Living in the Shadow of Mauna Loa

by

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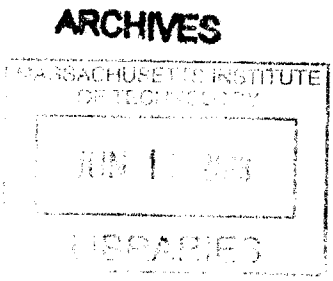




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## ABSTRACT

One of Hawaii's most dangerous natural hazards is sitting in plain sight: Mauna Loa volcano. The mighty mountain makes up more than fifty percent of the island and is the largest volcano on Earth. Since 1843, when people started rigorously recording Mauna Loa's eruptive activity, the volcano has produced raging lava flows, billowing sulfuric-rich clouds, and giant ground cracks, as well as triggered earthquakes, landslides, and even tsunamis. While geologists and emergency managers are concerned about and actively preparing for a future eruption, Hawaii's general public is largely ignorant or apathetic to their risk. This thesis explores what a future Mauna Loa eruption may look like in terms of geology, disaster response, and damage. It also identifies and profiles the most threatened Hawaiian communities and industries, as well as explores the factors driving differences in risk perception across various stakeholders on the island.

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# LIVING IN THE SHADOW OF MAUNA LOA


*A silent summit belies a volcano's forgotten fury*

By Zahra Hirji

The largest volcano on Earth is taking a nap. After twenty-nine years and counting, no one is quite sure when Hawaii's Mauna Loa volcano will again wake up. But odds are that it will be within our lifetime—sometime in the next couple of years or decades—and it will be spectacular.

Stretches of hot red lava will fountain up violently, hundreds of feet into the air, like a row of glowing geysers. An underground molten ocean will unleash, where waves of lava pour out of fresh giant cracks. A plume of sulfuric-rich smoke will climb into the sky, like a huge smoke stack. Emanating from the cracks, flows, and fountains, heat will flush cheeks from a dozen feet away. A volcanic chorus of splattering, hissing, crackling, and oozing noises will thunder in the ears.

It paints a hellish scene, but does it really pose a danger? It all depends on whether lava is confined to the mountain's highest levels, where even trees are not invited—or, as scientists and emergency managers fear, migrates downslope to the realm of people and

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commerce.

And it is not an unfounded fear. History warns us that Mauna Loa's current silence is anomalous. Etched into the rocky mountainside is a story of repetition: Over and over lava flows have painted the land red. Mauna Loa has erupted thirty-three times since 1843, when people started recording such events, an average of once every five years. And over the past 3,000 years, the geologic record testifies that the volcano has erupted an average of every six years. That means even if the next Mauna Loa eruption spares the Big Island community, the second, third, or fourth eruptions will likely not be so kind. It is just a matter of time.

Adding to the threat, Mauna Loa eruptions can occur along different points of the mountain. While most eruptions start at the mountain's very top, the eruption source, the physical point where lava comes spewing out of the ground, *can move*. Around forty-five percent of historical eruption sites have shifted to lower elevations—generally to the northeastern or southwestern sides of the mountain. Not a trivial amount.

Lying at the foot of the northeastern side like a welcome mat is the island's largest city, Hilo. Despite being the most recently threatened population by Mauna Loa back in 1984, Hilo residents are largely apathetic to their risk, said Frank Trusdell, a scientist at the Hawaiian Volcano Observatory and the world's leading Mauna Loa geologist. Part of the issue is the city's growing population, which has ballooned by nearly a third since the last eruption, from about 35,200 to 43,200. In response, development has pushed farther up Mauna Loa's slopes.

It has been over twice as long since Mauna Loa flows terrorized the southwestern side. Since that last eruption in 1950, subdivisions have sprung up like dandelions, including the world's largest, Hawaiian Ocean View Estates. And in over sixty years, the number of residents on the entire southwestern side has climbed from 8,000 to over 18,400. Tourism in the Big Island, especially on the western coast, has also skyrocketed in recent decades. Many newcomers and visitors are not even aware that Mauna Loa is still active, said Trusdell.

***Mauna Loa has erupted thirty-three times since 1843, when people started recording such events, an average of once every five years.***

Other disasters have likely distracted residents and visitors alike. Since 1983, Kilauea volcano has continuously erupted in the Big Island's southeastern corner, devouring entire neighborhoods. There have been tsunami scares, including two in the past two years. Wildfires and floods are an annual debacle, and over a dozen howling hurricanes have skirted past the island. Also, in 2006, an earthquake of magnitude 6.7 occurred; several houses shuddered and collapsed in response.

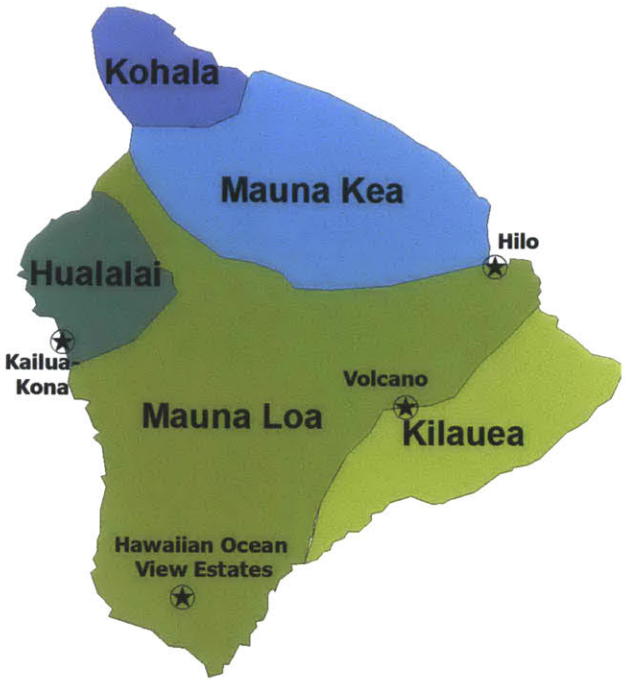
Time is a hindrance to scientists and emergency managers, too. Few people working in these fields today were around in 1984, and no one with that expertise is around from 1950. Compared to recent dangers, Mauna Loa's last few eruptions are but fading and fuzzy memories.

Yet the risk of a future catastrophic Mauna Loa eruption continues. In fact, the risk builds as more people and buildings pack into known hazardous areas like Hilo and Hawaiian Ocean View Estates. Is Hawaii prepared for another Mauna Loa eruption? And if not, what does it need to do to get there?

The first major Hawaiian volcano, named Kure, formed above a deep magma source, called a hot spot, on the sea floor nearly 70 million years ago. As it grew from a hill to a mountain to an island, the ocean plate moved slowly in a northwesterly direction, an average of two to four inches a year. Yet the magma source remained still. As the overlying volcano moved farther away from the source, the eruptions gradually reduced to zero; concurrently, a new volcano formed a few hundred miles away. This cycle repeated dozens of times resulting in the Hawaiian archipelago, a string of volcanic islands stretching across approximately 1,700 miles of the Pacific Ocean.

The hot spot currently resides underneath the youngest and easternmost anchor of the Hawaiian island chain, the Big Island. Larger than the other Hawaiian Islands combined, the Big Island (also called Hawai'i Island or Hawai'i) is deserving of the name.

The Big Island is a collection of five volcanoes. Looking down on the island, as if by plane or satellite, it looks like the profile of a fox head facing east. The oldest volcano, Kohala, makes up Hawai'i's upper northwest corner, or ear. The forehead, or northeastern corner, includes the second oldest volcano, Mauna Kea. At back of the head is the third volcano, Hualalai, which towers over the west coast city Kilauea-Kona. This volcano last erupted around 200 years ago and is considered active. To the




**In the Hawaiian language, Mauna Loa means "long mountain." Aptly named, Mauna Loa is the largest of the island's five volcanoes.**

southeast, composing the fox's nose and mouth, is the island's youngest volcano, Kilauea.

Positioned in the middle of the island like a queen upon her rocky throne is the second youngest volcano, Mauna Loa. The long mountain makes up most of the fox's brain and neck, covering more than half the island with flows that extend out to all coastlines—north, south, east and west. Beyond the summit, volcanic activity occurs along two areas of volcano expansion, called rift zones.

The northeast rift zone sprawls towards Hilo and looks like a double-tiered slide with alternating steep and horizontal slopes. The southwest rift zone, in contrast, is shaped similarly to a lopsided swing-set frame. There is a narrow, relatively flat ridge, with a sharp drop off to the west and a gradual slope to

the east. On steep sections of the mountain, lava sprints. On the flat stretches it slows, sometimes to a halt.

Hawaiian volcanoes make up more than the island's foundation; they are also the source of other regional hazards: earthquakes, tsunamis, and landslides. Moreover, the tall mountains such as Mauna Loa and Mauna Kea intrude upon the sky, influencing local wind and rain patterns. At the end of the day, Hawai'i is nothing without volcanoes.

The first island settlers were acutely aware of this truth. According to legend, when Polynesians arrived at the Big Island shores at least 1,300 years ago, volcanoes were exploding in awesome fury. Nature centers heavily in Hawaiian religion, and one of its most famous deities is Pele, the volcano goddess.

Hawaiians historically tracked eruptions through song and hula dances. Starting in 1843, European and American colonists started writing down recent eruptions. Comprehensive volcano monitoring started in 1912 when Thomas Jaggar, a Massachusetts Institute of Technology professor, founded the Hawaiian Volcano Observatory (HVO). Jaggar's vision of the observatory was "humanitarian," where his motivation for comprehensive volcanic monitoring was protecting life and property.

The observatory is perched on the edge of Kilauea's summit crater inside the Hawai'i Volcanoes National Park grounds. Jaggar chose this location because of its proximity to Kilauea's recurrent lava lake, while still offering views of Mauna Loa's remote summit. During his thirty-plus years living on Hawai'i, Jaggar witnessed Mauna Loa's hot temper assail both sides of the mountain, but his attention was more drawn to the northeast, which loomed over Hilo. Today, HVO geologists still keep a close watch on the exposed city.

▲ ▲ ▲

Beneath the shade of some large sinuous Ohia trees, empty of their bird-attracting red spindly flowers, former Mauna Loa geologist John ("Jack") Lockwood and I sat at a damp wooden picnic table and discussed the past. We met outside HVO, Lockwood's old stomping grounds, which have expanded and modernized since Lockwood retired in 1995.

The mountain's massive base stretched out behind us, but the summit was veiled in wispy white clouds during our discussion. Lockwood's skin is tan and speckled with sunspots, a clue to his life spent outdoors hiking volcanoes.

Lockwood arrived in Hawai'i in early 1974 on a two-year assignment and immediately fell in love with the land, job, and atmosphere. Before, he noted, he was doing esoteric academic research, "publishing papers that ten people would read." In Hawai'i, though, Lockwood became involved in applied volcanology, science that was "really important for people's lives," he said.

When Lockwood told his boss back on the "mainland"—the term Hawaiian residents use for the continental United States—that he wanted to remain on the Big Island permanently, there was push back. Desperate to stay, Lockwood considered quitting geology. He thought, "I was a pilot and I [could] set up a flying business," but then "all kinds of magic happened in the summer of '74." Namely, cracks across the summit crater of Mauna Loa started widening.

"They hadn't extended for fifteen years, and suddenly they had started expanding," said Lockwood. "I knew this

great mountain was awakening, and I [started] thinking a lot about the hazards associated with the next eruption, and basically my focus shifted to hazards...So this became my ticket to extend for one more year," explained Lockwood. Then in July 1975, the volcano erupted violently for less than twenty-hour hours. The short eruption stayed at the summit, and Lockwood witnessed the fearsome show by plane.

Weaving together data from that brief eruption with historical flow patterns over the last 200 years, Lockwood unlocked Mauna Loa's common two-step eruption style: a short-lived summit eruption followed by a longer eruption that starts at the summit but then quickly transitions downslope to the rift zones.

With this knowledge in hand, Lockwood made a prediction: The 1975 event was the opening act, and the main performance was to come along the northeast rift zone in approximately three or four years. "My prediction was correct as far as what was going to happen and where it was going to happen, but the timing was off," said Lockwood.

When Mauna Loa started showing signs of renewed activity, the 1970s were over, and Lockwood was a permanent HVO staff member. The volcano's early warnings were threefold: increasing seismic activity, a bulging mountainside, and an expanding summit crater. All these changes in volcanic form occurred over a two-year period. Yet despite these initial signals, the exact arrival, or onset, of the eruption was a surprise to everyone, including the scientists.

The night of the 1984 Mauna Loa eruption, the geologists were at a goodbye party for Robert ("Bob") Decker. HVO's scientist-in-charge for five years, Decker was returning to the mainland to work at a sister volcano observatory in Menlo Park, California.

The party was held at the Lava Lounge, a small bar nestled inside the Kilauea Military Camp located only a mile from the observatory. Adding to a collection of toasts, members of the HVO staff put on a short skit for Decker acting out the hypothetical scenario on everyone's mind: What if Mauna Loa erupted that very evening? According to Jack Lockwood, "we joked, we drank a lot; that was the end of it." By around midnight, everyone had turned in.

But as the geologists fell asleep, the volcano started stirring.

In the hours and minutes prior to the eruption, magma pushed rapidly up towards the surface with great force, and the volcano shivered in reaction. These special earthquake swarms, called seismic tremors, were a harbinger of an eruption. Volcanologists observed the changes in ground motion using seismometers. Normally, continuous seismic activity would have triggered an alarm that alerted the observatory geologists, but the alarms didn't go off that night in 1984. Due to high winds atop Mauna Loa in previous weeks, the summit seismic alarm had been turned off due to disruptive false alerts.

But the seismic activity did not go entirely unnoticed. Atop Mauna Kea, twenty-five miles northeast of Mauna Loa's peak, astronomers working late at night as usual felt an earthquake around 1 A.M. At the different telescopes, scientists played telephone tag: Did you feel that? And, there was another one!

The astronomers likely felt only the largest earthquakes that night, those of at least magnitude 2.5 on the Richter scale. But within a 115-minute span, starting at 11:27 P.M., thousands of small

***For Lockwood, the eruption's shift to Mauna Loa's lower elevations signaled the volcano "had the potential to threaten Hilo."***

earthquakes hit.

Around 1:30 A.M., Mauna Loa finally "awoke." Abandoning their telescopes, the night owl scientists huddled outside to watch. As reported in *Sky and Telescope* magazine, the astronomers recalled seeing "a brilliant crimson plume emanating from its summit caldera...and front lines of lava fountains." The spewing mountain's glow was so bright, it could be seen across the island.

Shortly after the eruption started, Harry Kim, then-Civil Defense Director for the island, received a phone call from an agitated police dispatcher about the eruption. Kim's next steps were automatic. He activated the island's emergency management response headquarters located in downtown Hilo and called the disaster response big guns, including the police and fire departments, public works, air traffic control, and, of course, the Hawaiian Volcano Observatory.

Rumor has it the HVO geologists were some of the last people in the know. Supposedly, astronomers called either the police or civil defense with word of the eruption. When the message finally got to Bob Decker, he sleepily brushed off the whole thing as a wild fire or a continuation of the party joke. It took a second call to convince Decker, who had dealt with fake volcano eruption sightings in the past, that the mountain was indeed bleeding lava.

Regardless of how they found out, geologists were at the observatory by early morning chugging coffee, groggily reading incoming data through sleep-filled eyes, and preparing for an eruption site visit. They needed to find out the scale of the eruption and fast. Meanwhile, an hour away in Hilo, emergency responders outlined an initial response plan. It would be a few hours before the news broke across the island—and the world—setting into a motion a very hectic twenty-two days that followed.

In the beginning, the eruption was fickle, changing directions every couple of hours. Lava first appeared within the isolated confines of the 13,679-foot summit crater. Within a few hours, the lava migrated around two miles downslope into the southwest rift zone, heading in the direction of the residential South Kona district. Before daybreak, around 4 A.M., the source of eruptive activity again changed location: new flows reappeared atop the mountain.

Around that time, Lockwood and Bob Decker arrived on the scene in a two-passenger plane. Hovering around 12,000 feet, the plane was not ideal for this first reconnaissance mission as it was too heavy to ascend all the way to the summit. But later that day the plane proved its worth as lava started erupting along cracks, called fissures, in a step-wise manner down the northeastern side of the mountain. For Lockwood, the eruption's shift to Mauna Loa's lower elevations signaled the volcano "had the potential to threaten Hilo."

Navigating around a crowded airspace

among military and civil defense planes and helicopters, Lockwood remembered watching Mauna Loa unzip. While the fresh cracks were not directly visible, their locations were inferred from an outpouring of highly sulfuric gas, which was whitish in color and smelled like rotten eggs. As the cracks increased in size, old volcanic lava fell in and released reddish rock dust that colored the gas. Then, abruptly, lava started fountaining some hundred feet into the sky. The gas was still there—and you could taste it on the tongue and feel it in the teeth—but it was less visible amongst the backdrop of spattering lava. That first day, Saturday, March 25, lava descended to the elevation of 9,350 feet, still a few miles away from any infrastructure. On the second day, the damage began.

Mauna Loa's upper slopes were barren save for two atmospheric research centers located along the northern section, far from the active rift zone. Their power source, which also served as a relay station bouncing television signals from Maui to Hilo, was not. It was inconveniently situated around the 6,000-foot elevation along the aptly named Power Line Road, directly in the line of fire.

On Sunday, March 26, fast-moving blocky, crumbly, black lava crossed the road and devoured a chunk of power lines. Two television stations were knocked off the air, although they acquired back-up generators a few days later. The atmospheric observatories were not so lucky; they lost power for nearly a month.

The next few days, braided flows continued even farther downslope, threatening a prison and the only cross-island highway, Saddle Road. As a precautionary measure, the highway was closed, causing headaches for commuters and those looking for close-up views of the flows.

Due to Mauna Loa's varied topography, lava switched composition from speedy black lava, called a'a (pronounced ah-ah), on the upper steeper slopes to a slower moving silvery ropey form, called pahoehoe (pronounced pa-hoy-hoy), on the lower flatter regions.

For the active flow fronts, which were too wide and unwieldy to approach by foot, geological monitoring and mapping was done by aircraft. At times, the flows were "moving far faster than anyone can run," said Lockwood. This method starkly contrasts the monitoring of recent Kilauea flows, which are routinely mapped by geologists walking next to the flow margins.

The scientists tracked the 1984 flow progress by sketching flow outlines on top of topographic maps. These were truly rough approximations, explained Lockwood. Mauna Loa is a shield volcano, meaning it has a gradual slope and little topographic relief. With few hills or noticeable landmarks, scientists had difficulty discerning the position of the flows correctly.

News of Mauna Loa's eruption flew across the globe, attracting reporters, tourists, and scientists. For nearly two weeks all flights into Hilo were booked.

"We were besieged" with calls asking for information, said Lockwood. To manage the media frenzy, the first and only HVO pressroom was set up. At the time, the observatory did not have a media relations officer so scientist-in-charge Bob Decker took on the job. He held daily morning press conferences and interviews at Kilauea Military Camp.

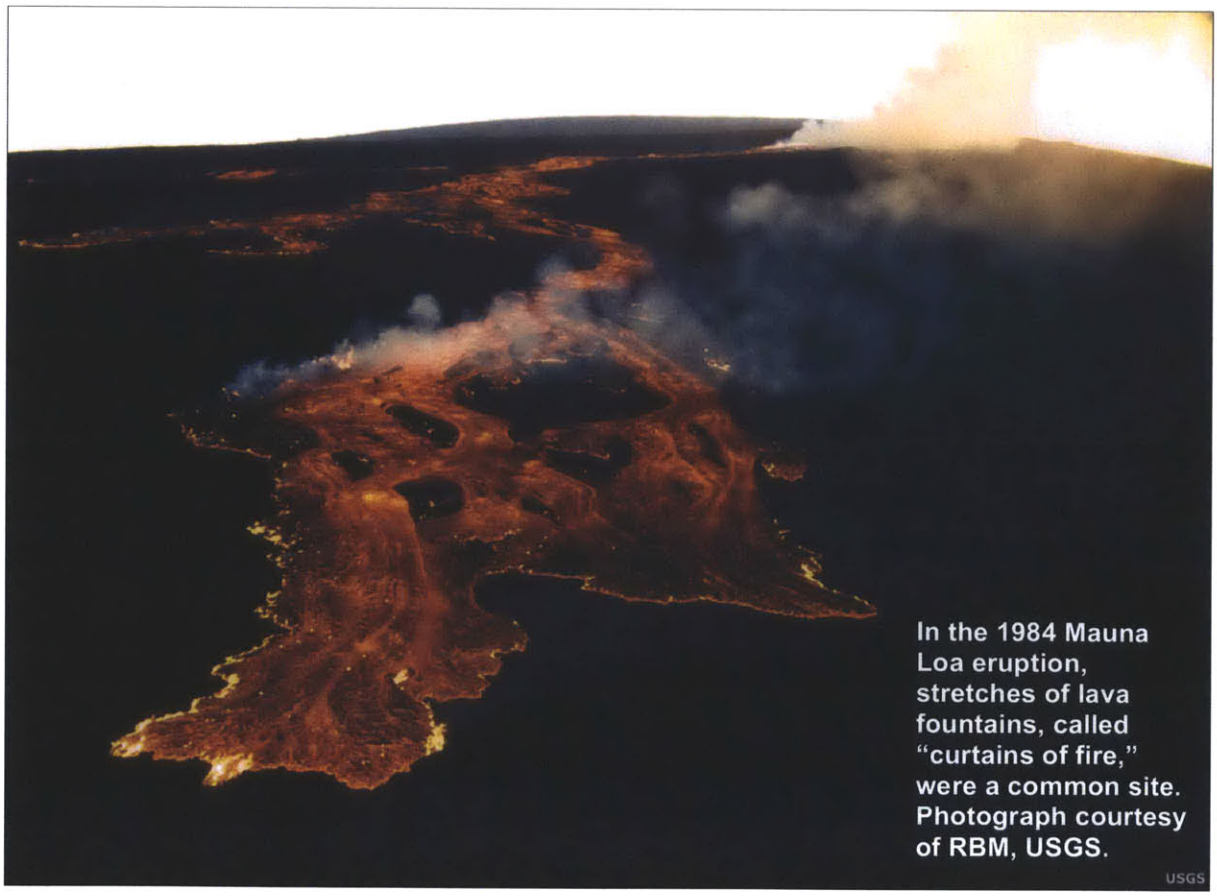
Meanwhile, Lockwood ran the volcano monitoring logistics and faced a different sort of assault during the eruption, one

from the scientific community. National and international volcanologists arrived uninvited with hopes to research the eruption. For safety's sake, Civil Defense decreed that all non-HVO personnel had to be accompanied in the field with a member of the observatory—a rule that persists today for any Hawai'i eruption. With no resources to spare, Lockwood had the burden of turning away many well-intentioned scientists.

Complicating matters further, Kilauea volcano erupted on March 30, 1984, prompting the first double eruption in nearly 116 years. While the Kilauea eruption only lasted a few days and remained within the Hawai'i Volcanoes National Park grounds, it stretched already gossamer-thin resources.

HVO was in charge of monitoring the eruption, whereas civil defense made the decisions about response and mitigation. The two groups provided a united front of authority, control, and consistency to the public. But in reality the two parties, particularly Lockwood and Civil Defense Director Kim, did not always agree. One source of contention between the two men was the issue of lava viewing access, where Lockwood favored greater access than Kim.

During the eruption, people hankering to get a view of the flows would wander off marked trails in the dark. To crack down on roving tourists and residents, Civil Defense closed Saddle Road. At a press conference about the decision, Kim said, "I cannot dish out resources for the benefit of some dingaling who wants to hike over the hill and see the eruption. Your safety is more important than some S.O.B."—(son of a bitch)—"who wants to




In the 1984 Mauna Loa eruption, stretches of lava fountains, called "curtains of fire," were a common site. Photograph courtesy of RBM, USGS.

go over and see Pele."

Lockwood was not pleased about Kim closing "the damn highway." According to the geologist, Saddle Road offered incredible close-up sights of the major eruption. Rather than have people drive there themselves, he figured, private buses could shuttle onlookers back and forth and make money along the way.

The geologist and civil defense director also disagreed over how to manage the escalating stress levels of Hilo residents. Every night for nearly three weeks, the skyline burned red with channelized lava seemingly directed at Hilo—a haunting sight. Some families living in the two subdivisions highest up the mountain, Kaumana City and Kaumana Estates, voluntarily evacuated in the first few days of the eruption.

To curtail anxiety, Kim announced that he would give residents twenty-four- hour evacuation notices. But this move had the opposite effect, according to Lockwood, who recalled receiving panicked phone calls from the community. Lockwood also knew residents would have at least a week's notice to evacuate based on the flow's slowing movements.

The geologist confronted Kim. "I think I chilled my bottom for about an hour" before finally making it through the director's door, said Lockwood. "Then I gave him my arguments and [he] paid no, absolutely no, attention at all," said Lockwood. The Civil Defense Director "kept on the warnings, kept scaring people after the eruption, and closed the Saddle Road."

Kim saw it differently. The eruption was proving highly uncertain. First, the flows moved towards South Kona, and a few hours later, they switched to the Hilo side. One morning the flows threatened a prison, and the next day they stopped. There was no guarantee that the flows would keep pace for a week, whereas there was higher certainty for lava movements within a twenty-four-hour window. Kim did not want to announce evacuations that ended up being unfounded.

A week into the eruption, the Big Island's Mental Health Association director said, "The greatest cause of stress is the feeling that you have little or no control over a situation...and let's face it; we have little or no control over Pele." But that statement was not entirely true. There was always the controversial option of lava mitigation—in other words, stopping or diverting the lava in some way.

The earliest known mitigation attempt dates back to Italy 1669. To protect against a menacing Mt. Etna volcano eruption, the town of Catania built a stone wall around the city. The barrier held for several days before one corner eventually gave out. Geologists call these structures "earthen barriers" or "diversionary structures," which are designed to obstruct a lava flow path while also cooling and solidifying the flow front, further disabling progress. This method is more successful when the barrier is positioned to redirect the flow of lava, rather than simply dam it.

HVO's founder Thomas Jaggar envisioned a barrier as the solution to Hilo's vulnerability, an idea he published in 1937. The U.S. Army Corps of Engineers did a preliminary study and concluded the idea had merit. However, the project never panned out because it was determined to be an inappropriate use of U.S. military resources—Hawaii was not yet a state at the time.

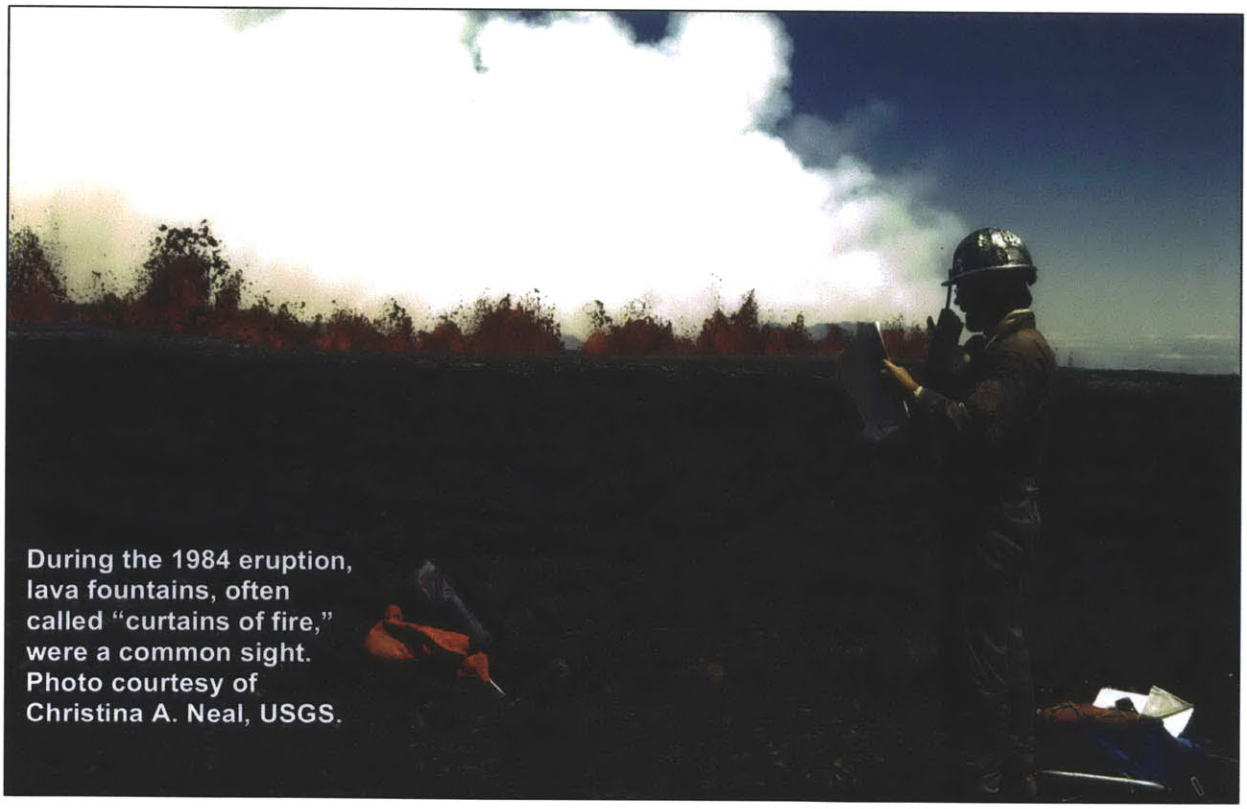
Hawaiian residents later embraced the barrier strategy in 1960 to protect the

southeastern town of Kapoho from a threatening Kilauea eruption. Located in a low-lying area, the village built a several-kilometer-long rocky barrier around the town. The diversionary structure held for a few days, but flows eventually won out. Although the town wasn't saved, the barrier provided people extra time to pack up and leave.

The most aggressive mitigation approach is pure cowboy—bombing lava flows. The theory goes that if a bomb is dropped on areas where lava collects within a flow, such as a lava cone, the explosion should temporarily disconnect the flow front from the lava source. Jaggar first tested the idea in 1935 when he convinced the U.S. military to drop bombs on a Mauna Loa flow headed towards Hilo. Bombs were similarly used to thwart another Hilo-bound Mauna Loa flow in 1942. Both trials were inconclusive, as the eruptions stopped naturally before lava ever made it to the city.

Like Jaggar, Lockwood was convinced that bombing a flow was a winning mitigation idea. To prove it, Lockwood needed to demonstrate that firepower could actually trigger the collapse of specific lava flow features. In the late 1970s, Lockwood recruited the military to drop thirty-six bombs on historical Mauna Loa flows along the northern part of the mountain, within an Army training area. Lockwood assumed the strength of the hardened old flows was comparable to active flows, which often develop a solidified exterior mid-eruption. The result of the experiment was awesome demolition, where bombing pockmarked flows with mini craters. The largest craters formed in areas where the rock was less dense. It was proof enough that bombing could work.

For any community contemplating



During the 1984 eruption, lava fountains, often called "curtains of fire," were a common sight. Photo courtesy of Christina A. Neal, USGS.

mitigation, there are three main considerations: money, manpower, and time. But in Hawai'i, the volcano goddess Pele provides an additional concern. According to Pele believers, "lava must flow." This means attempts to obstruct flows are considered culturally insensitive, even sacrilegious. In the past, especially before Hawaii became a state in 1959, the disaster management community largely ignored the native population's opinions on mitigation. But by 1984, there was a greater general island awareness of the goddess. Consequently, mitigation was largely scorned in public discussions.

On Tuesday, March 28, 1984, three days into Mauna Loa's eruption, the *Hawaii Tribune-Herald* reported that Mayor Herbert Matayoshi and Governor George Ariyoshi had discussed and rejected the possibility of trying to divert the lava flows heading toward Hilo. Two weeks into the eruption, however, it was communicated that Matayoshi was reconsidering mitigation measures, although no details were released.

Publically, elected officials were opposed to lava mitigation, explained Lockwood, "but behind closed doors," the governor's office was creating a contingency plan and asked the geologist for information on mitigation options. "And we weren't talking about the grand-scheme bombing up here. They were talking about building diversionary structures to protect certain facilities," said Lockwood. Bombing was avoided not because it couldn't work, he said, but because it meant involving the military, a publically unpopular move.

Harry Kim was against bombing but supported small-scale diversionary structures as a "last resort." But diversionary structures opened up a legal can of worms, explained Lockwood. For example, imagine the government builds a protective wall around an agreed upon essential public building, such as the hospital. The barrier might successfully redirect flows on a new path toward previously safe private buildings. As of 1984, it was believed that if those private buildings burned down, owners would likely have the grounds to sue the government for damages. However, according to a little-known legal opinion published in 2004, under a natural disaster declaration the governor can authorize the construction of certain diversionary structures that then endanger surrounding buildings. While the government must provide monetary compensation for any damaged buildings, it is believed that people could not sue for additional damages.

Despite the perceived liability issues, emergency managers and state officials were very likely going to approve a barrier in 1984. "There were basically plans afoot if lava diversion would have been necessary," said Lockwood. "The governor certainly would have considered it." Fortunately, mitigation was never necessary. On April 15, 1984, twenty-two days after Mauna Loa started adding a fresh lava coat to its rocky exterior, the eruption ended just as suddenly as it began. Lava flows stopped around 4.5 miles north of Hilo, sparing the city.

Volcanoes do not go boom in the middle of the night without warning. There are millions of subtle signs in the form of cracks, bulges, shakes, and steam. HVO geologists were vigilant for such signs in 1984, but they lacked the proper tools to rigorously spot and track them.

Since then, the observatory has taken great strides to remedy that. Rather than rely on a single seismometer on the

mountaintop for pre-eruption indicators, geologists now collect data from nearly fifty instruments speckled across Mauna Loa. Seismometers record seismic levels across different elevations. Tiltmeters measure how much the ground inflates, or "tilts," due to the volcano's internal accumulation of lava. Shoebox-size cameras are positioned along the volcano's most recent areas of activity, with views of the summit crater and upper northeast rift zone. There are GPS devices, which connect to satellite systems and provide geologists with precise locations, accurate down to a few millimeters, which are used for map-making.

Nowadays, alarms are more sophisticated, too. If a seismometer detects more than a specific pre-determined number of small, successive quakes—say 100 tremors in an hour—an alert is sent directly to a geologist's cell phone and email. Such alarms are not unique to seismometers; cameras and tiltmeters also have them.

Along with technological advances, scientists are now much better informed about Mauna Loa's long eruptive history. Following the 1975 eruption, Lockwood started a mammoth project mapping Mauna Loa's geology. More than three decades later, his successor, Frank Trusdell, continues the efforts.

Trusdell started at HVO as a summer intern back in 1980. While working towards a graduate degree in agriculture, he was brought on as an immediate hire to help with the 1984 eruption. The decision to abscond from school for three weeks mid-dissertation writing was a wake-up call that geology, not agriculture, was his true passion. After working at HVO as a temporary hire for a few years, Trusdell took over for Lockwood as Mauna Loa geologist in 1996, a position he has held ever since. Trusdell spends a significant amount of time mapping the giant. His voice boomed with pride when explaining that the kind of widespread detailed mapping done for Mauna Loa "is unprecedented for any other volcano in the world."

To drive home the sense of scale, Trusdell expanded: "Mauna Loa is almost as big as the rest of the Hawaiian Islands put together! So you can imagine when I'm doing a map, and I map something like 1,200 square kilometers, I've basically taken one of the Hawaiian Islands and mapped the whole thing."

Over 500 flows make up Mauna Loa's surface. Approximately thirty-five percent of them are radiocarbon dated, a process that uses the known rate of decaying carbon to determine a material's age. Carbon is generally found in organic materials—not lava. So instead, geologists dated the charcoal produced from burned vegetation beneath the cooled lava rock. Knowing the extent of certain historical flows then allowed researchers to simulate potential future flows in those same areas. Combining the historical and simulated eruption patterns, researchers produced Mauna Loa lava inundation maps for certain development-heavy parts of the island, such as Hilo. A Federal Emergency Management Agency-sponsored endeavor, those maps can help direct future eruption response efforts, such as evacuation decisions.

Still, there is one harrowing factor out of the observatory's control—the volcano's timetable—and this could inevitably be its Achilles heel. A major Mauna Loa eruption, with large, racing lava flows, has the potential to kill the very geologists monitoring it. "Seeing how quickly lava moves, whether it is a'a or the pahoehoe, makes me a believer that if you are not paying attention, you could die

working around them when you are out on the flow fields," said Trusdell. "There's no latitude for error."

According to Trusdell, the secret to understanding the scale and magnitude of a Mauna Loa eruption is experiencing one. When I asked Trusdell how many geologists currently working at HVO were around for the 1984 eruption, he gave a sobering response—"one," himself. The statistics are even bleaker at Civil Defense, where there is no overlap.

Aware of the implications of a catastrophic Mauna Loa eruption, Trusdell obsesses over evaluating the risk of such an event. This involves determining the frequency of such an eruption and marrying it with the social and financial implications.

In the past two hundred years, only one eruption has extended into Hilo's current city limits. This was the 1880 flow. At the time of the eruption, the flows actually stopped around a mile short of the old city limits. But because the city has grown since 1880, the old flows are now partially covered with houses, parks, and roads. As people build higher up the mountain, the outer reaches of the city are pushed into areas with a higher likelihood of experiencing a future eruption.

Driving around Hilo with Trusdell, he pointed out the historical flow margins using tall, greening Ohia trees as identifiers. The native trees are one of the first types of large vegetation to grow on previously lava-inundated ground. We traced the flows from one the city's uppermost reaches, Hoaka Road, down to their southern point in the backyard of some houses on Moholuli Street, a few blocks from the University of Hilo campus.

Trusdell used a prehistoric flow similar to the 1880 eruption as the basis of his representative worst-case scenario for Hilo. To determine the impacts of such an eruption occurring today, the geologist first accumulated infrastructure and tax data, as well as identified the city's critical infrastructure—namely, airports, bridge locations, police stations, electrical power plants, nursing homes—and their relative monetary value. Trusdell only accounted for land improvements (anything built on top of the land), not the value of the land itself. The scientist also created a cost per mile of road.

***Volcanoes do not go boom in the middle of the night without warning. There are millions of subtle signs in the form of cracks, bulges, shakes, and steam.***

"If we take the [historical] lava flow and cookie cut it through these parameters," then you can start to assess what could happen, explained Trusdell. The results are grim. The eruption could cause approximately $1.2 billion in damage, making it one of the most expensive natural disasters in recent Hawaiian history. And as high as it is, "this estimate is conservative," admitted Trusdell.

The model only looked at what the volcano may or may not do. Humans are an entirely different part of the story. Failures or successes in public response, including willingness to evacuate or attempting mitigation, could dramatically change the outcome of a future Mauna Loa flow.

The upper northern slopes of Mauna Loa are a painter's palate of red, brown, and black lava rocks. A cluster of scientific buildings stands out with their reflective white and silver rooftops against the Mars-like backdrop. Riding in the car with Trusdell, we turn off the cross-island highway and head up along a winding one-lane street. Rental cars are prohibited from officially making the trek, leaving the road eerily empty.

The paved portion of the path dead-ends into a parking lot for the Mauna Loa Weather Observatory and Solar Observatory, situated at an elevation of 11,145 feet. There the air is thin, and walking around can leave you lightheaded. The trick to avoiding an altitude headache is staying hydrated, said Trusdell.

Next to the observatories is a hiking trail up to the mountain summit that connects with another trail descending down the mountain's opposite side, letting out near the Hawai'i Volcanoes National Park entrance.

The 1984 eruption took a heavy toll on the twin observatories, knocking out the power and interrupting several experiments for nearly a month. Most notably, the data collection of carbon-dioxide measurements demonstrating man-made influences on climate change was disrupted. Some equipment also suffered weathering from the eruption's massive outpouring of sulfuric acid.

Post-eruption, the meteorologists reached out to HVO to design a protective diversionary structure around the observatory. This is what Trusdell and I were heading to see. Stepping out of the car, lava rock crunched beneath my boots. I followed Trusdell, who was outfitted in his standard field gear: thick-soled boots, the kind that won't melt immediately around molten lava, and a faded, fraying orange visor. A short ten-minute walk from the car, I noticed a mound of rock over ten feet high ahead and asked Trusdell if it was the wall, or just a flow.

"Want the punch line?" he responded. It was the barrier, which was composed of old flows bulldozed into an over 1,000-foot-long wishbone structure above the observatory.

Designed by Lockwood and a team of engineers, the structure was built in 1986 and takes advantage of the natural topography, enhancing existing highs and lows. In the case of a future eruption, summit flows would likely hit the structure from the side and surge along the edge of the barrier around the observatory. Although the research center would likely be saved, lava could cut off road access, putting scientists into a transportation pickle, and the observatory's power source located father down slope is still at risk. Nonetheless, the structure is a major acknowledgement of risk by the meteorologists.

Apart from the meteorologists, the majority of Hawai'i's general public has taken few steps to prepare themselves for a future eruption. Risk communication experts say people are more swayed by emotional and personal experience than science and math. For the meteorologists, the last northeast rift zone eruption resulted in tangible consequences—some expensive equipment broke and experiments stalled. But for most Hilo residents, the 1984 eruption provided nothing more than a month-long stress factor and mild commuting inconvenience. In other words, the event was not serious or scary enough to spur people to action.

Moreover, risk perception can be shaped by personal experience from something other than the main hazard at hand. And this is where Hawai'i's Kilauea volcano comes into play. Ever since Kilauea started its latest eruption in 1983—and Mauna Loa stopped shortly after—Big Island residents' perception of Mauna Loa risk has changed.

In the nineteenth century, Mauna Loa was the most active volcano in the world. Today, Kilauea is the rock star. Tourism agencies, journalists, civil defense, even HVO geologists have played a role in funneling public attention towards this active volcano. Consequently, some people ignore the other volcanic threats on the island, including Mauna Loa. For others, it has resulted in a distorted impression of Mauna Loa. Without knowing the differences between the two volcanoes, people walk away thinking that if they have seen and interacted with one, they know them all.

But this is a mistake. Mauna Loa flows are the rabbit, and Kilauea flows are the turtle. Kilauea flows, which the geologists jokingly call "piddly" and "puny," can take two to three weeks to reach the ocean, where it took the Mauna Loa flows from a massive 1950 eruption only 3.5 hours to travel a similar distance.

"What Mauna Loa was putting out in twenty minutes is what [Kilauea's crater] Pu'u O'o puts out in a whole day," said Trusdell. Another way to think about it is that one day's worth of Mauna Loa lava is equivalent to seventy-five days of eruptive activity at Pu'u O'o. And even though Kilauea has wiped out entire communities in recent decades, such as Royal Gardens, Kalapana, and Kapoho, none of those communities compare to Hilo in terms of population size or amount of critical infrastructure.

Fortunately, if Mauna Loa does threaten Hilo, topography is working in the city's favor. As evidenced with the 1984 eruption, and even the 1880 eruption, there would be plenty of warning time—likely on the order of weeks—to evacuate the threatened parts of the city. But this is not true for all developed areas downslope of Mauna Loa. An eruption on the opposite side of the mountain along the southwest rift zone, for instance, has the potential to be more than menacing. It could be deadly. Yet for many residents living there, the gravity of the situation is undercut by the

**Mauna Loa Observatory's lava barrier, shown aerially (left) and close-up (right), was constructed in 1986 in an effort to protect the research center from future volcanic eruptions. The aerial photograph is courtesy of NOAA's Earth System Research Laboratory.**

fact that Mauna Loa last terrorized the area in 1950. The threat of a future eruption may be real, but for most people it doesn't *feel* real.

▲ ▲ ▲

It was a chilly January morning, around fifty degrees Fahrenheit, in the neck of the Big Island. Stacey Sharkey's long blond hair was thrown up in a bun. While sipping a mug of award-winning Ka'u coffee, grown only a few miles down the road, Sharkey bluntly said she originally had no desire to live in Hawai'i. Hailing from Rhode Island, she and her husband already had their sights set on buying land in South Carolina or California.

***Ever since Kilauea started its latest eruption in 1983—and Mauna Loa stopped shortly after—Big Island residents' perception of Mauna Loa risk has changed.***

Approaching retirement age, the couple was planning to ditch their professional lives and start a farm some place warm and by the water.

But Hawai'i has a nagging way of commandeering dreams. When Sharkey came to the Big Island for vacation with friends in 2005, she recalled getting off the plane and "within twenty minutes, I knew I was going to live here." That vacation turned into real estate roulette. She looked "at a hundred lots" around the island in search of the perfect one.

The most promising piece of land was in the burgeoning subdivision Hawaiian Ocean View Estates (HOVE). The original listing price was out of her price range at $60,000. But on her last day, she decided to recheck the listing on a whim, and over the course of a few weeks the price had plummeted to $40,000. She returned to the empty lot. It was completely "raw," a mess of blocky black lava. She climbed partially up the old lava flow and was simply spellbound by the ocean vista. After phoning her husband with a decision, she paid for the land before flying back to the East Coast that same day.

The property is no longer a ragged plot of land. Sharkey gave me a tour, pointing out a small greenhouse; a few unfinished one-room guesthouses; small terraces exhibiting vegetables, herbs, and flowers; a bulldozed gravelly area with a basketball hoop; and the main house. The house is a piece of art, boasting high ceilings, an industrial kitchen with stainless steel counters, and wooden floors. In reference to the move, Sharkey said, "I am so glad we did. It's absolutely stunningly beautiful...we have sunrise, we have sunset." And there is an ocean view from almost every room in the house, as well as from the outdoor hot tub.

Although happy in her dream home, Sharkey made it clear that settling in was not all smooth sailing. It took nearly five years to build the house and ate up much of the family's savings to do it. This is because loans are generally not available for land in HOVE—the area is considered too risky by banks because of its close proximity to Mauna Loa's southwest rift zone.

Starting the farm was no picnic either due to lack of water and soil. Every house in the neighborhood is equipped with big water catchment tanks because there is

no networked water supply. Instead, water is delivered once a week from the neighboring towns or caught from rain. Relatedly, natural soil is a rare resource. The subdivision was predominantly built atop old lava flows; the most recent is around 100 years old. While volcanic soils are recognized in the farming world as being miracle food for plants, it takes hundreds of years for the rock to break down into desirable nutritious soil.

Before coming to Hawai'i, Sharkey wanted a farm. But living on the Big Island, she felt she *needed* one. Across the island, and especially in HOVE, people are paranoid about what would happen "if the boats don't come" with food or supplies. Sharkey told me a story from a few months ago of how the Kona-side Costco was without fruit for a couple days because the cargo ship hit stormy weather. It was a huge inconvenience. Equipped with a full farm, Sharkey can stress less about the prospect of island isolation. And if things get really desperate, Sharkey knows which local tree could best be used for toilet paper.

An item noticeably absent from Sharkey's list of concerns is a future Mauna Loa eruption.

As in Hilo, people living along the southwest rift zone are not thinking too hard about Mauna Loa. But unlike in Hilo, southwest-side residents would have less time to evacuate a threatening eruption. The 1950 eruption is evidence of this. The historical event was a catastrophe straight out of a Hollywood blockbuster that makes the 1984 eruption look like small change.

The massive mountain started quaking at 9:04 P.M. on June 1,1950. By 9:25 P.M, less than a half an hour later, Mauna Loa's upper southwestern flank glowed fire-engine red. The especially fast time between the first tremor and the appearance of lava set the heart-racing pace of the eruption.

The initial lava outbreak occurred along a 2.5-mile long fissure, or crack, running from the elevations 12,600 feet to 10,990 feet. The closest houses were less than two miles away. The first flow quickly lost momentum, petering out a few miles downslope. But another vigorous lava arm emerged even farther downslope, traveling southeastward into Kahuku Ranch and the upper limits of the Ka'u Forest Reserve, burning any vegetation in its path. A segment of this flow converted into a temporary stage for dancing lava fountains, where molten material leaped and twirled hundreds of feet into the air.

Later that night, the real damage commenced: A raging river of orange-red liquid lava crossed the region's only exit route, Highway 11. The burning asphalt released noxious fumes in a cloud of black, cough-inducing smoke. The flow then greedily consumed the Hookena Post Office, multiple houses, and a filling station, before emptying into the cold ocean and prompting a "billowing cloud of steam," reported geologists. From start to finish, the flow took only 3.5 hours to reach the ocean—one of the fastest times ever recorded for a rift zone flow to reach the sea. The lava's celerity was a combination of the high lava output and, more importantly, a steep slope. In contrast, the 1984 flows would have needed extra weeks, maybe months, to reach the ocean on the island's more gradually sloped eastern side.

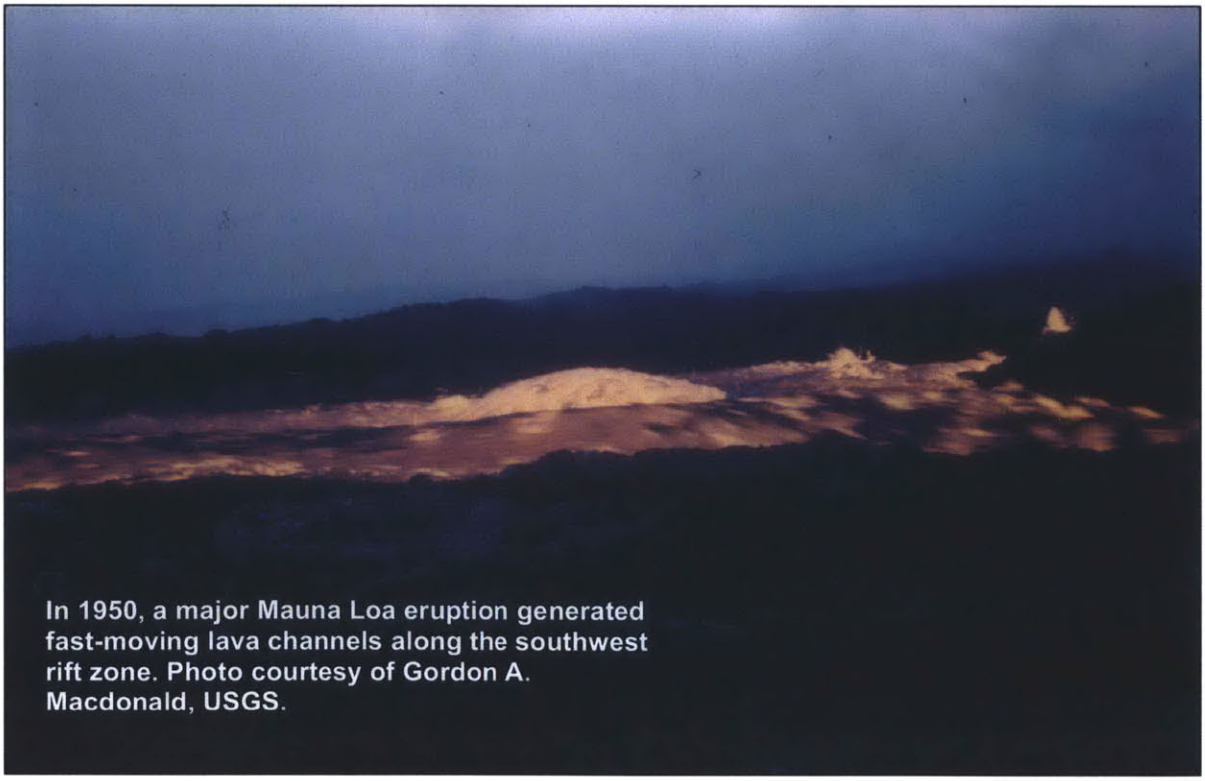
The nighttime volcanic debut posed problems for emergency management. The eruption was early enough in the evening that many of the geologists were still awake, but orchestrating evacuations

***By the time the eruption ended on June 22,1950, the ravenous eruption had produced eight discrete lava flows and enough lava to fill over 358 Empire State Buildings.***

and monitoring was difficult. Due to the eruption's unwieldiness, HVO recruited extra help from the National Park Service. From the ground, park rangers kept watch for indications of new flows from different points along the southwest rift zone.

That first week, flows pushed farther and farther down the mountainside, greedily devouring everything in sight with total indifference to the victim, whether house, farm, highway, hotel, or forest. The different fingers of lava looked like a bloody hand across the landscape, where the index finger, middle finger, and ring finger all crossed the highway in various locations.

By the time the eruption ended on June 22,1950, the ravenous eruption had produced eight discrete lava flows and enough lava to fill over 358 Empire State Buildings. Disruptions continued past the eruption's end. For example, many houses and farms, including the people and farm animals living there, were cut off by flows on both sides. And it took weeks for the flows to cool down enough to pave new roads.



In 1950, a major Mauna Loa eruption generated fast-moving lava channels along the southwest rift zone. Photo courtesy of Gordon A. Macdonald, USGS.

Following the eruption, people did what they always had done: rebuild. And after the rebuilding was done, people just kept on building. In 1958, this trend was further ignited by the arrival of two businessmen hailing from Denver, Colorado.

Named Glen Payton and David O'Keefe, these men introduced the Big Island to subdivisions. The first subdivision was called Hawaiian Acres, located in the Puna district, Kilauea volcano territory. The area included 12,000 acres sliced into 4,000 small, affordable plots, reported George Cooper and Gavan Daws in their book *Land and Power in Hawaii*. One can imagine the sales pitch went something like this: Under clear azure skies and only a short walk from the ocean, waits land that can be converted into your future home. At only $500-$1,000 with terms as low as $150 down and $8 a month, the plot is a steal!

According to Cooper and Daws, "The effect of this success was electrifying. A Big Island subdividing boom was on. For the next nine years new large-scale subdivisions were approved one after the other by Hawai'i County." Most subdivisions were located in areas with little or no intrinsic value, a euphemism for barren, lava-covered landscapes in the southeastern districts near Kilauea volcano and southwestern districts downslope of Mauna Loa. This is how a handful of subdivisions, including Hawaiian Ocean View Estates, cropped up a mere decade after the 1950 eruption.

Most new subdivision landowners were out-of-towners from Oahu or the mainland, many of whom bought land without even visiting the area. Instead, they relied on brochures, other advertisement, or word of mouth. And it was not the first time an exotic subdivision scheme took America by storm. Some forty years before in the 1920s in southern Florida, a parallel plotline played out: Low value land was divvied up, marketed across the nation as perfect vacation or retirement destinations, and sold cheaply to so-called "real estate amateurs," people who rarely visited the land before buying.

Despite the explosion in land sales, few people actually moved to Hawai'i, leaving the plots lying fallow. Of the ones who did move there, a large number shared an illicit motive. Wanting to grow marijuana off the grid, people in the drug business gravitated to the desolate emptiness.

Empty is one thing, but unsafe is another. The U.S. Geological Survey released a map of the Big Island with an initial set of lava hazard zone rankings in 1974. Rankings were last revised in 1987 and include nine levels of risk. Southwestern subdivisions are predominantly located in lava hazard zone one or two, the riskiest areas.

Were homeowners aware of this risky business? A survey conducted in the early 1980s regarding a subdivision near Kilauea volcano, called Royal Gardens, points to no. At the time of land purchase, some sixty-nine percent of Royal Garden residents did not know their lot was in a dangerous volcanic zone.

Today, the southwestern stretch of Highway 11 is lined with real estate signs, from the western town of Kilauea-Kona down to Hawaiian Ocean View Estates. And realtors are creeping into every small town hoping to convince vacationers to make Hawai'i their new perfect home. Like the rest of the United States, Hawai'i suffered a blow to the real estate market in the recent 2008-2009 depression, but now the market is potentially on an

upswing, said Arnold ("Arnie") Rabin, a real estate agent who has worked on the Big Island for thirty-five years.

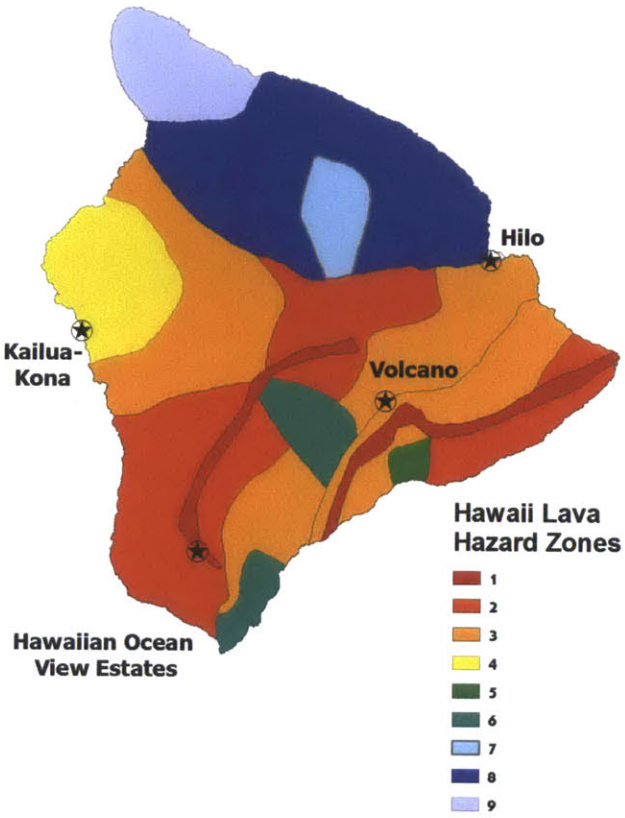
Rabin's office sits on the main stretch of a small town, Kealakekua, which is really just a chunk of the highway where through-traffic slows from fifty to twenty miles per hour for a few miles. It is one of three real estate offices along the stretch. When talking about how concerned people looking for real estate are about the volcano, Rabin said there was no clear response. "Different people have different levels of concern," he explained, where some care a lot and others not at all.

"I don't think many people think of it in their day-to-day existence," he continued. Turning the topic of conversation to himself, he added, "it's within my consciousness, but I choose to live here. And you know, the pros far outweigh the cons."

It is not the job of the realtor to dive into volcanic hazard details during a sale. The standard procedure is to refer people to the Hawaiian Volcano Observatory website or to a 1997 U.S. Geological Survey handbook called *Volcanic and Seismic Hazards on the Island of Hawai'i*, which skims through volcano, earthquake, and tsunami threats.

When the Hawaii lava zones were first published in the 1970s, insurance companies battled over where exactly the line fell between lava hazard zones two and three in the southwestern corner of the island. Rabin called up a geologist at HVO to get the answer, but not all real estate agents are as invested in understanding the area's geology. There are numerous horror stories of agents offering customers false information about the volcanoes.

Lockwood had one such story. When on assignment to map the historical flows in HOVE in the 1980s, the geologist ran




**To categorize the region's volcanic risk, the U.S. Geological Survey divided the Big Island into nine lava hazard zones; the riskiest areas are in zones one and two.**

into an angry resident while taking pictures of the land. The lady had stormed out of her house, asking Lockwood what he was doing. Lockwood replied that he was just documenting the lava flows. The woman responded with a long-winded rant, Lockwood said, something along the lines of, "You work for the volcano observatory? You bastards...I can't get insurance on my house. It's because of you...you know you placed us in lava zone two...How do you know if it is even real? The realtor when I bought this place, he told me the volcano was extinct...there hasn't been an eruption since 1907." The real estate agent had dated the flow correctly, but misinterpreted that this meant the

volcano was no longer active. A volcano is considered dormant only if it has not erupted for 10,000 years—not 100.

To avoid blindsiding customers by insurance and bank restrictions related to lava hazard zones, people who buy property on the Big Island are now required to sign the Hawai'i Island Disclosure, explained Rabin. But even in that two-page document, volcano risks are buried in a single paragraph sandwiched between property taxes and wastewater disposal. The disclosure is vague, saying that volcanoes "may affect the availability, limits and cost of property and/or liability insurance."

Specifically, banks and insurance companies steer clear of lava zone one, offering no loans, mortgages, or insurance coverage to people living there. Similarly, banks do not generally offer loans to people buying land in lava zone two. "So that's a big impact because a lot of people need to buy the land first and then get a construction loan" to build a house, Rabin explained. The Sharkeys had experienced this trouble first hand.

If you already have property on the island—whether a house, car, or land—there is one financially dicey way to get a loan. A Bank of Hawaii representative explained how this might work. Someone with property in a safer area of the island, such as in the north where the lava zone is nine, can use this property as collateral to take out a loan for land in a riskier area.

Private insurance companies also avoid offering homeowners insurance in lava zone two. For the few companies that do offer coverage, including Lloyd's of London, an insurance company that is famous for insuring everything from Tina Turner's legs to food critic Egon Ronay's taste buds, the price is exorbitant. But where private companies refuse to offer coverage, the state government fills the gap. Starting in 1992, the government created the controversial Hawaii Property Insurance Association (HPIA) that offers insurance coverage to residents in the riskiest parts of the island, including the southwest rift zone. Currently, the HPIA has 2,193 policyholders in the state of Hawaii, and 870 of those policyholders (forty percent) are in the Big Island's lava zone two. Still, HPIA policy premiums are pricey—an average rate of $1,745 a year, which can be two to three times higher than premiums for residences with similar property types in less risky locations.

According to a 2008 article in the *Honolulu Advertiser*, "The state-created HPIA has made rapid development possible in precisely those areas of the Big Island most likely to be devastated by lava flows from the Kilauea volcano, or from future eruptions of Mauna Loa volcano." There were also grumblings about this policy from different geologists at HVO.

When reflecting on Hawaiian land politics during the period between the 1950s and 1980s, Cooper and Daws concluded that all of those involved with the subdivision boom, from private investors to government bodies, "had their eye on real estate profits rather than natural hazards." Nearly thirty years later, the continued growth of subdivisions, combined with some legal, bank, and insurance flexibility, suggests that the lust for pro-development still commonly trumps concerns over volcanic hazards.

According to a survey conducted in 2003, *less than twenty-five percent* of Big Island residents living on the west and southwest coasts correctly knew that Mauna Loa erupted in the previous fifty years. Less than half (forty-eight percent) of the survey participants, comprising

school children and their parents and teachers, believed Mauna Loa could erupt again.

Since those survey results were published, replete with tips on how to expand resident's volcanic knowledge, it is unclear if any of its recommendations were ever followed. Even before the results came in, the survey's creator knew the responses would be illuminating. A principal of one of the participating schools asked the main researcher why the study was being conducted on her side of the island rather than on the southeast side near the currently erupting volcano Kilauea. "She said, 'besides how long has it been [since] we had a lava flow over here in [south] Kona? 500 years?'" No, it had only been a little over fifty years. In fact, the 1950 eruption had generated lava that flowed near that very school.

Similarly, geologists Trusdell and Lockwood have both talked with numerous residents living near the southwest rift zone about the risk posed by Mauna Loa, only to find out people were startlingly unaware. A major reason for this risk perception gap is the destruction and lack of delineation of past lava flows. In HOVE, some homes are built atop old, big fissures dating back to 1887. The land was bulldozed, Lockwood explained, so residents "don't know the fissures are there."

On Highway 11, about fifty miles north of HOVE, is another example of forgotten flows, those belonging to the destructive 1950 eruption. Driving south from Kilauea-Kona, I spotted the exposed lava flows sandwiching the highway. Early on a Saturday morning, the two-lane road was empty. I parked my rental car and hiked around.

The 1950 flow margins are roughly outlined on my Big Island road map, but their exact locations are hard to determine. Thanks to realtor Arnold Rabin, I knew to find at least one section between mile markers seventy-eight and seventy-six. There used to be signs on either end of the flows. They were put up in the 1970s and taken down about a decade later. Unconfirmed rumors claim that the government took the signs down to avoid scaring tourists, where highlighting major eruptions detracted from the "aloha" vibe.

When I asked Rabin beforehand what the flows looked like, he described an invasion of life. "It is just remarkable how the 1950 lava flow has changed since I got here in 1970...it was a stark, barren, stretches of lava, and not a living thing on it," he said. But suddenly, "lichen started to appear, and after lichen there were mosses, and then weeds, and then other plants, and now there are Ohia trees growing on them." His voice was full of wonder.

But upon seeing the flows for myself, I had an entirely different impression. Although there were some plants atop the flows, the area came across as bleak and dismal. Compared to Hilo's panoply of tropical trees and flowers, the flows more closely resembled a wasteland.

If a 1950-style eruption were to replay today, what would it look like? Infusing life into this "what if" scenario was the basis of a recent FEMA-funded two-day training course developed by the University of Hawai'i Manoa National Disaster Preparedness Training Center. Hawai'i Island was the subject of the original course; two spin-off scenarios were later designed for volcanoes in Alaska and in the Pacific Northwest Cascades.

During the summer of 2011, around

thirty Big Island emergency managers met for a pilot version of the course in the place where crisis situations are actually managed: the Civil Defense Emergency Operations Center (EOC). An unassuming off-white concrete building in downtown Hilo, the Civil Defense building sits behind the city's police department headquarters. From the foyer, offices are to the left and straight-ahead. The EOC is an open room to the right, and along the back wall are six flat-screen televisions. The other walls are filled with whiteboards and large maps to help track the progress of an unfolding emergency in terms of location, injuries/fatalities/missing persons, and event intensity. Four large square tables are assembled in the middle of the room, outfitted with phones. Every seat is dedicated to a particular organization. During a large-scale emergency, the room is packed.

The Emergency Operations Center was a familiar place for the pilot course attendees. Due to Kilauea eruptions, earthquakes, hurricanes, floods, and tsunamis, Hawai'i disaster response and relief personnel have congregated in the Hilo-based EOC so frequently in recent years that there is an unprecedented amount of cooperation across organizational lines. But is that collaboration enough to overcome a modern Mauna Loa catastrophe?

On day one of the course, Hawaiian Volcano Observatory scientists gave presentations reviewing the different volcanic hazards (earthquakes, lava inundation, gas emissions), pre-eruption warning signals (long term and short term), levels of uncertainty, and monitoring technologies.

On day two, the participants put their newfound volcanic skills to the test: simulating their response to an eruption. HVO's Trusdell and the University of Hawai'i Manoa team jointly designed the tabletop exercise, which was based closely on the 1950 eruption. However, this fact was *not* initially revealed to participants, who believed they were working with an invented southwest rift zone eruption, explained Bruce Houghton, director of the University of Hawai'i Manoa team.

Disaster response workers fall into four main categories: emergency management, first responders, health services and lifelines, and utilities. For the simulation, participants were divided into these four groups—with a twist. People were forced into positions *different* from their normal roles in order to expose them to unfamiliar decision-making processes. In this way, it is hoped that trained participants will ideally be more patient with each other during a real Mauna Loa catastrophe than former Mauna Loa geologist Lockwood and Civil Defense Director Kim were in 1984. Meanwhile, HVO's current scientist-in-charge John ("Jim") Kauahikaua played himself, and the course leaders acted as the volcano.

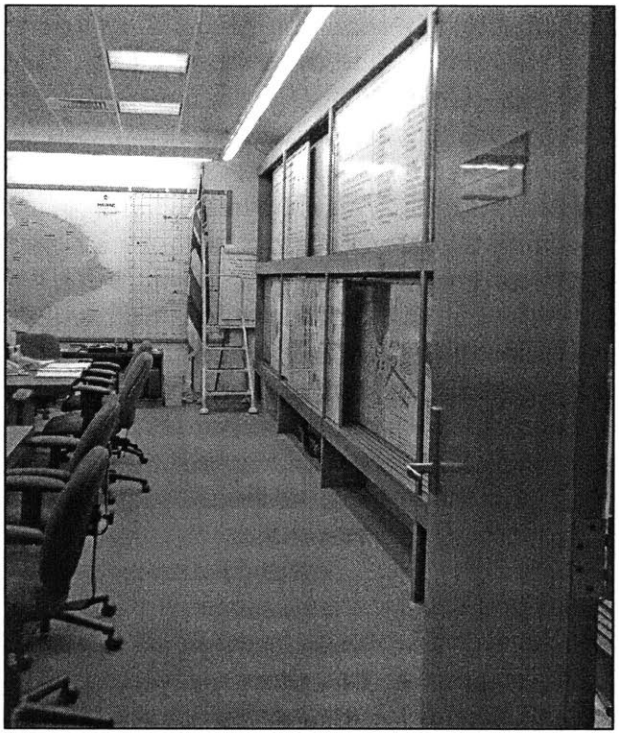
The exercise started with the very first signs of volcanic unrest (an inflating volcano and increased seismic activity) prompting participants to talk about preparatory actions. The group quickly dismissed mitigation options such as diversionary barriers because of uncertainty in lava flow location. Instead, their conversation focused on an evacuation strategy. With few exit roads available, participants decided that sections of Highway 11 should be converted into a one-way road, with all traffic directed out of the threatened area.

The eruption finally began in the middle of the night—this was a tweak to the scenario that embraced the 1984 eruption timing rather than that of 1950. At night, helicopters are generally not allowed to fly due to visibility concerns, so participants opted to recruit local firefighters and policemen to drive around with megaphones announcing evacuations. Additionally, participants publicized the eruption on the radio and television, as well as used reverse text messaging, a system through Civil Defense that sends out notifications via text message or email to registered residents.

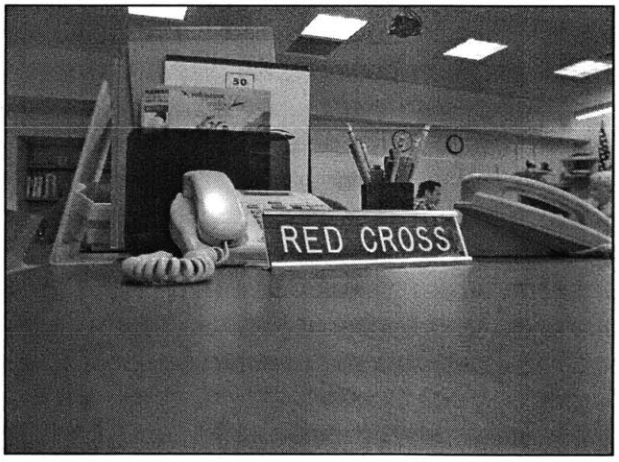
During the eruption, participants were given "real time" information about flow location. Using lava inundation maps to determine where the flows might end up, participants made decisions that ultimately affected whether there were injuries or fatalities. For example, a group may have decided to evacuate a community early, in which case there would likely have been no loss of life.

As in the real 1950 eruption, lava streamed down the mountain slicing and dicing up Highway 11, destroying buildings, and isolating communities. According to Houghton, some participants gawked at the speedy flow times, considering them a relic of scenario hyperbole.

In the case of Hawaiian Ocean View Estates, however, the scenario was altered to reflect a more serious situation than an exact 1950 eruption copycat. In real life, flows severed the highway to the left of HOVE, but in the new scenario, flows went on both sides of the subdivision. Moreover, it was assumed that the subdivision residents were "really independent" and "unlikely to take advice" from county and state emergency managers, said Houghton. (During my trip to HOVE, I spoke with multiple residents who said they would plan to stay put during a Mauna Loa eruption—and could use supplies from their personal farms to wait the disaster out.) Consequently, during the simulation, part of the population ended up trapped, and emergency responders were confronted with finding shelters for residents within



**The Big Island's Civil Defense Emergency Operations Center is one of the most active in the United States.**



the isolated area. But there was not enough space. For example, a nearby school gymnasium was targeted as a potential shelter. However, there were 4,000 evacuees and the gym could only safely hold 300 people.

In such a drastic scenario, the participants realized that outside reinforcements, including helicopter and boat rescue teams, were desperately needed from Oahu and the federal government. To the credit of the course attendees, everyone was quick to recognize and coordinate outside assistance—a lesson learned from their previous Big Island disaster experiences.

Perhaps the most revealing part of the course, however, was not what people learned from the simulation itself but from the scenario origins. At the end of the course, "the real shock was the very final slide," said Houghton. This is when the 1950 eruption map was shown and participants finally realized how closely the simulated and historical eruptions matched in terms of location, lava volume, and flow speed.

Course members walked away with a strong grasp of what a southwest rift zone Mauna Loa eruption might look like—and how it would be much worse than recent Kilauea volcano events in terms of size, pacing, and danger level. If Mauna Loa erupted with these participants still in their respective jobs, island residents would be in good hands. But some of the people have already retired, moved off the island, or changed jobs. Preserving institutional knowledge is one of the largest obstacles to long-term preparation for any rare, but serious hazard, whether a Mauna Loa eruption in Hawai'i, a big earthquake in San Francisco, or a major hurricane in New England. For example, it was concluded that an influential factor in FEMA's poor response to Hurricane Katrina, a major storm that devastated New Orleans, Louisiana, in 2005, stemmed from "the drain of long-term professional staff along with their instrumental knowledge and expertise."

Since the Mauna Loa volcano course training took place in 2011, the Big Island's Director of Civil Defense has changed twice. Aware of the frequency in job turnovers in the field, the University of Manoa team plans to organize another volcano training course for Hawaii state emergency managers later this year, or in 2014.

No matter how ready the geologists and emergency managers are for a future Mauna Loa eruption, their work amounts to little if the general public is unprepared—and by all accounts, they are not.

One of Hawai'i's other deadly disasters offers a cautionary tale: In 1960, a major tsunami inundated Hilo. There was no local earthquake to warn residents—a massive earthquake in Chile spawned the wave—but water in Hilo Bay receded before the big wave's arrival. Unaware of the natural warning, many unsuspecting beach-goers died. An eruption on Mauna Loa's southwest side could play out in a similar way. Due to the few escape routes and fast lava speeds, residents may need to evacuate as soon as they notice the volcano is erupting, possibly before official evacuation warnings. Will people see the red volcano top and know to leave, or will they stand outside and watch the natural fireworks? And even after hearing the evacuation announcements, will the public mobilize?

Volcanic eruptions draw on-lookers in a way that other hazards do not. Much of the Big Island's tourism revolves around Kilauea's activity. While a Mauna Loa eruption will be nothing like

a Kilauea one, the island's youngest volcano offers some lessons on appropriate lava viewing behavior. Most recent Kilauea-related injuries and deaths have resulted from careless acts: people who did not pay attention to experts and then got too close to active lava flows.

Every January for the past four years, HVO hosts the public outreach event, Volcano Awareness Month. Geologists give talks about the different island volcanoes and their respective hazards, both within the national park and in towns across the island. Frank Trusdell's annual speech is titled, "Mauna Loa: How Well Do You Know the Volcano in Your Backyard?"

Trusdell gave me a preview in his office. The speech echoed our previous conservations atop Mauna Loa and driving around Hilo. "People should be aware of where the hazards are," said Trusdell. "You can reduce your risk, your personal risk, by being prepared and planning for it." These personal steps are the same across disasters: stock an emergency kit with food, medicine, and extra clothes; keep extra copies of medical and financial papers; devise plans to connect with family and/or friends during an emergency.

The conversations surrounding Mauna Loa are focused on reacting—laying out plans for what the geologists, disaster managers, or individuals will do when an eruption starts. This mentality assumes that damages to buildings, roads, bridges, and parks are unstoppable. As in 1984, there are many Pele believers, and public discussions of mitigation strategies, from bombing to diversionary structures, are nonexistent.

However, the biggest elephant in the room is not Pele—it is Hawai'i's development addiction. Trusdell obliquely mentioned this in his talk: "Land use planning is the most effective tool for mitigating hazards." In other words, this involves restricting future building projects along Mauna Loa's slopes and discouraging people from moving into known, developed risky areas like HOVE and Hilo's upper slopes through insurance, real estate, and banks disincentives. But even these actions do not help existing infrastructure. Unless someone invents a way to lava proof a house, buildings in high-risk places have little protection.

For the Mauna Loa hazard to feel real, Hawaii residents need a more frequent reminder of Mauna Loa's hazard than Trusdell's annual talk. The key to effective preparedness is ingraining emergency planning into every day life. And this does not necessarily require grand efforts. For example, in California's San Francisco and Los Angeles cities, where earthquakes are the main natural hazard, many hotels have instructions in their room information packets for what to do in case an earthquake strikes. And in Hawai'i, similar precautions are taken with tsunamis. Today, numerous blue warning signs for tsunamis are sprinkled across the island, including in downtown Hilo and Kilauea-Kona

Meanwhile, Mauna Loa is not helping its own publicity campaign. During my time on the island, the volcano's peak remained largely masked in clouds and its base an unassuming backdrop of trees and houses. The volcano top occasionally made brief appearances early in the morning or mid-day, as if for a lunch-break. Even then, it did not appear intimidating.

But do not be fooled. As Trusdell said, "The volcano's going to erupt; it's not a dead volcano yet." ▲

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## Source Notes

Author's Note: Anything not sourced is from my personal experience either working on the Big Island as a Kilauea geology intern between April to July 2010, or from my thesis research, which included a trip to the Big Island between January 9-22, 2013.

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