



**In cooperation with the National Oceanic and Atmospheric Administration (NOAA), National Environmental Satellite, Data, and Information Service (NESDIS), National Climatic Data Center's Integrated Data and Environmental Applications (IDEA) Center**

# **Amount and Percentage of Current Societal Assets in Areas on Kaua`i, Hawai`i, within the 1992 Hurricane 'Iniki Storm-Surge Inundation Zone**

By Nathan Wood

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## **Introduction**

The Pacific Risk Management `Ohana (PRiMO) is a network of partners and stakeholders involved in the development, delivery, and communication of risk management-related information, products, and services across the Pacific Ocean (National Oceanic and Atmospheric Administration Pacific Services Center, 2008). One PRiMO-related project is the NOAA National Climatic Data Center's Integrated Data and Environmental Applications (IDEA) Center's Pacific Region Integrated Climatology Information Products (PRICIP) initiative, which seeks to improve the understanding of patterns and trends of storm frequency and intensity ("storminess") within the Pacific region and to develop a suite of integrated information products that can be used by emergency managers, mitigation planners, government agencies, and other decision-makers (National Oceanic and Atmospheric Administration Integrated Data and Environmental Applications Center, 2008a).

One of the PRICIP information products is a historical storm "event anatomy," which includes a summary of sector-specific socioeconomic impacts associated with a particular event, as well as information about the event and its climatological context. The intent of an event anatomy is to convey the causes of an extreme storm event and the associated impacts in a format that users can understand. The event anatomies also are intended to familiarize users with the in-place and remotely sensed products typically employed to track and forecast weather and climate. The first event anatomy developed as a prototype and hosted on the PRICIP portal is for Hurricane `Iniki (National Oceanic and Atmospheric Administration Integrated Data and Environmental Applications Center, 2008b), a Category 3-4 hurricane that made landfall on the south coast of Kaua`i Island on September 11, 1992, with estimated maximum sustained winds of more than 140 mph and gusts as high as 175 mph. Storm-surge inundation occurred on the southern and northeastern coast of Kaua`i Island.

In an effort to increase the amount of available information on the Hurricane `Iniki event anatomy of the PRICIP portal, representatives from the NOAA NCDC IDEA Center contacted the U.S. Geological Survey (USGS) in 2007 for assistance in determining what current societal assets are in areas that were inundated by storm surge during Hurricane `Iniki in 1992. This report contains data summarizing the amount and percentage of current societal assets on Kaua`i Island, Hawai`i, that exist in the historic Hurricane `Iniki storm-surge inundation zone. Coupled with an array of information on

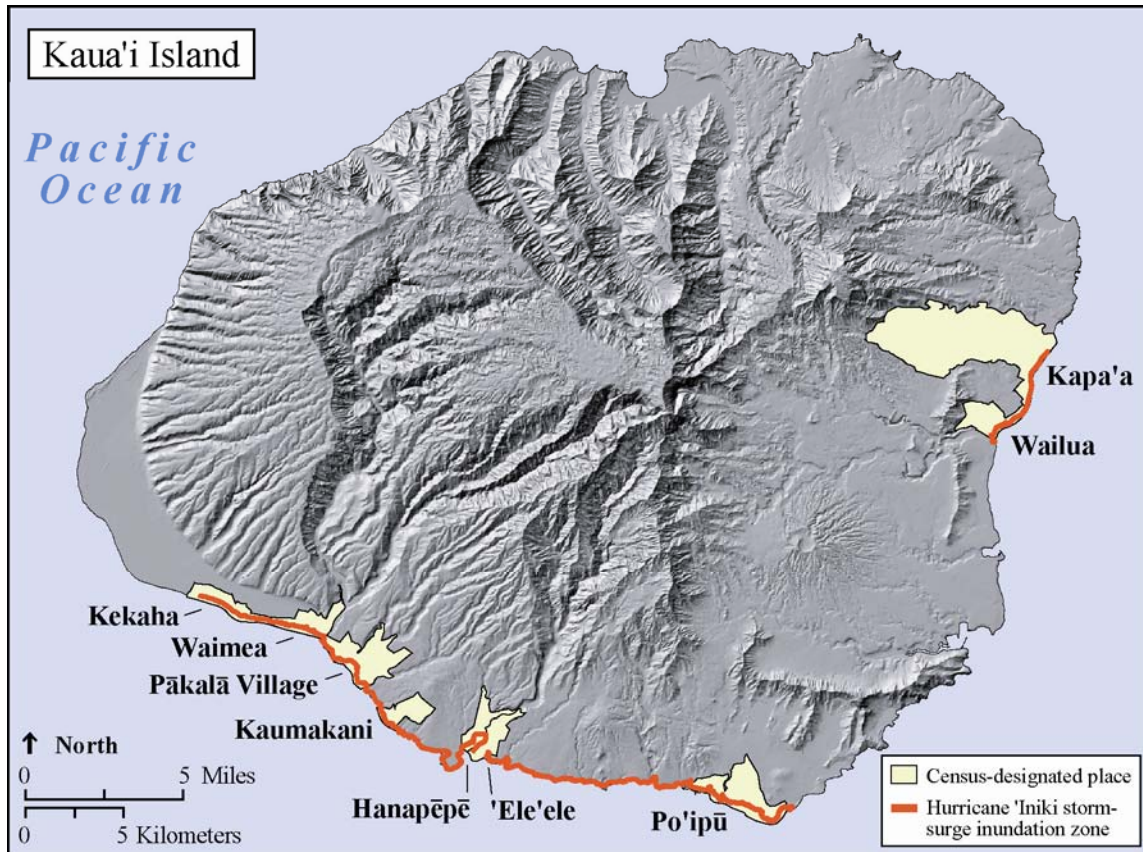
the socioeconomic impacts of Hurricane ‘Iniki and distributed through the PRICIP portal, the results of this effort will help managers and the general public to understand the current risks posed by extreme storms in the Pacific Basin.

## Methods

To describe current land on Kaua‘i Island that was inundated during Hurricane ‘Iniki and current societal assets in the area that would be impacted, geographic-information-system (GIS) tools were used to integrate publicly available hazard and socioeconomic data. Land inundated by storm surge during Hurricane ‘Iniki is delineated spatially by using a series of overwash lines developed for the State (Hawai‘i Office of Planning, 2008) by the University of Hawai‘i School of Ocean and Earth Science and Technology (SOEST). The State of Hawai‘i does not have incorporated cities; therefore, census-designated place (CDP) boundaries from the U.S. Census Bureau were used to delineate communities (Hawai‘i Office of Planning, 2008; U.S. Census Bureau, 2005). A CDP is a delineation used by the U.S. Census Bureau to identify areas of settled concentrations of populations that are identifiable by name and often are defined in cooperation with local or tribal officials, but are not legally incorporated and lack separate municipal governments (U.S. Census Bureau, 2005). On the basis of the intersection of CDP boundaries and historical inundation lines, nine communities on Kaua‘i Island—‘Ele‘ele, Hanapēpē, Kapa‘a, Kaumakani, Kekaha, Pākalā Village, Po‘ipū, Wailua, and Waimea— have land that was inundated by the Hurricane ‘Iniki storm surge (fig. 1). Information about current societal assets in historical storm-surge zones is summarized for each of the nine communities. Societal assets found in inundated land outside of these communities are aggregated and reported as “Kaua‘i Island (remainder).”

Societal-asset calculations focus on the amount and percentage of developed land, populations (residential and employees), economic assets, and critical facilities. These assets are determined because U.S. jurisdictions are encouraged to collect similar data as they develop State and local mitigation plans (Federal Emergency Management Agency, 2001), a requirement to qualify for funds under the U.S. Hazard Mitigation Grant Program in accordance with the Disaster Mitigation Act of 2000, Public Law 106-390. Data used in this analysis include:

- **Land cover** – based on the distribution of developed land and determined by using the low-intensity and high-intensity developed classes of the 2001 National Land Cover Database, which was compiled for the State of Hawai‘i by the NOAA Coastal Change Analysis Program (NOAA CSC 2007; Dobson and others, 1995);
- **Residents**—based on block-level population counts compiled for the 2000 U.S. Census (U.S. Census Bureau, 2008);
- **Employees and business community**—based on the 2006 infoUSA Employer Database, a proprietary business database that identifies location, number of employees, total sales volume, and the North American Industry Classification System (NAICS) code;
- **Critical facilities**—based on the 2006 infoUSA Employer Database; and
- **Tax-parcel value**—based on the 2008 tax-parcel dataset for the State of Hawai‘i (Hawai‘i Office of Planning, 2008), which includes information on property value, content value, exemptions to property values, and exemptions for content value (all in 2008 U.S. dollars).



**Figure 1.** Map of Kaua`i Island, Hawai`i, including census-designated places that intersect the historical storm-surge inundation zones from 1992 Hurricane `Iniki.

Prior to analysis, geospatial data were transformed to share the same datum (North American Datum of 1983) and projection (Universal Transverse Mercator coordinate system zone 4N), thereby conforming to existing GIS data from the State of Hawai`i’s GIS database. Spatial analysis of vector data (for example, business points and tax-parcel polygons) focused on determining whether or not points and polygons are inside the storm-surge zones. Slivers of polygons that overlap administrative boundaries and storm-surge zones were taken into account during analysis, and final values were adjusted proportionately.

To compare communities, composite indices were developed for the ten geographic units (9 communities and the remaining land on Kaua`i Island) and are based on the amounts and percentages of four categories—developed land, residents, employees, and total tax-parcel values (minus exemptions). Composite indices of amounts and percentages were developed by first normalizing values in each of the four categories to the maximum value found within that category. Normalizing data to maximum values creates a common data range of 0 to 1 for all four categories and is a simple approach for enabling comparisons among disparate datasets. The four normalized values are then summed, resulting in one final score ranging from 0 to 4 for each of the 10 geographic units. These relative scores are developed to compare the 10 geographic units and have no stand-alone meaning for a community.

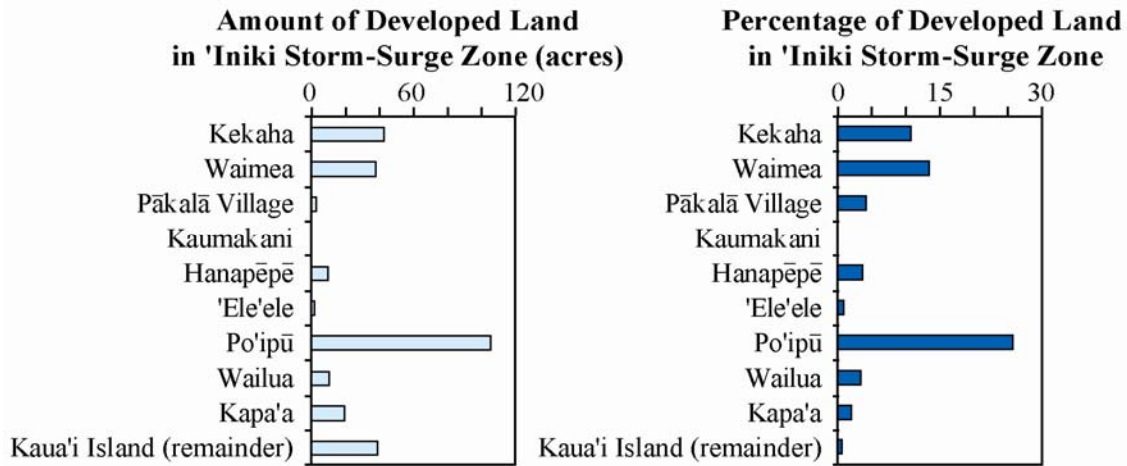
## Results

Data presented in this report were generated to provide information for the Hurricane ‘Iniki event anatomy on the PRICIP Internet-based portal and to support the collaborative PRiMO-related PRICIP initiative. Results are presented in both tables and graphs to satisfy developers and various users of the PRICIP portal. Results include information about the amount and percentage of developed land, residents, businesses, employees at and sales volume generated by these businesses, and tax-parcel values that are in the Hurricane ‘Iniki storm-surge inundation zone. Additional demographic attributes include the number and percentage of residents younger than 5 years, residents older than 65 years, total households, and renter-occupied households in the historical storm-surge zones.

Currently, there are approximately 270 acres of developed land in the various communities in the Hurricane ‘Iniki storm-surge inundation zone (table 1; fig. 2). The largest amount (105 acres) and highest percentage (26 percent) of developed land in these areas are in the community of Po‘ipū. The majority of this land (101 acres) is classified as low-intensity developed, a classification that denotes cells that contain 50 to 79 percent of constructed surfaces and typically represent small buildings, streets, and cemeteries (Dobson and others, 1995).

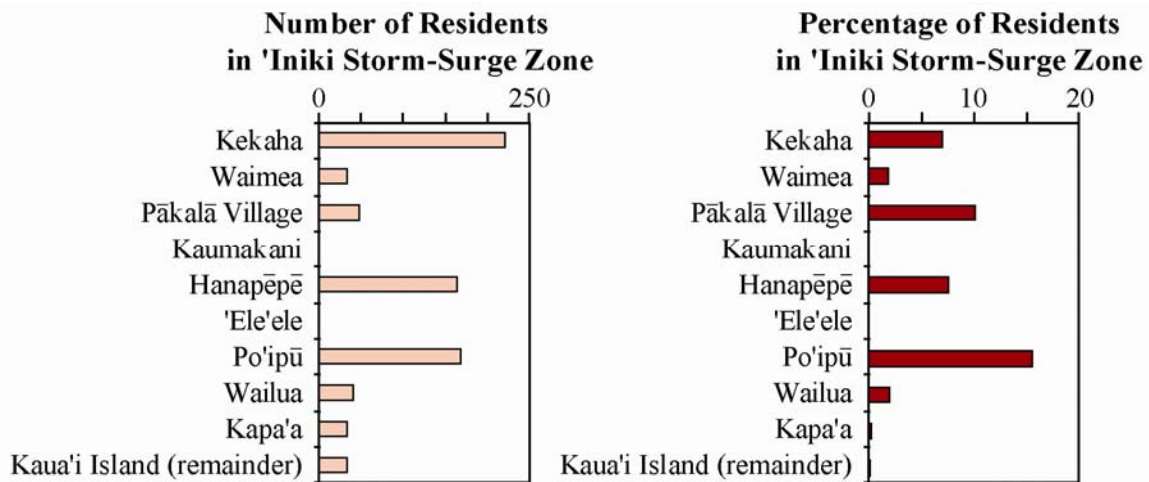
**Table 1.** Amount (acres) and percentage of land classified as developed within the 1992 Hurricane ‘Iniki storm-surge inundation zone, Kaua‘i Island, Hawai‘i.

Census designated place	High- and Low-Intensity Developed			High-Intensity Developed			Low-Intensity Developed		
	‘Iniki zone, in acres	Total, in acres	%	‘Iniki zone, in acres	Total, in acres	%	‘Iniki zone, in acres	Total, in acres	%
‘Ele‘ele	2	238	1	1	61	1	1	177	1
Hanap p	10	260	4	0	37	1	9	224	4
Kapa‘a	19	944	2	2	54	4	17	890	2
Kaumakani	0	109	0	0	21	0	0	88	0
Kekaha	43	395	11	5	39	14	37	356	10
P kal Village	3	76	4	1	4	13	3	72	4
Po‘ip	105	409	26	5	27	17	101	382	26
Wailua	10	300	3	1	19	4	10	281	3
Waimea	38	282	14	0	70	0	38	212	18
Kaua‘i Island (remainder)	39	6,635	1	2	1,023	0	37	5,611	1
TOTAL	270	9,649	3	17	1,356	1	252	8,293	3



**Figure 2.** Amount (acres) and percentage of developed land within the 1992 Hurricane 'Iniki storm-surge inundation zone, Kaua'i Island, Hawai'i, based on 2001 NOAA C-CAP land-cover data. Communities are ordered from west to east.

Based on 2000 Census data, the Hurricane 'Iniki storm-surge inundation zone currently contains 743 residents and 298 households (fig. 3; table 2). The highest numbers of residents in the Hurricane 'Iniki storm-surge inundation zone are in the communities of Kekaha (222 residents) and Po'ipū (168 residents). The highest community percentage is in Po'ipū, where 16 percent of the 1,075 residents are in the Hurricane 'Iniki storm-surge inundation zone. Four percent of the 743 residents in the Hurricane 'Iniki storm-surge inundation zone are younger than 5 years, and 17 percent are older than 65 years—two age groups considered to have high vulnerability to extreme events (Morrow, 1999). Forty-six percent of the 298 households in the Hurricane 'Iniki storm-surge inundation zone are occupied by renters, a group identified in past studies to be typically less prepared than homeowners for catastrophic events (Burby and others, 2003).



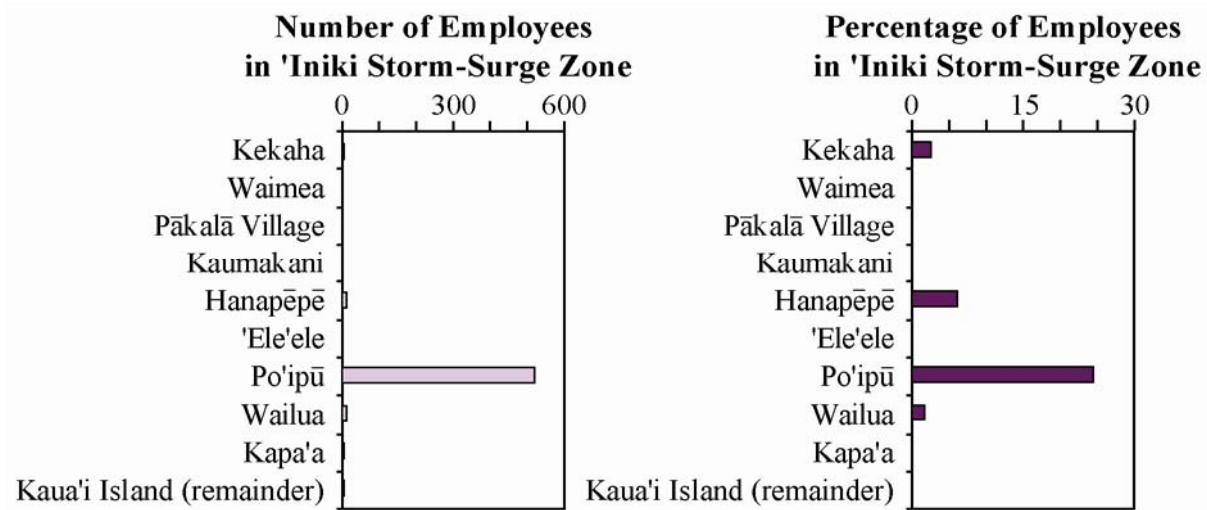
**Figure 3.** Number and percentage of residents currently within the 1992 Hurricane 'Iniki storm-surge inundation zone, Kaua'i Island, Hawai'i.



**Table 2.** Number and percentage of residents currently within the 1992 Hurricane ‘Iniki storm-surge inundation zone, Kaua`i Island, Hawai`i.

Census designated place (CDP)	Total population			Residents younger than 5 years			Residents older than 65 years			Households			Renter-occupied households		
	‘Iniki zone	Total	%	‘Iniki zone	Total	% of exposed population	‘Iniki zone	Total	% of exposed population	‘Iniki zone	Total	% of CDP	‘Iniki zone	Total	% of exposed population
‘Ele‘ele	0	2,040	0	0	140	0	0	330	0	0	626	0	0	147	0
Hanap p	164	2,153	8	11	141	6	15	260	9	56	706	8	27	216	47
Kapa‘a	33	9,472	0	2	655	6	7	983	20	15	3,129	0	8	1,401	53
Kaumakani	0	607	0	0	23	0	0	121	0	0	207	0	0	204	0
Kekaha	222	3,175	7	7	171	3	34	494	15	87	1,073	8	37	376	43
P kal Village	49	478	10	2	18	4	10	114	21	12	150	8	10	141	83
Po‘ip	168	1,075	16	4	37	3	36	220	21	78	472	16	33	185	42
Wailua	41	2,083	2	1	131	3	13	363	32	21	781	3	9	338	41
Waimea	34	1,787	2	3	103	9	5	348	15	12	620	2	9	289	74
Kaua‘i Island (remainder)	33	35,433	0	2	2,166	6	8	4,829	26	17	12,383	0	5	4,470	28
TOTAL	743	58,303	1	32	3,585	4	129	8,062	17	298	20,147	1	137	7,767	46

The Hurricane ‘Iniki storm-surge inundation zone contains 27 businesses that employ 545 employees and generate more than \$38 million in sales volume (fig. 4; table 3). These numbers account for low percentages of the total business community of Kaua‘i (1 percent of businesses and total sale volume and 2 percent of employees). The percentage of business exposure is greater within some communities, such as Po‘ipū, where 24 percent of the community workforce works in the Hurricane ‘Iniki storm-surge inundation zone. The majority of the employees (66 percent) in the Hurricane ‘Iniki storm-surge inundation zone are in the accommodation and food services sector (table 4; fig. 5). There are no dependent-care facilities or critical facilities in the Hurricane ‘Iniki storm-surge inundation zone (see Appendix 1 of Wood and others, 2007, for descriptions of these facilities). Finally, property and content value (minus exemptions) for land in the Hurricane ‘Iniki storm-surge inundation zone is valued at more than \$1.2 billion, representing 6 percent of the total tax-parcel values on Kaua‘i Island (table 3; fig. 6).



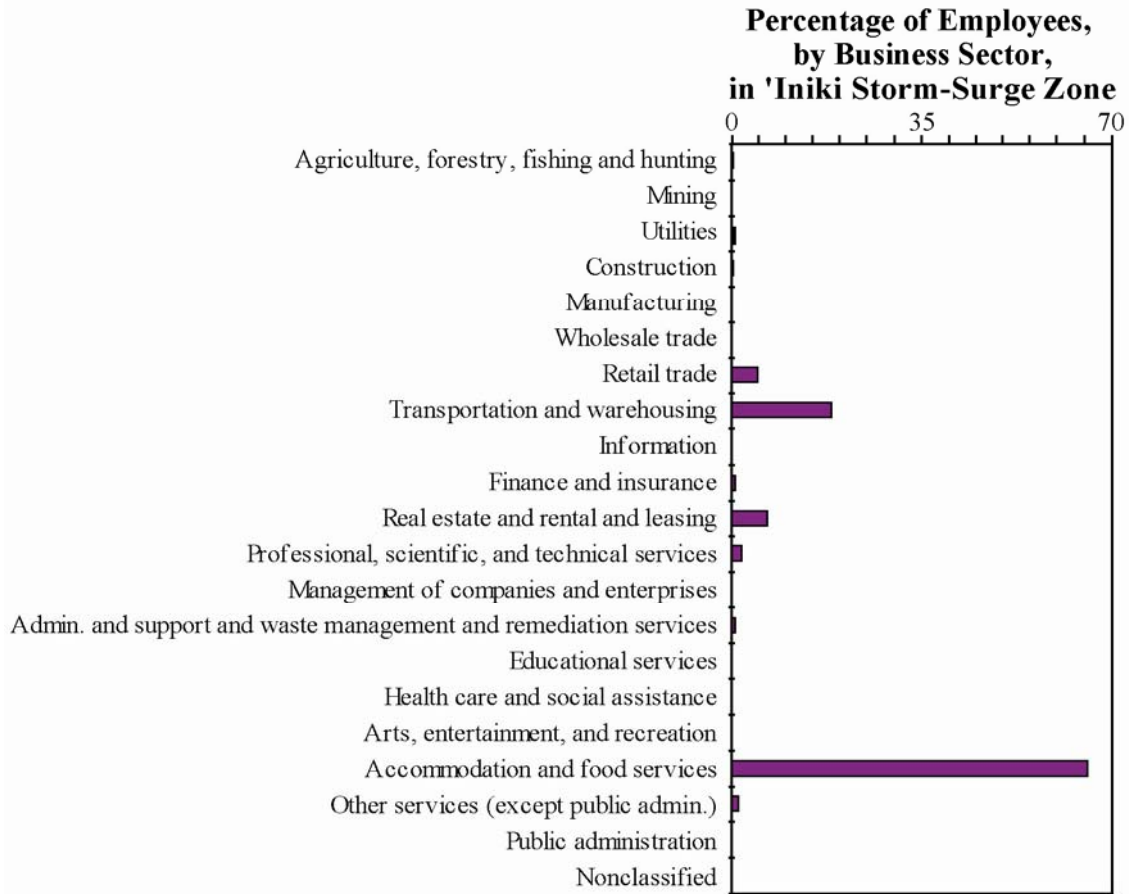
**Figure 4.** Number and percentage of employees within the 1992 Hurricane ‘Iniki storm-surge inundation zone, Kaua‘i Island, Hawai‘i. Communities are ordered from west to east.

**Table 3.** Amount and percentage of current economic assets within the 1992 Hurricane ‘Iniki storm-surge inundation zone, Kaua‘i Island, Hawai‘i.

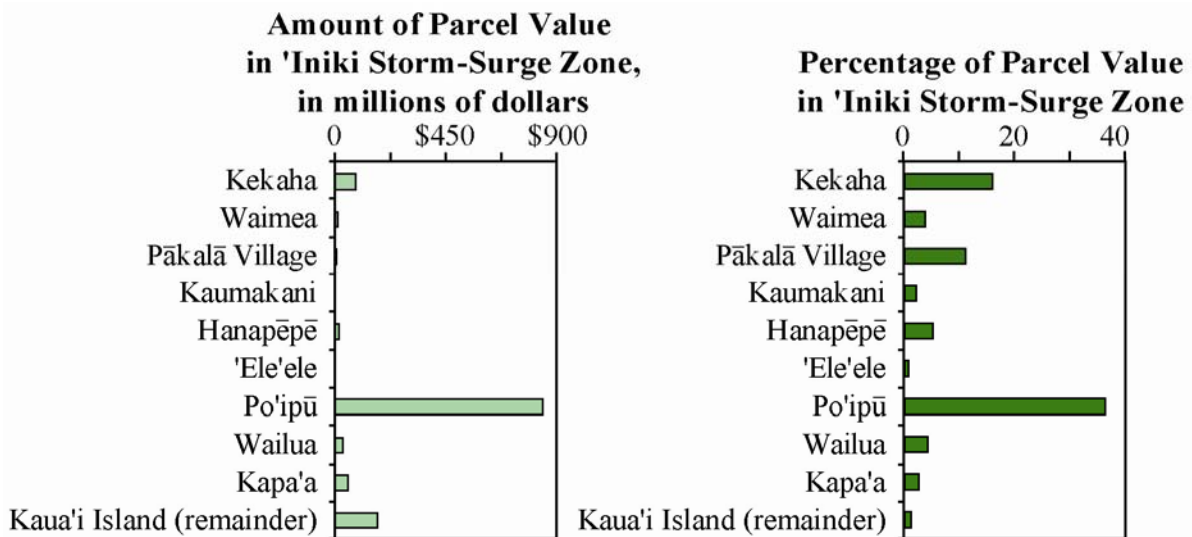
Census Designated Place	Total parcel value (minus exemption)			Businesses			Employees			Sales volume		
	‘Iniki zone, in \$, thousands	Total, in \$, thousands	%	‘Iniki zone	Total	%	‘Iniki zone	Total	%	‘Iniki zone, in \$, thousands	Total, in \$, thousands	%
‘Ele‘ele	1,854	276,463	1	0	45	0	0	586	0	0	172,404	0
Hanap p	15,417	303,430	5	4	52	8	10	160	6	1,010	22,965	4
Kapa‘a	51,812	2,092,322	2	1	489	0	2	3149	0	314	425,947	0
Kaumakani	42	2,052	2	0	10	0	0	259	0	0	101,478	0
Kekaha	82,219	515,321	16	3	21	14	4	148	3	802	12,933	6
P kal Village	2,900	26,477	11	0	0	0	0	0	0	0	0	0
Po‘ip	849,979	2,326,459	37	16	134	12	514	2101	24	34,642	231,304	15
Wailua	32,933	772,032	4	2	73	3	12	699	2	944	75,299	1
Waimea	11,201	296,879	4	0	92	0	0	1315	0	0	192,291	0
Kaua‘i Island (remainder)	175,445	14,478,150	1	1	2,399	0	3	23,458	0	399	3,994,225	0
TOTAL	1,223,801	21,089,584	6	27	3,315	1	545	31,875	2	\$38,111	\$5,228,846	1

**Table 4.** Distribution of employees, by business sector, within the 1992 Hurricane ‘Iniki storm-surge inundation zone, Kaua’i Island, Hawai’i. Business sectors are classified according to the North American Industry Classification System (NAICS).

NAICS Code	Sector description	Employees			
		‘Iniki inundation zone	Island total	Percentage of island total in inundation zone	Percentage of the businesses in inundation zone
11	Agriculture, forestry, fishing and hunting	2	290	1	0
21	Mining	0	25	0	0
22	Utilities	0	418	0	0
23	Construction	1	2,563	0	0
31-33	Manufacturing	0	1,100	0	0
42	Wholesale trade	0	1,975	0	0
44-45	Retail trade	26	4,933	1	5
48-49	Transportation and warehousing	100	2,017	5	18
51	Information	0	498	0	0
52	Finance and insurance	4	860	0	1
53	Real estate and rental and leasing	36	2,595	1	7
54	Professional, scientific, and technical services	9	832	1	2
55	Management of companies and enterprises	0	0	0	0
56	Administrative and support and waste management and remediation services	4	770	1	1
61	Educational services	0	1,761	0	0
62	Health care and social assistance	0	3,055	0	0
71	Arts, entertainment, and recreation	0	766	0	0
72	Accommodation and food services	357	4,364	8	66
81	Other services (except public administration)	6	1,257	0	1
92	Public administration	0	1,679	0	0
99	Nonclassified	0	117	0	0
Total for Kaua’i Island		545	31,875	2	100

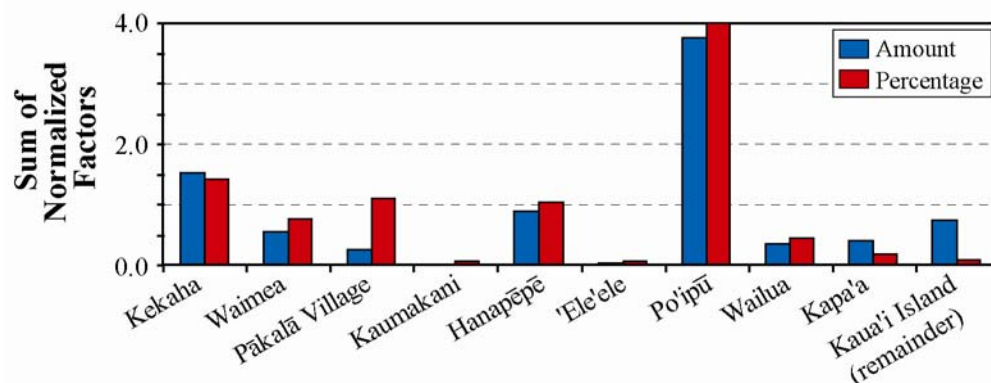


**Figure 5.** Percentage of employees, by business sector, currently in the 1992 Hurricane 'Iniki storm-surge inundation zone, Kaua'i Island, Hawai'i.



**Figure 6.** Current amount, in dollars, and percentage of total tax parcel value (minus exemptions) within the 1992 Hurricane 'Iniki storm-surge inundation zone, Kaua'i Island, Hawai'i. Communities are ordered from west to east.

Composite indices of current asset amounts and percentages in the Hurricane ‘Iniki storm-surge inundation zone for each of the 9 communities and the remaining land in Kaua’i Island are the sums of normalized data in 4 categories—developed land, residents, employees, and total parcel value. Figure 7 summarizes the composite amounts and percentages, each with a range from 0 to 4. In this analysis of the four data categories, Po‘ipū has the highest relative amount and percentage of its assets in the Hurricane ‘Iniki storm-surge inundation zone.



**Figure 7.** Sum of normalized factors for both the amount and percentage of various assets for each community with land in the 1992 Hurricane ‘Iniki storm-surge inundation zone, Kaua’i Island, Hawai’i. Assets include developed land, residents, employees, and total parcel value.

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