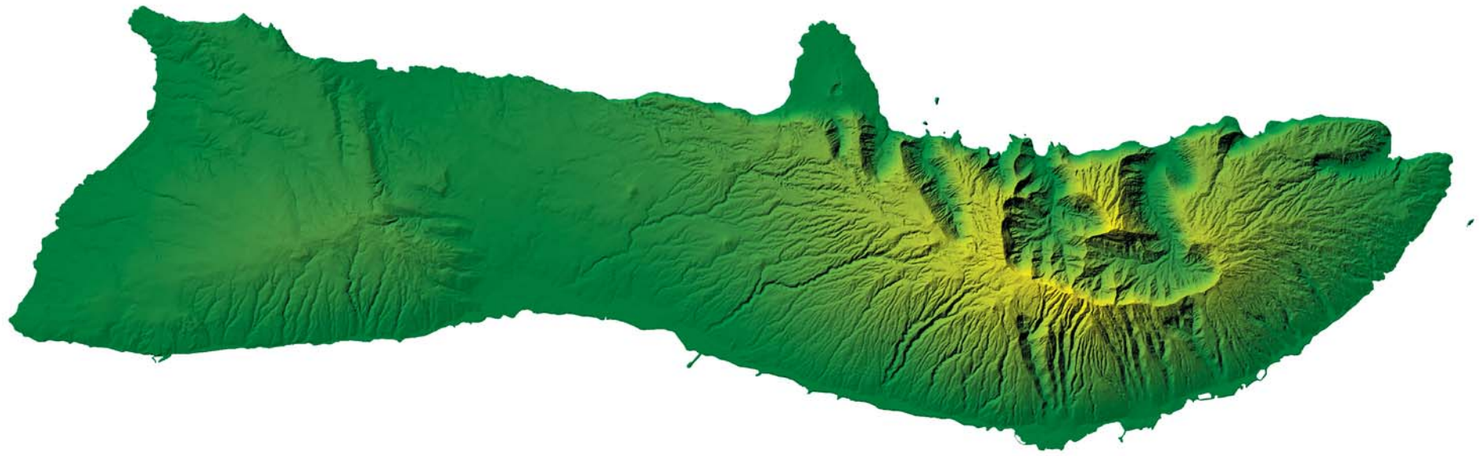
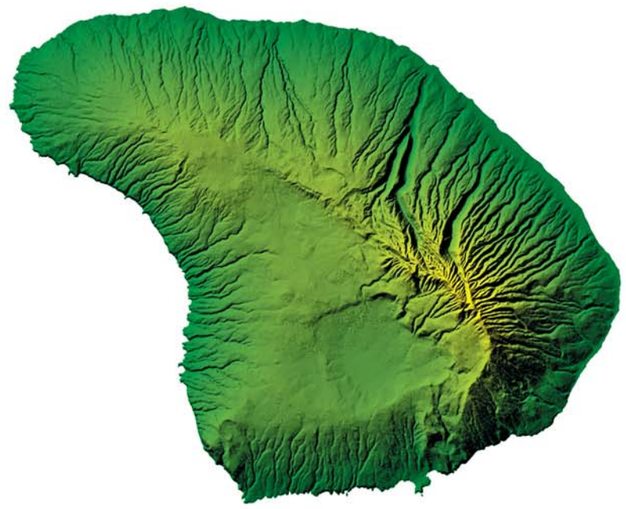
Molokai and Lanai

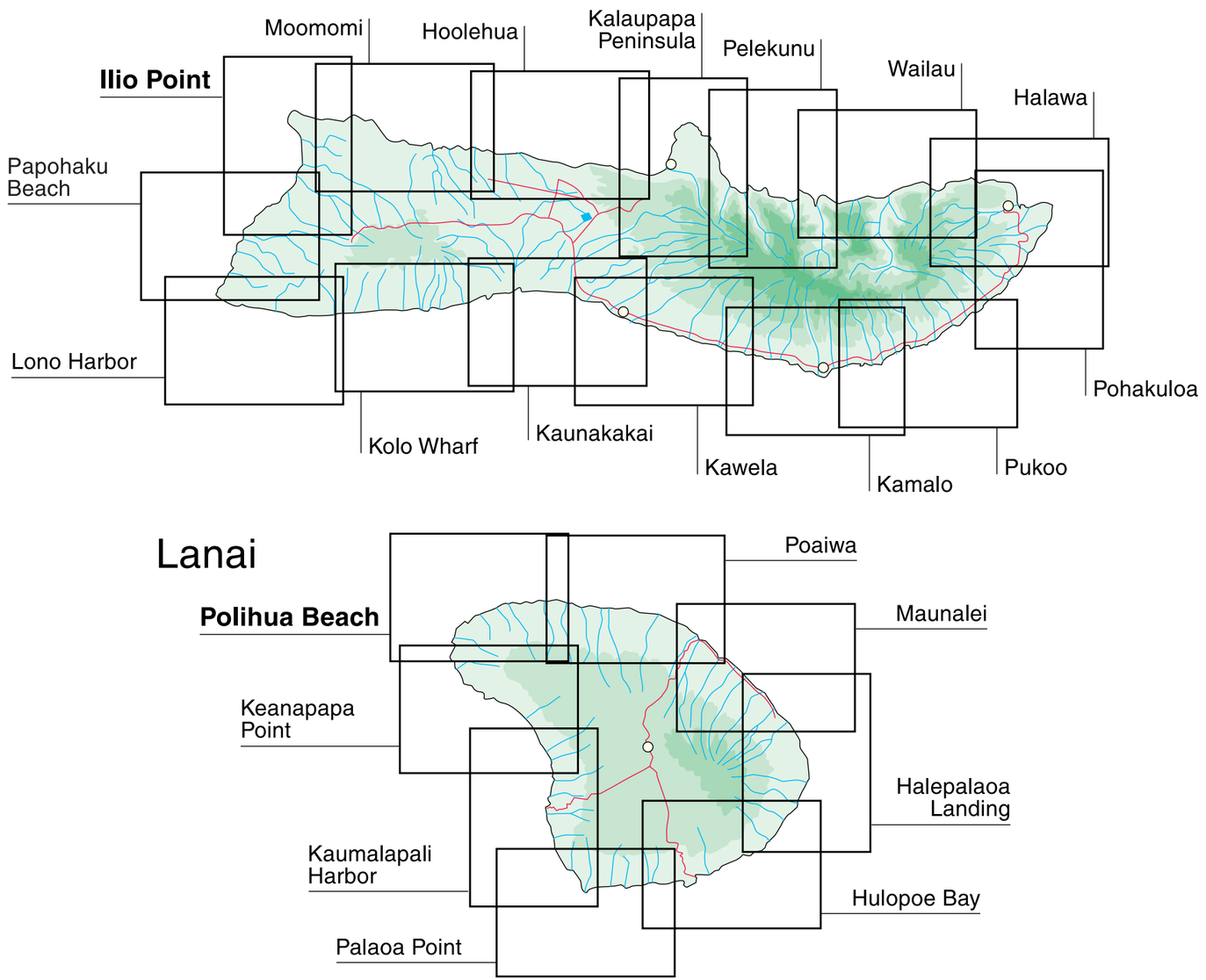
Molokai and Lanai are the least populated and smallest of the main Hawaiian Islands. Both are relatively arid, except for the central mountains of each island and northeast corner of Molokai, so flooding are not as common hazards as on other islands. Lying in the center of the main Hawaiian Islands, Molokai and Lanai are largely sheltered from high annual north and northwest swell and much of south-central Molokai is further sheltered from south swell by Lanai. On the islands of Molokai and Lanai, seismicity is a concern due to their proximity to the Molokai Seismic Zone and the active volcano on the Big Island. Storms and high waves associated with storms pose a threat to the low-lying coastal terraces of south Molokai and northeast Lanai.





Molokai and Lanai

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 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. Predicting the specific form of a tsunami at a shoreline is not yet possible because of many factors. Because they can be miles in length, when a tsunami passes, the water level can rise for 10's of minutes at a time. As a result, even small tsunamis can have a tremendous impact on the shoreline because the elevated water levels enable more wave energy to reach the shore and the peak of the tsunami wave to push farther inland than ordinary waves.

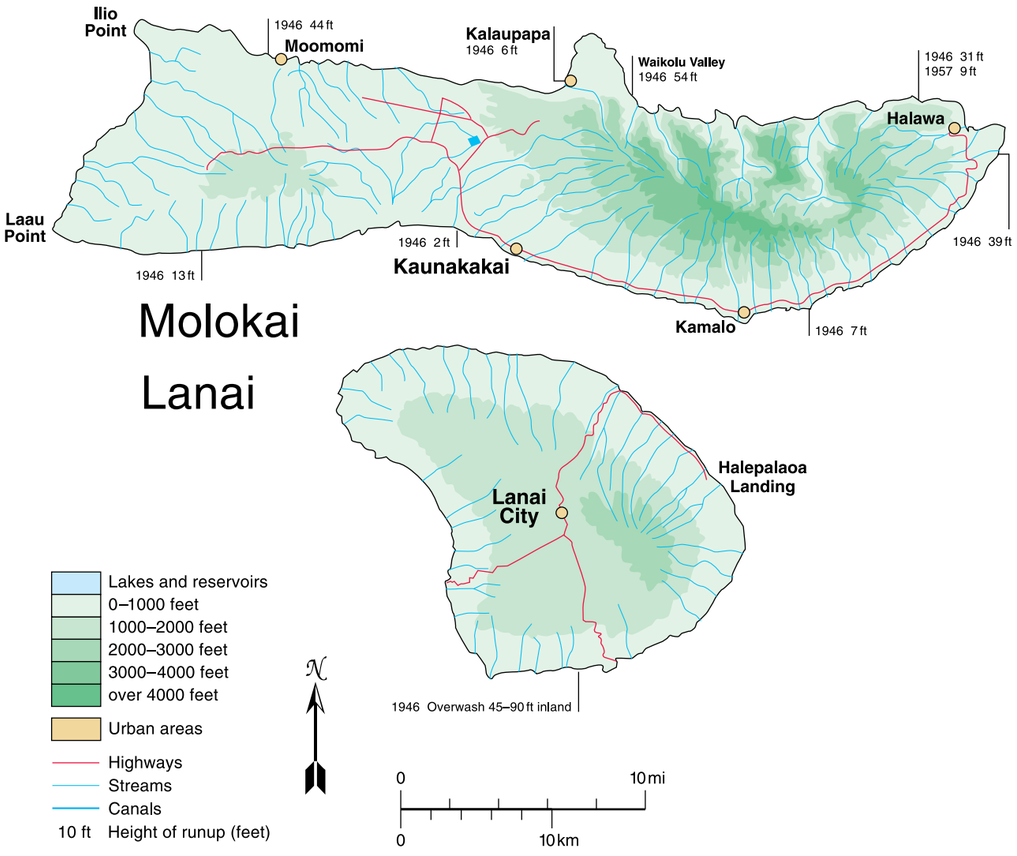
History has shown that their impact on the shore can be considerably different within very short distances. This has been observed throughout Hawaii and especially on Molokai. During the 1946 tsunami, for example, the runup height on the west side of Kalaupapa Peninsula was recorded at 6 ft while on the east side it was 54 ft! The only general relationship found in the database of Hawaiian tsunami observations is that the runup heights tend to be greatest near headlands where the steeper offshore bathymetry enables greater wave energy to reach the shore. Along gentle-sloping coasts, runup heights are reduced as wave energy is dissipated upon shoaling. Inundation, however, can be significant along low-lying coastal plains and is usually greatest there.

Since 1812, 26 tsunamis have made landfall within the Hawaiian Islands and 8 have had significant damaging effects on either Molokai or Lanai. This translates into one tsunami reaching the Hawaiian Islands on average every 7 yr, and a damaging tsunami reaching Molokai or Lanai once every 23 yr. However, the four last tsunamis that had a damaging effect occurred during the period 1924 to 1960. During this time, a damaging tsunami occurred once every 9 yr. An important observation is that since 1960 no damaging tsunamis have affected either island, and with an average return interval of 23 yr, one could claim that a damaging tsunami is overdue. Another important observation of the historical tsunami data is that they can originate from seafloor displacements as far away as Alaska and Chile or as close as the Island of Hawaii, like the 1975 and 1868 tsunamis that were generated by earthquakes along the flanks of Kilauea Volcano. The travel time of tsunamis from distant sources can be on the order of 10's of hours, while those originating on the Big Island can arrive within minutes.

Molokai and Lanai

Tsunamis

(after Lander and Lockridge, 1989)



Tsunamis with reported effects on Molokai and Lanai

1946 Apr 1
1957 Mar 9
1960 May 22

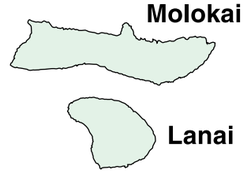
Large tsunamis* (>1m, 3.3 ft) with reported damage in the Hawaiian Islands

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.



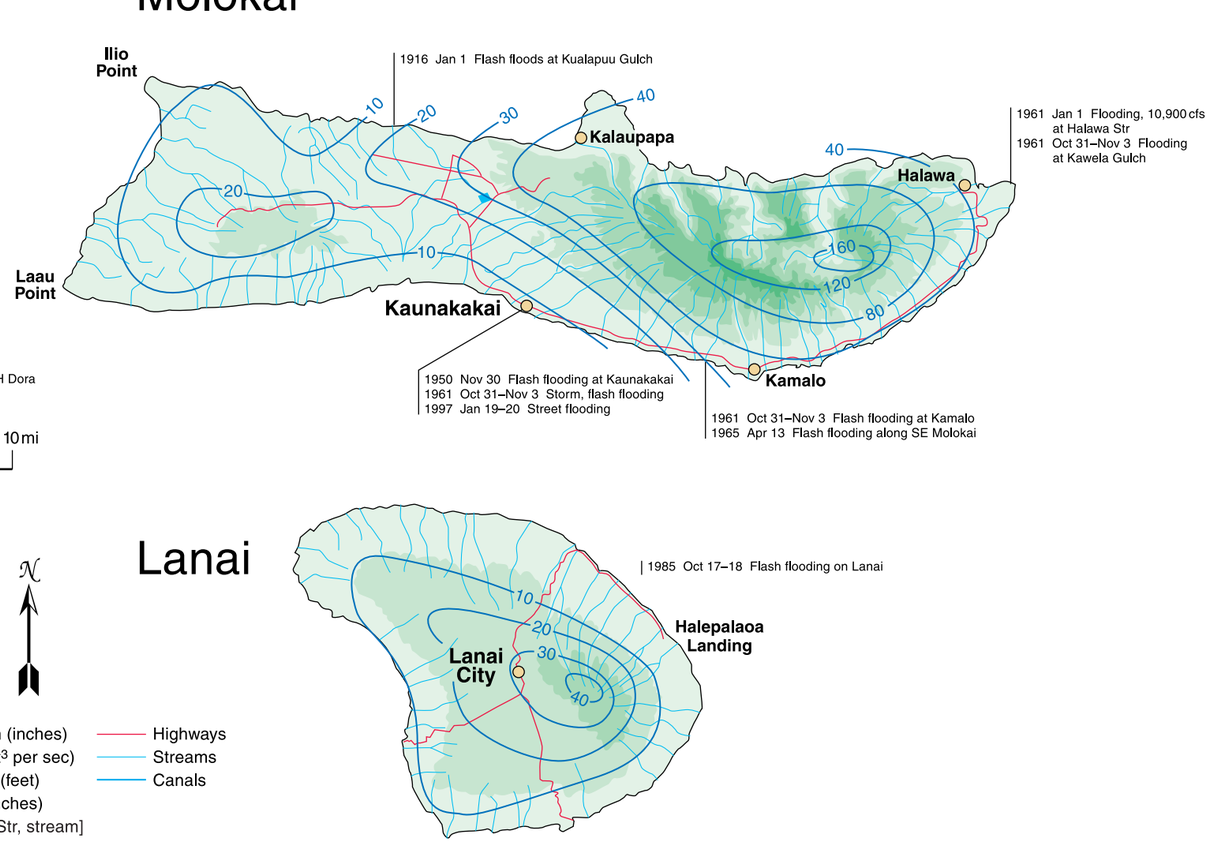
Molokai and Lanai

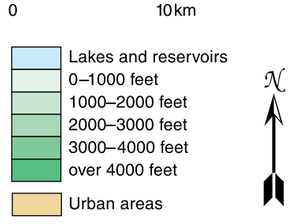
Stream flooding

Molokai

Statewide stream flooding because of heavy rains that probably affected Molokai and Lanai

1971 Jan 27–28 Storm, flooding
1980 Jan 6–14 Flooding
1981 Oct 27–28 Flash floods
1981 Aug 3–4 Flooding
1981 Dec 25–26 Flooding
1982 Mar 17 Flooding
1982 Mar 30–31 Flooding
1982 Aug 14–16 H Kristy, flash floods
1983 Dec 24–25 Flash floods
1984 Dec 24–25 Flash floods
1985 Feb 14 Flooding
1985 Oct 17–18 Flash flooding
1986 Nov 10–11 Flash floods
1987 Apr 21–22 Flash floods
1987 May 5–6 Flooding
1988 Sep 26–27 Flooding
1988 Nov 4–5 Flooding, up to 10" rain
1988 Dec 5–6 Flooding, over 10" rain
1989 Feb 10–11 Flooding
1993 Jul 21–23 Flooding, remnants of H Dora



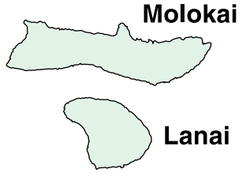


Lanai

11" Max. rainfall from storm (inches)
1070 cfs Max. peak discharge (ft^3 per sec)
5 ft Max. height of flooding (feet)
—30— Mean annual rainfall (inches)
[H, hurricane; R, river; Str, stream]

Highways
Streams
Canals

NOTE: Because of the low population density on Molokai and Lanai, the extent and location of flood history is poorly known.



Stream flooding

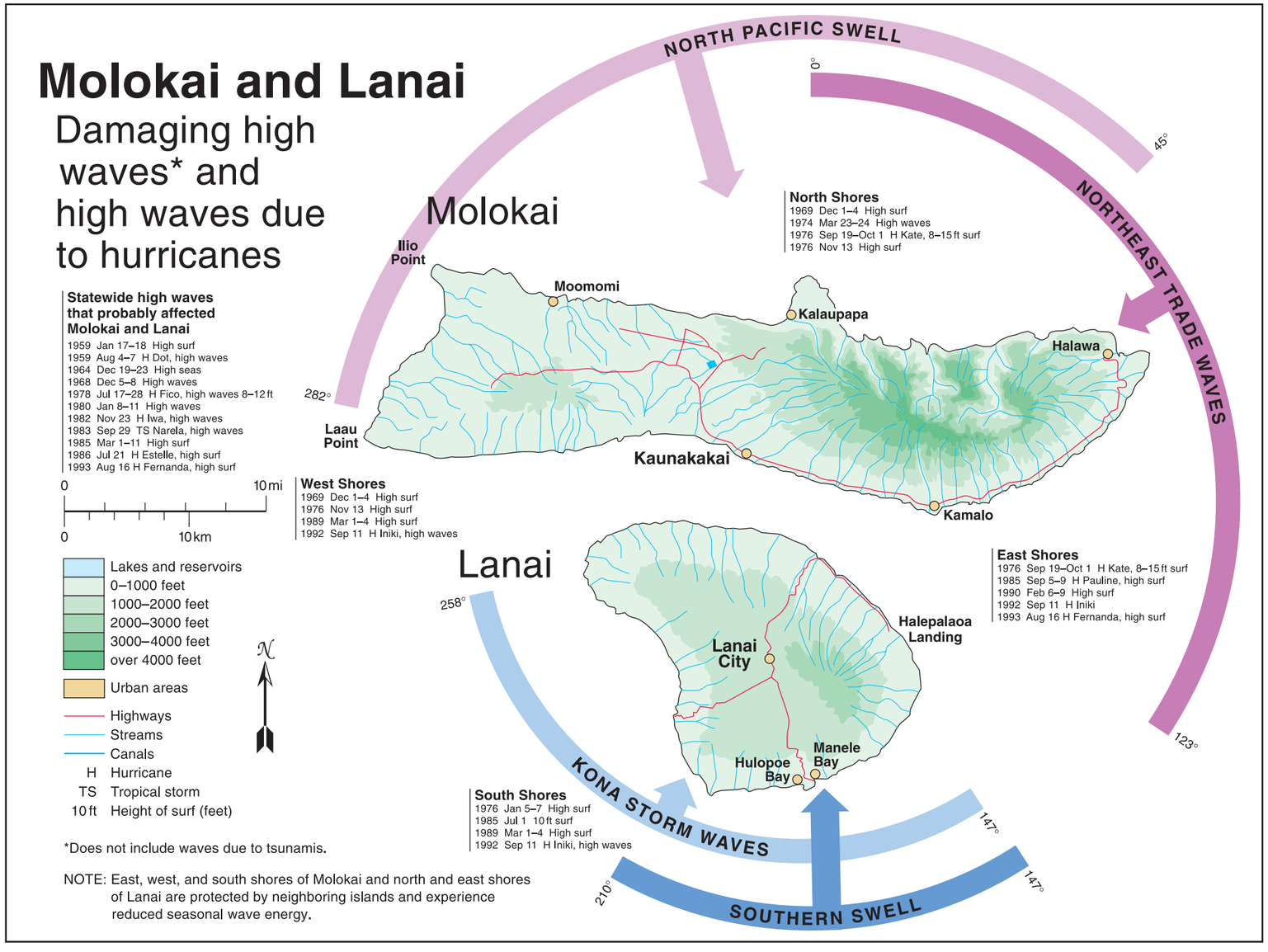
While East Molokai receives on average 160 in of rainfall each year, West Molokai and Lanai are relatively arid and experience only 20 and 40 in of rain, respectively. Even though records of flooding on Molokai and Lanai date back to as early as 1916, most of the reports are from the period 1970 to present. In addition, rainfall and stream flooding measurements have been relatively sparse on these two islands. The observational data shows that flash flooding and street flooding do occur in the arid regions of Molokai and Lanai, and as a result it is probable that stream flooding in the more isolated and wetter areas of both islands also results. However, there are only a few locations on either island that stream flooding can have an impact on the coastal zone, and these coincide with low-lying coastal plains where streams empty to the sea. On Molokai, they include Halawa Valley, the low coastal plains of Kamalo and Kaunakakai, and isolated embayments along the southwest, west, and northern shores. On Lanai, low coastal plains susceptible to flooding occur only along the northern and eastern shores and inside Hulopoe and Manele Bays.

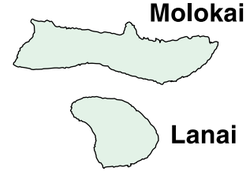
Amidst the sparse data for flooding on Molokai and Lanai, a few observations show that flash flooding occurs in the arid, low-lying regions, like the events of November 1950, October 1961, and January 1997 in Kaunakakai. Intense, short-lived rainfall that produces flash floods can trigger street flooding, as on January 19 and 20 of 1997. Because of the limited development in the coastal zone on Molokai and Lanai, the hazard due to stream flooding might be better considered one that affects the natural environment rather than coastal development. Some of the most expansive fringing reefs in the state occur along the southern coast of Molokai. From the air on rainy days, one can observe plumes of red-brown sediment lining the entire south shore. Where the shoreline progrades seaward, the reef flat becomes buried in mud which often hosts large communities of alien mangroves. Much of the mud comes from excessive soil erosion in watersheds that have been denuded by deforestation and feral ungulates. Continued siltation on the reef because of poor upland management may impact coral habitats.

High waves

High waves from winter North Pacific swell, trade wind swell, summer South Pacific swell, tropical storms and hurricanes, and Kona storms affect shorelines on Molokai and Lanai. While the largest waves that reach Molokai are typically associated with north swell and hurricanes, Lanai is partly sheltered from north swell by the island of Molokai. High waves from large northwest swell refract into Lanai's northwest coast. The north shore of Molokai is dominated by steep sea cliffs east of Kalaupapa Peninsula, so high waves from north swell ranging 15-20 ft are a greater threat to more accessible and frequented areas along the north-facing shores between Ilio Point and Moomoomi, and near Halawa. High waves from trade wind swell range 3-5 ft along the eastern shores, but are considerably less energetic than waves from north swell, due to their shorter wave period. Waves from south swell generally range 3-6 ft and affect Lanai's south shore, but are dampened along Molokai's southern coast due to the presence of Lanai to the south. The only low-lying area along Lanai's south coast is within Hulopoe and Manele Bays, so the greatest threat from high waves occurs there. Winter Kona storms kick up winds and waves from the south and southwest, which can reach heights of 3-6 ft along south-facing shorelines of both Molokai and Lanai.

By far the highest waves that impact shorelines along Molokai and Lanai are generated by hurricanes as they approach and pass the islands. Since the 1970s, several hurricanes including Kate in 1976, Fico in 1978, Pauline in 1985, Iniki in 1992, and Fernanda in 1993, have produced high waves that have impacted Molokai and Lanai shorelines. Most recently, Hurricane Fernanda generated high waves ranging 8-10 ft that damaged one house on East Molokai. While no damage was sustained during Hurricane Iniki, high surf was observed on the east-, south-, and west-facing shores of both islands. Hurricane Pauline generated waves of 10-15 ft along eastern shorelines, while Fico kicked up 8-12 ft surf which was observed on many coastal segments on Molokai and Lanai coastline. Hurricane Kate produced 8-15 ft surf along Molokai's north and east shores.



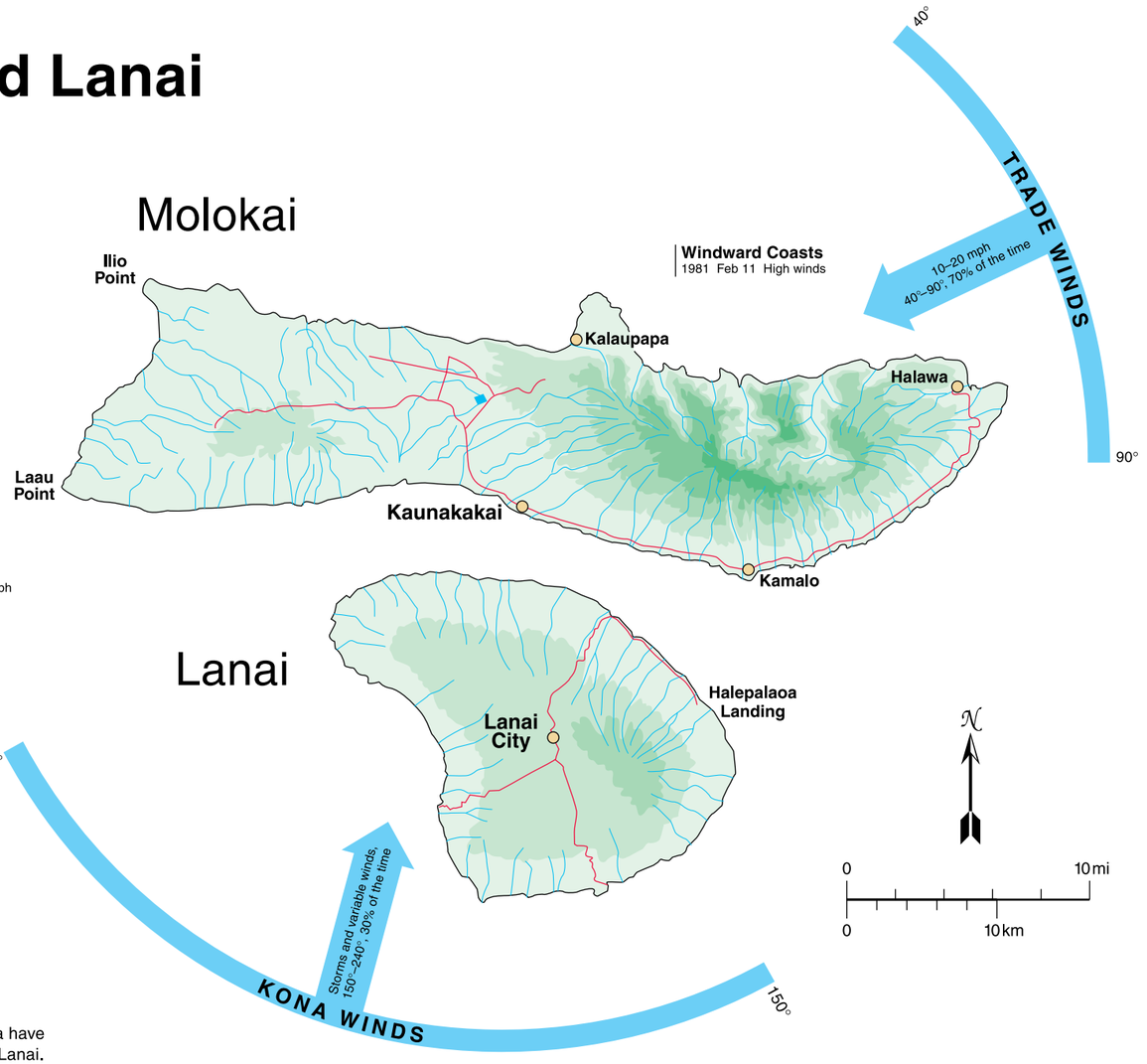


Molokai and Lanai

Strong winds

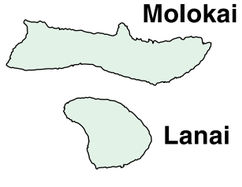
Statewide high winds that probably affected Molokai and Lanai

1870 Sep 21–24 TS, strong winds
1957 Nov 30–31 H Nina, high wind
1959 Jan 17–18 High SW wind
1959 Aug 4–7 H Dot, strong winds
1967 Nov 2–11 High winds
1970 Dec 25–29 50–60 mph winds
1971 Jan 8–18 TS Sarah, 60 mph winds
1971 Jan 27–28 High winds
1976 Jan 5–7 High winds
1980 Jan 8–11 Storm, high winds
1981 Aug 3–4 High winds
1982 Feb 11 High winds
1982 Dec 18–19 High winds
1983 Sep 29 High winds
1983 Dec 24–25 Gusts to 50 mph
1984 Dec 24–25 Kona storm, high winds
1985 Mar 1–11 Gale force trade winds
1985 Nov 30 Strong northerly winds
1987 Jan 19 High winds, 35–60 mph
1988 Nov 4–5 Gusty winds
1988 Dec 30–31 40–50 mph
1989 Dec 9–11 Gusty winds
1990 Feb 6–9 Strong winds, gusts to 60 mph
1991 Jan 27 Strong winds, local gusts 60–80 mph
1992 Feb 13–14 High winds
1993 Dec 4–6 Strong trade winds 60–80 mph
1996 Dec 26–31 Strong southerly winds



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

NOTE: No site-specific high wind data have been recorded on Molokai or Lanai.



Strong winds

Strong winds on Molokai and Lanai derive from passing tropical storms and hurricanes, strong trade wind events, and winter Kona storms. While hurricanes have dealt winds greater than 150 mph to Kauai, Molokai and Lanai have been spared a direct hit by a hurricane. Tropical storms and depressions have passed in close proximity and have caused damage to isolated locations on both islands. Hurricanes and tropical storms are largely summer and fall events and because they usually approach from the east and swing around the islands to the northwest, the east-, south-, and west-facing shores are most vulnerable. However, Molokai's elongated orientation east to west, makes its north shore more variable to high winds out of the east. Trade winds, which dominate on average 70% of the year blow from the east and northeast and usually range from 10-20 mph. Periodically, they intensify and strengthen to 25-40 mph for several days on end. Kona storms originate out of the south and southwest generally in the winter and can reach significant velocities, impacting south and southwest shores.

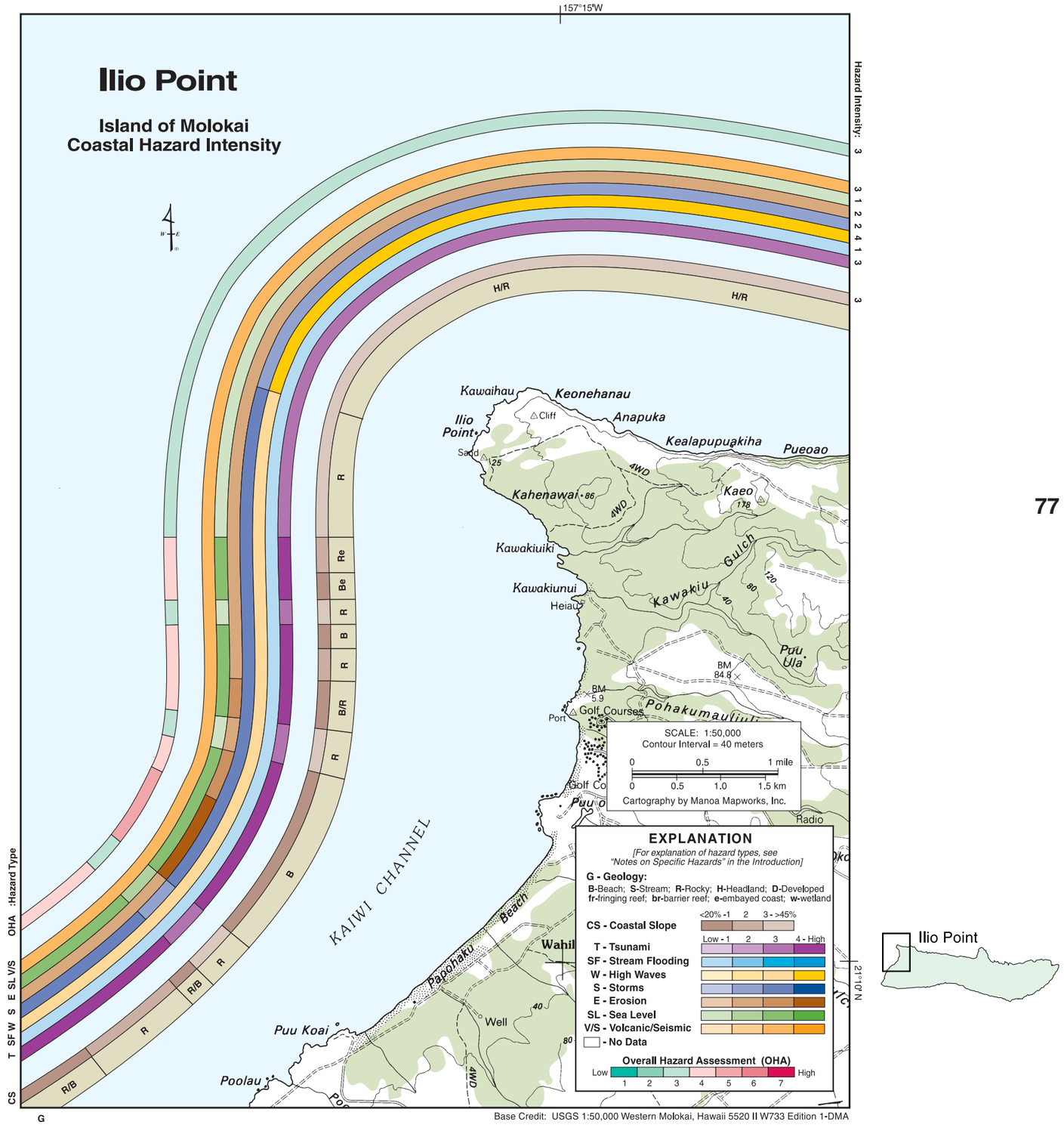
The most damaging high winds to affect either Molokai or Lanai were those associated with tropical storms Sarah in 1971 and Die Deutsche Seewarte III in 1874. Tropical storm Sarah destroyed 5 houses while the earlier storm destroyed 50 houses at Kalaupapa. While data of high wind events is relatively scarce for Molokai and Lanai, it is safe to say that since 1870 at least 25 high wind events, which affected the rest of the main Hawaiian Islands, probably affected these two islands as well. Several of these include strong and gusty trade wind events, a few extraordinary north winds, and many Kona storm winds. Lanai is somewhat fortunate in that it is partly sheltered from high winds and associated waves emanating from a northeasterly direction due to the location and massive size of Maui to the northeast. Lanai also serves as a small barrier to southerly winds and waves for the southeastern coastal zone of Molokai.

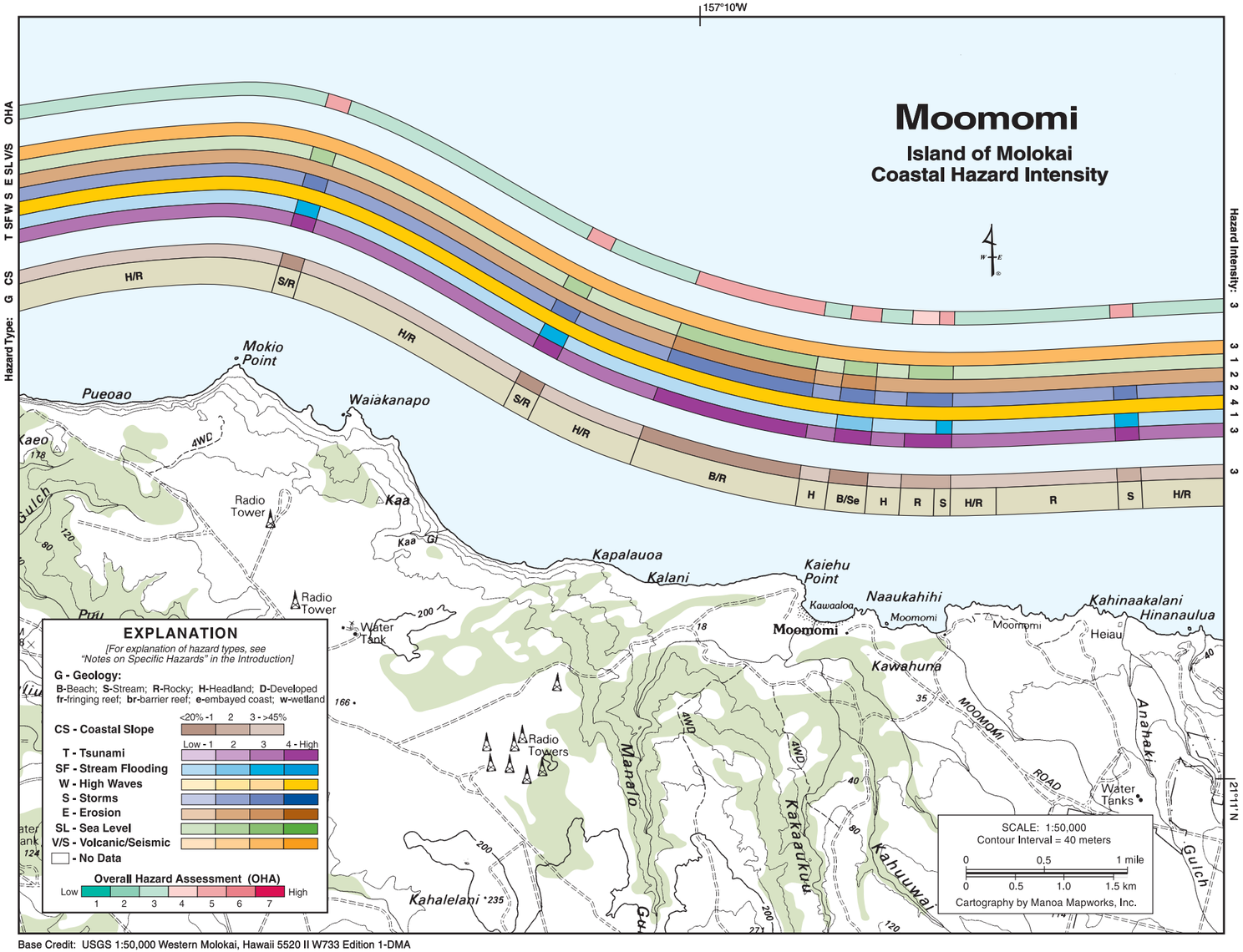
Ilio Point

From Puu Koai to Pueoao, the coast makes a broad curve toward the northwest tip of Molokai at Ilio Point, which looks out across the Kaiwi Channel toward Oahu. Beyond Ilio Point, the coast trends due east. The long and beautiful white sandy beach of Papohaku extends two miles northeast from the basalt headland at Puu Koai. Small patch corals grow on either side of a large sand field offshore of Papohaku, while small rocky islets are found near Poolau, Puu Koai, and Puu o Kaiaka. During the 1960s and 1970s Papohaku's carbonate sands were extensively mined for Oahu's construction industry. Low-lying isolated beaches occur along Ilio Point and at Kawakiunui, the starting point of the first interisland Molokai to Oahu canoe race in 1952. East of Ilio Point the coast is rocky and relatively steep. This western region of Molokai is the most arid of the island and only few intermittent streams enable small wetlands to form near Kawakiuiki and Kawakiunui. The Ilio Point area is relatively undeveloped except for the resort located immediately north of Papohaku Beach. Access to the surrounding parts of Ilio Point is by four-wheel drive trails and footpaths.

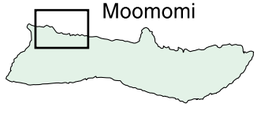
The Overall Hazard Assessment (OHA) for Ilio Point is moderate to low (3) north and east of Ilio Point where the coast is rocky and relatively steep and the threat of tsunami flooding is moderately high, high waves is high, storms are moderately low, erosion is moderately low, and sea-level rise is low. Stream flooding is low and the volcanic/seismic threat is moderately high throughout the entire Ilio Point region. To the southwest of Ilio Point, the threat from high waves is reduced to moderately high while the storm hazard is increased to moderately high, although the OHA between Ilio and Kawakiuiki Points does not change. South of Kawakiuiki Point, however, the OHA is moderate (4) along the low-lying beaches, where the tsunami threat is high and sea-level rise is moderately high. It is moderate to low (3) along the headlands of Kawakiunui and Puu Koai, where tsunami and sea-level rise are reduced to moderately high and moderately low, respectively. In addition, erosion is increased from moderately low to moderately high along Kepuhi and the northern portion of Papohaku beach. In the southern portion of Papohaku where erosion is high, the OHA is increased to moderate to high (5).

Ilio Point (foreground) is wind-swept with active linear dunes extending landward from the coast. The shoreline is bordered by fossil and lithified dunes that are eroding into steep 30-50 ft cliffs. The long, white sandy Papohaku Beach and west Molokai are in the background.





Base Credit: USGS 1:50,000 Western Molokai, Hawaii 5520 II W733 Edition 1-DMA



Moomomi

The north coast of Molokai between Pueoao and Kahinaakalani is a wind swept, rocky coast with a few isolated beaches and tall, vegetated sand dunes. The rocky headlands range between 50 and 100 ft at Mokio and Waiakanapo, and 30 to 50 ft at Kaiehu, and gradually become less steep toward Kahinaakalani. A long sandy beach occurs at Moomomi; whereas rocks and a terrace of beachrock often protrudes from beneath a thin veneer of sand along Kalani. Despite a very arid climate, several streams that experience flash floods have incised deep gulches in the coastal zone. A small wetland has developed at Moomomi. This region of north Molokai is undeveloped and access is by four-wheel drive vehicle, foot trail, or boat. Trade winds and north swell create rough seas along this coast for a large portion of the year. Only small patch corals grow under these conditions.

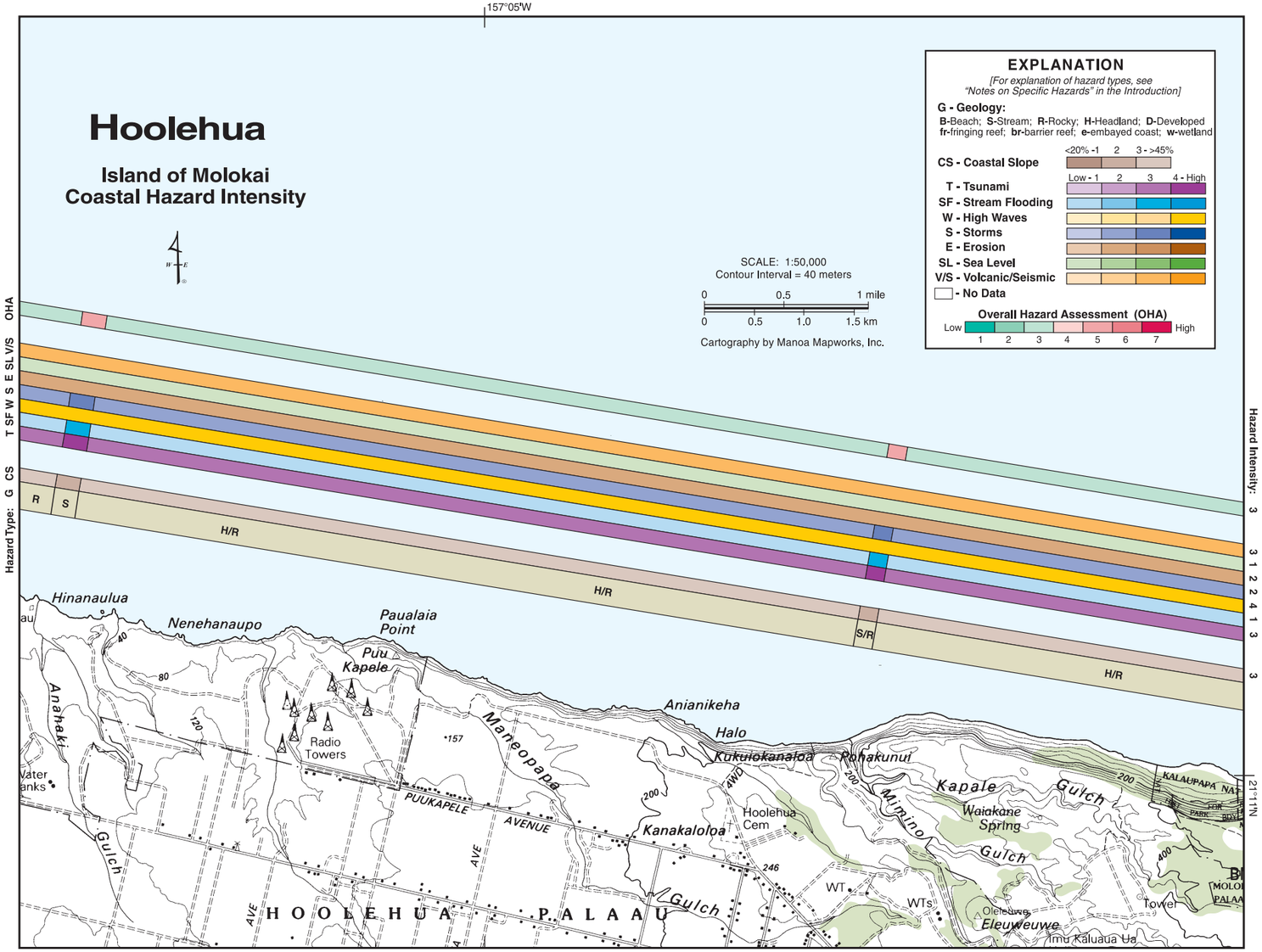
The Overall Hazard Assessment (OHA) for the Moomomi coast alternates between moderate to low (3) along the steep rocky headlands and high (5) at the low-lying beaches and stream mouths found at Kaa Gulch, Kalani, and the eastern sides of Mokio Point and Naaukahihi. This increase is primarily a result of the high tsunami and stream flooding, moderately high storm, and moderately low sea-level threats found in the lower coastal plain environments. Despite low stream flooding along Kalani, erosion is moderately high and contributes to the moderate to high (5) OHA there. Erosion is also moderately high at Moomomi and contributes with the moderately low stream flooding there to an OHA ranking of moderate to high (5). Where stream flooding is low along the western half of Naaukahihi, the OHA is reduced to moderate (4). Similarly, the OHA is moderate (4) at the steeper Anahaki Gulch mouth where the storm and sea level threats are moderately low and low, respectively. Along the steeper rocky headlands of the Moomomi region, tsunami is moderately high, stream flooding is low, storms are moderately low, and sea-level rise is low. The high waves and volcanic/seismic threats are high and moderately high, respectively, throughout the entire Moomomi coastal area.

A small pocket beach and headland near Moomomi give way to sparse vegetation and eroded landscape in the hinterland.

Hoolehua

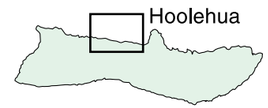
The rocky Hoolehua coast gradually becomes steeper between Hinanaulua and the west edge of Kalaupapa National Historic Park where grand sea cliffs drop more than 1000 ft to the sea. The only low-lying areas are the embayments at the mouths of the Anahaki stream in Hinanaulua and the Mimino stream at Pohakunui. Trade winds and waves, as well as north swell in winter make the ocean difficult to access in anything other than calm conditions. Few corals grow in this high-energy coastal environment which drops off rapidly to deep water. There is greater precipitation toward Kalaupapa where air masses rising up the steep sea cliffs are able to entrain moisture until condensation occurs and the moisture falls as rain. Only the central portion of Hoolehua is developed, and only above the sea-cliff bluffs.

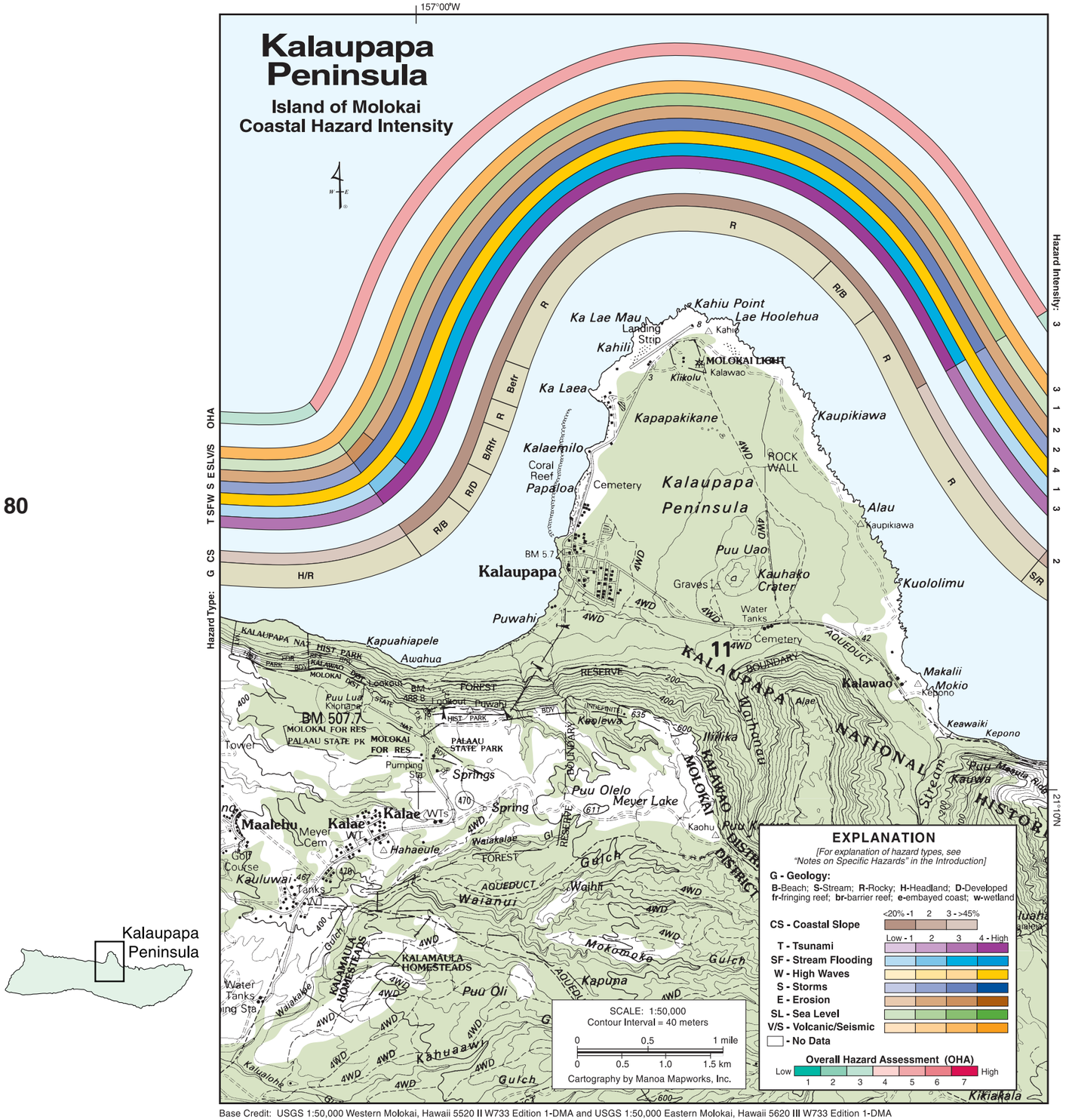
The Overall Hazard Assessment (OHA) for the Hoolehua coast is moderate to low (3) except for the stream mouths of Anahaki and Mimino Gulches, where it is moderate (4) and moderate to high (5), respectively, and the tsunami, stream flooding and storm hazards are higher. Along the steep rocky headlands of Hoolehua tsunami is moderately high, stream flooding is low, the high wave threat is high, storms are moderately low, erosion is moderately low, sea-level rise is low, and the volcanic/seismic hazard is moderately high. The important difference in the rankings for the Mimino Gulch mouth is that tsunami and stream flooding are high, and storms are moderately high, translating into a higher OHA there.



Base Credit: USGS 1:50,000 Western Molokai, Hawaii 5520 II W733 Edition 1-DMA

Steep seacliffs along the Hoolehua coast expose layers of lava and show several large landslide scars.





Base Credit: USGS 1:50,000 Western Molokai, Hawaii 5520 II W733 Edition 1-DMA and USGS 1:50,000 Eastern Molokai, Hawaii 5620 III W733 Edition 1-DMA

Kalaupapa Peninsula

Kalaupapa Peninsula is a large, isolated coastal plain built of lavas that eminated from Kauhako Crater, now a 450-ft-deep pit that extends below sea level and is filled with brackish water and lush vegetation. The peninsula's isolation, more than 1000 ft below the towering sea cliffs of central North Molokai, led the Hawaiian Board of Health in 1866 to establish this area as a colony for the growing number of people in Hawaii with leprosy, now referred to as Hansons Disease. Kalaupapa's shoreline is cliff-faced west of Puwahi and low and rocky to the east. Between Kalaupapa and Ka Laea an extensive fringing reef protects the rocky coast. Between Ka Lae Mau and Kaupikiawa the rocky shore is rugged and wind blown. Small perched carbonate beaches and narrow vegetated sand dunes exist on the west side of the peninsula between Kaulapapa and Ka Laea and on the east side just south of Lae Hoolehua. At Awahua, known as Black Sands Beach, the sand has a large terrigenous detrital component compared to the white carbonate sands of Papaloa, Kahili, and Hoolehua, born of storm-deposited rubble from offshore. Only small streams reach the sea west of Puwahi, however, there can be significant runoff to the east. Development is concentrated at the town of Kalaupapa and the airstrip near Ka Lae Mau. Kalaupapa is only accessible by plane, boat, or foot trail.

The Overall Hazard Assessment (OHA) for Kalaupapa Peninsula is moderate to high (5) except to the west of Puwahi, where it is moderate (4). The threat of high waves is high and the volcanic-seismic threat is moderately high throughout the entire region. Tsunami is high and stream flooding is moderately high along the low-lying peninsula and moderately high and low, respectively, on either side, except for stream flooding at Puwahi which is moderately low. Storms are moderately high and the threat from sea-level rise is moderately low along Kalaupapa Peninsula, while to either side they are moderately low and low, respectively. Erosion is moderately low for the entire Kalaupapa coast except for a small section of coast at Puwahi where it is moderately high. At Puwahi, stream flooding is moderately low, however, this and the higher erosion there do not alter its OHA of moderate to high (5). The volcanic/seismic hazard is moderately high in this vicinity which lies within the Molokai Seismic Zone.

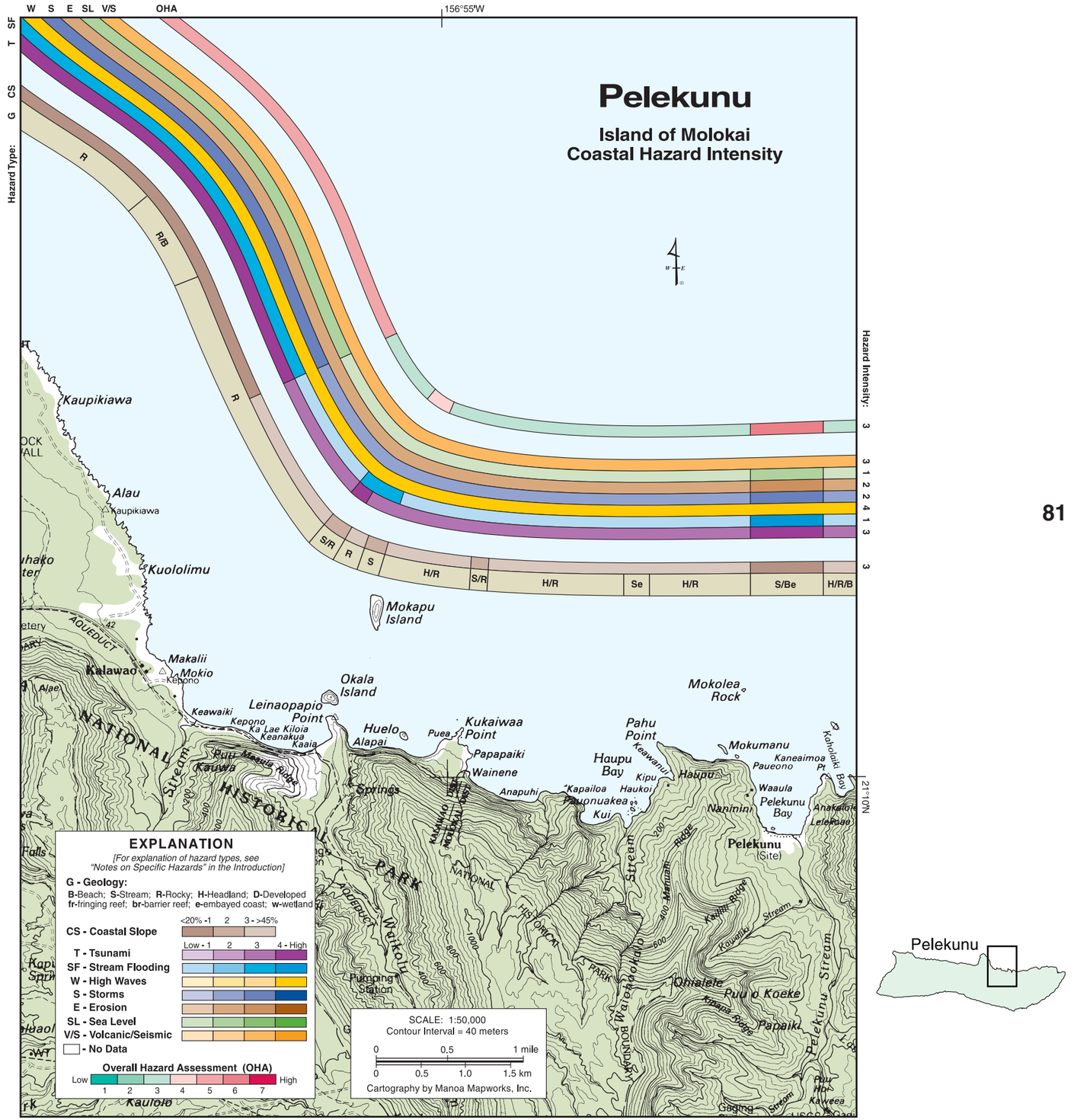
A view of the western shore of the Kalaupapa Peninsula shows the narrow fringing reef, low-relief of the peninsula, and steep terrain of the forest reserve in the background.

Pelekunu

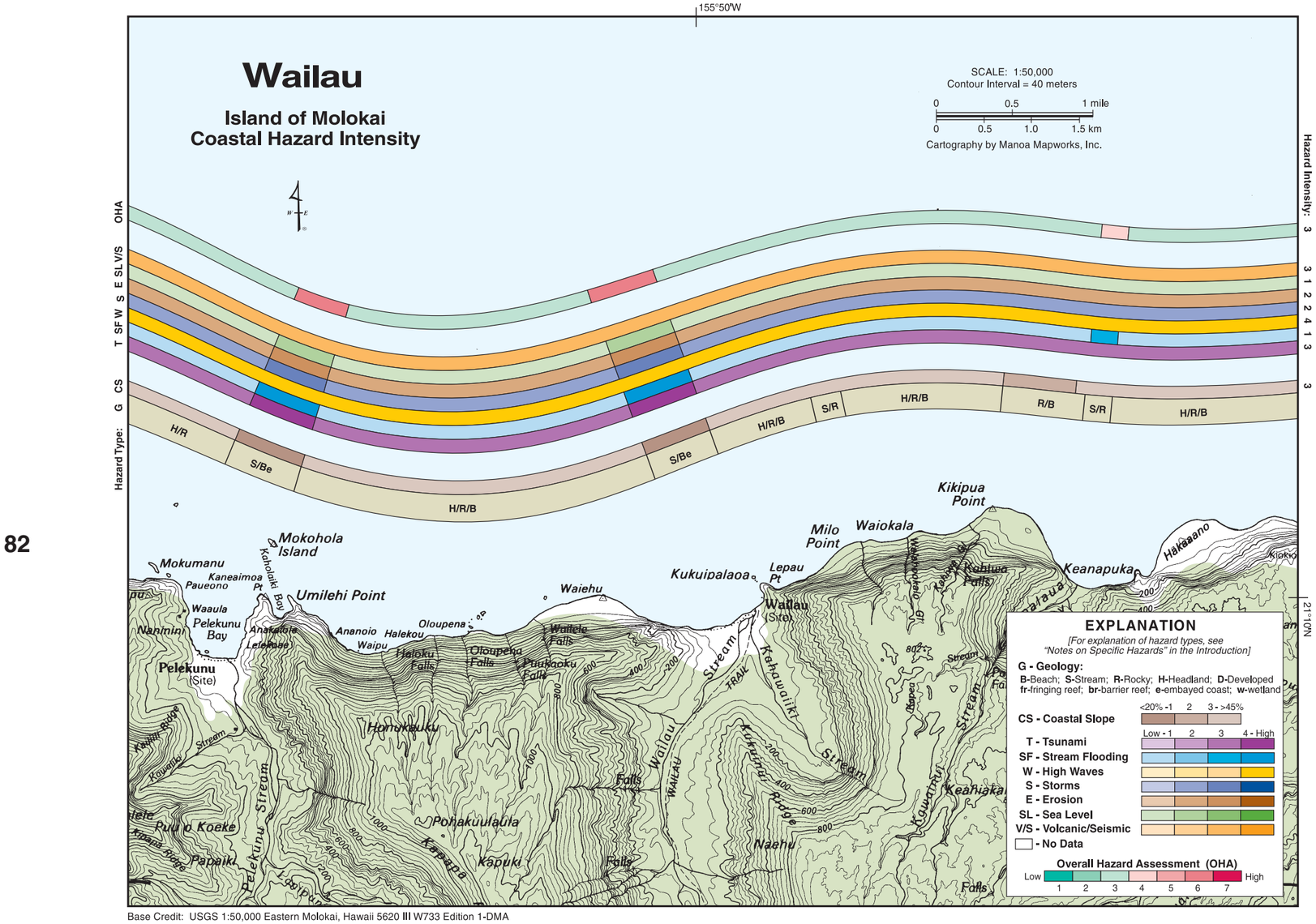
The low-lying coastal peninsula along Kaupikiawa and Kuololimu gives way to the steep coastal cliffs of North Molokai east of Kalawao. Deep and narrow stream valleys have been cut into this steep, rocky, headland coast and the only low-lying areas are at the stream mouths at Keawaiki, Kaaia, Wainene, and inside Pelekunu Bay. Beaches along this stretch of coast are mostly rocky boulder beaches with temporary dark detrital sand during periods of sustained calm conditions. Beautiful rock islets, including Mokapu and Okala Islands, Mokolea Rock, Huelo, and Mokumanu stand just offshore of the towering coastal cliffs that in places rise 2000 - 2500 ft from the shoreline. Only patchy corals have developed in the more protected areas along this high-energy coastline. While archaeological evidence shows this coast was once populated by large numbers of Hawaiians and cultivated with taro, today development is largely absent and access is only by boat or foot trail.

The Overall Hazard Assessment (OHA) for the Pelekunu coast is moderate to high (5) west of Alau and moderate to low (3) to the east, except at Keawaiki where it is moderate (4), and at Pelekunu Bay where it is high (6). West of Alau, where tsunami and high waves are high, stream flooding and storms are moderately high, and erosion and sea-level rise are moderately low, the OHA is moderately high (5). The OHA is moderately low (3) east of Alau to Mokio and between Huelo and Pelekunu Bay where tsunami and storms are reduced to moderately low, and stream flooding and sea-level rise are reduced to low. The volcanic/seismic threat is moderately high throughout the entire region. At Keawaiki, both tsunami and stream flooding are high and the OHA is increased to moderate (4). At Pelekunu Bay, tsunami and stream flooding are high, whereas storms, erosion and sea-level rise are moderately high, resulting in the high (6) OHA within the low-lying Pelekunu coastal plain and embayment.

A view looking south at Pelekunu Bay and up the valley of Pelekunu Stream shows the steep coastal cliffs and deep, narrow stream valleys of north Molokai.



Base Credit: USGS 1:50,000 Eastern Molokai, Hawaii 5620 III W733 Edition 1-DMA



Base Credit: USGS 1:50,000 Eastern Molokai, Hawaii 5620 III W733 Edition 1-DMA

Wailau

Between Umilehi Point and Hakaaano, the beautifully scenic amphitheater valley of Wailau dominates the North Molokai coast, which is mainly cliffs. Its valley walls are often adorned with numerous waterfalls that feed the valley floors 3000 - 4500 ft below. Springs, streams, and waterfalls contribute enormous amounts of water to Kahawaiiki and Wailau Streams that drain across Wailau's low-lying coastal plain. In the 1800's and early 1900's, Wailau was populated and taro was grown commercially. However, the 1946 tsunami inundated the valley with wave runup heights of 25 ft and destroyed the agricultural infrastructure. Today it is undeveloped and access is by boat or foot trail. Sea conditions are often very rough as trade wind waves and north swell persistently modify the shoreline. To the east, the small embayment of Keanapuka (Papalaua) sits amidst two rocky boulder beach points of Kikipua and Hakaaano. Only small patchy corals exist along this coast.

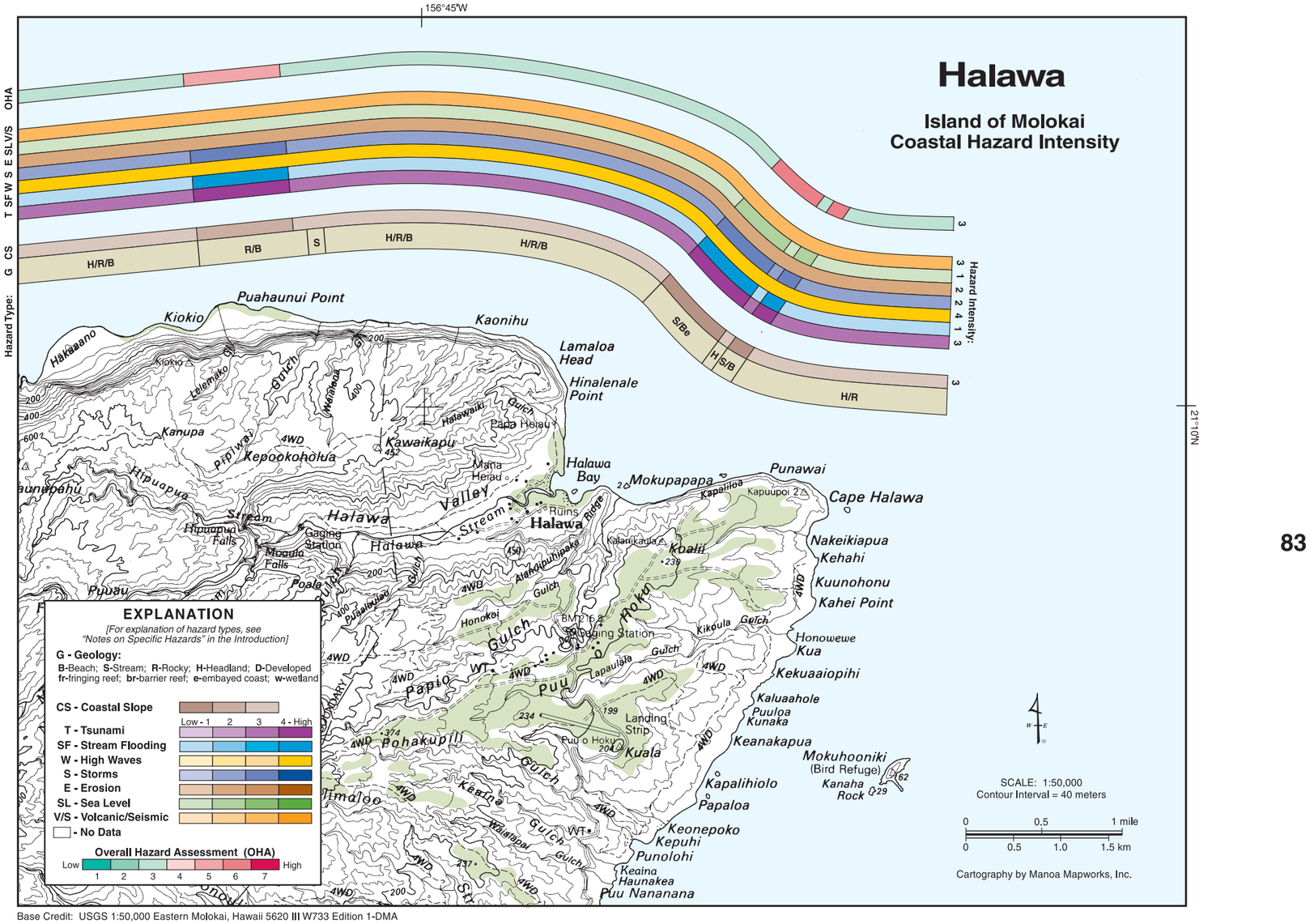
The Overall Hazard Assessment (OHA) of Wailau alternates between moderate to low (3) along the steep rocky headlands and high (6) in the Pelekunu and Wailau embayments. This is the result of the increase in tsunami, stream flooding, storm, erosion, and sea-level threats at the low-lying coastal embayments. Inside the bays, tsunami and stream flooding are high, while storms and erosion are moderately high, and sea-level rise is moderately low. Along the steep cliffs of the headlands, tsunami is moderately high, while storms and erosion are moderately low, and stream flooding and sea-level rise are low. The high wave and volcanic/seismic threats are high and moderately high, respectively, throughout the entire Wailau region. At Keanapuka, only the high ranking for stream flooding is greater than along the surrounding rocky headlands, and as a result, the OHA there is moderate (4).

A view of the rugged Wailau coast of northern Molokai (looking west) shows the steep cliffs and peninsulas, which are sites of ancient landslides.

Halawa

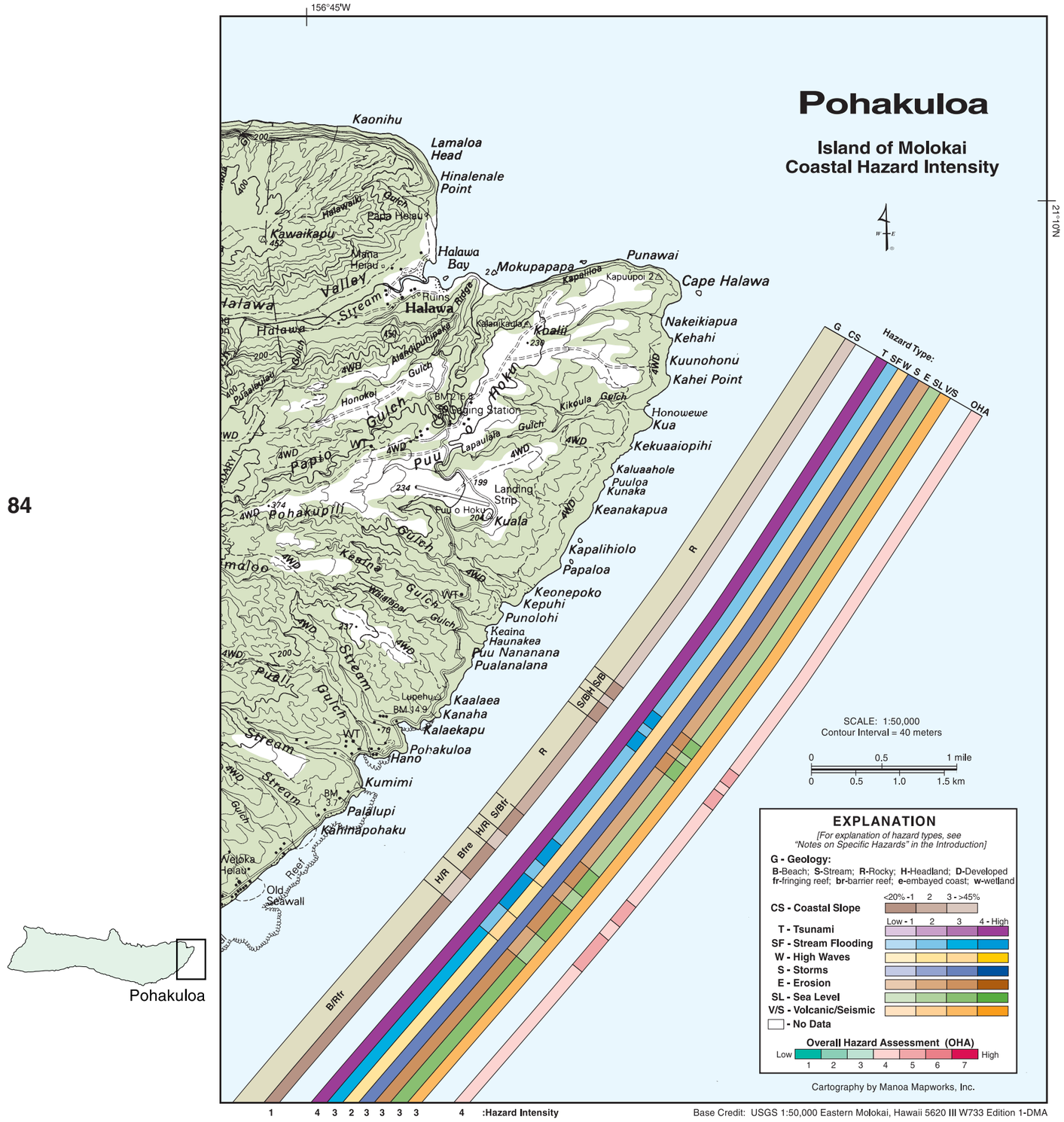
East of Hakaaano, the steep, towering rocky sea cliffs taper off toward Halawa, the last of the deep stream-cut valleys of the North Molokai coast. The coastal slope is steep along most of the Halawa coast, except near Puahaunui, where it is moderate, and inside Halawa Bay, where it is low lying. The beaches along this region of north Molokai are rocky boulder beaches except within Halawa Bay, which comprises a mixture of detrital terrigenous and marine carbonate sands. The sandy beaches of Halawa Bay occur along two inlets, which are separated by a rocky boulder point in the middle of the bay. Trade winds blow directly into Halawa and have formed sand dunes that line the back beach. Offshore of the rocky point a small patch reef of coral has developed amidst the rocky bay bottom. East of Halawa, the shoreline is a rocky headland coast to Punawai and Cape Halawa.

The Overall Hazard Assessment (OHA) for Halawa is moderate to low (3) along the steep cliffs to the west and east of Halawa Bay. Along the Puahaunui Point coastal plain it is moderate to high (5) and to either side of the rocky ridge protrusion in the center of Halawa Bay, it is high (6). Along the rocky headlands tsunami and the volcanic/seismic threats are moderately high, while stream flooding and sea-level rise are low. High waves and erosion are ranked high and moderately low, respectively. The moderate to high (5) OHA at Puahaunui Point is a result of the high tsunami and stream flooding and moderately high ranking for storms along this lower-lying portion of coast. At the two low-lying beaches inside Halawa Bay, tsunami and stream flooding are high, while storms are moderately high and sea-level rise is moderately low. This results in the high OHA ranking on either side of the central rocky outcrop in the bay.



Base Credit: USGS 1:50,000 Eastern Molokai, Hawaii 5620 III W733 Edition 1-DMA

The coastline along Halawa Bay is rocky and in the center of the bay a small rocky point separates two stream mouths that empty significant amounts of terrigenous sediment into the bay from the deep valley in the background.



Pohakuloa

The Pohakuloa coast is rocky with numerous small coves and rocky headlands that are steepest between Kahinapohaku and Kaalaea. Several small streams cross the coastal zone and transport terrigenous sediments to the shoreline. Often nearshore waters run brown with silt runoff while offshore the waters are crystal clear. Trade-wind waves and refracting north swell persistently erode the rocky shoreline leaving sea stacks strewn offshore from Papaloa to Cape Halawa. Between Kumimi and Kalaekapu, the wave energy associated with trade wind waves and north swell diminishes sufficiently that an extensive fringing coral reef flourishes. Small isolated sand and boulder beaches occur at Punolohi, Kalaekapu, Pohakuloa, Kumimi, and Kahinapohaku. Several forsaken fishponds lie submerged offshore in ruins from waves and lack of upkeep, while a few refurbished ponds stand strong above the waves maintaining a long heritage of Hawaiian fishing culture.

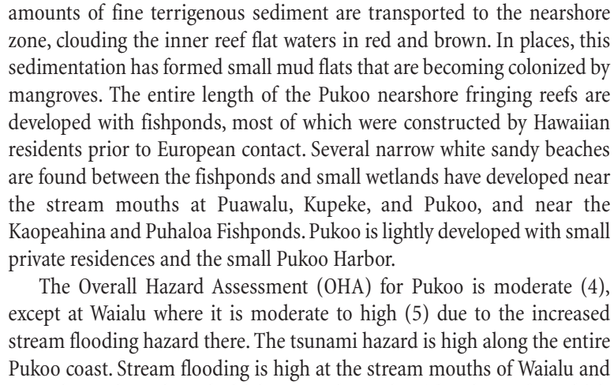
The Overall Hazard Assessment (OHA) for Pohakuloa alternates between moderate to high (5) at the low-lying beaches and stream mouths of Punolohi, Haunakea, Pohakuloa, and Kumimi, and moderate (4) along the surrounding rocky headlands. Along the entire Pohakuloa coast the tsunami hazard is high, while storms and the volcanic/seismic threats are moderately high. Inside the four small embayments at Punolohi, Haunakea, Pohakuloa, and Kumimi, stream flooding, erosion, and sea-level rise are ranked moderately high, while along the headlands they are moderately low, except for stream flooding to the west of Kahinapohaku where it is moderately high because of the lower coastal slope. The threat of high waves is moderately high east of Kumimi and at Palalupi, but is reduced to moderately low at Kumimi and to the west of Kahinapohaku where significant north swell and trade-wind swell refraction reduces its impact.

Beyond the steep, rugged east coast of Pohaku (foreground, looking southwest), the longest continuous fringing reef in the main Hawaiian Islands stretches from Kumimi (background) nearly 30 miles to the west end of southern Molokai.

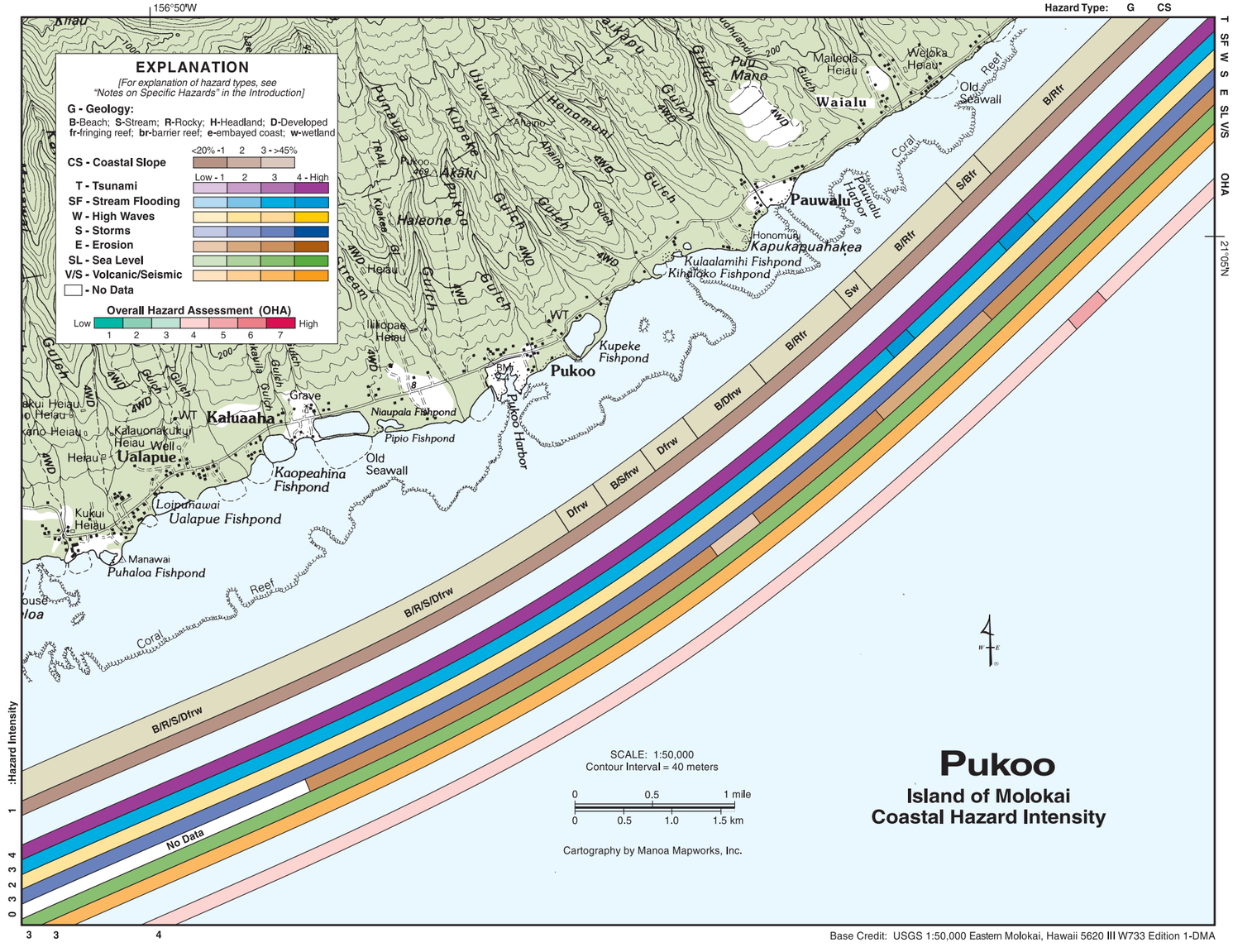
Pukoo

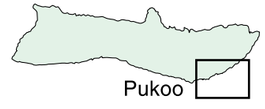
Between Waialu and Ualapue, the Pukoo coast is low-lying and comprises a relatively narrow coastal terrace with an increasingly wider fringing reef toward the west. The uplands are gently sloping and incised by numerous small streams that generally have low flow but do experience flash flooding with heavy precipitation. Despite a relatively arid climate (<40 in average annual rainfall) and low stream discharge, significant amounts of fine terrigenous sediment are transported to the nearshore zone, clouding the inner reef flat waters in red and brown. In places, this sedimentation has formed small mud flats that are becoming colonized by mangroves. The entire length of the Pukoo nearshore fringing reefs are developed with fishponds, most of which were constructed by Hawaiian residents prior to European contact. Several narrow white sandy beaches are found between the fishponds and small wetlands have developed near the stream mouths at Puawalu, Kupeke, and Pukoo, and near the Kaopeahina and Puhaloa Fishponds. Pukoo is lightly developed with small private residences and the small Pukoo Harbor.

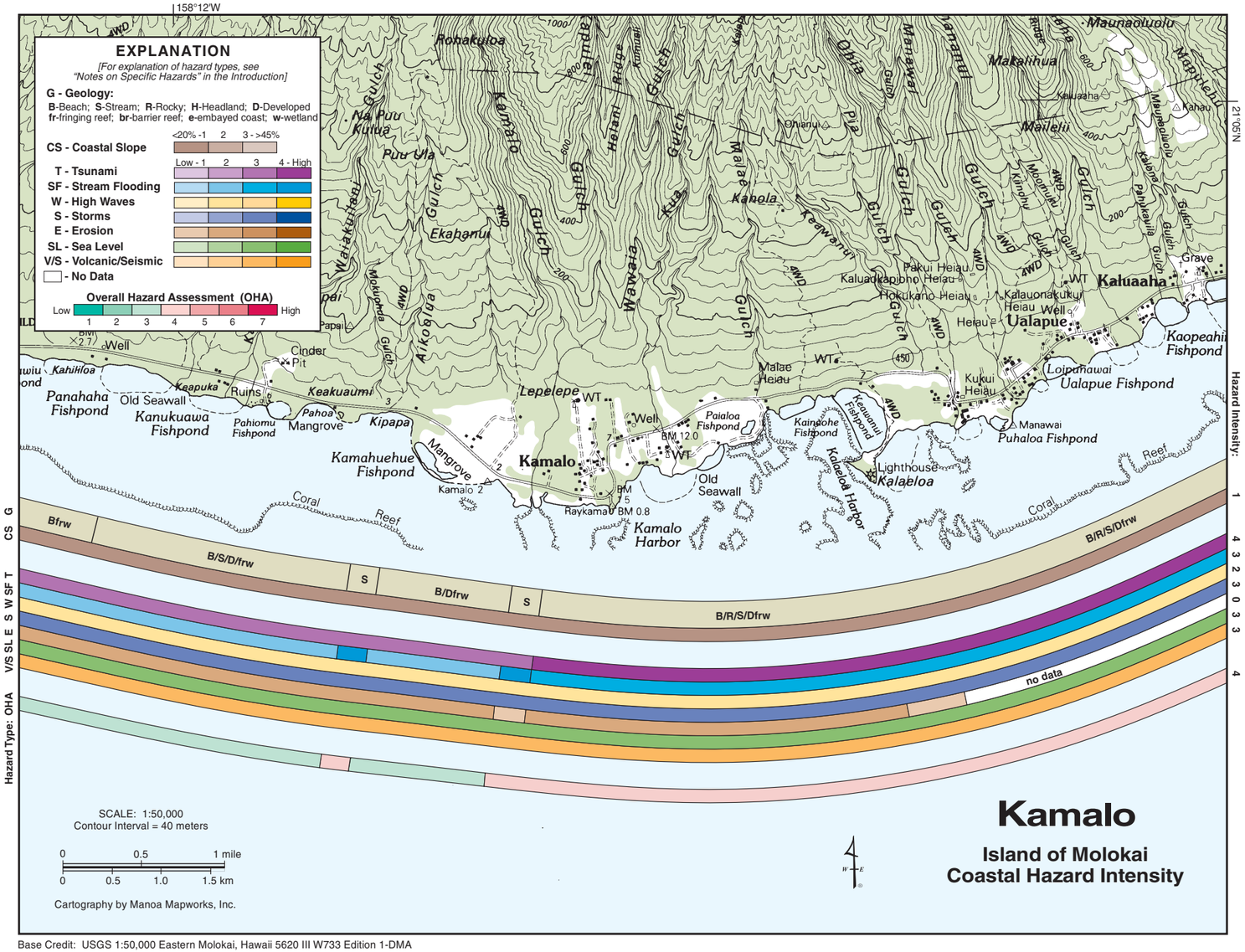
The Overall Hazard Assessment (OHA) for Pukoo is moderate (4), except at Waialu where it is moderate to high (5) due to the increased stream flooding hazard there. The tsunami hazard is high along the entire Pukoo coast. Stream flooding is high at the stream mouths of Waialu and Puawalu, and moderately high everywhere else. The threat from high waves is moderately low along the Pukoo coast because of the buffering effect of the wide fringing reef offshore and because it receives only moderately low south swell and refracted trade-wind waves. Storms are moderately high along the Pukoo coast, which receives significant winds and storm-generated waves from passing tropical storms. Erosion is moderately high throughout most of Pukoo, except at Pauwalu and Kupeke Fishpond, where it is moderately low and low, respectively. The hazards from sea-level rise, volcanism, and seismicity are moderately high throughout this entire section of Molokai's south coast.



The broad fringing reef of southeast Molokai near Kupeke Fishpond is generally very shallow and often brown with sediment shed from the land. Blue holes occur within the reef platform.







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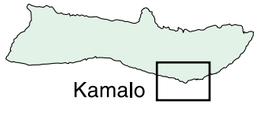


Kamalo

Molokai's southern shoreline around Kamalo is constructed of a low-lying coastal plain with a wide fringing reef offshore. Numerous small, isolated patch reefs amidst sand fields occur between Kalaeloa Harbor and Kamahuehue Fishpond. This region of the southern coast of Molokai is relatively arid, but intermittent stream flow and basal groundwater flow feed wetlands near the mouths of most of the streams. Mangrove forests have formed near Kamahuehue Fishpond and Keakuaumi within terrigneous silt deposits. The majority of this coast is rocky and lined with seawalls and fishponds. Only small, narrow sand beaches occur near Kanukuawa, Kamahuehue, Paialoa, and Puhaloa Fishponds. Most of the Kamalo coast is privately developed except for the Kalaeloa and Kamalo Harbors.

The Overall Hazard Assessment (OHA) for Kamalo is moderate (4) east of Kamalo, and generally moderate to low (3) to the west, except at the stream mouth at Kipapa, where it is moderate (4). The tsunami hazard is high east of Kamalo, and reduced to moderately high to the west, because of the shadowing effect of the island of Lanai. Stream flooding is moderately high east of Kamalo where it is wetter, and moderately low in the more arid region to the west. Exceptions are at the stream mouths at Kamalo and Kipapa where it is high. High waves are moderately low along the Kamalo coast, which is relatively sheltered from northwest swell by west Molokai, Oahu, and Kauai to the west, and from south swell by the island of Lanai to the south. Storms, sea level, and the volcanic/seismic hazards are ranked moderately high. Erosion varies between moderately low along most of the rocky coast, to low at Kalaeloa, which appears to be stabilized by sedimentation within and around Keawanui Fishpond and at Kamalo where the coast is prograding in response to sedimentation at the stream mouth.

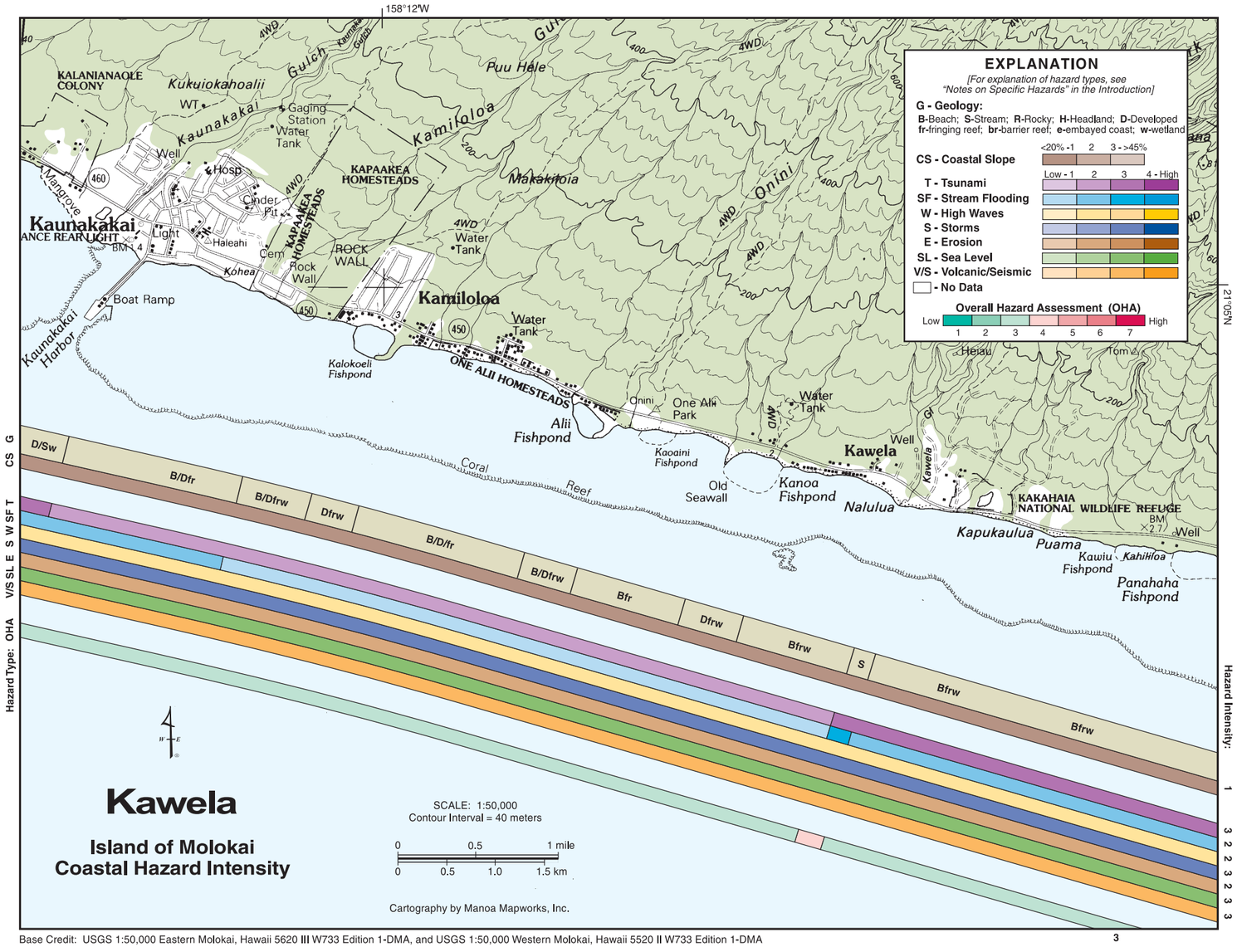
The broad and low-lying coastal plain of Kamalo (background) is fronted by a fringing reef which has a natural reef passage offshore of Kamalo Harbor (foreground).

Kawela

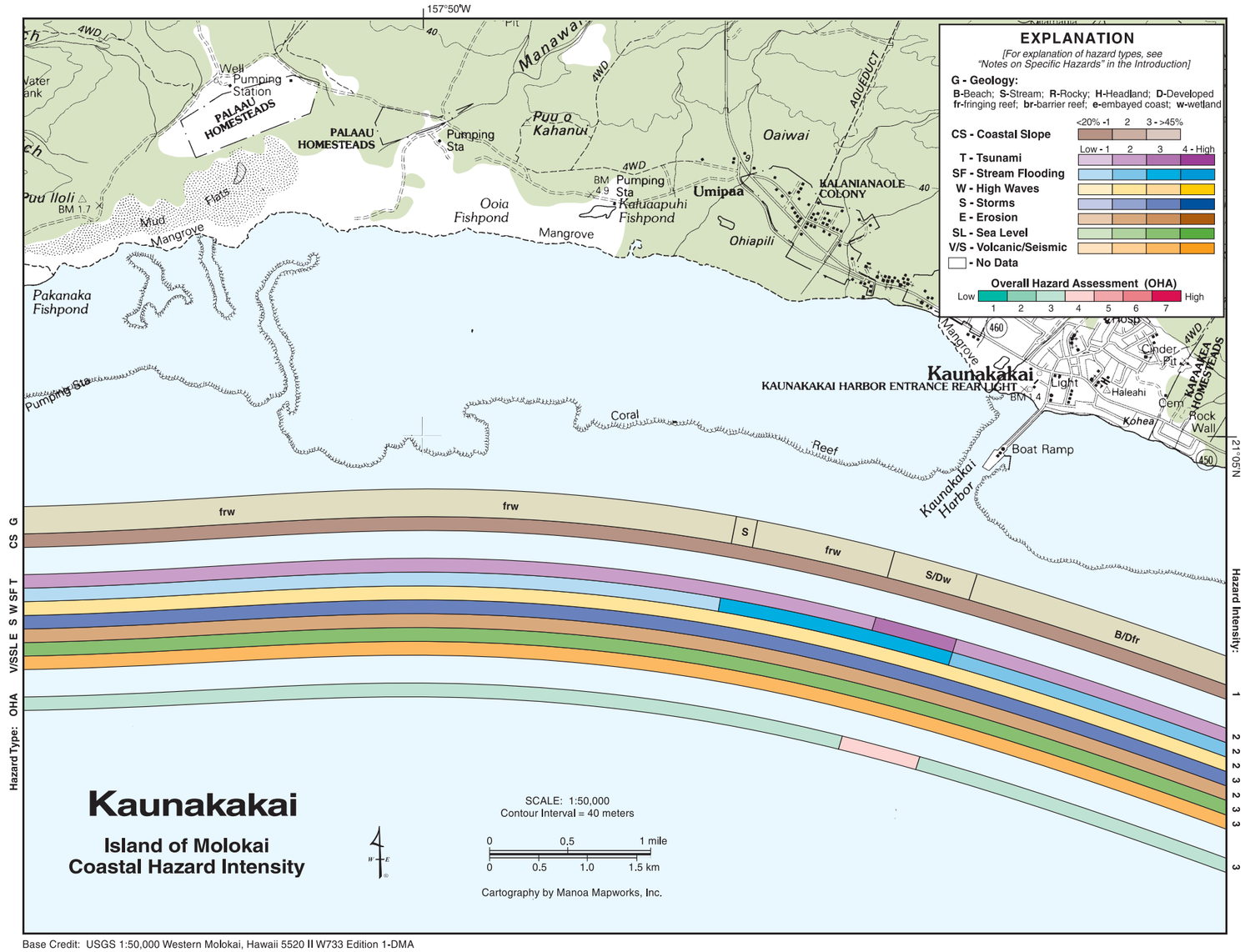
The Kawela shoreline along Molokai's southern shore is generally low-lying with a wide fringing reef offshore. Despite an average annual rainfall between 10 and 20 in, a significant volume of terrigenous sediment makes its way into the nearshore waters. Where this sediment has prograded out into the shallow, low-energy reef flat environments at stream mouths, mangrove forests have developed. Commonly, immediately landward of these mangroves, wetlands have formed. Narrow carbonate beaches line most of the Kawela coast, except at stream mouths where the sand has a high terrigenous component and where fishponds harden the shoreline, although there appears to be some sedimentation along the eastern edges of Alii and Kalokoeli Fishponds. Development increases to the west with the urbanization of Kamiloloa and Kaunakakai extending up to the shoreline.

The Overall Hazard Assessment (OHA) for the Kawela coast is moderately low (3), except at the Kawela stream mouth where it is moderate (4). This is primarily because of the high stream-flooding hazard at Nalulua, which has a history of flash flooding and sedimentation at the outflow of Kawela stream. Tsunami is moderately high east of Nalulua and moderately low to the west to Kaunakakai. Stream flooding east of Nalulua is moderately low while to the west it is low to the Kamiloloa stream mouth. Beyond the Kamiloloa Stream it is moderately low. Wave energy is generally low along Molokai's southern coast, where it is sheltered from south swell by the islands of Lanai and Kahoolawe. The storm hazard is moderately high because storms that often pass to the west generate modest winds and waves along this coast. Erosion is moderately low due to the rocky nature of the coast, while the sea-level hazard is moderately high because of the low elevation and slope of the coastal zone. The volcanic/seismic threat is moderately high in this part of Molokai which lies within the Molokai Seismic Zone.

Numerous fishponds like the Alii Fishpond (foreground) line the south coast of Molokai. The hillslopes of south Molokai (background) are arid and sparsely vegetated. Extensive erosion occurs during episodic high rainfall events and as a result of excessive grazing, bringing soil and sediment from the land which settles on the reef flat and in the fishponds.



Base Credit: USGS 1:50,000 Eastern Molokai, Hawaii 5620 III W733 Edition 1-DMA, and USGS 1:50,000 Western Molokai, Hawaii 5520 II W733 Edition 1-DMA



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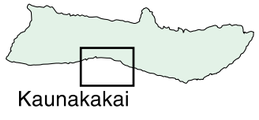


Kaunakakai

The Kaunakakai shoreline is built on a low-lying coastal terrace that reaches nearly 1 mi in width near Ooia Fishpond. An extensive fringing reef offshore buffers approaching swell. It is composed of diverse coral gardens near its crest, however, in the nearshore waters, the reef flat suffers from widespread siltation. Land use practices including deforestation, overgrazing, and open-ground agriculture have accelerated erosion and runoff of the uplands, which reaches the nearshore with high sediment concentrations, altering the water clarity during the entire year. West of Kaunakakai, a prograding shoreline comprised of mudflats and mangrove forests is forming from continued deposition of terrigenous sediments. Associated with many of these mangroves are extensive wetland areas. Kaunakakai is relatively arid, receiving on average less than 10 in of rain each year. Only a few streams reach the coastline, mainly in the vicinity of the town of Kauanakakai. Most of the shoreline is muddy or sandy, except immediately east of Kauanakakai Harbor where there is a small carbonate beach. Development on the coast is centered near the harbor.

The Overall Hazard Assessment (OHA) for the Kauanakai Coast is moderate to low (3), except at Kaunakakai Harbor where greater tsunami and stream flooding hazards translate into an OHA of moderate (4). While the entire Kaunakakai coastal zone is low-lying, the tsunami hazard is greater at the harbor because the deep reef pass there allows greater wave energy to reach the shore. As a result, the tsunami hazard is moderately high at the harbor and moderately low to either side. Stream flooding generally decreases to the west. It is moderately low east of Kaunakakai and low to the west. In the immediate vicinity of Kauanakakai, where several streams reach the sea, the flooding hazard is moderately high. High waves are only a moderately low threat while storms are moderately high along most of the south shore of Molokai. Erosion is moderately low along this shore, while the sea-level hazard is moderately high due to the low slope of the coastal terrace. The volcanic/seismic hazard is also moderately high, as this region of Moloaki lies within the Molokai Seismic Zone.

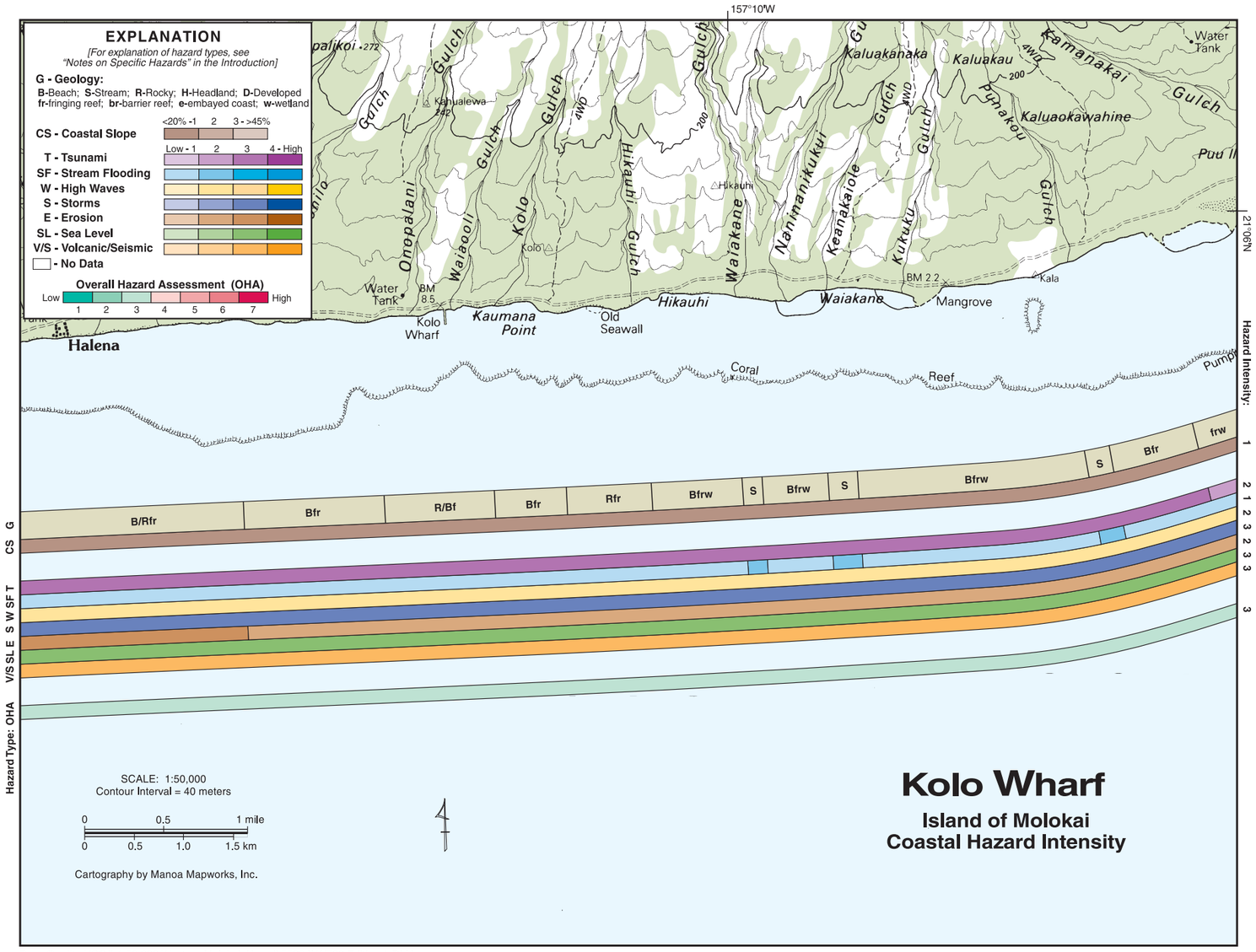
The main port for Molokai is the Kaunakakai Harbor (foreground), which is situated within a dredged reef pass that extends across the entire reef flat of south Molokai. Mangroves continue to colonize much of the central south Molokai coast as excessive sediment resulting from erosion of the interior hillsides builds the shoreline out across the reef.

Kolo Wharf

Along the relatively undeveloped Kolo Wharf coast, the offshore fringing reef narrows slightly to the west, siltation decreases, and mud flats give way to carbonate beaches. The widest beaches occur west of Kolo Wharf, an old dilapidated pier. Extensive outcrops of beachrock along the shore and sometimes stranded offshore, suggest recent erosion. Scarped dunes and fallen trees west of Hikauhi support this interpretation. Many of the beaches west of Kolo Wharf are perched upon beachrock. Only a few streams make it to the coast in this arid region of Molokai, which on average receives less than 10 in of rainfall annually. Numerous wetlands have formed behind the coastal dunes and mangroves, which help trap runoff and groundwater flow from the west Molokai mountains above.

The Overall Hazard Assessment (OHA) for the Kolo Wharf region is moderately low (3). The tsunami hazard increases from moderately low in the east to moderately high in the west, away from the shelter provided by the islands of Lanai and Kahoolawe. Stream flooding is low along the Kolo Wharf Coast, except at the Punakou, Keanakaoile, and Waiakane Stream mouths where it is moderately low. High waves are ranked moderately low, while storms are moderately high, like most of the south coast of Molokai. Erosion is moderately low along the coast east of Kolo Wharf but moderately high to the west, where beachrock exposures and scarping of dunes suggest active retreat. The sea level and volcanic/seismic threat is moderately high, as it is along the entire Molokai coast due to its location within the Molokai Seismic Zone.

The formation of an alluvial fan at the shoreline near Waiakane (center) results from the erosion of the arid and sparsely vegetated west Molokai mountains (background) during episodic rainfall events. Although some of the sediment accummulates in the alluvial fan much of it also makes its way to the sea, settling on the reef and filling in abandoned fishponds (foreground).



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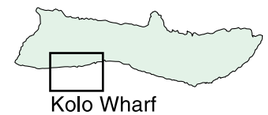

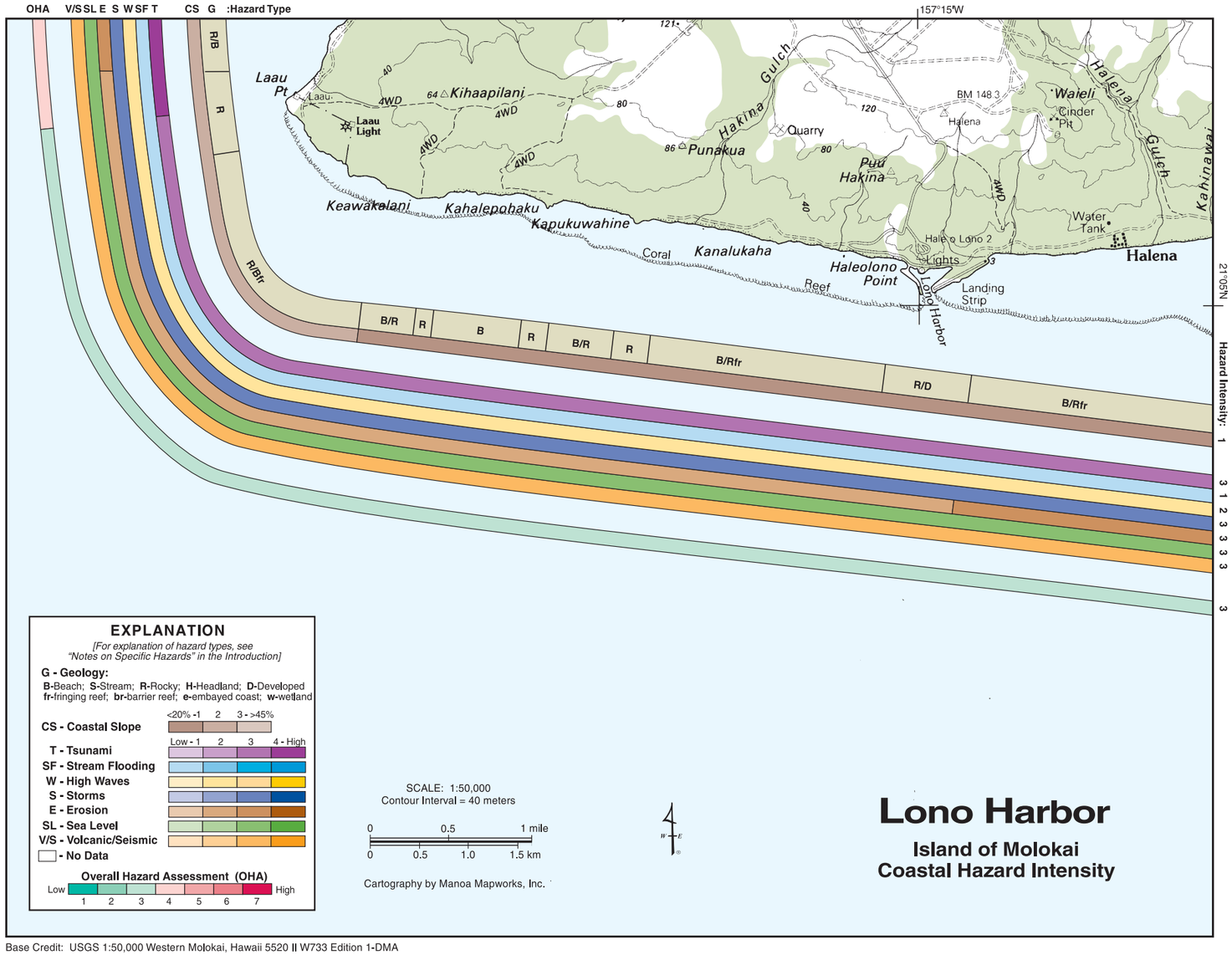

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Lono Harbor

West of Halena, the Lono Harbor coast reaches to Laau Point, the southwestern-most corner of Molokai. Lono Harbor is famous for being the starting point of the annual inter-island Molokai to Oahu canoe race. Long carbonate sand beaches give way to pocket beaches between rocky volcanic headlands west of Haleolono Point. Many of the pocket beaches are perched above old and low-lying wave abrasion terraces formed in the volcanic rock west of Keawakalani and above beachrock between Lono Harbor and Keawakalani. East of Lono Harbor, exposures of beachrock at the shoreline and immediately offshore, along with scarped dunes and fallen trees near Halena, suggest recent erosion. Water clarity generally improves to the west, due to greater circulation and less siltation of the nearshore waters and inner reef flats. The fringing reef narrows toward the southwest corner of the island and aridity increases. The only development along this coast is Lono Harbor and the small village of Halena.

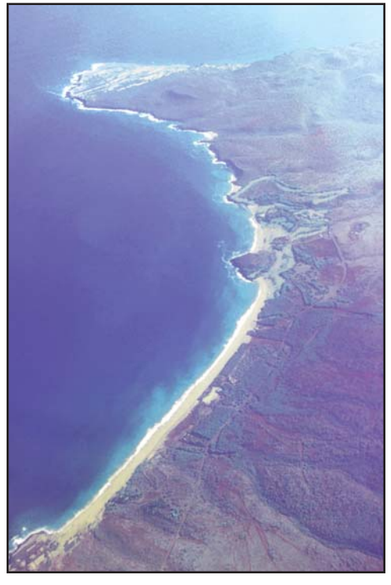
The Overall Hazard Assessment (OHA) for Lono Harbor region is moderately low (3) between Halena and Laau Point and moderate (4) northwest of Laau Point. This increase is due to the increased tsunami hazard along the lower-lying coast northwest of Laau Point where the tsunami hazard is ranked high; it is only moderately high along the steeper coast to the east. Because of very low rainfall and few streams, stream flooding is ranked low. The high wave hazard is moderately low here where most wave energy reaching the shore is from south swell or refracting northwest swell. Because tropical storms most often track to the west of the islands, the storm threat along the west-facing Lono Harbor coast is moderately high. Because of the low coastal slope and proximity to the Molokai Seismic Zone, the sea-level and the volcanic/seismic hazards, respectively, are moderately high along this coast. Erosion is moderately high at Halena, where dunes are scarped and offshore beachrock ridges marking the past position of the shoreline are exposed. Erosion is moderately low to the west of Lono Harbor where beaches are perched above fossil wave abrasion terraces.

A view of Lono Harbor at Haleolono Point, developed along a narrow coastal terrace at the base of the west Molokai mountains.

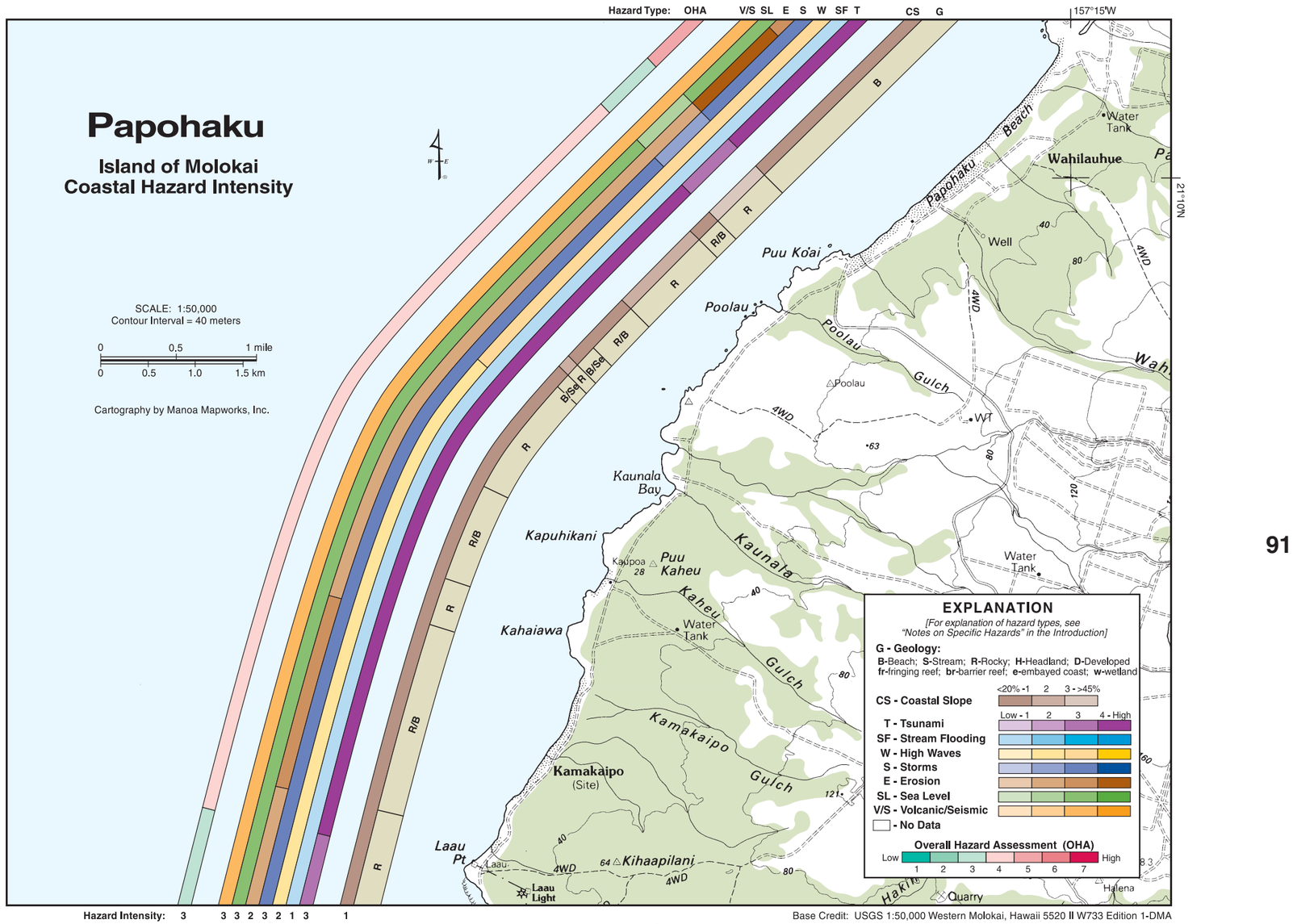
Papohaku

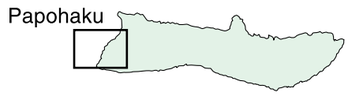
Rocky, low-lying wave abrasion terraces and headlands interspersed with pocket beaches characterize the Papohaku coast between Laau Point and Puu Koai. Northeast of Puu Koai lies Papohaku Beach, one of Hawaii's most beautiful white sandy beaches. A rocky boulder and sand beach exists at Kamakaipo, and small carbonate beaches occur inside the three small, isolated embayments at Kaunala Bay and Poolau. These are also areas where small streams, although often dry, reach the sea. Development along the rocky portion of this coast is minimal and access is by four-wheel drive or footpaths. It is interesting that reefs are not well established along this portion of the west Molokai shore, yet there appears to be abundant carbonate material available for beaches as evidenced by Papohaku Beach. Despite an abundant source of carbonate sands, Papohaku Beach has suffered extensive human-induced erosion, as significant volumes of sand were removed in the early 1900s to nourish beaches on Oahu. It is now of interest to researchers to see if Papohaku can recover in the face of natural erosion associated with global sea-level rise.

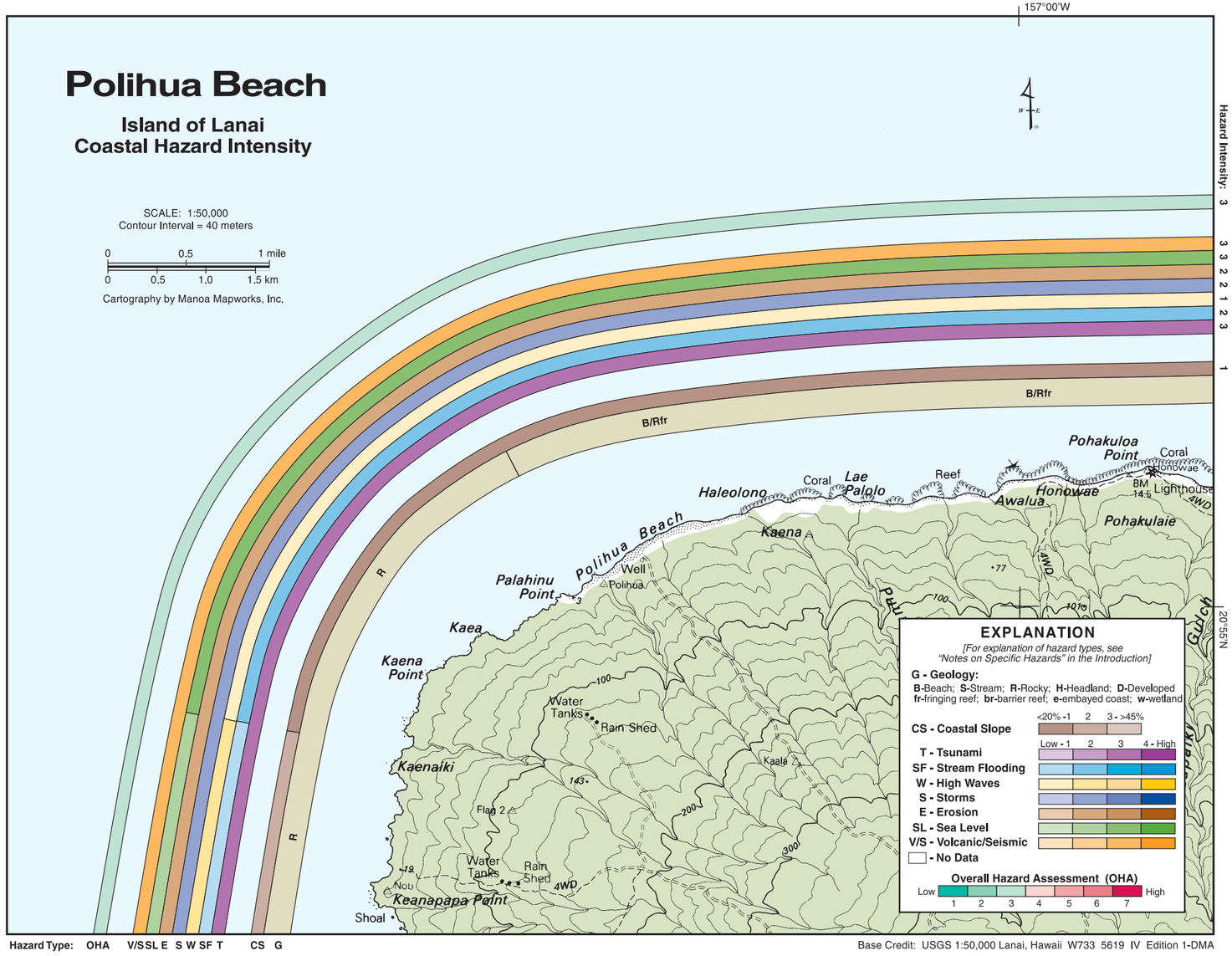
The Overall Hazard Assessment (OHA) between Laau Point and Papohaku Beach is moderate (4) except for the Puu Koai headland which is relatively steep and where the OHA is moderately low (3), and Papohaku Beach where it is moderately high (5). Tsunami is high along the low-lying rocky terraces and moderately low at Puu Koai. Stream flooding is low along the entire coast, where few streams and low rainfall occur. High waves are moderately low from Laau Point to Kaunala Bay and moderately high to the north and east, where greater wave energy from northwest swell reaches the shoreline. The storm hazard is moderately high along this coast except at Puu Koai where it is only moderately low. Erosion varies between moderately high between Laau Point and Kahaiawa, low north to Puu Koai, and high along Papohaku Beach, which has undergone significant beach loss this century. Sea-level rise is a moderately high threat along the low coastal terraces and only low at the headland of Puu Koai. The volcanic/seismic hazard is moderately high between Laau Point and Papohaku Beach, in accordance with its location within the Molokai Seismic Zone.

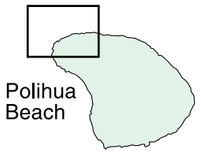


A view of the broad, extensive carbonate beach at Papohaku (foreground) and Ilio Point (background) on Molokai's west shore.









Polihua Beach

The gently sloping rocky points between Keanapapa and Palahinu Points give way to the longest white sand beach on Lanai at Palihua Beach. It is a narrow strand beach along Lanai's north shore with patchy corals offshore that become more extensive to the east. The nearshore deepens rapidly. Although the coast faces north, it is protected from large northwest, north, and northeast swell by the islands of Molokai and Maui. This coast receives significant wind energy that can set up strong currents immediately offshore. The winds and currents have taken their toll on boats here in the past, as evidenced by several shipwrecks found along Polihua and Pohakuloa Point to the east. The Polihua Beach coast on average receives less than 10 in of rainfall. Streams do experience flash flooding at times and can carry vast amounts of terrigenous sediment to the shoreline. This remote region of Lanai is undeveloped and access is by four-wheel drive, footpath, or boat.

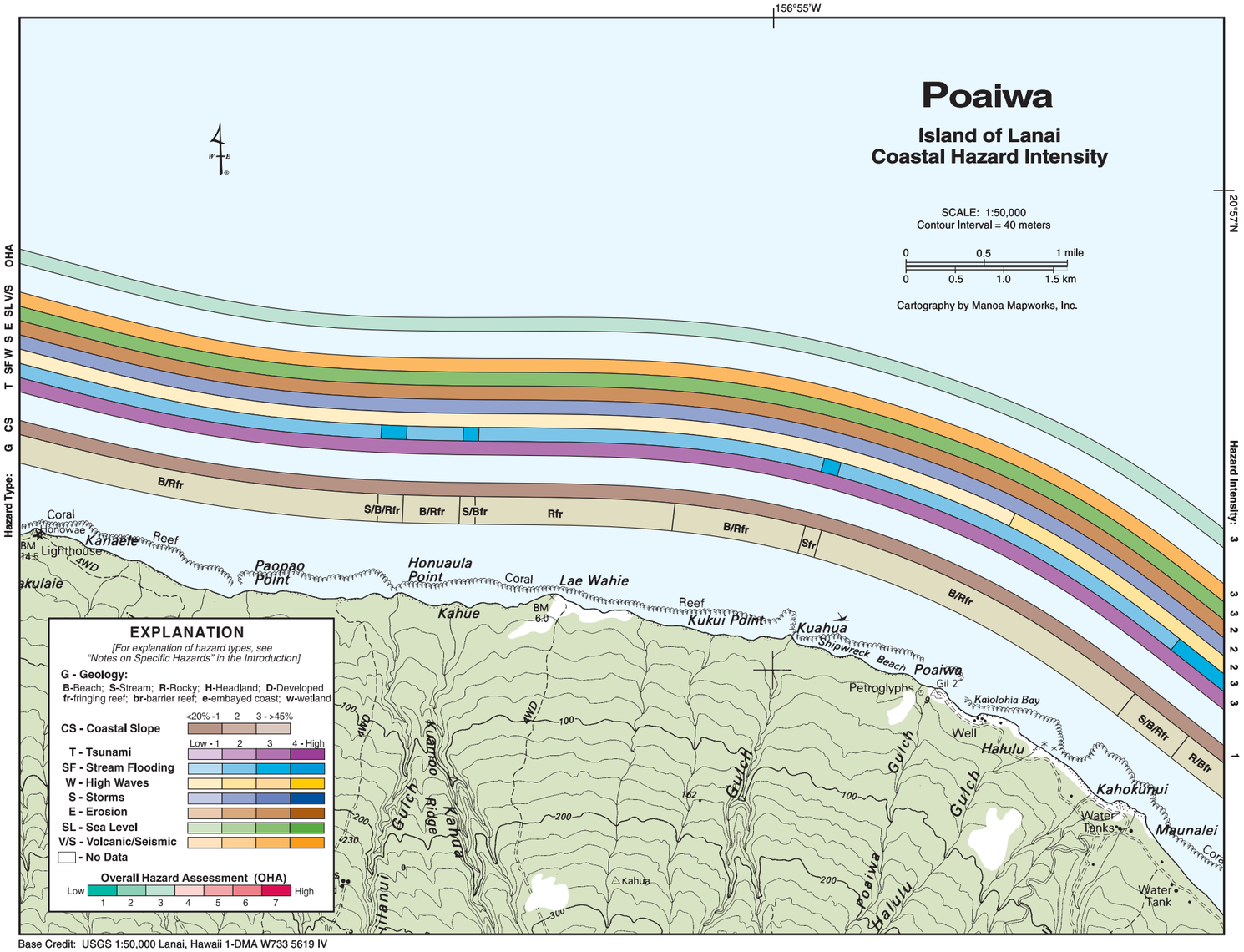
The Overall Hazard Assessment (OHA) for the Polihua Beach coast is moderate to low (3). The tsunami hazard is uniformly moderately high along Polihua Beach. Stream flooding is low southwest of Kaenaiki, where streams reach the sea along moderately steep sea cliffs, but is increased to moderately low to the east along Polihua Beach and on to Pohakuloa Point where streams enter the sea along a low coastal terrace. The high wave hazard is moderately low southwest of Kaenaiki, and low to the east, where wave energy is reduced by the islands of Molokai and Maui to the northwest and northeast. Storms and erosion are moderately low. The sea-level-rise hazard is moderately low along the steeper rocky coast southwest of Kaenaiki and moderately high along the low-lying beach of Polihua. The volcanic/seismic threat is moderately high here as it is along the entire Lanai coastline, because of its position within the Molokai Seismic Zone.

A view of the remote west end of Polihua Beach (looking south) that reaches to the low volcanic bluffs of northwest Lanai.

Poaiwa

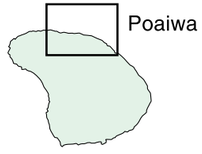
Between Kanaele and Poaiwa, the coast is a low-lying coastal terrace with a long, narrow sand and gravel beach west of Lae Wahie and numerous pocket beaches to the east. Small rocky headlands occur at Kukui Point and Halulu. Several small streams drain the arid mountains to the south. Rocky cobble and boulder deltas often occur at their mouths, reflecting periodic high stream discharge. A narrow fringing reef fronts the entire length of this coastal segment and water clarity generally improves immediately offshore of the sediment-loaded nearshore waters. Trade winds blow persistently along this coast and small dunes that are often vegetated have formed behind the beach. These dunes provide a large sand resource for natural beach nourishment during shoreline migration. This remote area of Lanai is mostly used for recreational purposes. One of the attractions along this coast is the large shipwreck at Kuahua, otherwise known as Big Shipwreck Beach.

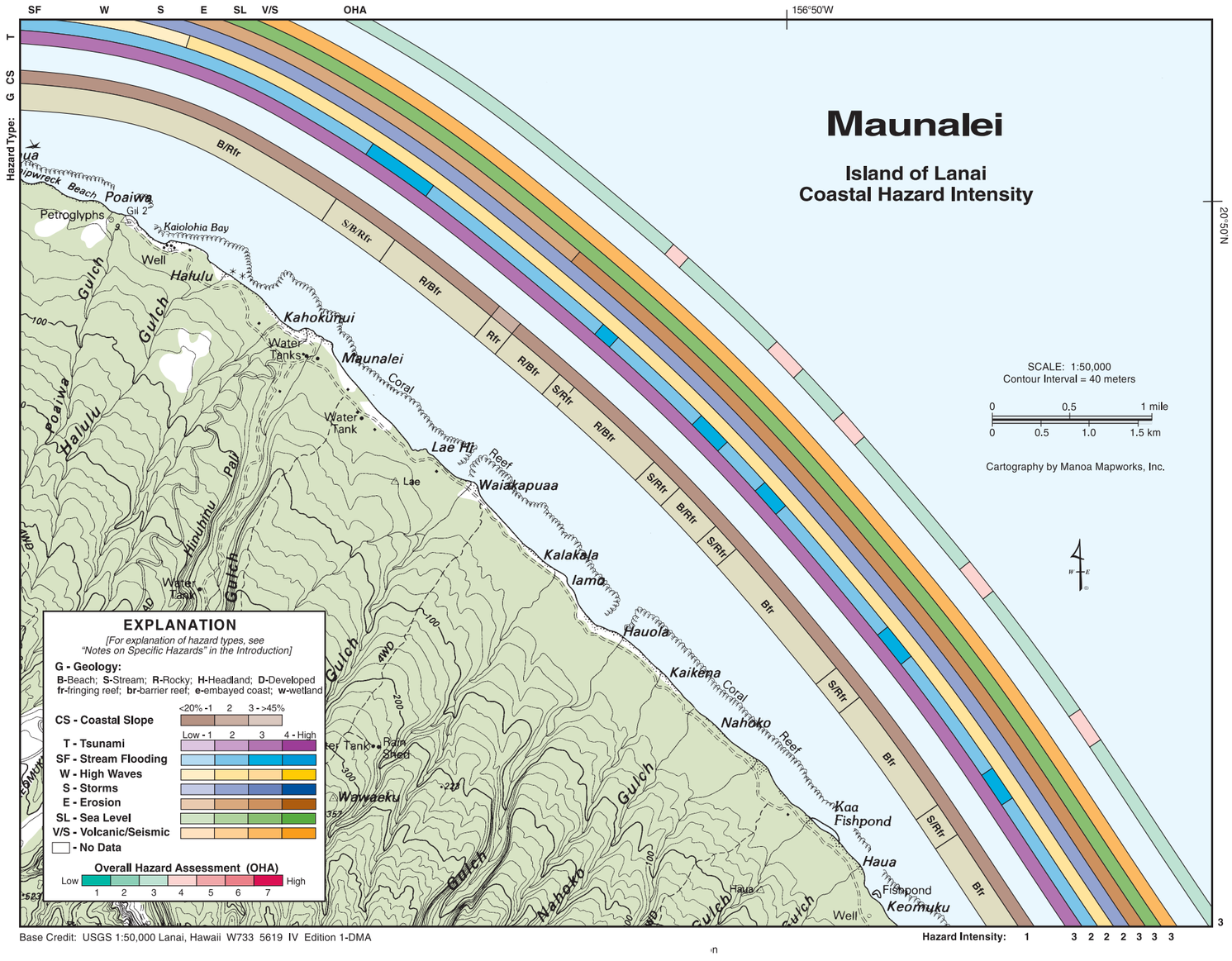
The Overall Hazard Assessment (OHA) for the Poaiwa Coast is moderate to low (3), reflecting the relatively low stream flooding, wave, and storm hazards. The tsunami hazard is moderately high along this low-lying coast. Stream flooding is moderately low except at the three stream mouths. The high waves threat is low between Kanaele and Poaiwa and moderately low to the east, where south swell refracts and reaches the shore. Storms are ranked moderately low along this shoreline which is sheltered from storms approaching from the east by Molokai and Maui. The erosion hazard is moderately low, due to the generally rocky nature of the shoreline. The sea-level rise hazard is moderately high due to the low coastal slope, while the volcanic/seismic threat is moderately high as it is along the entire Lanai coastline, which lies within the Molokai Seismic Zone.

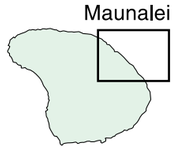


Base Credit: USGS 1:50,000 Lanai, Hawaii 1-DMA W733 5619 IV

One of several shipwrecks along the north coast of Lanai is found at Kuahua (foreground) just offshore of the shallow fringing reef and Shipwreck Beach.







Maunalei

Strong trade winds shape the shoreline and its vegetation along the Maunalei coast which extends from Poaiwa to Haua. Along this segment of coast the beach is narrow with occasional rocky outcroppings, usually found at stream mouths, but also as small protrusions where the descending mountain ridges meet the sea. The beaches narrow toward the southeast, whereas the fringing reef widens. Erosional scarps in the beachface are prominent southeast of Lae Hi, indicating recent retreat of the shoreline. Several ancient fishponds that lie offshore, are now infilled with sediment. This coast is undeveloped and popular for recreation. It is accessed by a paved road that descends from central Lanai to the coast at Mauanalei. The road continues unpaved along the narrow coastal terrace to the southeast.

The Overall Hazard Assessment (OHA) for the Maunalei Coast is moderate to low (3) along the narrow beaches and moderate (4) at the stream mouths southeast of Lae Hi. The tsunami hazard is moderately high along this low-lying coast, and stream flooding is relatively low, except at the stream mouths where it is moderately high. The hazard due to high waves increases from low to moderately low toward the southeast of Poaiwa because south swell can refract around eastern Lanai and reach the Maunalei shore. Storms are ranked moderately low throughout the entire area, because of the sheltering effect the islands of Molokai and Maui provide when tropical storms pass by, usually from the east to the west. The erosion hazard is moderately low west of Lae Hi, and moderately high to the east, where scarping is clearly evident along the already narrow beaches. The sea-level and volcanic/seismic threats are moderately high along the Maunalei coast which is low sloping and within the Molokai Seismic Zone.

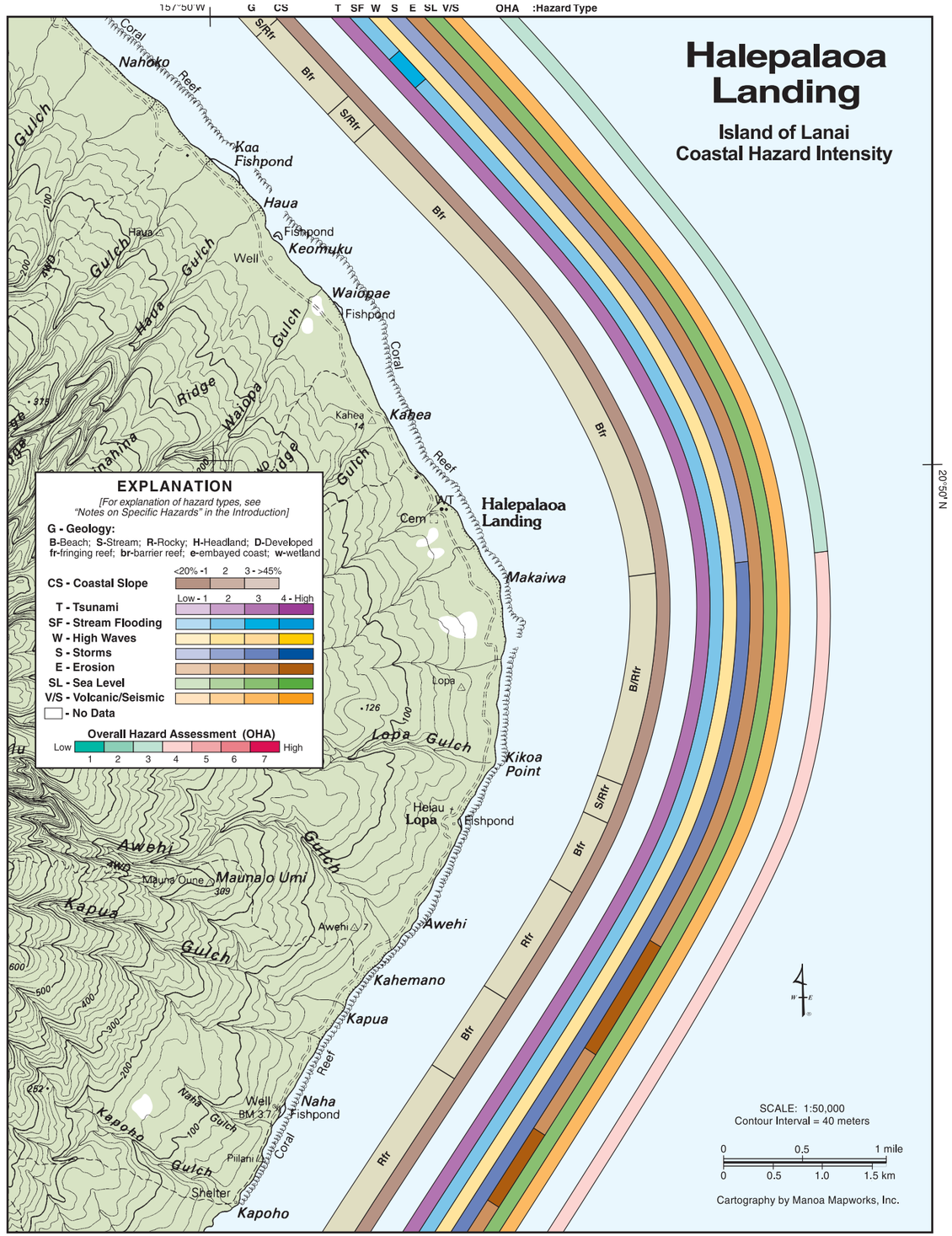
Erosion of the large stream valley inland of Maunalei (background) has led to the development of an alluvial fan at the shoreline.

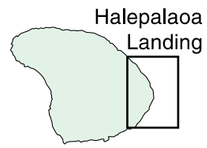
Halepalaoa Landing

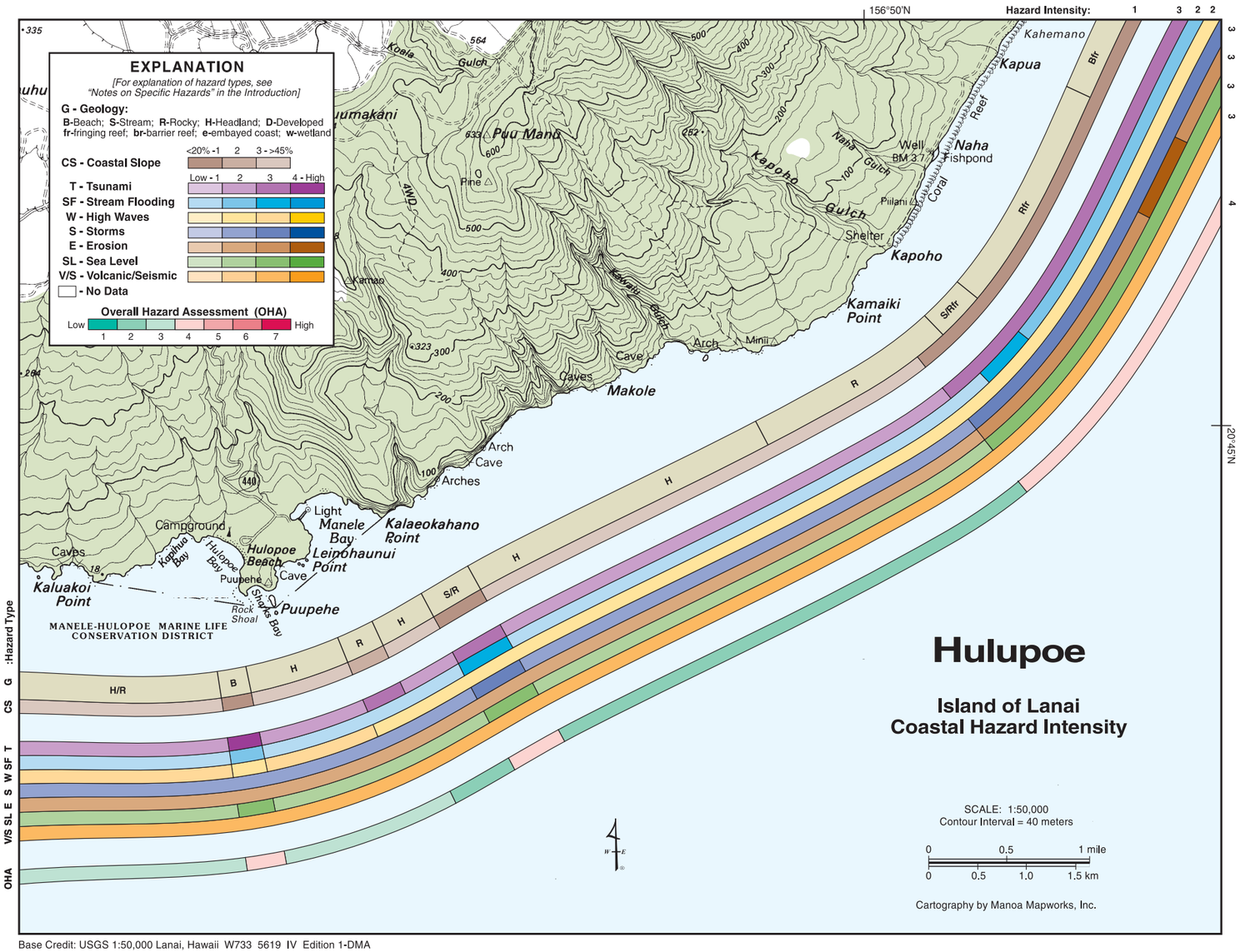
Between Haua and Naha, the Halepalaoa Landing coast wraps around the easternmost portion of Lanai along a long narrow beach at Kikoa Point. The coast slopes very gently and most of the shoreline is a low-lying coastal terrace with vegetated dunes and small forests in the backshore. The long continuous beach of Halepalaoa changes to a rocky coast near Awehi, where overhanging vegetation indicates rapid coastal retreat in the recent past. A short and narrow beach extends from Kahemano to Kapua but ends abruptly just south of Kapua. The waters are often turbid at the shore but can be very clear out at the fringing reef crest. The fringing reef becomes narrower south of Kikoa Point, a sign that wave energy increases to the southeast. Most of the beaches have small rocky outcrops where streams reach the coast.

The Overall Hazard Assessment (OHA) for the Halepalaoa Landing coast is moderate to low (3) northwest of Makaiwa and moderate (4) to the south. This increase is primarily due to the higher storm intensity along the southern portion of this coast, because of its greater exposure to storms that usually pass to the south. For this reason, the storm hazard is ranked moderately low northwest of Makaiwa and moderately high to the south. Tsunami is moderately high throughout the area and stream flooding is moderately low, except at the Haua Stream mouth where it is moderately high. High waves are ranked moderately low because of the sheltering effect of Molokai and Maui to the northwest and north. Erosion is moderately high along most of this narrow shoreline, except at the rapidly eroding areas of Awehi and Naha, where it is high. The threat of sea-level rise is moderately high because of the low elevation and slope of the coastal terrace. The volcanic/seismic hazard is moderately high here and along the entire Lanai coast because of its location within the Molokai Seismic Zone.

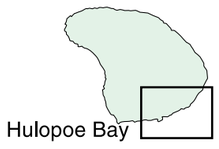
Gentle and sparsely vegetated hillslopes meet the east coast of Lanai at Halepalaoa Landing (center) where the coastal plain and offshore fringing reef are narrow.







Base Credit: USGS 1:50,000 Lanai, Hawaii W733 5619 IV Edition 1-DMA



A view of Hulupoe Bay (background) and the rocky headland surrounding Shark's Bay (foreground).

Hulopoe Bay

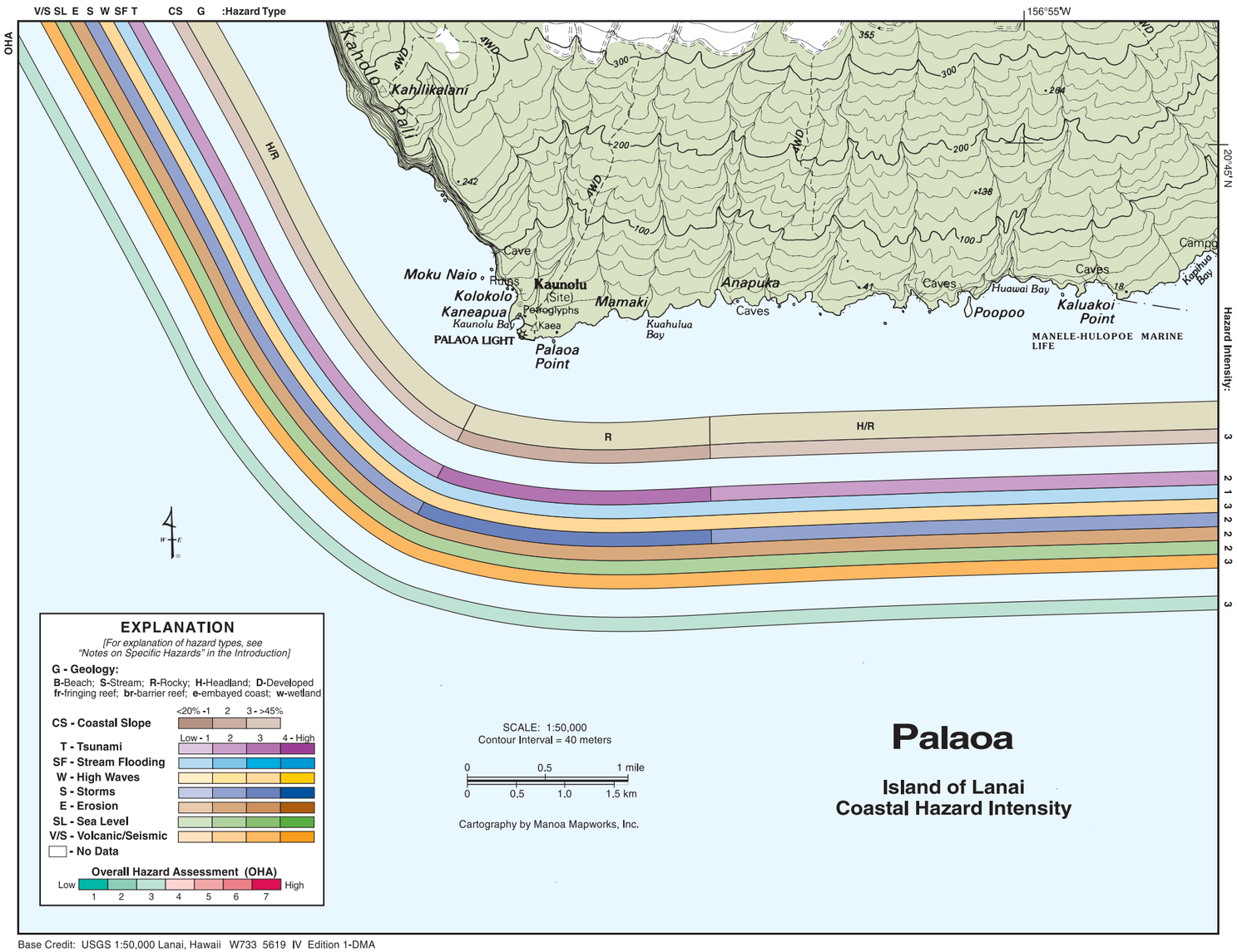
The low-lying and narrow coastal terrace of Naha and Kapoho abruptly gives way to steep sea cliffs at Kamaiki Point. Between Kamaiki and Kaluakoi Points, the Hulopoe Bay coast is extraordinary and scenic, with arches and caves awash with waves, and tall, sheer rocky cliff faces that are often lined with perching birds. The coastline here is arid, like most of Lanai's coast, receiving on average less than 10 in of rainfall annually. Even so, many gulches cut through the relatively young rocky slopes. Several streams that have not yet eroded valleys to the shoreline can be found hanging above the steep headland sea cliffs. The fringing reef of Lanai's north and east coast ends near Kapoho and only small patch reefs are found strewn amidst many small rock remnants or sea stacks along the southeast corner of the island. Several small embayments occur along this coast, including Manele and Hulopoe Bays. Manele Bay is the primary harbor on Lanai and Hulopoe Bay is famous for being frequented by spinner dolphins that can often be seen showing off their agility and grace as they flip and twist above the water.

The Overall Hazard Assessment (OHA) for the Hulopoe Bay coast varies between low (2) along the steep sea cliffs of Makole to moderate (4) at the low-lying coastal terrace of Naha and inside Manele and Hulopoe Bays. The OHA is moderate to low (3) along the coastal cliffs of Puupehe and Kaluakoi Point where the high wave hazard is increased due to a more direct exposure to south swell. The tsunami hazard is moderately high northeast of Kamaiki Point and moderately low to the southwest, except at the stream mouth of Kalaeokahano Point and Manele Bay, where it is moderately high, and inside Hulopoe Bay, where it is high. Stream flooding is moderately low northeast of Kapoho and low to the west, except at the stream mouths at Kapoho and Kalaeokahano Point where it is moderately high. Inside Hulopoe Bay it is moderately low. The high wave threat is moderately low northeast of Leinohaunui Point and moderately high to the west, except for Hulopoe Bay where wave diffraction reduces this threat to moderately low. Storms are ranked moderately high northeast of Kamaiki Point and moderately low to the southwest, except at Kalaeokahano Point where it is moderately high. Erosion is moderately high northeast of Kamaiki Point, except at Kapua where it is high. Southwest of Kamaiki Point, erosion is moderately low. Sea-level rise is moderately high along the low coastline northeast of Kamaiki and moderately low along the steep sea cliffs to the southwest. At the stream mouth of Kaleaokahano Point and the beach of Hulopoe Bay, the sea-level threat is moderately high. The volcanic/seismic hazard is moderately high along the entire Hulopoe Bay coast because of its location within the Molokai Seismic Zone.

Palaoa Point

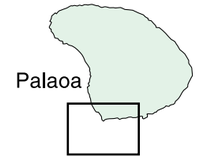
The coast gradually steepens toward the west from Kaluakoi Point to Palaoa Point, Lanai's southwest corner. Beyond Palaoa Point to the northwest, dramatic sea cliffs ranging from 500 to 1000 ft high descend straight down into the sea. Beautiful exposures of dike intrusions and individual volcanic flow units can be seen amidst the steep Kaholo Pali walls. Rock slumps along the steep headlands suggest slope failures are common. Numerous rock islets and sea caves line the rocky south coast, which has only a few very small boulder beaches at stream mouths. The steep, cliffed coast to the northwest of Palaoa Point has no beaches and instead has a narrow wave abrasion terrace with only occasional slump deposits, perhaps a sign that wave overwash removes fallen debris. Offshore, the water depth increases rapidly but patchy corals colonize the submerged rocky points and ridge protrusions. Several stream channels cut through this arid portion of Lanai and generally flow only after significant rainfall.

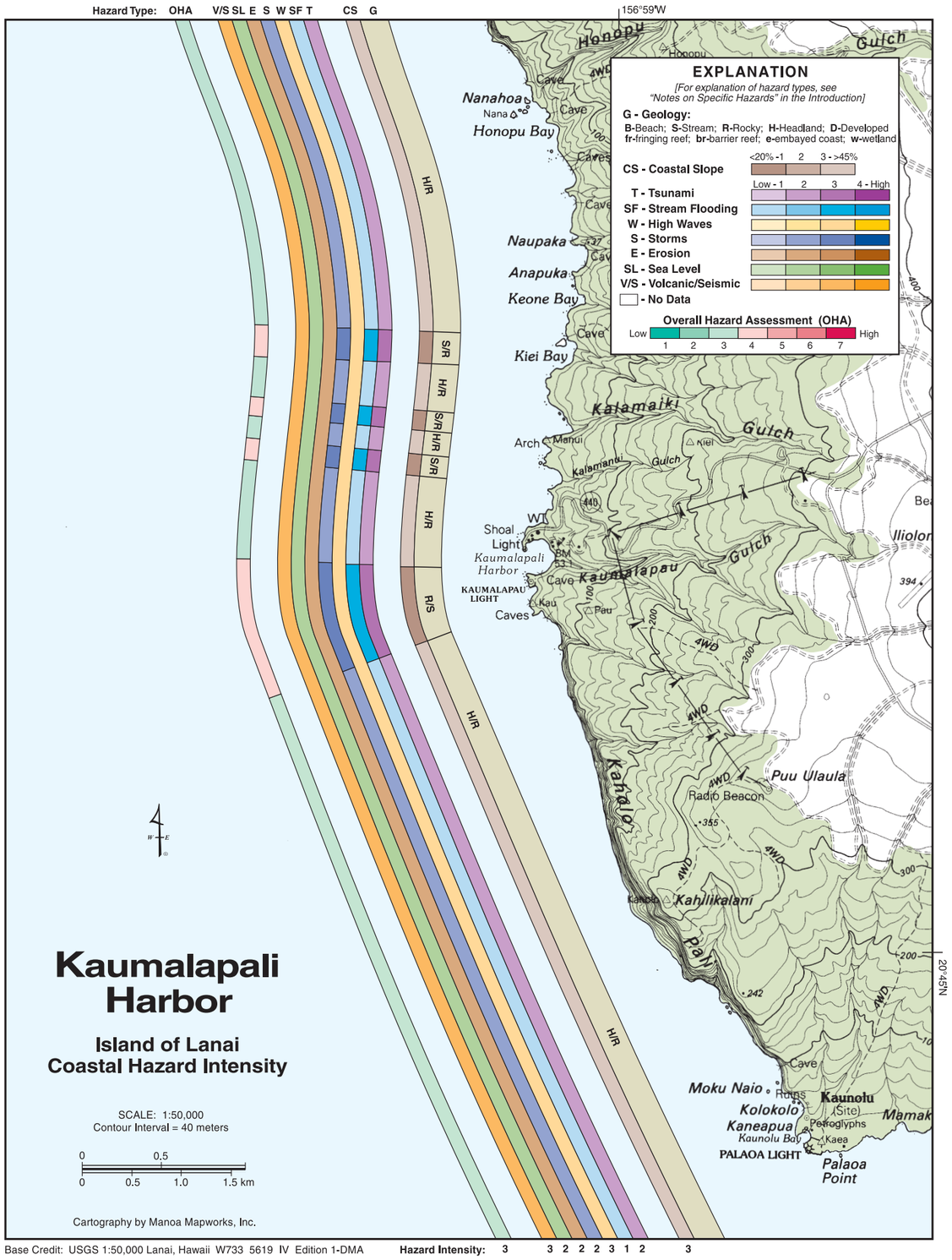
The Overall Hazard Assessment (OHA) for the Palaoa Point coast is moderate to low (3). Tsunami is moderately low, except for the lower coastal terrace between Kuahulua Bay and Kaneapua where it is moderately high. Stream flooding is low along this arid coast. High waves are ranked moderately high where northwest swell refracts to the shoreline. Storms are moderately low along the steep rocky shore and moderately high along the lower coastal terrace between Kuahulua Bay and Kaneapua. Erosion and the sea-level hazard are moderately low along this relatively steep, rocky coast around Palaoa Point. The volcanic/seismic hazard is moderately high as it is along the entire Lanai coast, due to its proximity to the Molokai Seismic Zone.

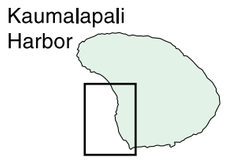


Base Credit: USGS 1:50,000 Lanai, Hawaii W733 5619 IV Edition 1-DMA

West of the lighthouse at Palaoa Point (lower left) the southwest coast of Lanai is lined by the steep and high Kaholo Pali (cliffs) and small rocky islets offshore, like Moku Naio.







Kaumalapali Harbor

The west Lanai shoreline around Kaumalapali Harbor is a rocky headland coast with steep sea cliffs along Kaholo Pali to the south of Kaumalapau Lighthouse and numerous rocky embayments north to Nanahoa. The near vertical walls of Kaholo Pali reach in places 100 ft above the sea and show signs of slumping with talus cones and rock-fall debris at their base. The embayments of Kiei, Kalamaiki, Kalamanui, and Kaumalapali Bays are low-lying, while the rocky points and steep cliffs 30 to 50 ft high surround them. Like most of Lanai, this coast is very arid and the primary streams empty into the bays listed above. Numerous small rocky islets occur along this coast and are probably a result of cliff collapse or landward erosion of the headlands. Although a paved road reaches Kaumalapali Harbor, Lanai's primary shipping port, access to the surrounding coast is limited to four-wheel drive roads along a few of the ridge crests to the north, Palaoa Point in the south, and the top of the Kaholo Pali.

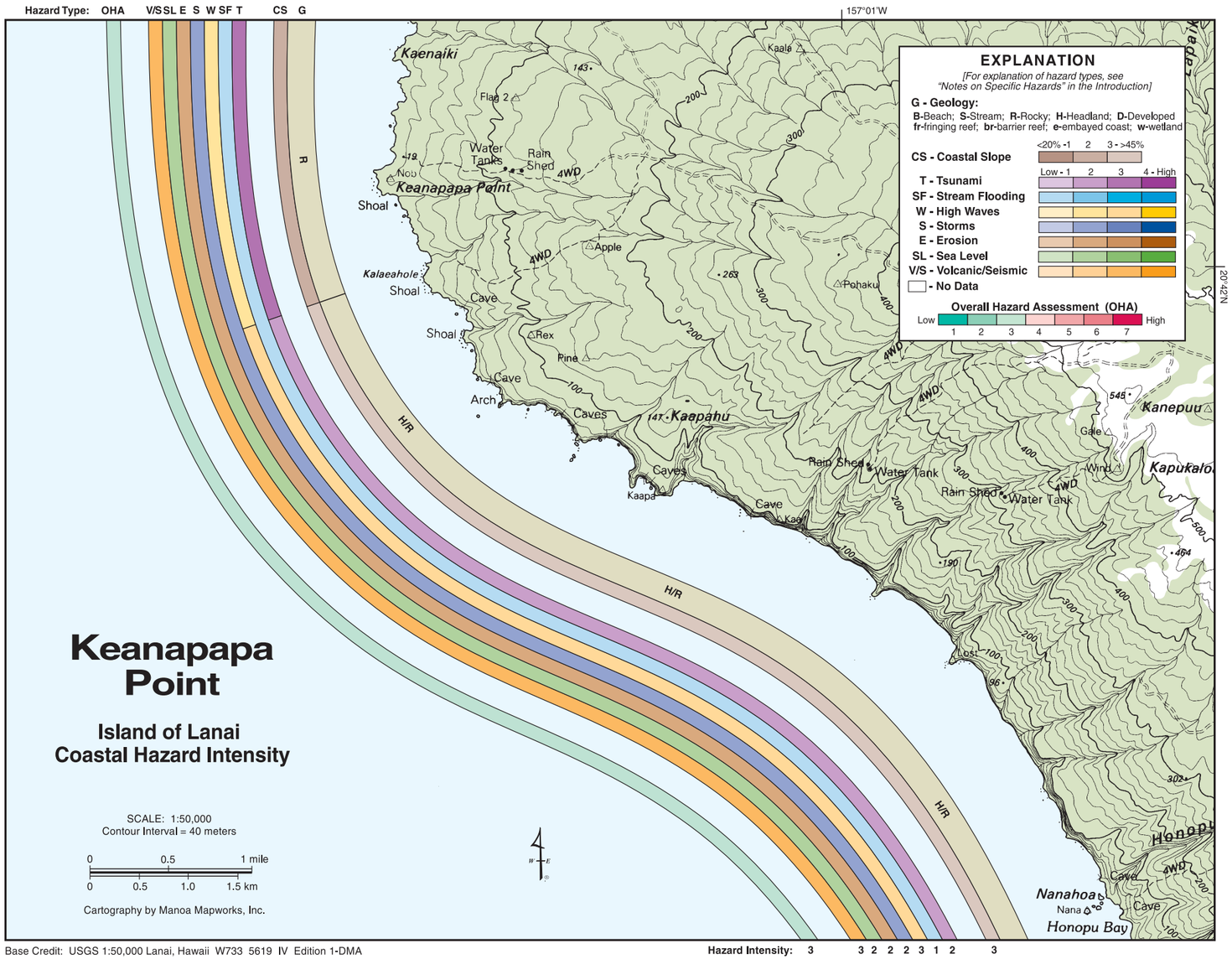
The Overall Hazard Assessment (OHA) for the Kaumalapali Harbor coast is moderate to low (3), except at the low-lying embayments of Kiei, Kalamaiki, Kalamanui, and Kaumalapali where it is moderate (4) because of the higher flooding and inundation hazards there. Tsunami is moderately low along the steep sea cliffs and rocky headlands and moderately high in the low bays. Stream flooding is low along the headland shoreline and moderately high at the stream mouths inside the embayments. The hazard from high waves is moderately high along the entire coast, which is subject to northwest swell in the winter and southwest swell in the summer. The storm threat is moderately low along the steeper rocky headlands and moderately high in the low-lying embayments. Erosion and sea-level rise are moderately low due to the rocky shoreline and steep slope. The volcanic/seismic hazard is moderately high along the entire coast around Kaumalapali Harbor, in accordance with its position within the Molokai Seismic Zone.

The Kaumalapali harbor is bordered by rugged and steep rocky cliffs to the north and south.

Keanapapa Point

Between Nanahoa and Kaenaiki, the Keanapapa Point coast is rocky with steep sea cliffs ranging 50 to 100 ft high in the south, and rocky points surrounding irregular embayments in the north. Between Kalaeahole and Kaenaiki, the coast is lower and more gently sloping than to the south. Below the steep sea cliffs between Nanahoa and Kaapa a boulder beach is perched upon a narrow wave abrasion platform cut into the volcanic headlands. Several streams cut through the steep cliffs in the south, but most are left hanging above sea level as waterfalls. To the north, the streams have incised their way to the shoreline, but the climate is relatively arid and stream flow is not common. Several caves and natural arches have formed in the rocky headwalls and protruding points. Only small patch corals have colonized the rocky bottom offshore.

The Overall Hazard Assessment (OHA) for the Keanapapa Point coast is moderate to low (3). Along the steep sea cliff coast in the south, tsunami is moderately low, while along the lower-lying coast in the north it is moderately high. Stream flooding is low throughout the entire map area due to the significant aridity. High waves are moderately high between Nanahoa and Kalaeahole and moderately low to the north because of the sheltering effect on northwest swell provided by west Molokai. Storms, erosion, and sea level are moderately low hazards along this rocky and relatively steep coast. The volcanic/seismic hazard here is moderately high as it is along all of Lanai's shoreline which lies within the Molokai Seismic Zone.



A view of the steep, rocky cliffs that line the west coast of Lanai between Kaapa and Nanahoa.