances, the highest recorded gusts associated with passing storms have occurred on the side of the island opposite the storm approach as winds burst in downdrafts across ridge crests from the steep palis (cliffs) to the coast below.

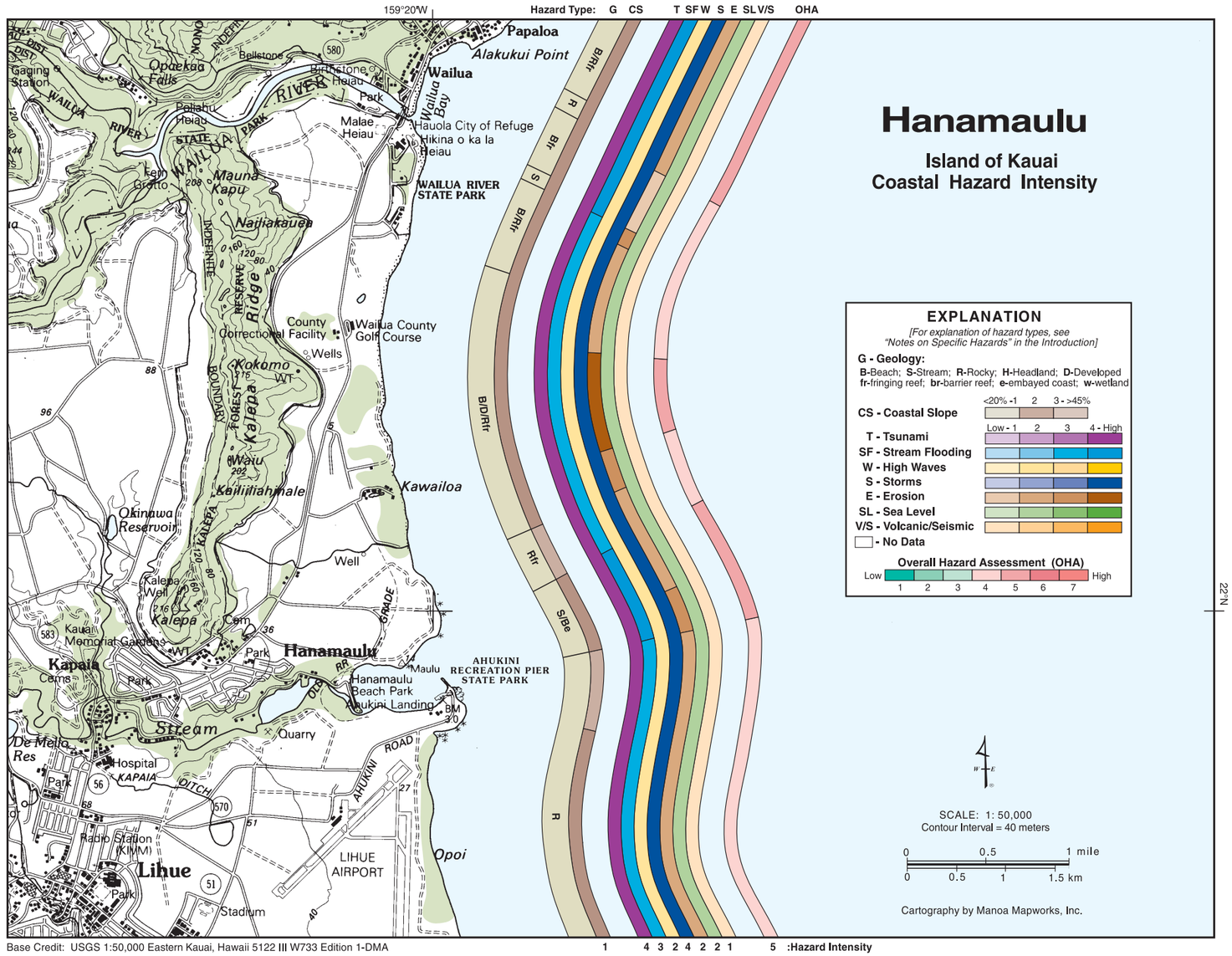
On Kauai numerous high wind events have affected the entire island, and many of these events were associated with passing storms. Hurricanes Dot in August 1959, Iwa in November 1982, and Iniki in 1992 were exceptionally damaging. Hurricane Dot packed sustained winds of 75 mph with gusts of 165 mph as it passed directly over Kauai. While the storm-generated surf was not particularly damaging, winds and flooding led to $5.5-6 million in agricultural losses and hundreds of houses and trees were damaged. Hurricanes Iwa and Iniki both produced high waves ranging 20-30 ft in addition to winds over 125 mph. Although Hurricane Iwa passed to the northwest of Kauai, the high surf it produced, combined with a 5-6 ft storm surge, flooded 600 ft inland in areas between Kekaha and Poipu and caused $312 million in damage. Ironically, despite the massive flooding and wind damage to the Poipu area, redevelopment following Iwa occurred in precisely the same location, only to be devastated 10 yr later by Hurricane Iniki. Today, these same areas are once again densely developed. On September 11, 1992, Hurricane Iniki, the strongest and most destructive hurricane to hit the Hawaiian Islands, made landfall just west of Port Allen on Kauai's south shore. Iniki's winds were sustained at 130 mph and gusts topped 160 mph. Winds and waves destroyed 1,421 houses and caused minor to heavy damage to 13,000 other houses.

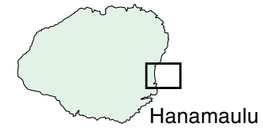
Hanamaulu

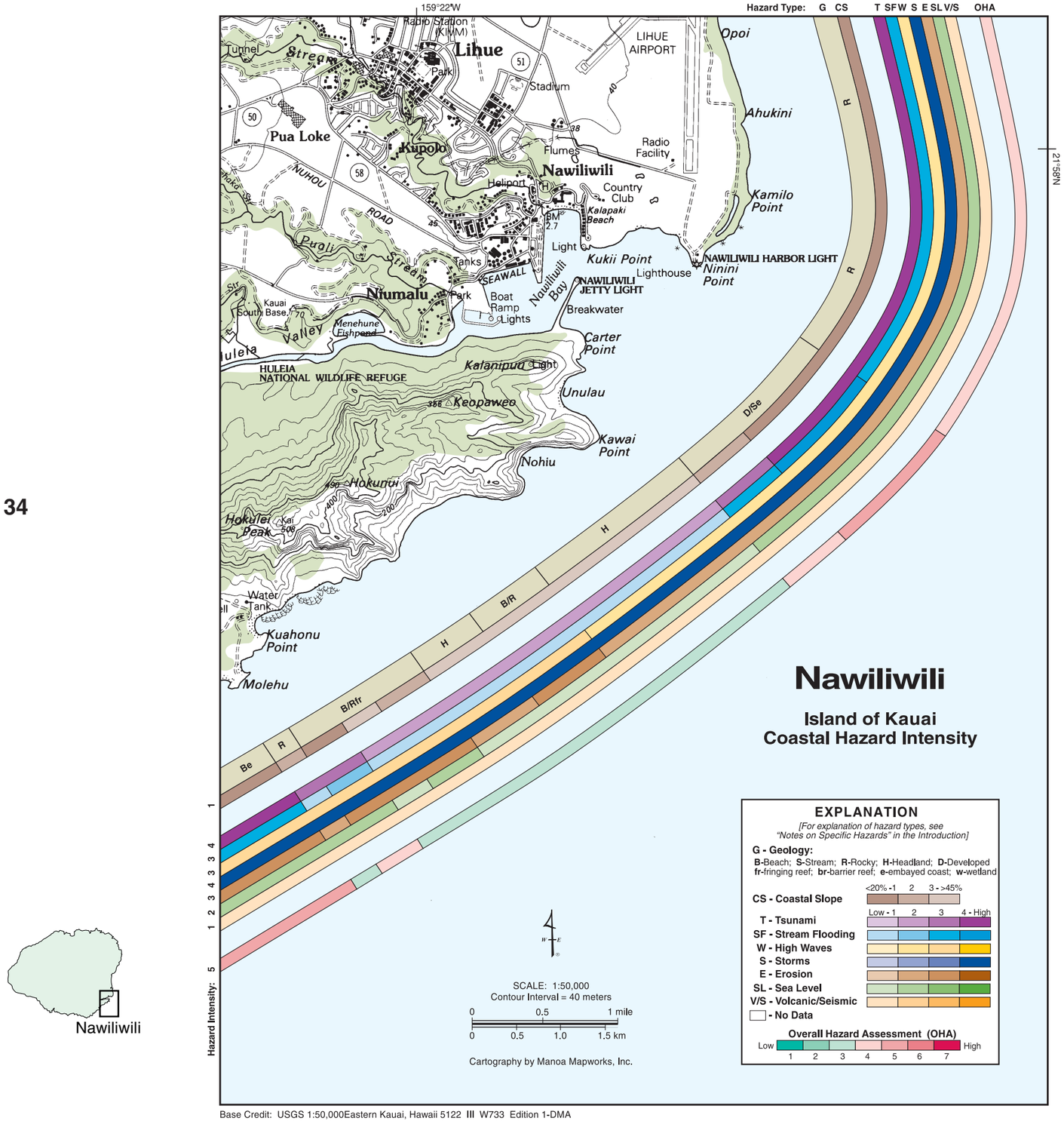
The Hanamaulu coast, from Alakukui Point south to Opoi, is lightly developed with several resorts, the Wailua County Golf Course, and Lihue Airport. The region has a relatively low slope, except along the rocky headlands bordering Hanamaulu Bay. Two prominent beach systems are located at Wailua and Hanamaulu Bays, which lie at the mouths of Wailua and Hanamaulu Rivers, respectively. Wailua River is one of the few navigable rivers in Hawaii. It is wide and during floods it can have significant discharge which can reshape the southern portion of Wailua Beach and the sandbar that forms at its mouth. Hanamaulu Beach is a 1500 ft long arcuate beach at the head of Hanamaulu Bay. The inner portion of the bay is covered mostly with sand, but small fringing reefs occur near the rock headlands. A relatively narrow fringing reef parallels the Hanamaulu coast 200 to 300 ft offshore. Facing east, this trade-wind swept coast is relatively arid, receiving on average 40-60 in of rainfall each year.

The Overall Hazard Assessment (OHA) for the Hanamaulu Coast is moderate to high (5) north of and including the northern half of Wailua Bay and moderate (4) to the south. This distinction is largely dictated by the higher stream-flooding hazard in the low-lying Wailua embayment and to the north. Except at the river mouth, Wailua Bay has a lower erosion hazard than to the north of Alakukui Point, resulting in a moderate (4) OHA for the Wailua Bay segment of the Hanamaulu coastline. The tsunami hazard is high along the entire Hanamaulu coast. The potential for stream flooding is high north of the Wailua River and moderately high to the south except in Hanamaulu Bay where it is also high. The threat of high waves and sea-level rise are moderately low, while storms are high along this entire east-facing coast. Erosion is moderately low, except between the Wailua River and just south of Alakukui Point where it is low, at the headland south of the Wailua River where it is moderately high, between the Wailua County Golf Course and Kawailoa where it is high, and immediately south of Kawailoa where it is moderately high. Erosion is also moderately high along Hanamaulu Beach Park. The volcanic-seismic hazard is ranked low along the Hanamaulu coast as it is around the entire island of Kauai.

The narrow, wind-swept shoreface of the Wailua County Golf Course is composed of a narrow sandy beach eroding against a long seawall protecting the fairway. To the north and south, beach erosion has left the shoreline mostly rocky.







Base Credit: USGS 1:50,000Eastern Kauai, Hawaii 5122 III W733 Edition 1-DMA

Nawiliwili

South of the Lihue Airport to Molehu Point, the coast is highly irregular; its shape is controlled by the elongated and drowned Huleia Stream valley forming Nawiliwili Bay. This embayment is largely protected by a rocky headland at Ninini Point and a breakwater that extends into the bay from Carter Point. Between Carter and Kuahonu Points, relatively steep-sloping hills meet the sea in three beautiful pocket coves. Nearly the entire Nawiliwili coast is rocky with headlands, except for two beaches in the southernmost coves near Kuahonu Point, and the gently-sloping Kalapaki Beach inside Nawiliwili Bay. A narrow fringing reef exists offshore of Kuahonu Point, otherwise most of the Nawiliwili region is open to approaching south, southwest, and refracting trade wind swell. Nawiliwili Bay is relatively industrial, while the region to the southwest is primarily undeveloped.

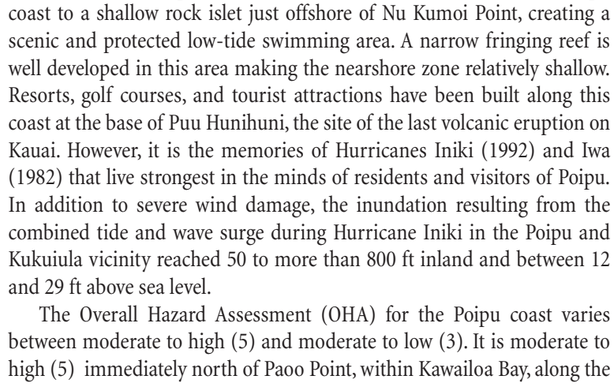
The Overall Hazard Assessment for the Nawiliwili coast varies between moderately high (5) in Nawiliwili Bay and southwest of Molehu, to moderately low (3) between Kawai and Kuahonu Points and along the Molehu headland. A moderate (4) OHA is assigned to the region north of Ninini Point, between Carter and Kawai Points, and between Kuahonu Point and Molehu. The tsunami hazard is high north of the Nawiliwili breakwater, moderately high along the breakwater and moderately low along the steep sea cliffs to the south. It is increased to moderately high along the less steep coastal plain between Kuahonu Point and Molehu. Stream flooding increases from moderately high in the north to high in Nawiliwili Bay. Along the breakwater it is moderately high, and to the south it is moderately low until the Kuahonu coastal plain where it is moderately high. High waves are ranked moderately low along the east-facing coast north of Nohiu and moderately high to the south, where south swell approach is more direct. Storms are ranked high along the entire coast. Erosion is moderately low along most of Nawiliwili except at the low-lying beaches south of Nohiu and Kuahonu where it is moderately high. The sea-level threat is moderately low north of Kawai Point and low along the steeper rocky coast to the south, except for the lower-lying beaches near Kuahonu Point where it is moderately low. The volcanic-seismic threat is low along the entire Nawiliwili Coast.

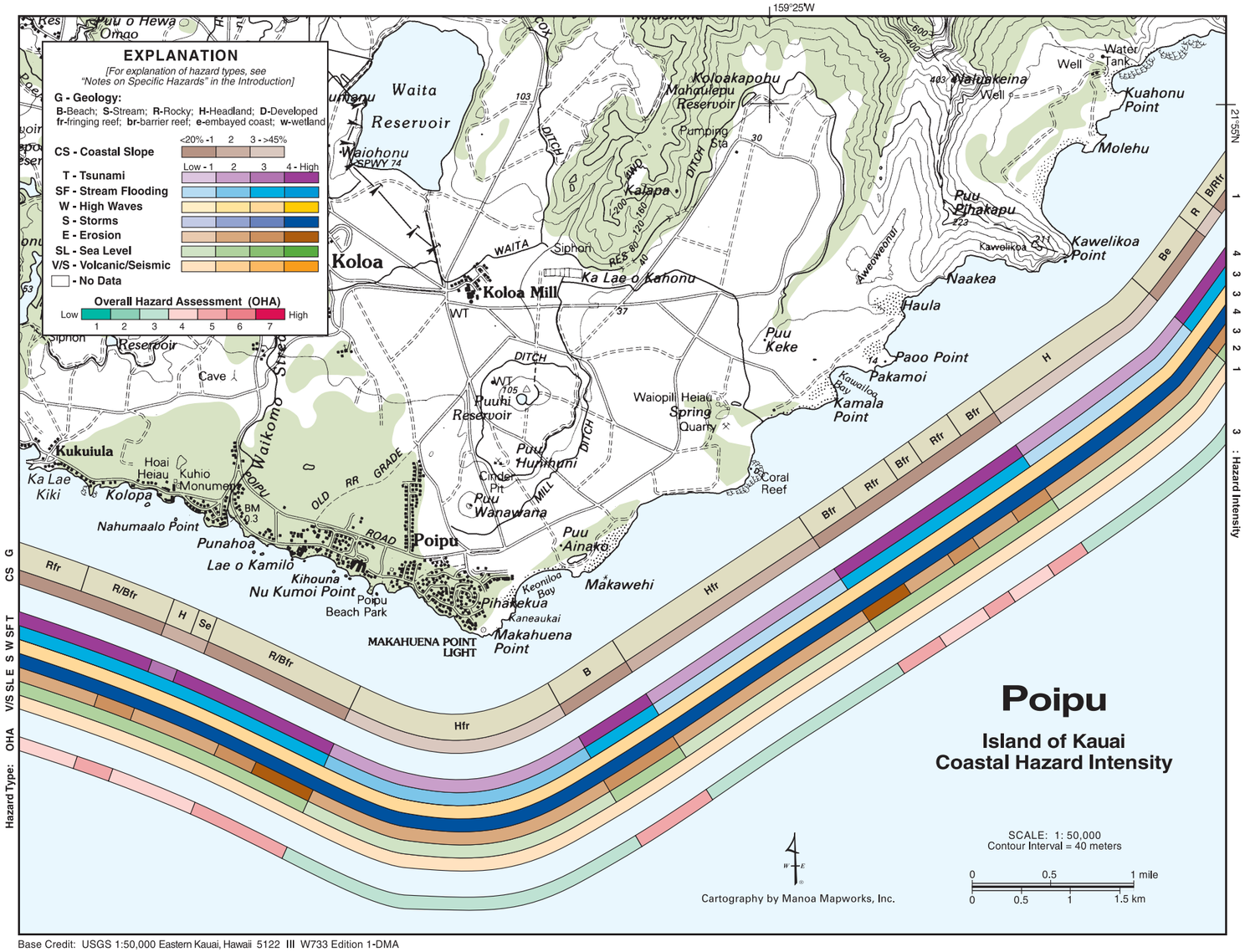
Relatively steep, rocky cliffs with some sea caves form the shoreline south of Nawiliwili Bay and Kawai Point.

Poipu

Makahuena Point in Poipu is the southern tip of Kauai. This is primarily a rocky headland coast with small, arcuate coves carved into the steep-sided hills. Small sandy pocket beaches are found at Kolopa, Kihouna, Keoniloa Bay, and just to the south of Kamala Point, Haula, and Molehu Point. A strip of sand, known as a tombolo, connects the Poipu coast to a shallow rock islet just offshore of Nu Kumoi Point, creating a scenic and protected low-tide swimming area. A narrow fringing reef is well developed in this area making the nearshore zone relatively shallow. Resorts, golf courses, and tourist attractions have been built along this coast at the base of Puu Hunihuni, the site of the last volcanic eruption on Kauai. However, it is the memories of Hurricanes Iniki (1992) and Iwa (1982) that live strongest in the minds of residents and visitors of Poipu. In addition to severe wind damage, the inundation resulting from the combined tide and wave surge during Hurricane Iniki in the Poipu and Kukuiula vicinity reached 50 to more than 800 ft inland and between 12 and 29 ft above sea level.

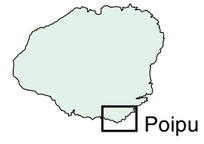
The Overall Hazard Assessment (OHA) for the Poipu coast varies between moderate to high (5) and moderate to low (3). It is moderate to high (5) immediately north of Paoo Point, within Kawailoa Bay, along the southern side of the embayment south of Kamala Point, within Keoniloa Bay, between Poipu Beach Park and Lae o Kamilo, and between Nahumaalo Point and Kolopa. The OHA is moderate (4) between Paoo Point and Pakamoi, immediately south of Kamala Point, at Punahoa, and west of Kolopa. It is moderate to low (3) along the steeper headlands northeast of Paoo Point, northeast of Makawehi, and around Makahuena Point. The tsunami hazard is high along the low-lying embayed sections of coast and moderately low along the steeper headlands in between. At Nahumaalo Point the embayed coast is relatively steep, so the tsunami hazard is moderately high. Stream flooding varies between low along the headland segments of the coast of Naakea and Makawehi, and moderately high along the low-lying embayments. It is moderately low along the Makahuena Point headland. The high wave hazard is moderately high, storms are high, and the sea-level and volcanic-seismic hazards are moderately low and low, respectively, along the entire Poipu Coast. Erosion is moderately low along the steep headlands and high at the southwestern beach of the Kamala Point area and at Poipu Beach Park. It is moderately high immediately north of Paoo Point, at Kawailoa and Keoniloa Bays, and inside the small bays immediately west of Kihouna and Nahumaalo Point.

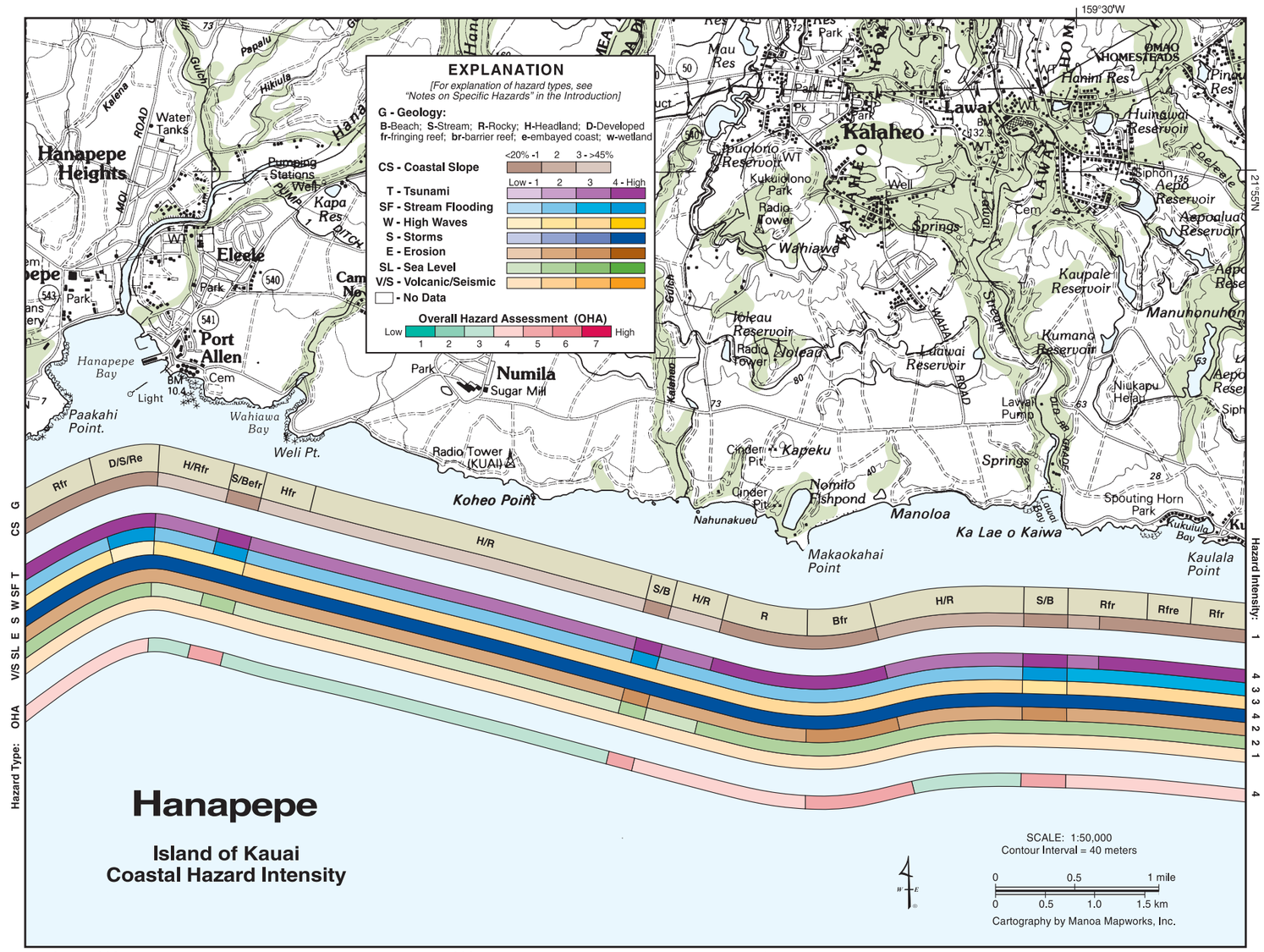




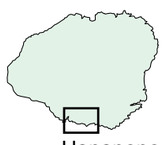
Base Credit: USGS 1:50,000 Eastern Kauai, Hawaii 5122 III W733 Edition 1-DMA

The extensively developed region of Poipu is built on the rocky basalt coastal plain of Puu Hunihuni forming Makahuena Point, the southernmost point on Kauai.





Base Credit: USGS 1:50,000 Western Kauai, Hawaii 5022 II W733 Edition 1-DMA, and USGS 1:50,000Eastern Kauai, Hawaii 5122 III W733 Edition 1-DMA



Hanapepe

The Hanapepe coast between Hanapepe Bay and Kaulala Point is lined with gentle to moderately sloped, rocky coastal cliffs separated by four stream mouth embayments: Wahiawa Bay, Nahunakueu, Lawai Bay, and Kukuiula Bay. Many small beach systems occur along this coast, with more significant ones at Wahiawa Bay, the mouth of Kalaheo Gulch, just east of Makaokahai Point, and Lawai Bay. Small patch and fringing reefs border the coast, except in the more deeply incised embayments, such as Wahiawa Bay, where sand fields predominate. Hanapepe Bay is largely infilled with terrigenous-rich sediment and is a common breeding site for hammerhead sharks. A unique fishpond, Nomilo Fishpond, has been created inside the Nomilo volcanic cinder cone just landward of the shoreline at Makaokahai Point. On the rocky shore at Spouting Horn Beach Park, just west of Kukuiula Bay, is one of Hawaii's most famous blowholes and a popular tourist attraction on Kauai. This region was devastated by the heavy winds and high storm surge of Hurricane Iniki in 1992. To some degree, the low coastal cliffs here mitigated the marine flooding to lower levels than the shoreline to the east (Poipu).

The Overall Hazard Assessment (OHA) for the Hanapepe coast varies between moderate to low (3) east of Port Allen to moderate to high (5) at the low-lying coastal areas of Waiawa Bay, Nahunakueu, Makaokahai Point, and Lawai Bay. The OHA is moderate (4) inside Hanapepe Bay, between the western, rocky edge of the Kalaheo Stream mouth and Makaokahai Point, and east of Ka Lae o Kaiwa. The tsunami hazard is high, except along the relatively steep rocky headlands, where it is moderately high. Stream flooding is moderately high to the east and moderately low to the west of Lawai Bay except at Lawai Stream mouth, Kalaheo Gulch, Wahiawa Bay, and Hanapepe Bay, where it is high. The high wave hazard is moderately high east of Weli Point except at Lawai Bay where it is moderately low; to the west it is moderately low, except in Hanapepe Bay where it is low. The storm threat is high and the volcanic-seismic hazard is low along the entire Hanapepe Coast. Erosion varies between moderately high at Lawai Bay, Makaokahai Point, and the Kalaheo Stream mouth to moderately low along the surrounding coastline. Sea-level rise is moderately low east of Nahunakueu and low to the west, except at the Kalaheo Stream mouth, Wahiawa Bay and west of Port Allen.

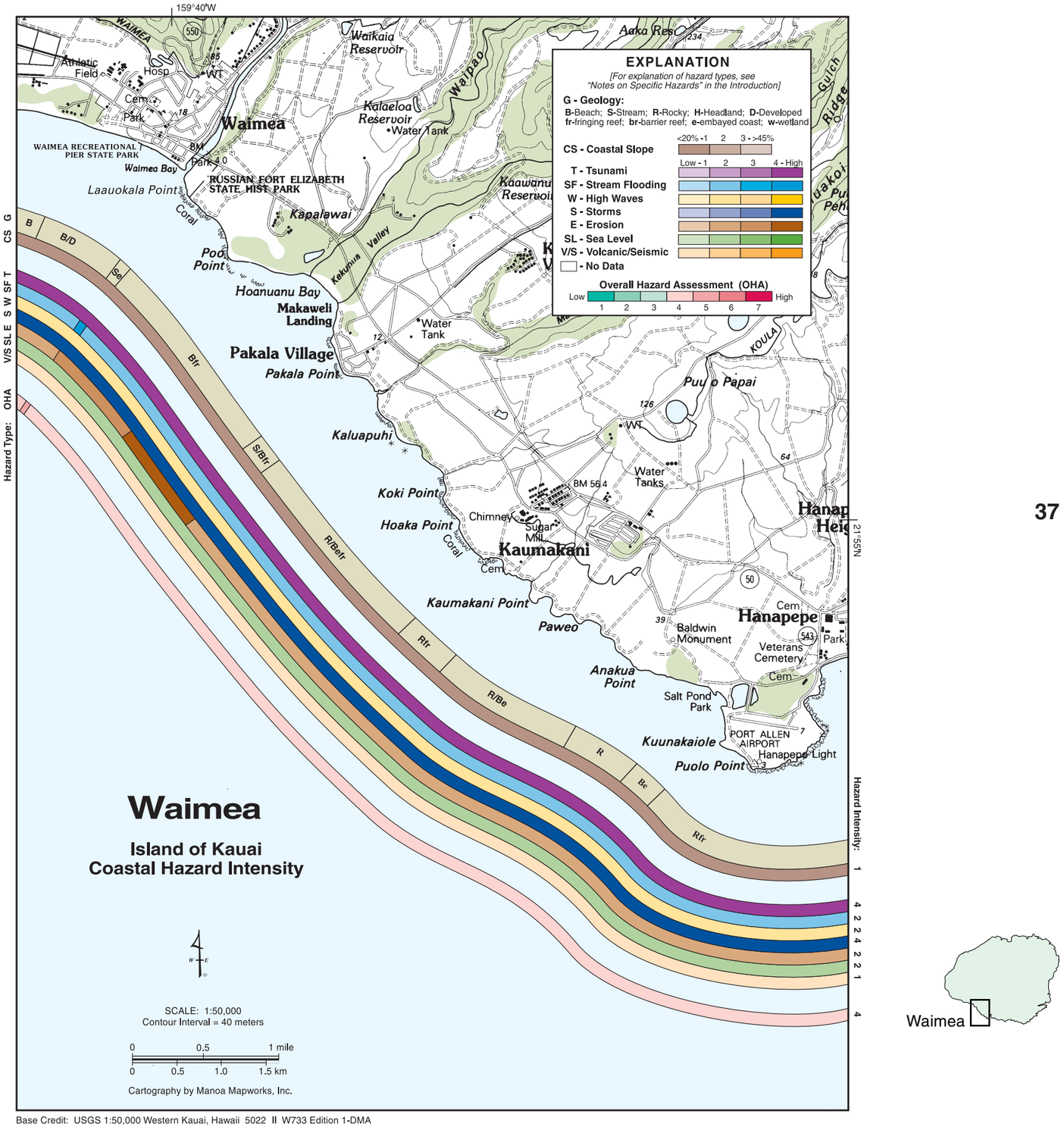
Much of the Hanapepe Coast is agriculturally developed and terrigenous sediment (along with many nutrients and pesticides) is often delivered to its nearshore waters by wind, surface runoff, and stream runoff.

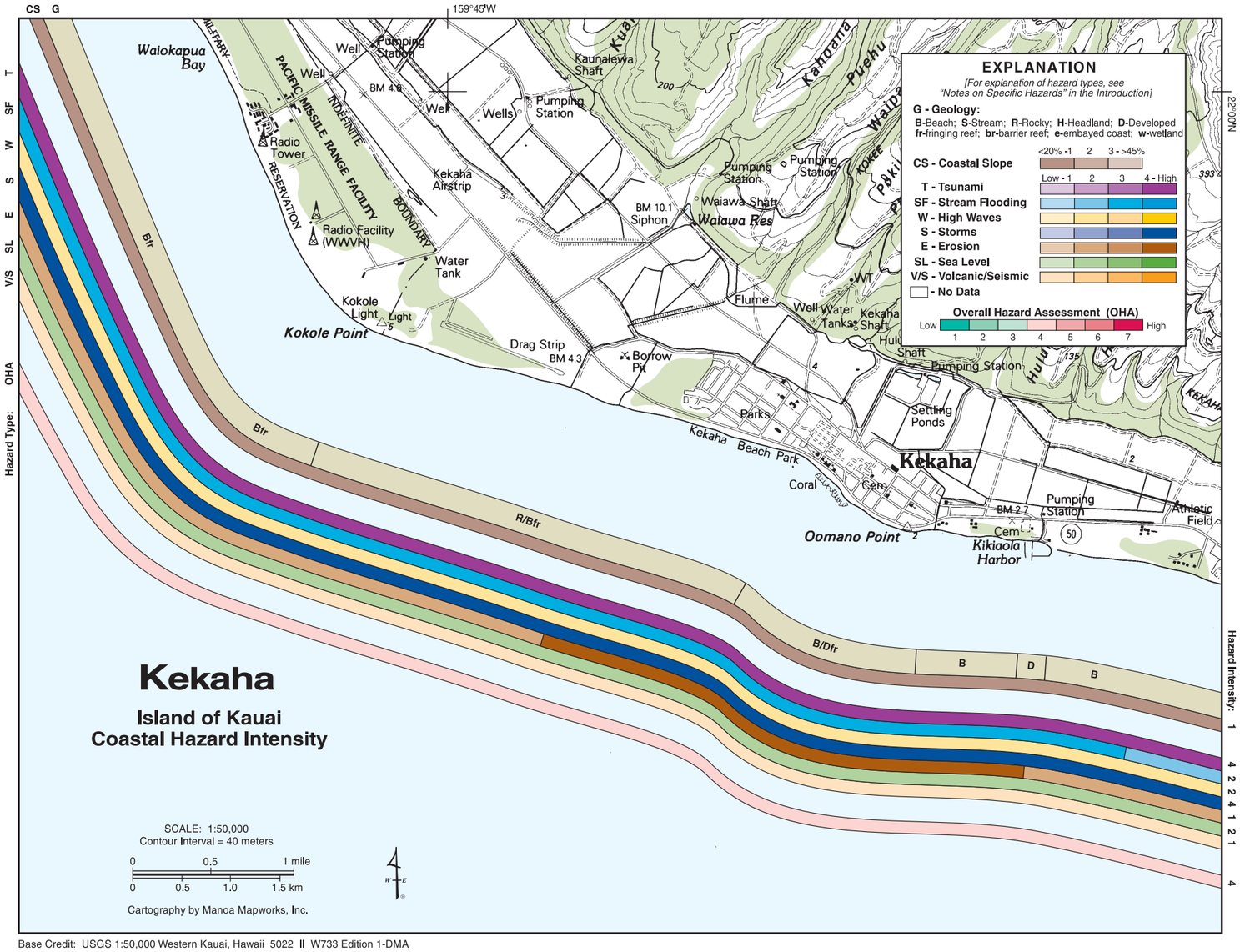
Waimea

Between Waimea and Puolo Point (Port Allen Airport) the Kauai coast is relatively gently sloping with an extensive fringing reef offshore. Rocky promontories at Hoaka, Kaumakani, Paweo, Anakua, and Puolo Points protect small isolated pocket beaches that grade into narrow, nearly continuous, sand beaches that line the Pakala and Waimea shore. The beach along Waimea is primarily derived of terrigenous sand and debris washed down from the Grand Canyon of Hawaii by the Waimea River, which empties into the Waimea Bay just west of Laauokala Point. A predominant westward longshore current is responsible for transporting sediments to the west toward Kekaha just west of the map. The fringing reef extends about 700 ft offshore of Pakala, which makes good surfing at the reef crest and a relatively protected nearshore zone. The only traditional Hawaiian salt pond still in use is located just west of Kuunakaiole where a relatively arid climate and optimal elevation allows for salt production at Salt Pond Park during the summer months.

The Overall Hazard Assessment (OHA) of Waimea is moderate (4), except for a thin sliver of coast at the Waimea River mouth, where it is moderate to high (5) because of the high stream-flooding hazard there. The tsunami hazard is high along the entire low-lying Waimea coast and stream flooding is moderately low, except at the Waimea River mouth, where it is high. Facing southwest, the hazard due to high waves is moderately low, while the threat from storms is high. In 1992, the eye of Hurricane Iniki made landfall across the village of Kaumakani. Erosion is moderately low east of Pakala Point and moderately high to the west, except between Pakala Point and the west end of Hoanuanu Bay, where it is high and seawalls line the shore. Erosion is also moderately low west of Waimea River mouth. The sea-level and volcanic-seismic hazards are moderately low and low, respectively.

The town and shoreline of Waimea is founded on the flood plain of the Waimea River, which is constructed of river sediments deposited during past large floods.





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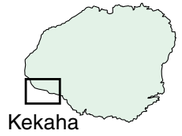


Kekaha

Kikiaola Small Boat Harbor in Kekaha marks a transition between the rocky coves and intermittent beaches to the east and a 15 mi long, continuous, and relatively wide sand beach that extends northwest to Polihale (see Polihale map). The harbor, built in 1959, has been implicated in causing and/or exacerbating beach erosion to the immediate west, threatening several homes. A strong west-moving longshore current develops during high surf. To the northwest of Kekaha, the U.S. Navy's Pacific Missile Range Facility is fronted by a gently-sloping beach with active and vegetated dunes. During seasonal high waves and temporary erosion events, long beachrock ridges become exposed at the water line. Offshore, a fringing reef parallels the coast around Kokole and Oomano Points to Kikiaola Harbor, while landward of the reef, sand bars often develop near Kekaha Beach Park. This portion of Kauai is the most arid, receiving on average less than 20 in of rainfall each year. Nearly all of the streams that drain the mountains of Waimea have been channelized and redirected toward Waimea town (see Waimea map) by the Waimea and Kekaha irrigation ditches.

The Overall Hazard Assessment for the entire Kekaha Coast is moderate (4). This reflects a uniformly high ranking for tsunami and storms and a moderately high assessment for stream flooding, except along the Waimea Recreational Pier State Park (see Waimea map), where stream flooding is moderately low. The threat from high waves is moderately low. Erosion is also moderately low, except for the segment of coast west of Kikiaola Harbor and including Kekaha Beach Park, where it is high. The hazard from sea-level rise is moderately low and the volcanic-seismic threat is low along the Kekaha Coast.

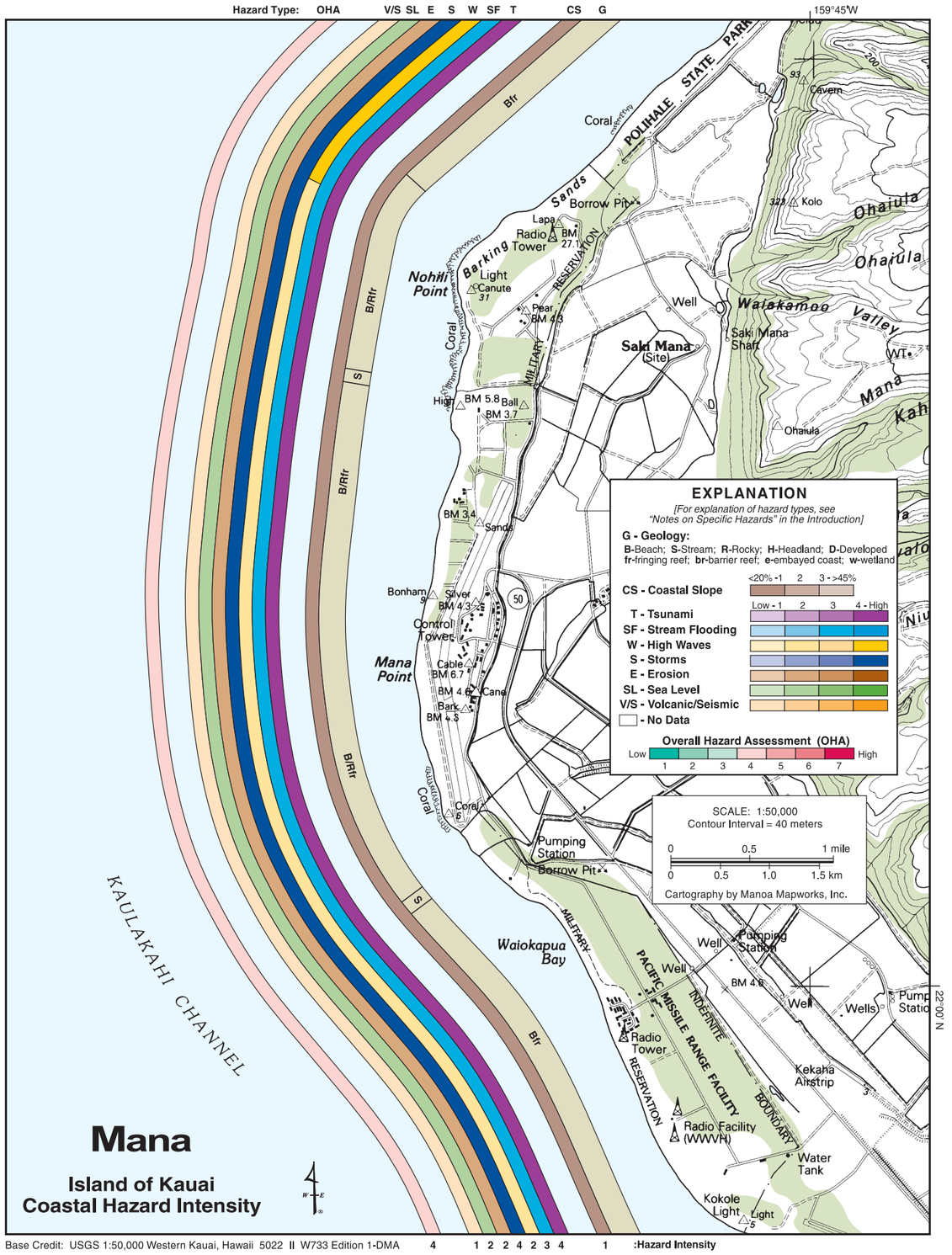
Erosion has narrowed the beaches of Kekaha and sediment-rich runoff, especially during heavy rain events, often leaves the nearshore waters silty.

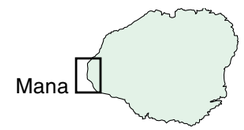
Mana

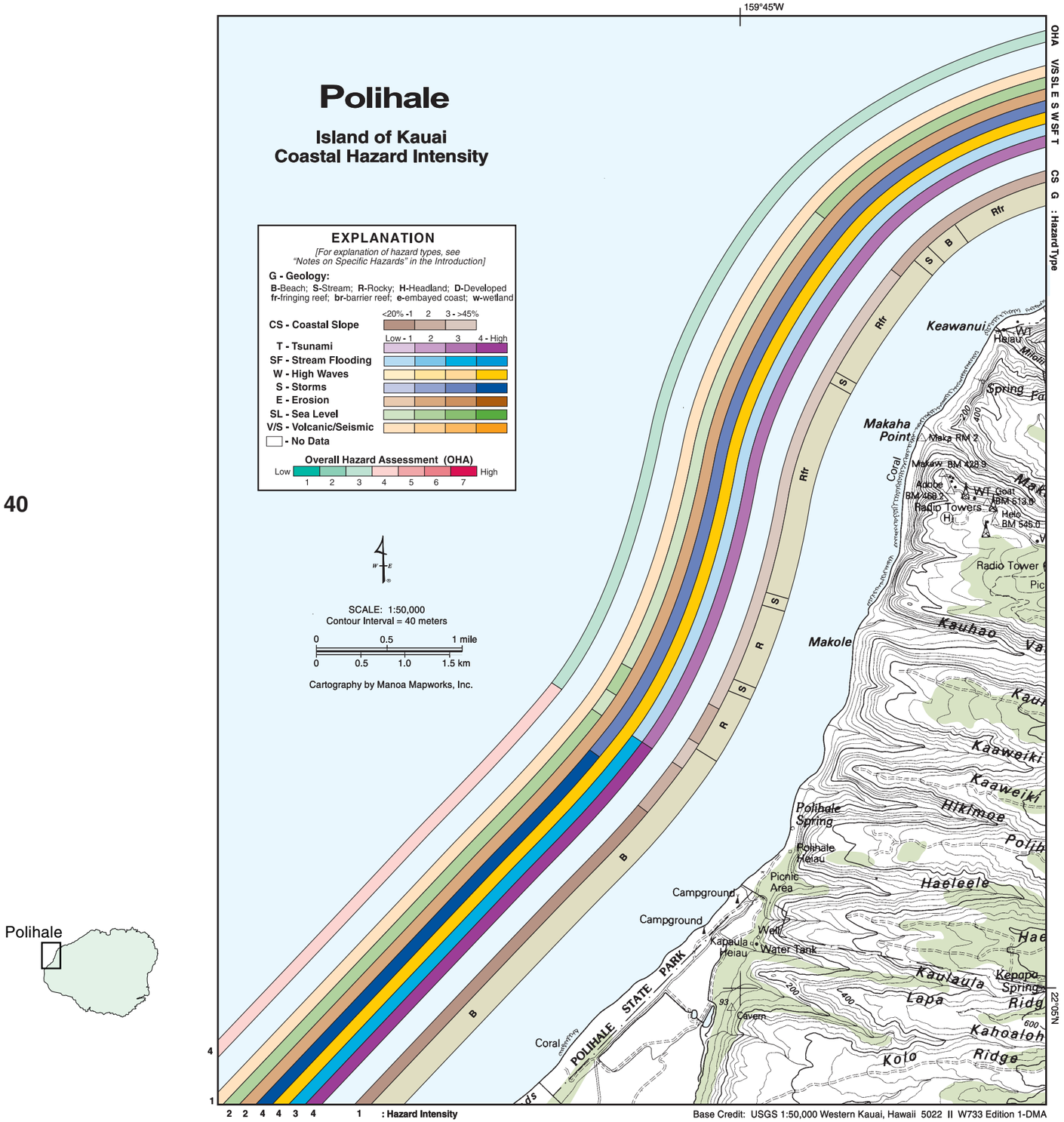
At the westernmost corner of Kauai, the Mana coast provides great vistas of the steep sea cliffs of eastern Niihau (to the west of Kauai) across the Kaulakahi Channel. One of Hawaii's longest continuous beaches extends south along the Mana coast from Polihale State Park beyond the U.S. Navy's Pacific Missile Range Facility. Extensive dunes and sands are known to sing and vibrate with resonant sounds when set in motion by the wind and gravity. For this reason the beautiful sand coast near Polihale was named Barking Sands. Two prominent points, Nohili and Mana Points, face west toward an extensive fringing reef that buffers the long beaches from large northwest and moderate southwest swell. Two streams enter the sea just south of both Nohili and Mana Points. Extensive outcrops of beachrock occur near Nohili Point, a sign that recent beach erosion has taken place to exhume the underlying lithified sands. The coastal plain along the Mana shore slopes gently and is relatively arid.

The Overall Hazard Assessment (OHA) for the Mana Coast is moderate (4) reflecting the uniform ranking of the coastal hazards throughout this low-lying coastal segment of Kauai. The only hazard that changes along the length of the Mana Coast is that of high waves. It is moderately low south of Nohili Point, which is partly sheltered from northwest swell by the island of Niihau (to the west), and high to the north which faces directly into approaching north and northwest swell. The tsunami hazard is high along the low-lying Mana coastal terrace and storms are ranked high because the Mana coast receives significant wind and waves generated by tropical storms that generally pass to the west of Kauai. Stream flooding is moderately high along the low-lying coastal zone. Erosion is moderately low, although there can be large seasonal variations in beach width. Sea-level rise is moderately low and the volcanic-seismic threat is low here as it is along the entire Kauai shoreline.

The broad low-lying Mana coastal plain consists of marine carbonate sands deposited by the convergence of two coastal currents from the north and south and the fall of sea level 3000 yr ago. Longshore parallel exposures of beachrock near the water's edge are evidence of recent erosion.







Polihale

Polihale

Along the Polihale coast the long sandy beaches of west Kauai end and the rugged Na Pali Coast begins. Na Pali is Hawaiian for "the cliffs" and represents 15 mi of tremendously scenic coast accessible only by foot or boat. Here, intense wave energy wears away at the north side of the island, producing steep cliffs that send waterfalls cascading 100's to a 1000 ft to the sea. A narrow fringing reef extends north-northeast offshore of Makole past Keawanui and is broken only in a few locations by streams draining Waimea Canyon State Park and the Kuia Natural Area Reserve. During large rainfall events, these streams transport significant quantities of sediment from the mountains and valleys to the ocean, creating extensive brick-red sediment plumes in the nearshore zone.

The Overall Hazard Assesment (OHA) for the Polihale Coast is moderate (4) along the beach of Polihale State Park and moderate to low (3) to the north along the steep rocky headlands of the Na Pali Coast. The tsunami hazard is high and stream flooding is moderately high along the low-lying coast of Polihale, whereas to the north, the tsunami ranking is moderately high and stream flooding is low. High waves are a serious threat due to the Polihale coast's exposure to north and northwest swell. The hazard from storms is high along the low-lying Polihale Beach and moderately high along the steeper Na Pali headlands. Erosion is moderately low along this entire coastal segment. The sea-level hazard is moderately low except at the steepest headlands found at Polihale Spring and along the Makole and Makaha Point areas where it is low. The volcanic-seismic hazard is low along the entire Polihale coastline.

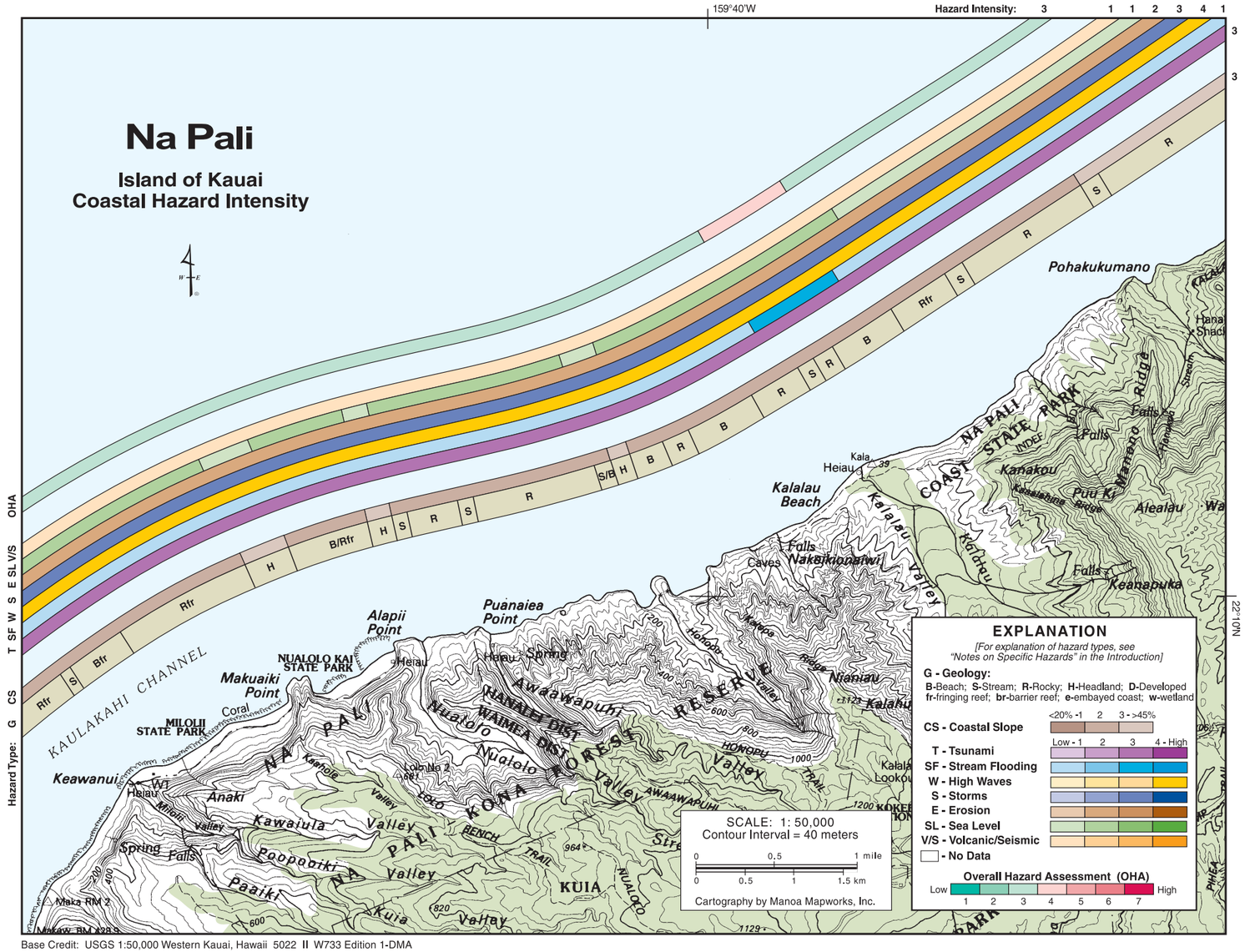
The long, white, carbonate sand beaches of west Kauai meet the steep northwest cliffs of Na Pali at Polihale Spring.

Na Pali

The Na Pali Coast and wilderness area is world famous for its steep coastal cliffs and rugged terrain, accessible only by walking and boating. Between Keawanui and Pohakukumano, several sand beaches lie inside small isolated bays such as between Milolii and Kalalau. Knife-edge ridges descend from the upper reaches of the Pali Kona Forest Reserve to form prominent rock headlands that separate the bays. Numerous small streams cut deep v-shaped valleys between the ridges and across the narrow Na Pali coastal plains after cascading 1000's of feet in dramatic waterfalls. Small patch reefs and/or fringing reefs exist inside some of the small bays, and between Keawanui and Alapii a fringing reef lines the coast. The steep, north-facing cliffs attest to intense wave energy and erosion, especially during the winter months when north swell can reach breaking heights of 30+ ft. As a result of high waves, and the funneling of trade winds through the Kaulakahi Channel offshore, longshore and rip currents can be very strong along this coast.

The Overall Hazard Assessment (OHA) for the Na Pali Coast is moderate to low (3) except at the Kalalau Stream mouth, where it is moderate (4) due to the increased stream-flooding hazard at the low-lying stream delta. The tsunami hazard along the entire steep Na Pali coast is moderately high, while stream flooding is low except at Kalalau where it is high. The threat of high waves along this northwest-facing coast is high, while that of storms is moderately high. Erosion is moderately low along the remote and natural Na Pali coastline. The hazard due to sea-level rise is moderately low except at the steepest headlands of Makuaiki Point, Alapii Point, immediately east of Honopu Valley, and near Pohakukumano where it is low. The volcanic-seismic hazard is low along the Na Pali coast as it is along the entire Kauai coast.

Steep, rocky cliffs interspersed with small pocket beaches line the Na Pali Coast west of Haena Point (see Haena map).



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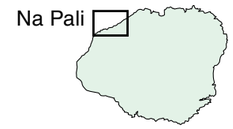
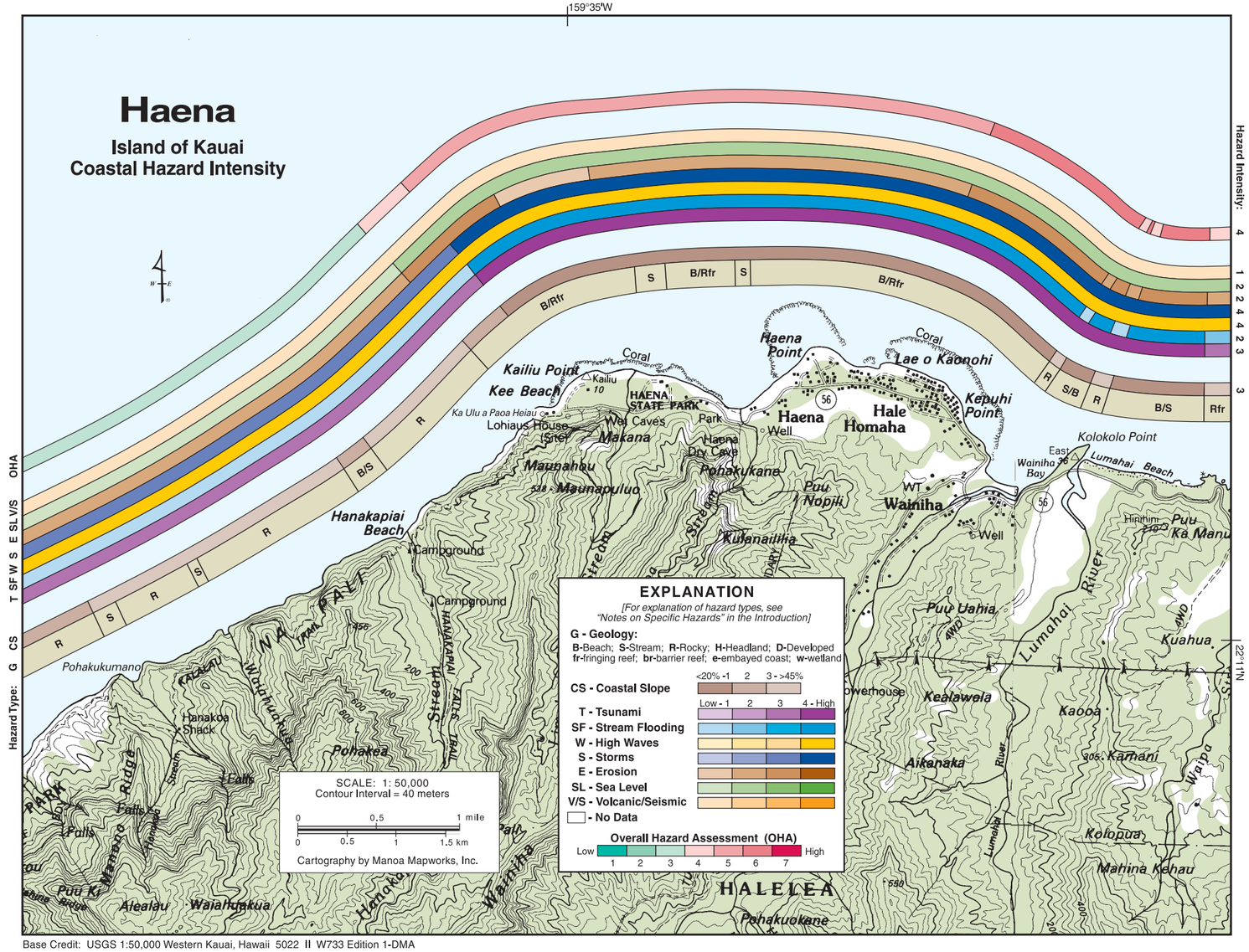




Base Credit: USGS 1:50,000 Western Kauai, Hawaii 5022 II W733 Edition 1-DMA

Haena

At Haena, the knife-edge ridges of Na Pali that descend as steep sea-cliffs to the ocean, become broader, more moderately sloping, and spaced by wide valleys, to the east. The road that runs west around the north shore of Kauai ends at Kee Beach. The rocky, cliffed coast west of Makana is only accessible by foot or boat. Hanakapiai Beach is the only beach along the Na Pali coast northeast of Pohakukumano. Several stream mouths, however, have created small embayments in this region. Northeast of Kee Beach, the valleys and coastal plains between ridges are wider and the beaches longer. Wide fringing reefs have developed offshore of the rocky points, but are sometimes cut where streams discharge, as in Haena and Wainiha Bays. The beach at Lumahai is also an exception; its steep beach face is the product of intense wave energy due to the absence of a fringing reef. A small settlement exists at Haena, otherwise, most of this coast is undeveloped.

The Overall Hazard Assessment (OHA) for Haena varies between moderate to low (3) along the steep Na Pali headlands west of Kee Beach, to high (6) along the low-lying coastal terraces of Kepuhi Point, Wainiha Bay, and Lumahai Beach. The OHA is moderate (4) at Kee Beach, moderate to high (5) between Kailiu Point and Lae o Kaonohi, and moderate (4) at the two steep, rocky headlands, surrounding Wainiha Bay. Tsunami hazards are moderately low west of Kailiu Point and high to the east. Stream flooding is low west of Kailiu Point and high to the east, except at the two steep headlands surrounding Wainiha Bay where it is low. The hazard due to high waves is high along this entire north-facing coast. The storm threat is moderately high along the steep Na Pali headlands west of Kailiu Point and high along the low-lying coast to the east. Erosion is moderately low except along Kee Beach and the sandy portion of Kailiu Point where it is moderately high. Along the rocky eastern corner of Kailiu Point, erosion is low. Erosion is moderately high along the Lae o Kaonohi coastal plain, Wainiha Bay, and Lumahai Beach. Sea-level rise is low along the Na Pali headlands and moderately high along the lower-lying coast to the east. The volcanic-seismic threat is low along this coast and all of Kauai's shoreline.

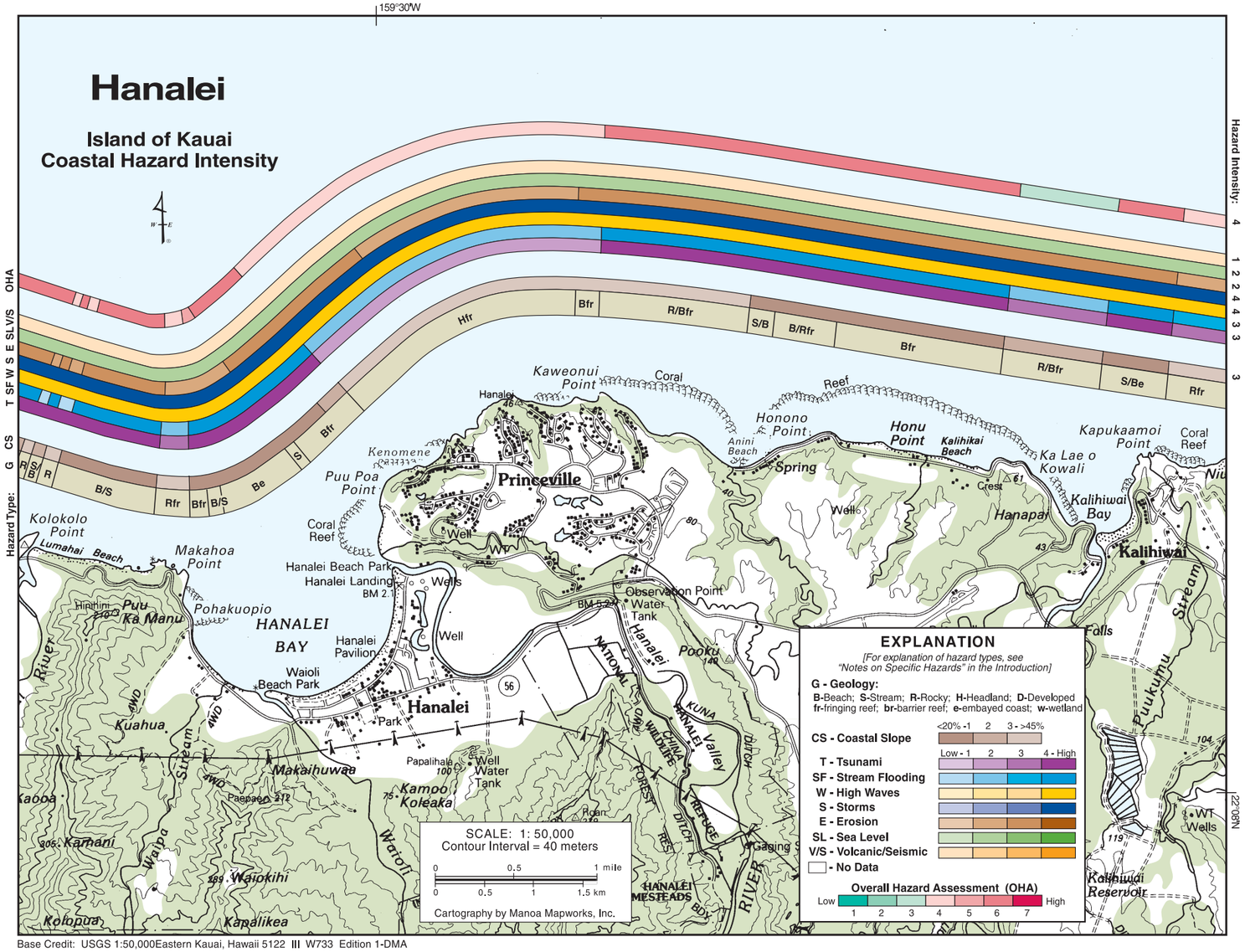
Extensive and wide fringing reefs have become well established along the Haena Coast and most of the northern half of Kauai.

Hanalei

One of the most scenic views in Hawaii is that of Hanalei Bay, with Haena (see Haena map) in the background, viewed from the Princeville headland. The Hanalei River carries nutrient-rich sediment along its broad meanders to the taro-cultivated Hanalei coastal plain, a series of fossil shorelines resulting from a higher sea between 1500 and 4000 years ago. The shoreline has evolved as a classic embayed semi-circle. It supports a long, sand beach between Puu Poa Point, a remarkable surfing site on the east side of the bay, and Makahoa Point on the west. A well-developed fringing reef extends 500-1000 ft offshore along the generally rocky headland coast of Princeville east to Kapukaamoi Point. It is broken only at the stream mouths at Anini Beach and Kalihiwai Bay, where there are small sandy beaches. Sand beaches also reside upon the narrow coastal plains surrounding Anini and Kalihikai. The Hanalei region, on average, receives between 80 and 120 in of rainfall annually, but sustained rains and/or flash flooding in the precipitous interior often generate flooding in the coastal zone. Three decades of stream gauge data show that the Hanalei River overflowed its banks at the Hanalei Bridge 29 out of the last 32 yr!

The Overall Hazard Assessment (OHA) for Hanalei ranges between high (6) along Lumahai Beach, Hanalei, and Kalihiwai Bays and along the Anini Beach and Honu Point coastal terrace and moderate to low (3) along the steeper rocky coast of Ka Lae o Kowali. The OHA is moderate (4) at the rocky Makahoa Point and along the steep Princeville headland where tsunami and stream flooding are lower. The tsunami hazard is high except at Makahoa Point, Ka Lae o Kowali, and immediately east of Ka Lae o Kowali at Niu, where it is moderately high. Along the Princeville headland tsunami hazard is moderately low. Stream flooding is high except at Makahoa Point, Ka Lae o Kowali, and the Princeville headland where it is ranked moderately low. Immediately east of Ka Lae o Kowali, along Niu, stream flooding is moderately high. The hazards due to high waves and storms are high. Erosion is moderately high except for Makahoa Point, Hanalei Beach which appears to be stable, the Princeville headland, and the Niu region, where it is moderately low. The sea-level rise and volcanic-seismic hazards are moderately low and low, respectively.

Hanalei Bay is bordered by a steep headland and prominent fringing reef immediately north of the river mouth.



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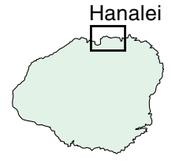
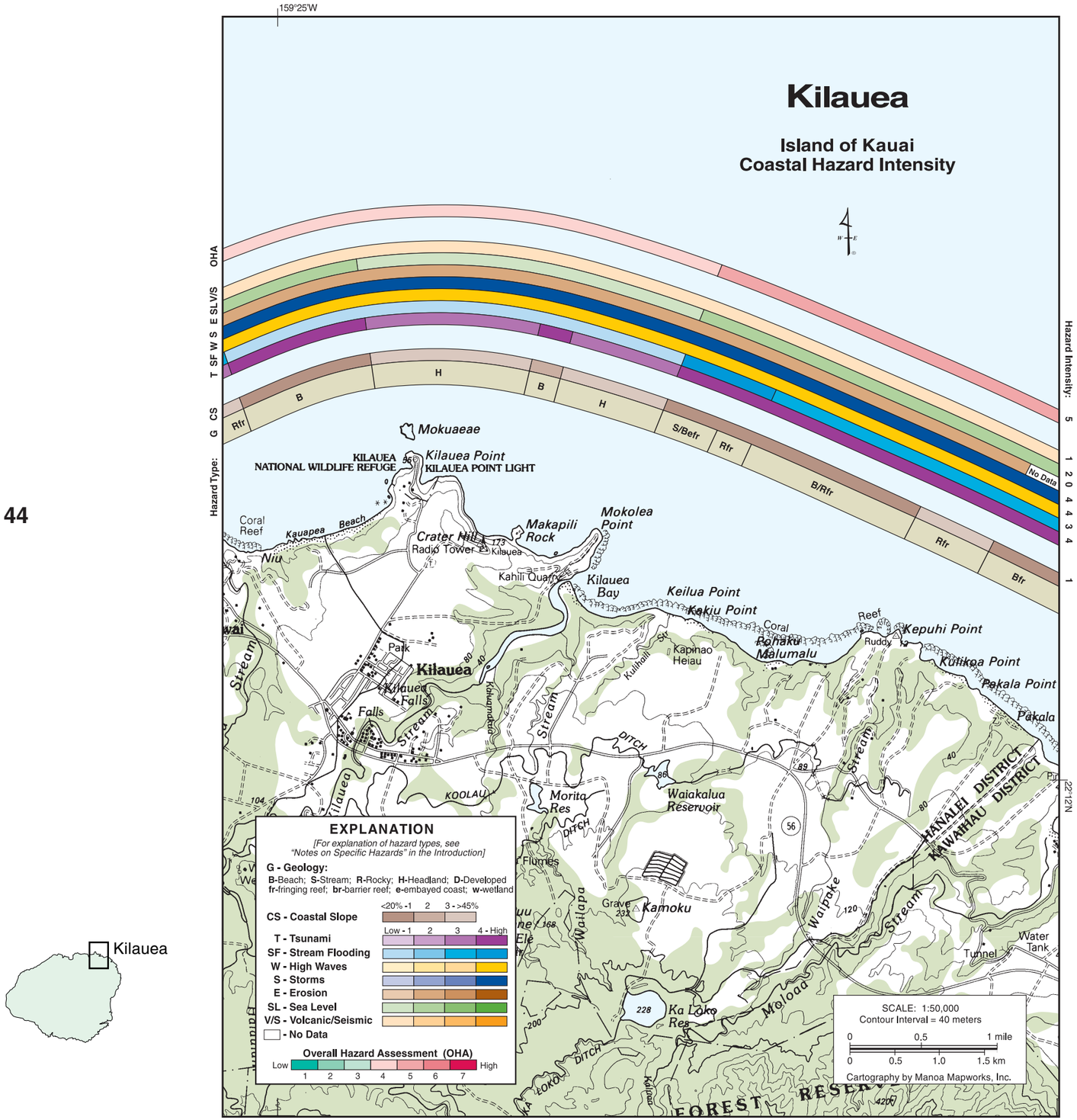




Base Credit: USGS 1:50,000 Eastern Kauai, Hawaii 5122 III W733 Edition 1-DMA

Kilauea

Kilauea Point is the northernmost point on Kauai. In addition to the point, the rock island Mokuaeae that sits offshore of the Kilaeua Point lighthouse, Crater Hill, and Mokolea Point form the Kilauea National Wildlife Refuge. The refuge harbors numerous species of central Pacific seabirds. Among these rock headlands lie the beautiful sand beaches of Kauapea, Makapili, Kilauea Bay, Kakiu Point, and Pohaku Malumalu. The coastal slope is steeper between Kilauea and Mokolea Points than along the eastern portion between Kilauea Bay and Pakala Point. The relatively large Kilauea Stream drains into Kilauea Bay after cascading in two sets of falls just landward of the low-lying coastal plain. An extensive fringing reef runs east between Mokolea Point and Pakala. Facing northeast, the Kilauea region is heavily swept by trade winds, and as a result, currents generally travel east to west. Kilauea's coast is only lightly developed with few villages along the shore.

The Overall Hazard Assessment (OHA) for the Kilauea coast is moderate (4) west of Mokolea Point and moderate to high (5) to the east. The higher overall hazard to the east is largely a function of the lower coastal slope, which results in higher hazards due to flooding and inundation associated with high waves. The tsunami hazard is moderately high west of Mokolea Point except at the lowest-lying beaches near Makapili Rock and at Kauapea Beach, where it is high. East of Mokolea Point tsunami is ranked high. Stream flooding is low west of Mokolea Point and moderately high to the east, except for the low-lying Kilauea Bay coastal plain where it is high. The hazards due to high waves and storms are both high along this coast, which receives high north and northwest swell as well as significant wind and wave energy from tropical storms approaching from the east. Erosion is moderately low along the entire Kilauea coast. The sea-level rise threat is moderately low except along the steep headlands between Kilauea Point and Mokolea Point where it is low. The volcanic-seismic threat is low.

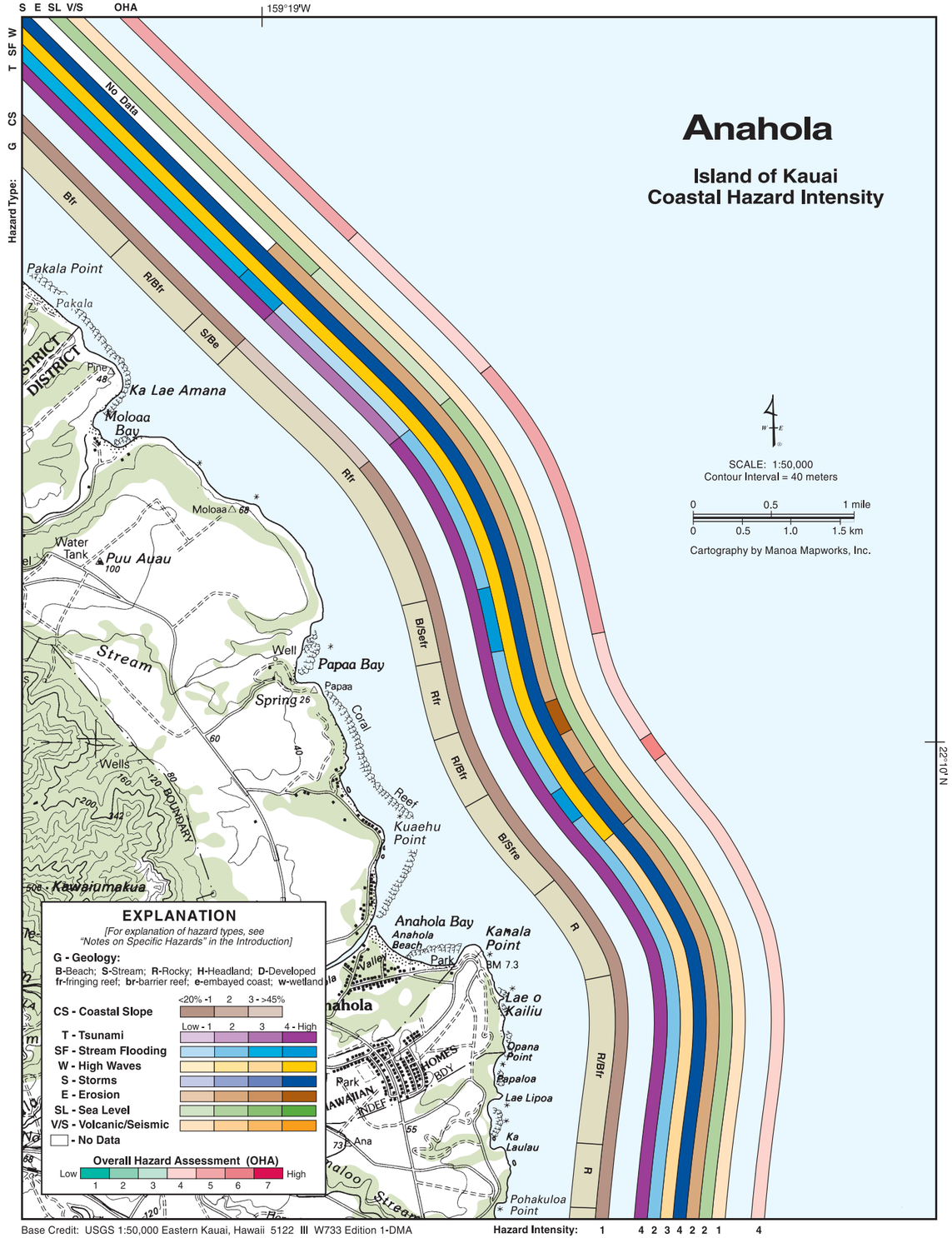
The Kilauea Point lighthouse and the surrounding steep, rugged rocky cliffs are an important refuge for many Pacific sea-faring migratory birds, including the Red-tailed tropic bird, Wedge-tailed and Newell's shearwaters, and the Laysan Albatross.

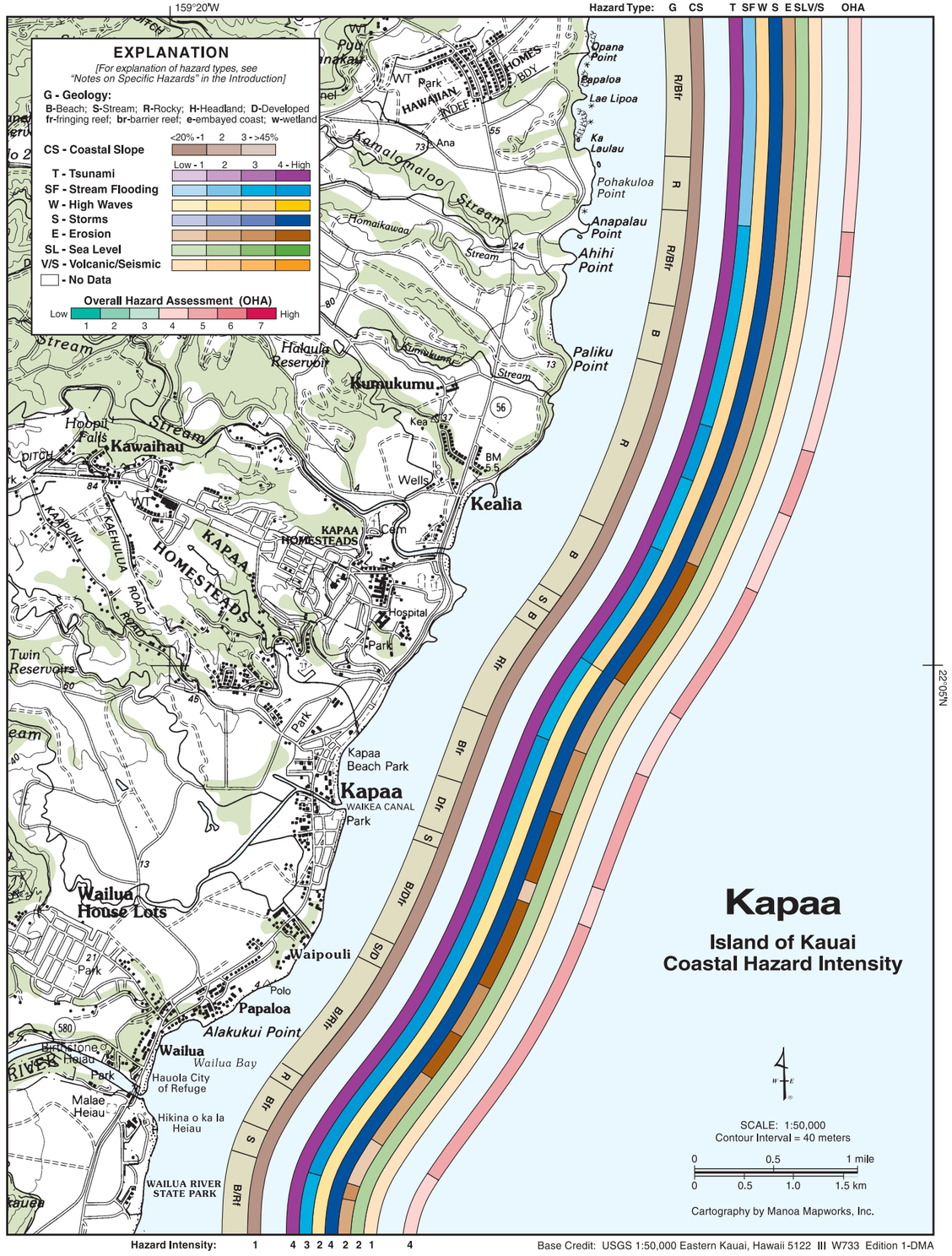
Anahola

The Anahola coast, extending from Pakala south to Pohakuloa Point, is characterized by a relatively narrow coastal plain at the foot of moderately steep hillsides that reach 100 to 200 ft above sea level. It is one of the windiest coasts on Kauai, facing directly into the northeast trade winds, but some of the embayed beaches are sheltered by the surrounding headlands. The Moala, Papaa, and Anahola Streams dissect the high coastal hillsides and discharge their waters into Moala Bay, Papaa Bay, and Anahola Bay, respectively. Despite its attempt to transport runoff through its channels to the sea, the Anahola River frequently overflows and floods the village of Anahola when there is intense precipitation in the mountains. Several times in the historical past upwards of 20+ in have fallen in a matter of a day or two, resulting in damaging floods in the Anahola area. Low rocky headland cliffs front the Moloaa coast, Kuaehu Point, and the region between Kamala and Pohakuloa Points. Extensive but relatively narrow fringing reefs exist along this coast except at the major stream mouths. Inside Papaa Bay coral cover is moderately high around a central sand-bottom channel.

The Overall Hazard Assessment (OHA) for the Anahola coast ranges between high (6) inside Anahola Bay and moderate (4) along the Moloaa rocky shoreline, between Papaa and Kuaehu Point, and south of Kamala Point. This is due to a combination of higher waves north of Kamala Point and the influence of slope on flooding and inundation. The OHA is moderate to high (5) north of and including Moloaa Bay, and between Moloa and Papaa, where there is greater stream flooding than the areas to the immediate north and south. The tsunami hazard is high except along the steeper rocky southern Moloaa shore where it is moderately high. Stream flooding is high in Moloaa, Papaa, and Anahola Bays. It is moderately high north of Moloaa Bay and moderately low to the south except along the steeper southern Moloaa segment where it is low. The threat from high waves is high north of Kamala Point and moderately high to the south where north swell refracts and looses energy when reaching the shore. Storms are ranked high along the entire Anahola Coast. Erosion hazard is moderately low except in Anahola Bay where it is moderately high and immediately north of Kuaehu Point where it is high. Sea level hazard is moderately low except along the steeper rocky Moloaa shoreline where it is low. The volcanic-seismic hazard is low along the entire Kauai coast.

The Anahola Coast is generally low lying with numerous sandy beaches lining small embayments. Debris lines high on the beach attest to the wave-swept nature of this northeast-facing shoreline.





Kapaa

The low-lying coastal plain around Kapaa is developed with moderate density resorts, golf courses, beach parks, and residences. South of Kealia the coastline is relatively straight with the exception of Wailua Bay which is an arcuate-shaped embayment. It is a little more irregular north of Paliku Point where several small coves, formed between wind-swept rocky headland points, create a winding shoreline. Numerous streams drain into the sea near Kapaa, the largest being the Kapaa Stream and Wailua Rivers. These streams form tidal inlets that influence the beach processes at Kealia and Wailua. The Wailua River is a wide river by Hawaiian standards and floods often reshape the southern portion of Wailua Beach and the sandbar that forms at its mouth. Low dunes exist behind Kealia Beach and have been mined for sand in the past. Beachrock occurs at the water's edge along the beach at Waipouli and erosion along Kapaa Beach has led to the emplacement of revetments and seawalls that have temporarily protected coastal property at the expense of losing the sandy beach. Fringing reefs parallel most of the coast, but considerable wave energy still reaches the shore face. Overall, the beaches from Waipouli to the north end of Kapaa town are largely deficient of sand and experience chronic erosion.

The Overall Hazard Assessment (OHA) for the Kapaa coast is moderate (4) except at the stream mouths immediately south of Anapalau Point, Paliku Point, and inside Kealia Bay where stream flooding is higher and the OHA is moderate to high (5). The OHA is also moderate to high (5) along the majority of coast between the Kapaa Beach Park and Wailua River State Park, where there is higher erosion and stream flooding. Tsunami and storm hazards are high along the entire Kapaa Coast. Stream flooding is moderately low north of Anapalau Point and moderately high to the south except at the Kamalomaloo and Kumukumu Stream mouths and along the Kealia Bay, Kapaa, and Wailua Bay shorelines, where it is high due to stream flash flooding and urban flooding on the flat coastal plain. The hazard due to high waves is moderately high north of and including Kealia Bay and moderately low to the south. Erosion is moderately low to the north of Kealia. To the south, erosion is high, as evidenced by the numerous seawalls that exist between Kapaa and Wailua, except north of Kapaa Beach Park, Waipouli, and Papaloa where it is moderately high, near Kapaa hospital where it is moderately low, and at the Waikea Canal and the Wailua River mouth, where it is low. The sea-level and volcanic-seismic hazards are moderately high and low, respectively.

Low-lying coastal plains lined with narrow sandy beaches characterize the Kapaa Coast, which has experienced chronic erosion during the 1980s and 1990s.