An Assessment of the Environmental and Natural Resource History of a Coastal Hawaiʿi Community: A Case Study of Anini, Kauaʿi

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Collaborative Care and Management of Natural Resources

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ACRONYMS

BBD – Black Band Disease
CFU – Colony Forming Unit
CZM – Coastal Zone Management Program
DAR – Department of Aquatic Resources
DLNR – Department of Land and Natural Resources
DOD – Department of Defense
DOH – Department of Health
DOW – Department of Water
FWS – Fish and Wildlife Services
EIS – Environmental Impact Statement
EPA – Environmental Protection Agency
ESA – Endangered Species Act
HIMB – Hawaiʻi Institute of Marine Biology
KICRI – Kauaʻi Island Coastal Resource Inventory
KIUC – Kauaʻi Island Utility Cooperative
KCCCHA – Kauaʻi Climate Change and Coastal Hazards Assessment
MGD – Million Gallons per Day
NOAA – National Oceanic and Atmospheric Administration
NWIS – National Water Information System
OSDS – On-Site Sewage Disposal Systems
PDC – Princeville Development Corporation
PPM – Parts per Million
SOEST – School of Ocean and Earth Science and Technology
USFWS – U.S. Fish and Wildlife Service
USGS – U.S. Geological Survey

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1.0 INTRODUCTION

1.1 BACKGROUND

This report is an overview of the documented environmental and natural resource history of a traditionally Native Hawaiian community on the North Shore of Kauaʻi, Hawaiʻi. The community of interest in this report covers a project site ranging from Anini Stream to Kalihiwai River, which will be referred to in this report as "Anini." Known for its large fringing reef, protected waters, and aesthetic views, Anini has become a popular travel destination for both residents and visitors. Anini's beauty has also attracted development, mainly from the vacation and resort industry. Furthermore, the relatively recent human degradation of Anini's reef has been a cause for concern, and efforts are being made to understand the stressors that are behind it, particularly those of anthropogenic origin. Understanding the current conditions in Anini and how they compare to past baselines may help in forming better management practices for the conservation of its natural resources.

Over the course of four months, a group of five students from University of Hawaiʻl at Mānoa], in a Natural Resources and Environmental Management Departmental course, NREM 691: Kaiaulu Collaborative Resource Management worked on researching the environmental and natural resource aspects of the area, , in conjunction with two other groups of students who researched policy and culture. This report provides insight into the past and current state of natural resources in Anini, and includes future outlooks and recommendations.

1.2 PURPOSE

The purpose of this report is to gather and document information and knowledge regarding past and present natural resource conditions in Anini. This report focuses on terrestrial (including freshwater) and marine ecosystems, noting key changes and their potential causes. The goal of this paper is to improve comprehension and awareness of the environmental history of the area and the issues impacting or with the potential to impact the local ecosystem, taking into account past baselines. This report contains a compilation of literature that communities would otherwise find difficult and time consuming to access on their own. It is the intent of the authors that this report assists in guiding current and future generations of the Anini community with regards to management of Aniniʻs land and coastal natural resources.

1.3 GUIDING TOPICS AND QUESTIONS FOR THE TERRESTRIAL ECOSYSTEM IN AND AROUND ANINI

The first part of this report covers terrestrial (including fresh water) ecosystems. Topics include geological structure, local watersheds, terrestrial land changes, biodiversity, and water and wastewater management. Key questions this section will address include:

1. What are the underlying geological and hydrological characteristics of Anini?
2. What terrestrial developments or changes have occurred and what are the effects of these changes on land?
3. What species are present within the site, especially with regards to invasive and non-native species?
4. What are the historic and current conditions of surface water and groundwater reserves and are there identifiable threats to these sources?

1.4 GUIDING TOPICS AND QUESTIONS FOR THE MARINE ECOSYSTEM IN AND AROUND ANINI

The second part of this report covers the marine ecosystem. Topics include past and current states of reef health, coral disease, coral bleaching, and algae or seaweed (limu). This report also investigates fish and invertebrate life, and considers potential impacts of sedimentation, climate change, and sea level rise on Anini. Key questions this section will address include:

1. How has marine life changed on Anini reefs? What were the causes of these changes and how widespread are the effects?
2. How will sea level rise impact Anini? Can we anticipate significant changes in the shoreline?
3. How have terrestrial changes and development affected the marine environment at Anini?
4. How do fishing practices impact the reef ecosystem?

1.5 METHODOLOGY

The majority of the content in this paper was derived from an extensive review of secondary sources. Most of the sources of information used were based on published scientific journal articles and gray literature, such as reports by government bodies, research theses, websites, media articles, state documents, environmental impact statements (EIS), conference papers and personal communication with local community members. Printed literature was also utilized, specifically geared towards species diversity and bird life histories and demographics. Results were compiled to identify key environmental issues, changing health and potential threats to marine and terrestrial ecosystems. The search for information was driven by the guiding questions as well as the desire to document as much knowledge as possible on the environment and natural resources. We also interviewed ten scientists and other experts who have worked extensively in Anini over the years observing and documenting change.

2.0 TERRESTRIAL ECOSYSTEM

2.1 GEOLOGICAL STRUCTURE

The island of Kauaʻi is one of the eight main Hawaiian Islands and is approximately 3.8 million years old. The major shield volcano, Mt. Waiʻaleʻale, which creates large slopes on the northeastern side of the island, forms the island. Some of the heaviest rainfall occurs on this side of the island where Anini is located, yielding higher sediment erosion from the two rivers, Anini Stream and Kalihiwai Stream, and creating a floodplain (Fletcher and Calhoun, 1995).

The Eastern point of the island, where Anini is located, is dominated by the Lihuʻe basin, which is about 110 km^2 shaped in a semicircular depression. Around the basin are larger cliffs, such as the ones that can be seen in the Princeville area. Within the Lihue basin, the Koloa lava flow is identified as the land characteristic, comprised of primitive lava rocks: alkaic basalt, basnite, nephelinite, and melilitite. This eastern region is about 1.5 million years old, and is considered young compared to the Waimea volcanic flow, consisting of the Western region of Kauaʻi as seen in Figure 1 (Reiners et al., 1999).

Anini is located in a newer region of Kauaʻi, characterized for having large plateaus surrounded by higher cliffs. This potentially makes the area more susceptible to landslides and flooding from the steep cliff angles (Figure 1). The soil is predominantly of the Makapili series, which is characterized as being well-drained silty clay and clay loam soils having low fertility. Additionally, the erosion potential ranges from moderate to very severe depending on the slope (EIS, 1983, II-4). This is consistently identified in EIS statements 1983 and 2011 (Figure 2). In addition, Anini upper land is Pooku soil, which is similar to Makapili soil but less erodible (EIS, 1983, II-4).

Land and sea interactions cause changing surf seasons with larger swells in the north during the winter (October to April), and larger swells in the south during the summer months (May to September). Roughly 50% of the shoreline is sand (178 km perimeter) and the other half is rocky terrain. Anini is characterized by long fringing near shore reefs that provide barriers from the deep ocean waves. This makes Anini a popular spot for fishing in the shallow reefs and swimming for novices.

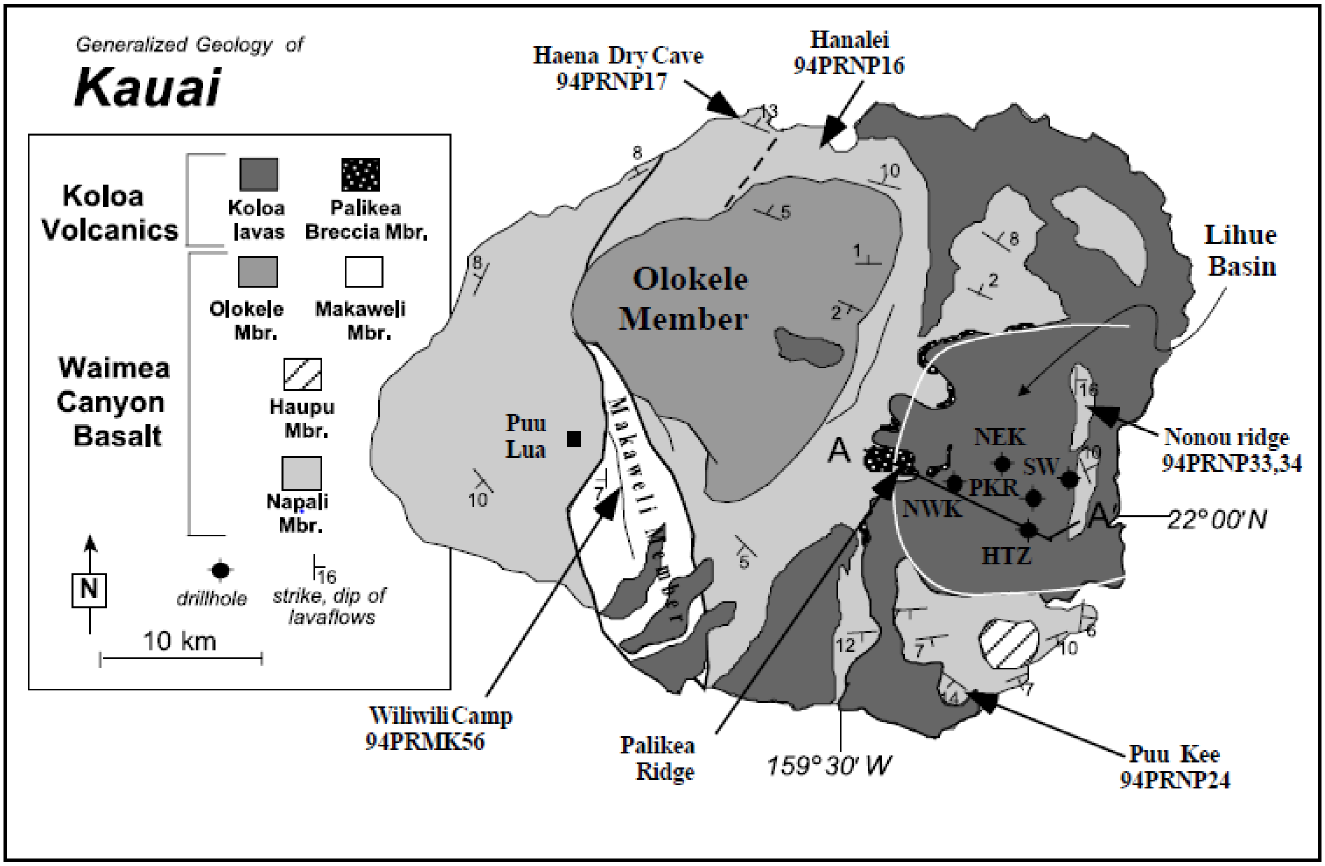


Figure 1: Geologic map of Kauaʻi based on different volcanic flows (Reiners et al., 1998).

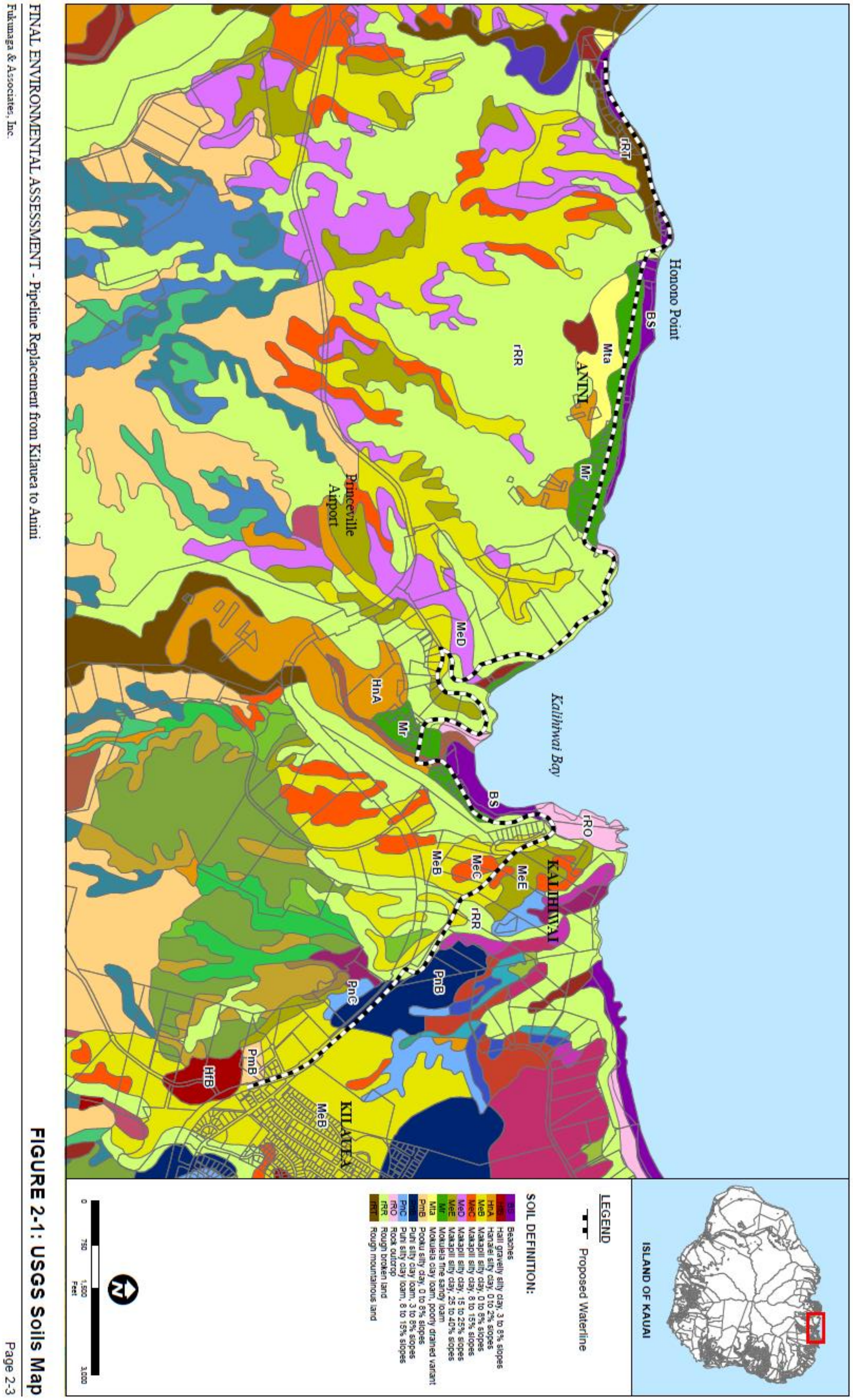


Figure 2: Soil characteristics from Kalihiwai to Anini (EIS, 2011).

2.2 LOCAL WATERSHEDS

The site encompasses five watersheds: Anini, Honu, Kowali, Kalihikai, and Kalihiwai River. Information about each watershed is summarized in the table below, and each watershed is depicted in the following watershed figures (Hawaiʻi Division of Aquatic Resources, 2008).

Table 1: Watershed Properties (Hawaiʻi Division of Aquatic Resources, 2008).

	Watershed				
	Anini	**Honu (Kalihikai West)**	**Kalihikai (Kalihikai Center)**	**Kowali (Kalihikai East)**	**Kalihiwai River**
Area (sq. mi.)	2.3	0.3	0.2	0.5	10.8
Max. Elevation (ft)	1037	335	341	384	3209
Percent land use district	64.3% agricultural, 11.1% conservation, 24.6% urban	91.9% agricultural, 8.1% urban	59.4% agricultural, 40.6% urban	74.9% agricultural, 0.2% conservation, 24.9% urban	28.4% agricultural, 71.6% conservation
Land Stewardship (management)	14.2% state managed, 85.8% privately managed	100% privately managed	100% privately managed	100% privately managed	73.9% state managed, 26.1% privately managed
Land Management Status (biodiversity protection and management created by the Hawaiʻi GAP program)	14.2% protected but unmanaged, 85.8% unprotected	100% unprotected	100% unprotected	100% unprotected	73.9% protected but unmanaged, 26.1% unprotected
Streams present	Anini Stream	Honu Stream	Kalihikai Stream	Kowali Stream	Kalihiwai River, Kaumoku Stream, Pouli Stream

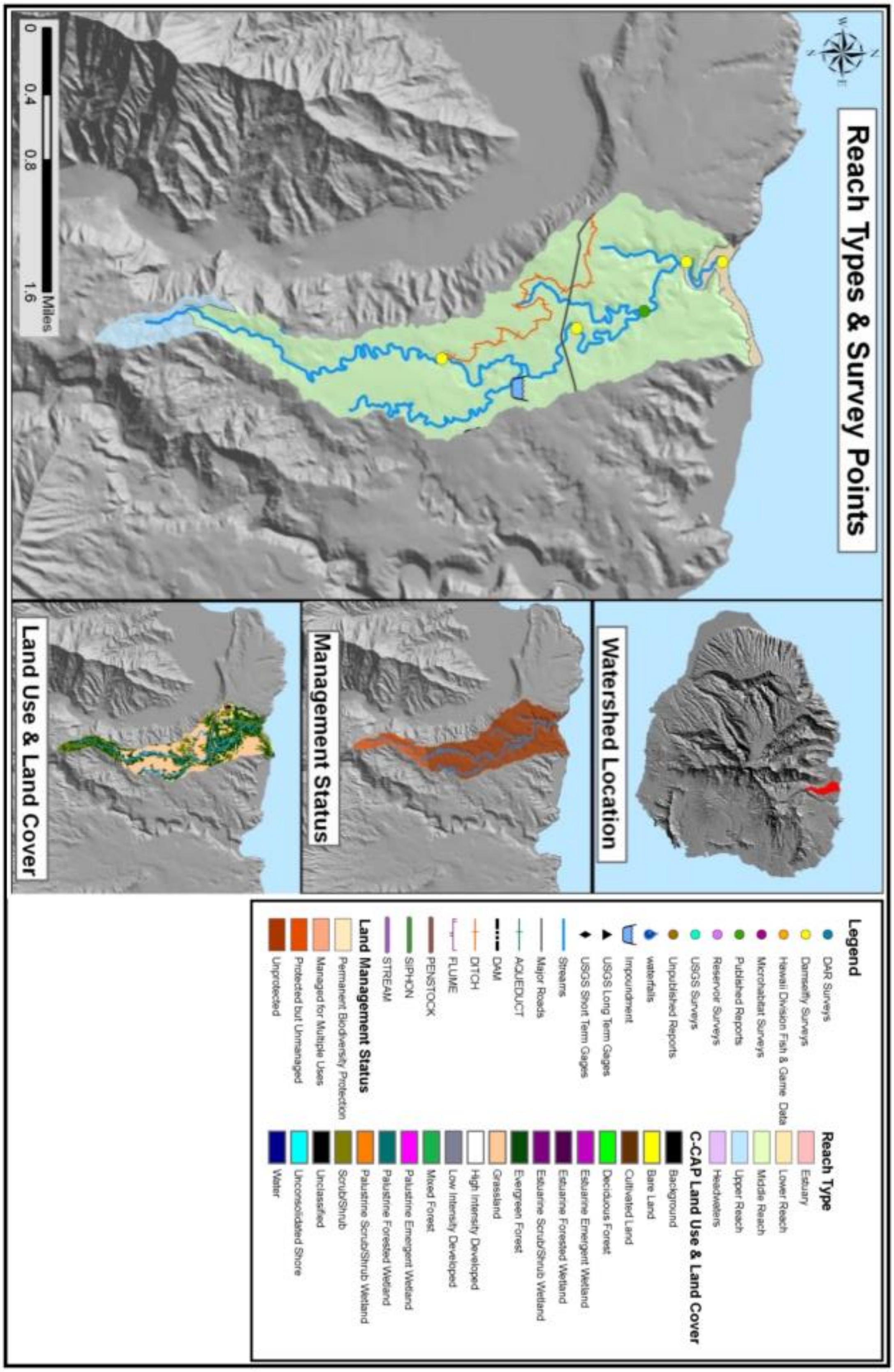


Figure 3: Anini Watershed (Dar, 2008).

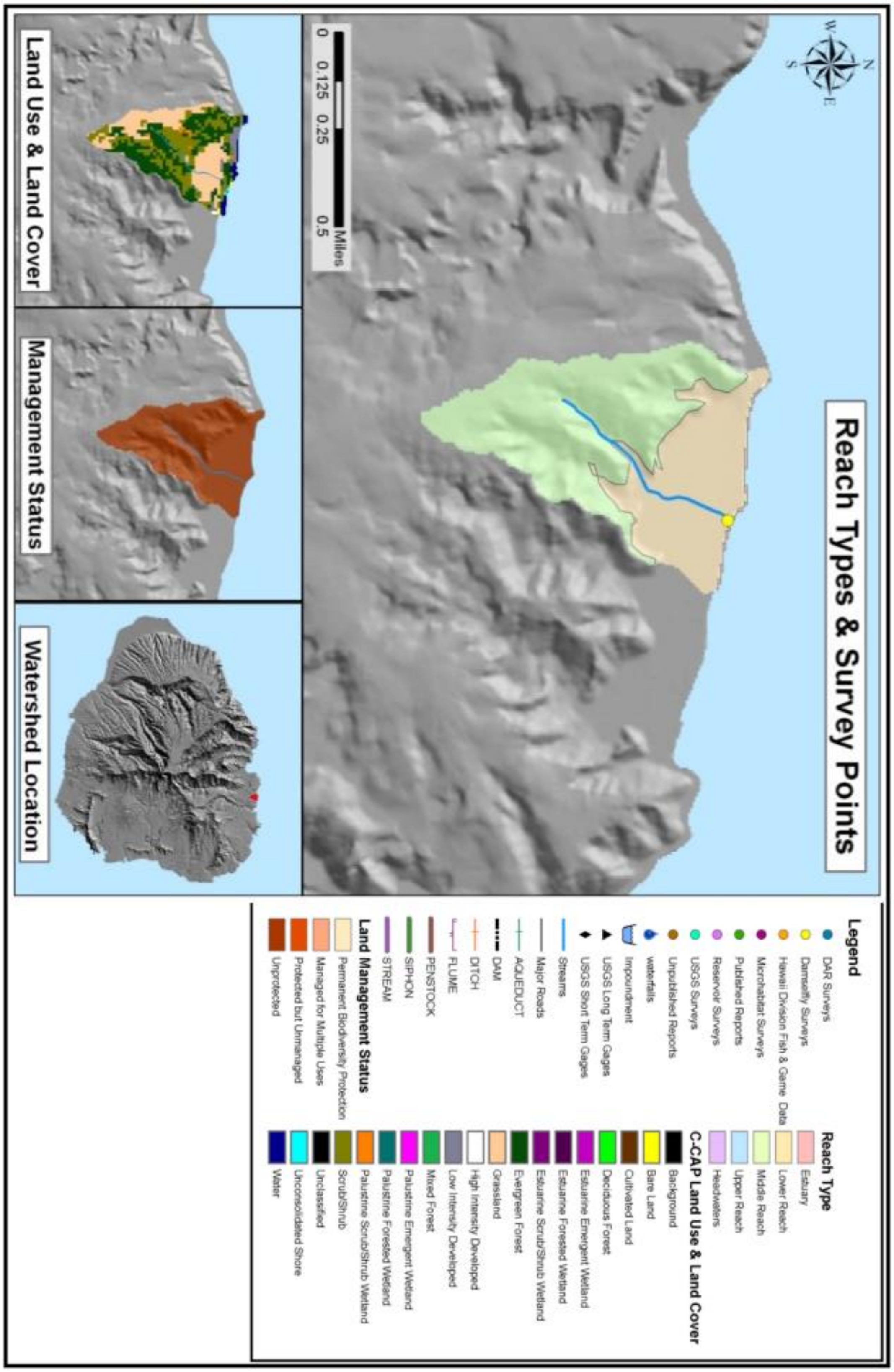


Figure 4: Honu Watershed (DAR, 2008).

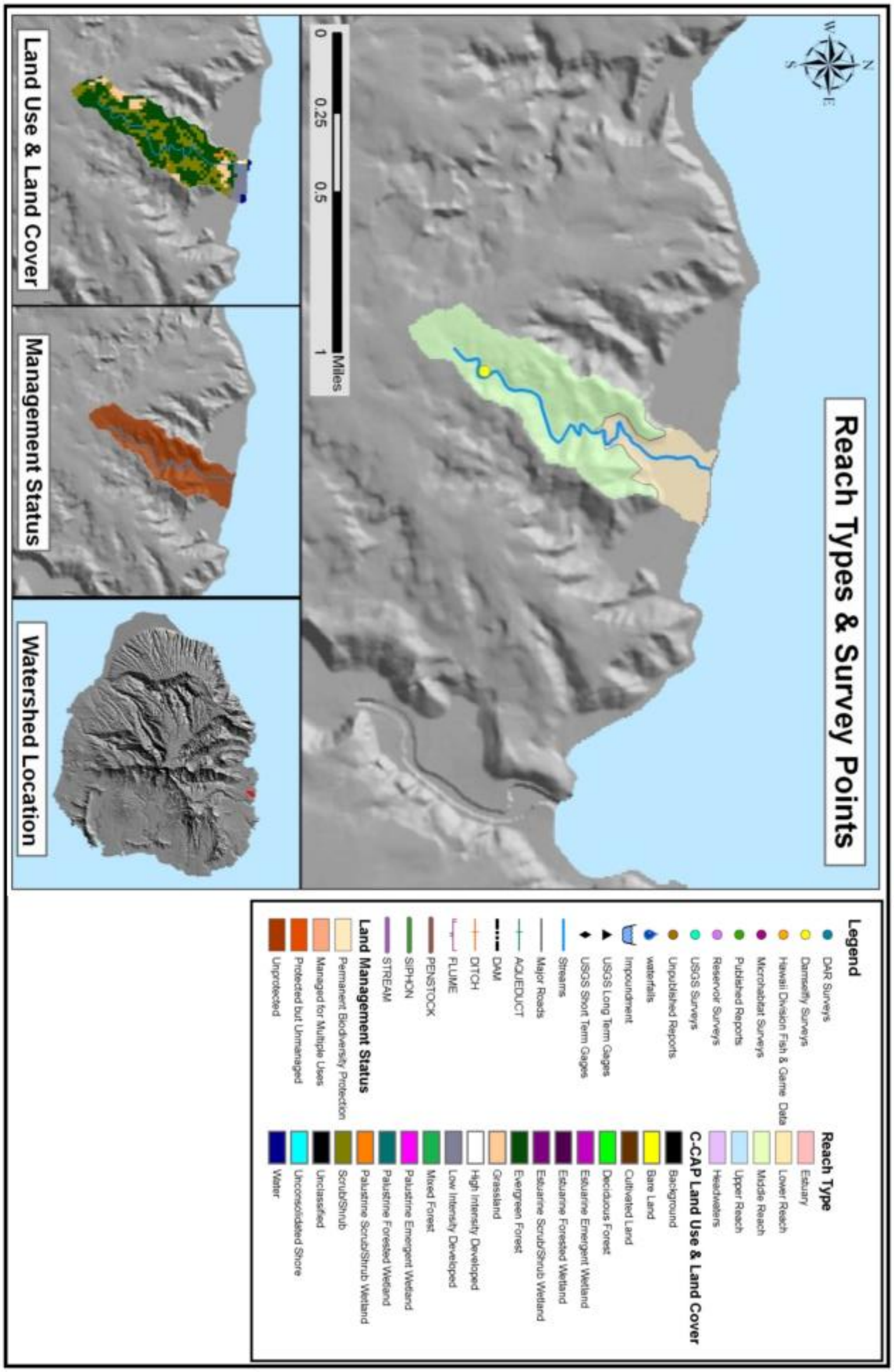


Figure 5: Kalihikai Watershed (DAR, 2008).

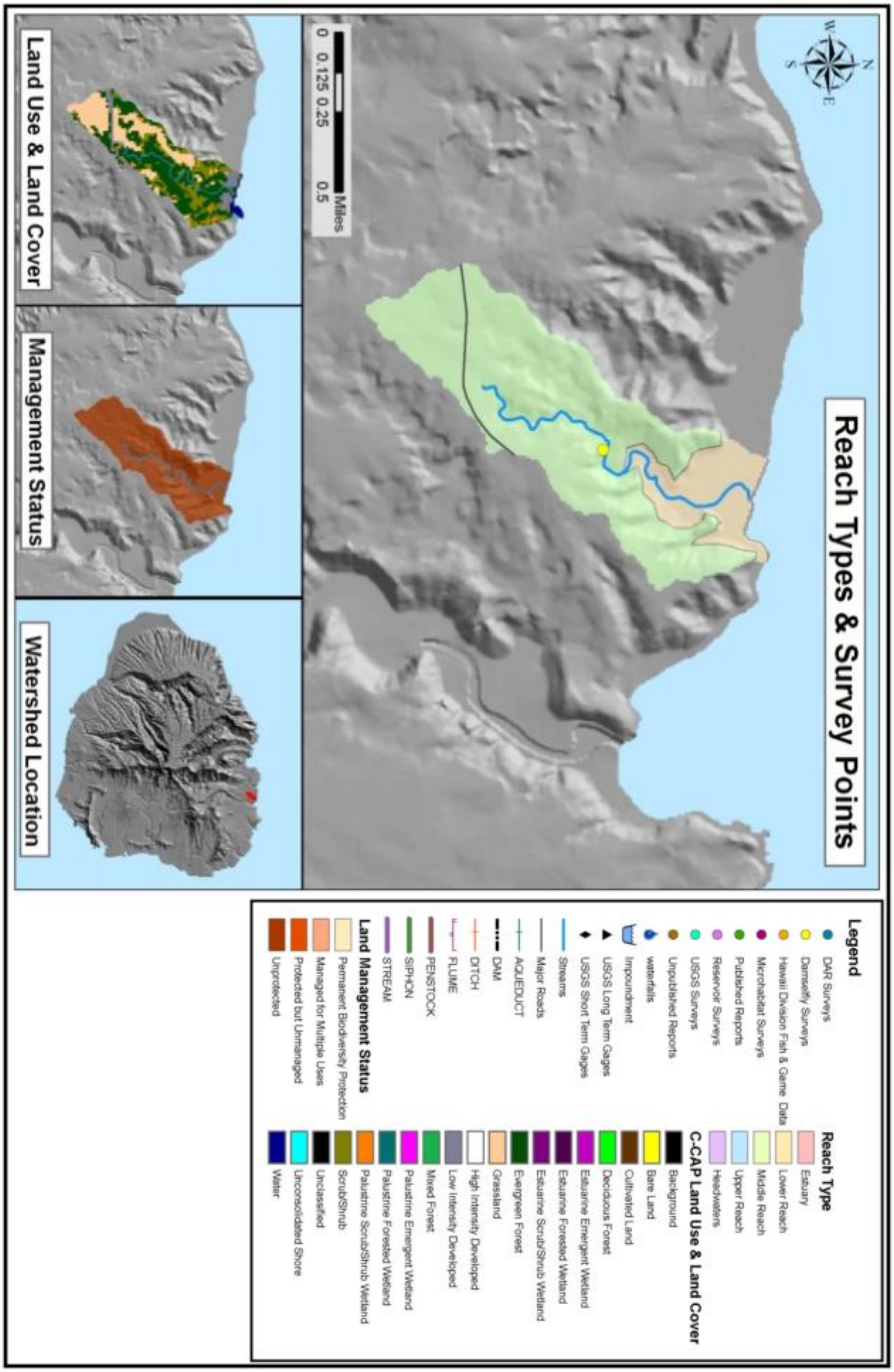


Figure 6: Kowali Watershed (DAR, 2008).

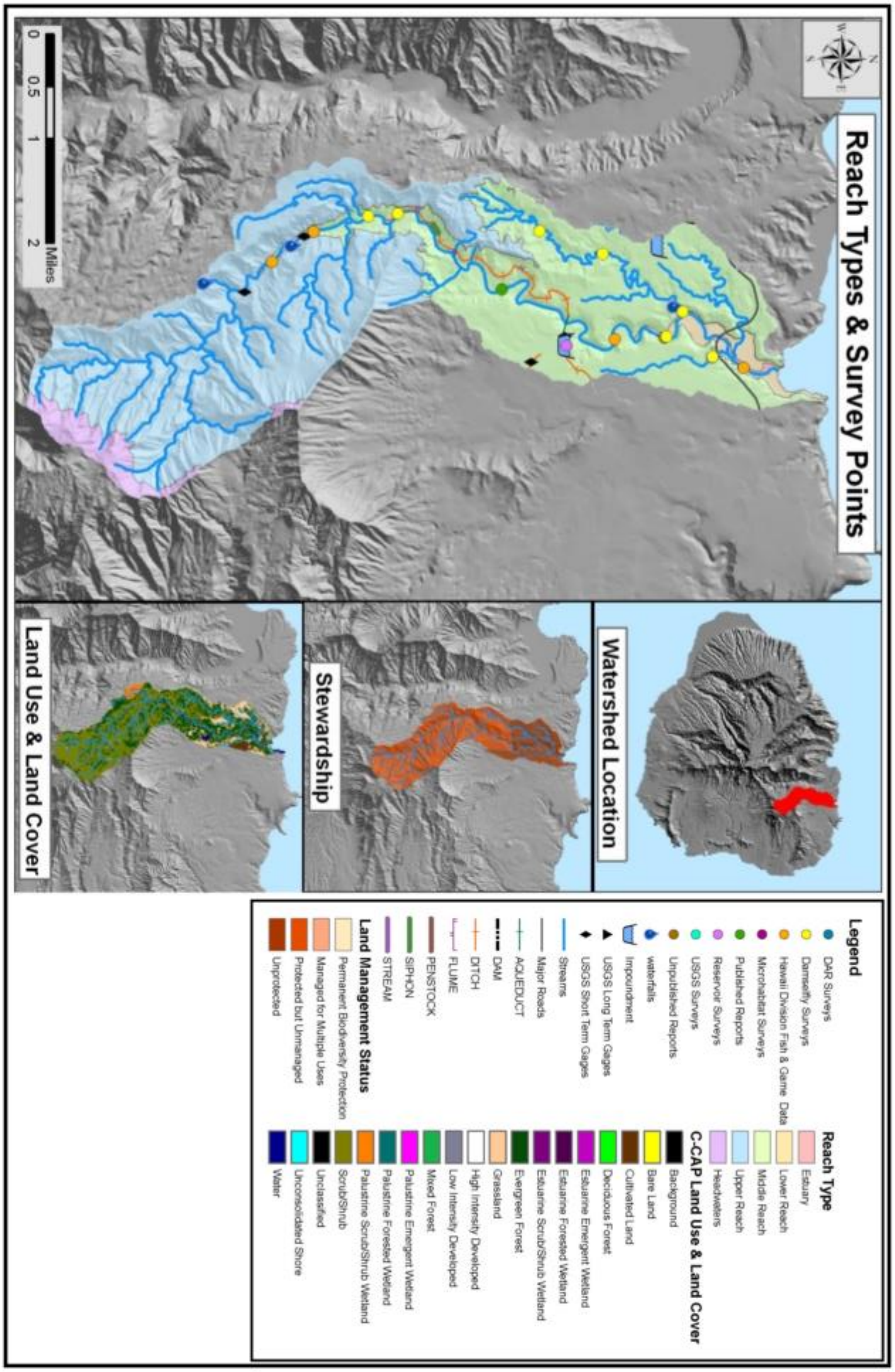


Figure 7: Kalihiwai River Watershed (DAR, 2008).

2.21 FRESHWATER RESOURCES

The project site is bordered by Kalihiwai River to the East, and Anini Stream to the West, both of which are perennial. There are several smaller, non-perennial streams in between including Honu Stream, Kalihikai Stream, and Kowali Stream (Hawaiʻi Division of Aquatic Resources, 2008). Prior to the 1980s, very little was known about Hawaiian streams. Presently, stream health can be measured using a system of metrics known as the Hawaiʻi Stream Bioassessment Protocol, a method developed in the late 1990s and early 2000 by Michael Kido, a stream biologist with the Pacific Biosciences Research Center. According to Kido, among these metrics, water diversions and land development are the most commonly seen mechanisms for stream and watershed deterioration. Livestock and feral animals can also play a role in stream deterioration by destroying native riparian (stream bank) vegetation and trampling streams causing erosion and sedimentation. Furthermore, animal waste is a known source of water contamination. This is particularly the case in the upper parts of the watershed, where the effects can be magnified downstream (Kido, M., personal communication, 2015). Due to the Princeville Ranch, cattle were known to be present in the area near Anini Stream, and may have contributed to early degradation (EIS, 1985). Rivers at Anini have also been historically diverted. Kalihiwai River had a complex diversion system for sugarcane, while Anini Stream has had several diversions for small scale agriculture (EIS, 1985; Wilcox, 1999). These diversions are likely to have impacted stream depth, flow quantity, and habitat for freshwater organisms.

Leptospirosis, a bacterial infection, can easily contaminate freshwater bodies, and potentially all streams in Hawaiʻi can become contaminated (H-DOH, Clean Water Branch 2014). Rats are often the culprits in contamination, especially if they form large populations in the upper watershed areas. There have been reports of humans being infected with leptospirosis after swimming in Kalihiwai River/Bay, and contamination may be exacerbated by periods of heavy rain (Kido, personal communication, 2015). Currently, leptospirosis is not a component in most water quality testing.

The Hawaiʻi Department of Health monitors the water quality of water bodies and provides data and sampling results in their water quality report. In their 2014 report, Kalihiwai River was the only freshwater body within the site that was listed, and there has not been enough data sampling to evaluate the water quality. The water quality report does not include every water body in the state, as not every body of water has been assessed (H-DOH, Clean Water Branch, 2014). The streams and freshwater sources in the site are mostly off the radar of regulating agencies and water quality data is sparse, although it is generally understood that streams like Anini are not in very good condition (Kido, personal communication, 8 2015). The Kauaʻi Island Coastal Resource Inventory (1982) cited a report (Timbol & Maciolek 1978) stating that “Anini stream had an ecological quality rating of III: moderate to low natural and/or water quality (well exploited, modified or degraded)”. Also, in 1983, the ecological quality of Anini Stream was considered to be poor. The landfill that was adjacent to Anini Stream at this point was described as a source of pollution in the stream (EIS, 1983).

There are multiple groundwater wells in the site, including five that are operated by Princeville. Three of these are currently in use and supply drinking water to the Princeville area as well as to customers along Anini Road. These are discussed further in Section 2.6 below.

Common threats to groundwater are over-pumping, contamination, and saltwater intrusion. Saltwater intrusion is a larger concern with wells that are closer to the ocean. Changes in precipitation, evapotranspiration, and land cover may also impact groundwater reserves. The clearing of land, especially forest, can reduce precipitation and affect groundwater recharge. Princeville and the bluffs above Anini beach were cleared prior to 1900 for cattle grazing and for a short time, the sugarcane industry. This may have caused hydrological changes at Anini.

An important aspect connecting streamflow and groundwater is base flow, the below ground component of streamflow. While streamflow often reflects trends in surface-runoff rates, base flow can reflect the amount of groundwater recharge and storage. Across the Hawaiian Islands, there has been a statistically significant downward trend in base flow over the past century (Keener et al., 2012). This long-term decline in base flow is related to long-term changes in rainfall, which has also been trending downward over the past century, and future changes in rainfall will likely impact streamflow (Bassiouni & Oki, 2012; Keener et al., 2012). Furthermore, the downward trends in base flow indicate a decrease in groundwater discharge to streams. While there doesn't appear to be a statistically significant trend in total streamflow in most locations, there is a general downward trend in streamflow, especially during low-flow (streamflow during periods of drought) (Bassiouni & Oki, 2012). In general, streamflow in Hawaiʻi is expected to be less consistent in the future due largely to changes in rainfall and overall climate change. Perennial streams may become seasonally dependent in the future, only flowing at certain times of the year. Streams that were once intermittent or had low flows may cease to flow at all (Keener et al., 2012). This general downward trend may correspond to the reductions in streamflow in Anini Stream and the ephemeral streams within Anini that have been noticed by residents of the area, which was discussed through personal communication. However, other factors like water diversions also likely play a role. According to long-time community member "Uncle Blondie" Woodward, all of the smaller streams in Anini used to have constant water flow, with oʻopu, prawns, ʻōpae, and tilapia to name a few. The streams were noted to be so deep that they used to dive off of the bridge into some of the streams. He also mentioned that the streams, which now only flow after heavy rains, lost stream flow after Princeville diverted water, although the time of this or the diversions are unknown at this point. Also, the reduction of fresh stream water may have played a role in the loss of limu ʻeleʻele, which needs brackish water to grow (Reyes & Reyes, personal communication, 2015). In addition, the construction of portions of Princeville Phase II was noted to possibly cause a "very slight decrease" in the base flow of Anini Stream (EIS, 1983).

The downward trend in base flow of streams over the past century has significant water-resource management implications. Reductions in base flow can result in less water available for agriculture, and may impact traditional Hawaiian customs such as the cultivation of taro (Bassiouni & Oki, 2012). Many of the land commission awards (LCAs) granted within Anini make note of loʻi (taro patches) and the growing of taro on the properties, and longtime residents have noted that they were raised growing taro by utilizing the springs and streams in the area. In present times there does not appear to be enough freshwater to do so, which may be an effect of decreasing stream base flow, as well as water diversions. The reduction in freshwater discharging into the ocean may have impacts on marine changes, such as the decline of limu. The withdrawal of groundwater may be a factor. Reductions in groundwater reserves have significant implications for Hawaiʻi since more than 90% of drinking water is sourced from groundwater (Bassiouni & Oki, 2012).

2.22 WETLANDS

There are several wetland areas in Anini, with two freshwater emergent wetlands near Kalihikai beach. The coast along Anini is identified as an estuarine and marine wetland. Several other small wetlands are located more inland, especially towards Princeville (U.S. Fish and Wildlife Service, 2015).

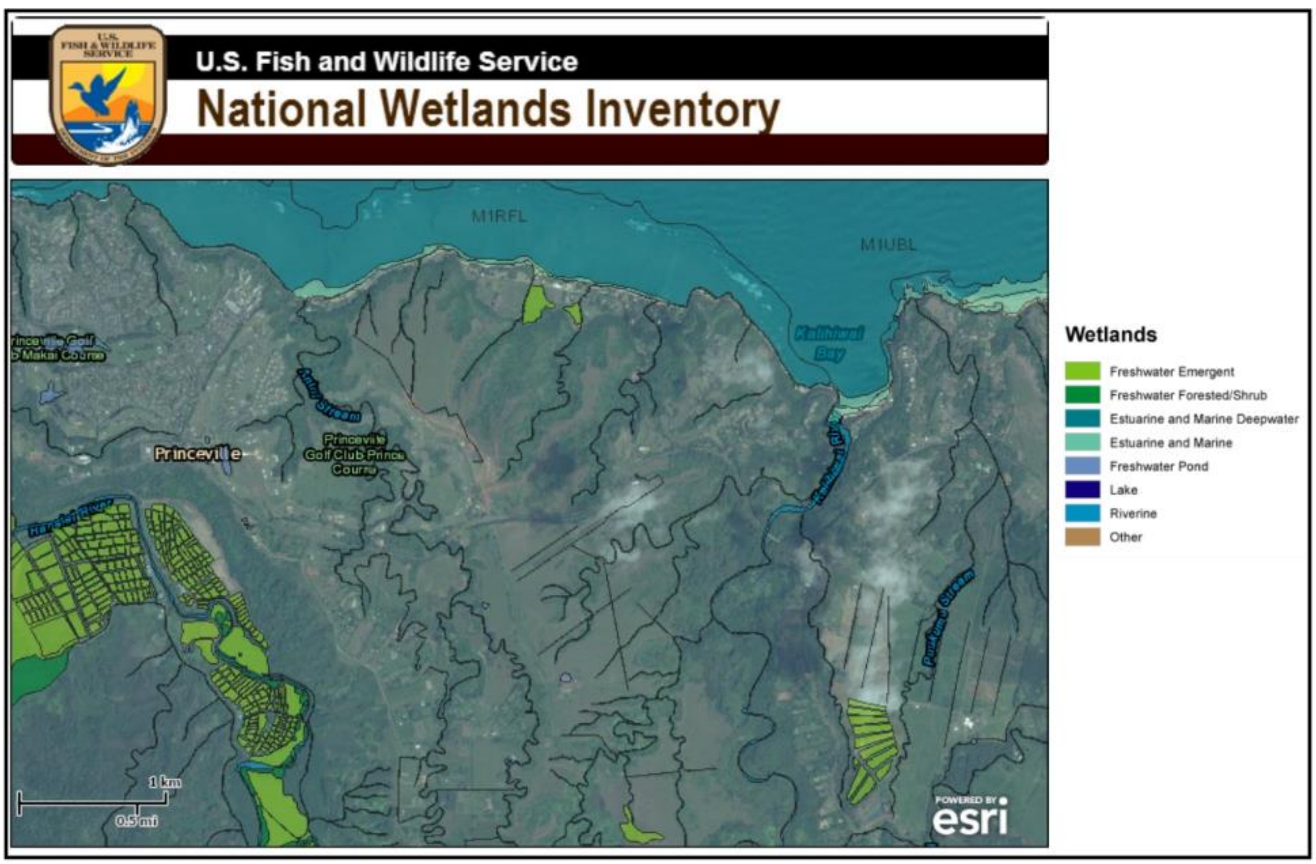


Figure 8: Map of local wetlands (USFWS, 2015).

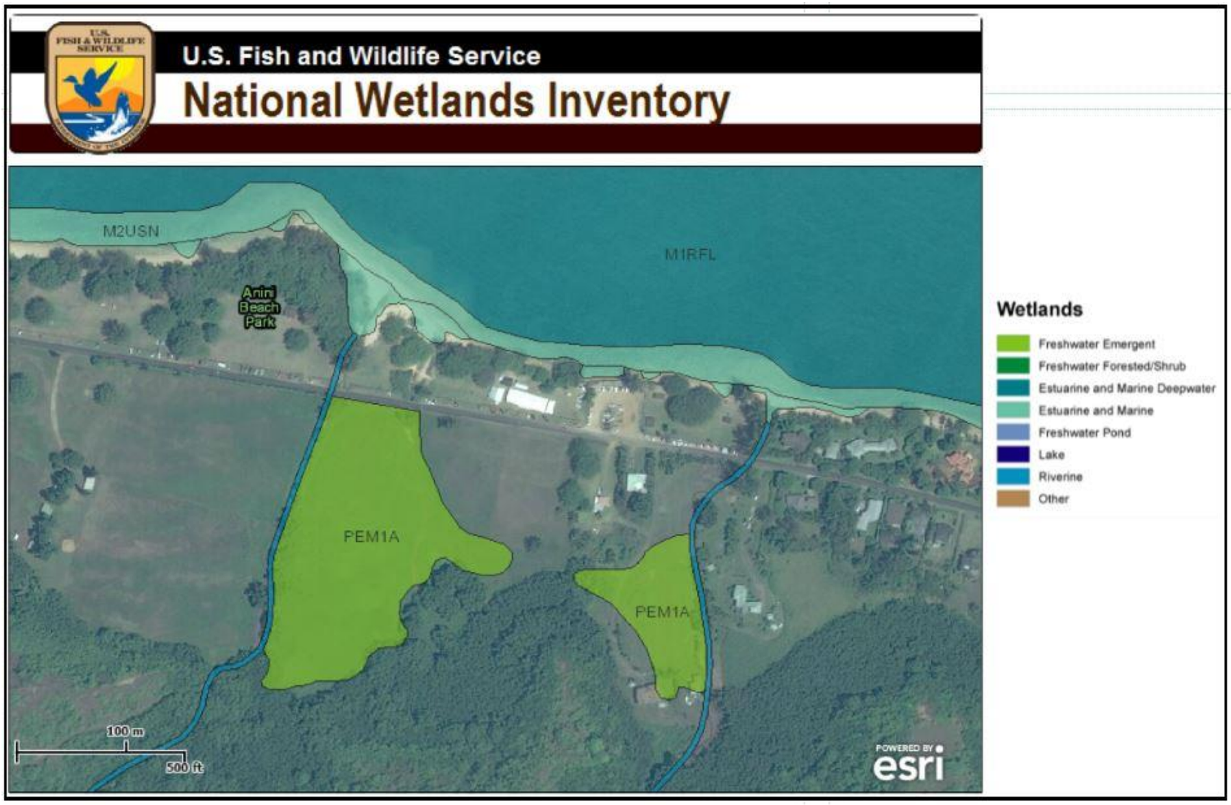


Figure 9: Zoom in of Anini wetlands (USFWS, 2015).

Wetland irrigation and modification dates back to 600 AD on Kauaʻi and 1200-1400 AD on Oahu and Molokai, when Polynesian settlers used wetlands for taro cultivation and fishpond buffers. Expansion of Polynesian irrigation systems may have allowed the permanent colonization of Hawaiʻi by waterbirds. Whether or not this is true, it is likely that these habitats were used by native Hawaiian waterbirds in the same fashion as they are today (Pacific Coast, 2006).

After European contact, wetland modification increased exponentially to allow for plantation style sugarcane and pineapple. This change in land use drastically altered the landscape by draining wetlands for massive irrigation. At the same time, increased deforestation and livestock grazing created large amounts of soil erosion that filled coastal wetlands. The introduction of plant and animal species has indirectly modified wetlands. Plants such as mangrove, California grass, and pickleweed have spread throughout many wetland areas and altered the natural vegetation and sedimentation patterns. These exotic plants out-compete native plants and reduce the interspersion of open water and vegetated areas, thereby decreasing native wetland habitat. Introduced animals have led to the population decline of endemic waterbirds, which has, in some cases, led to their extinction. An example of this is the Hawaiian duck, which is threatened due to its ability to hybridize with the non-native mallard (Pacific Coast, 2006; Ducks Unlimited, 2012).

Currently, housing and resort development is considered to be the largest threat to Hawaiian wetland habitats. Since World War II, a decrease in agriculture and an increase in tourism have opened up prime areas for high dollar developments. Past developments nearby Anini including residential and commercial development may have impacted wetlands in the area. Future developments, such as the proposed Princeville expansion, may also be a non-point source of pollution in these wetland areas (Pacific Coast, 2006). Another threat to wetland health is the diversion and manipulation of nearby surface and groundwater. Wetlands are usually fed by groundwater, and mixed with surface water. Underground water diversions can particularly affect wetlands by depleting their source of replenishment (Kido, personal communication, 2015). There has also been a history of stream diversions such as those from the Kilauea Sugar Company and Princeville, which are discussed later in this document (EIS, 1985; Wilcox, 1999).

Wetland protection in the State of Hawaiʻi is not solely designated under any one law, but rather it is partly addressed in several different state laws that address different properties and aspects of wetlands, such as wildlife, land and natural resource use, and water quality. Managing and enforcing these laws is therefore split between multiple federal and state agencies. On the federal side, these include the U.S. Environmental Protection Agency (EPA), U.S. Army Corps of Engineers, National Resources Conservation Service (NRCS), U.S. Fish and Wildlife Service (FWS), U.S. Department of Defense (DOD), National Oceanic Atmospheric Administration (NOAA), and the National Park Service. The state agencies involved are the Hawaiʻi Coastal Zone Management Program (CZM), Department of Land and Natural Resources (DLNR), and the Department of Health (DOH) (Pacific Coast, 2006).

2.3 LAND USE AND DEVELOPMENT HISTORY

2.31 PRINCEVILLE HISTORY AND DEVELOPMENT

The lands known as “Princeville,” located within the ahupuaʻa of Hanalei, are characterized by sloping, broad, upland ridges and a large plateau cut by gulches that open out on to Anini Beach. Princeville is an important area in relation to Anini because it is located directly above the beach on a cliff. Because of the direct relationship, activities in Princeville potentially affect the beach and streams in Anini. One issue of significant concern to the Anini community is storm water runoff from Princeville, which potentially contains contaminants originating from the golf course, inevitably ending up in streams and coastal waters.

Princeville received its Western name in the 1800s. It was named to honor a visit by Prince Albert Kamehameha in 1860 when he was the age of four. Prince Albert Kamehameha was the son of King Kamehameha IV and Queen Emma. His parents dedicated this place to their son on that visit. The area developed into a plantation, owned by Robert Crichton Wyllie from 1822-1876. Wyllie grew coffee starting in 1853, and switched to sugar in 1962. Wylie continued developing sugar cane until his passing, at which time he left Princeville to his nephew, Elisha Hunt Allen. Allen allowed the Chinese firm of Chulan and Company to rent the land for five years in 1880 for rice cultivation. In 1865, Elisha Allen sold the plantation and in the 1890’s, A. S. Wilcox converted the property to be used for cattle grazing. In 1916, the Lihue Plantation Company Ltd acquired the land and operated a cattle ranch. In addition, approximately 400 acres of pineapple land was cultivated in 1958 (Belt, 1962). In 1968 the land was sold to Eagle County Development, now known as Princeville Development Corporation (PDC), for the development of a resort and golf course (Hackler, 1982).

Historically, the land at Princeville was grasslands, but was bulldozed to make way for the development of the Princeville resort and golf course in 1970. Soon after, Princeville became a tourist destination. The area became known as Princeville Resort, and includes two golf courses, a shopping center, and a commercial airport (EIS, 1983-17). There is also a residential community, with more than 11, 000 acres of prime real estate overlooking Hanalei Bay from the cliffs (EIS 1983-54). In 1985, the hotel was renovated for $120 million, adding 252 luxury rooms, 20 tennis courts, and a theater. Of the two golf courses, one is the famous 27-hole Makai course and the other is the 18-hole Prince course (Figure 2) (EIS, 1983-54).

According to an EIS conducted in 1983 for Princeville Phase II, there were two cattle burials in the area, a result of anthrax epidemics that hit Princeville ranch in 1890 and 1917 (EIS 1983). The cows were buried 20 feet below ground to prevent anthrax spores from spreading. Currently, one of two burials is located under single-family homes. The second burial is under the Prince golf course (EIS 1983, IV-88) (Figure 7).

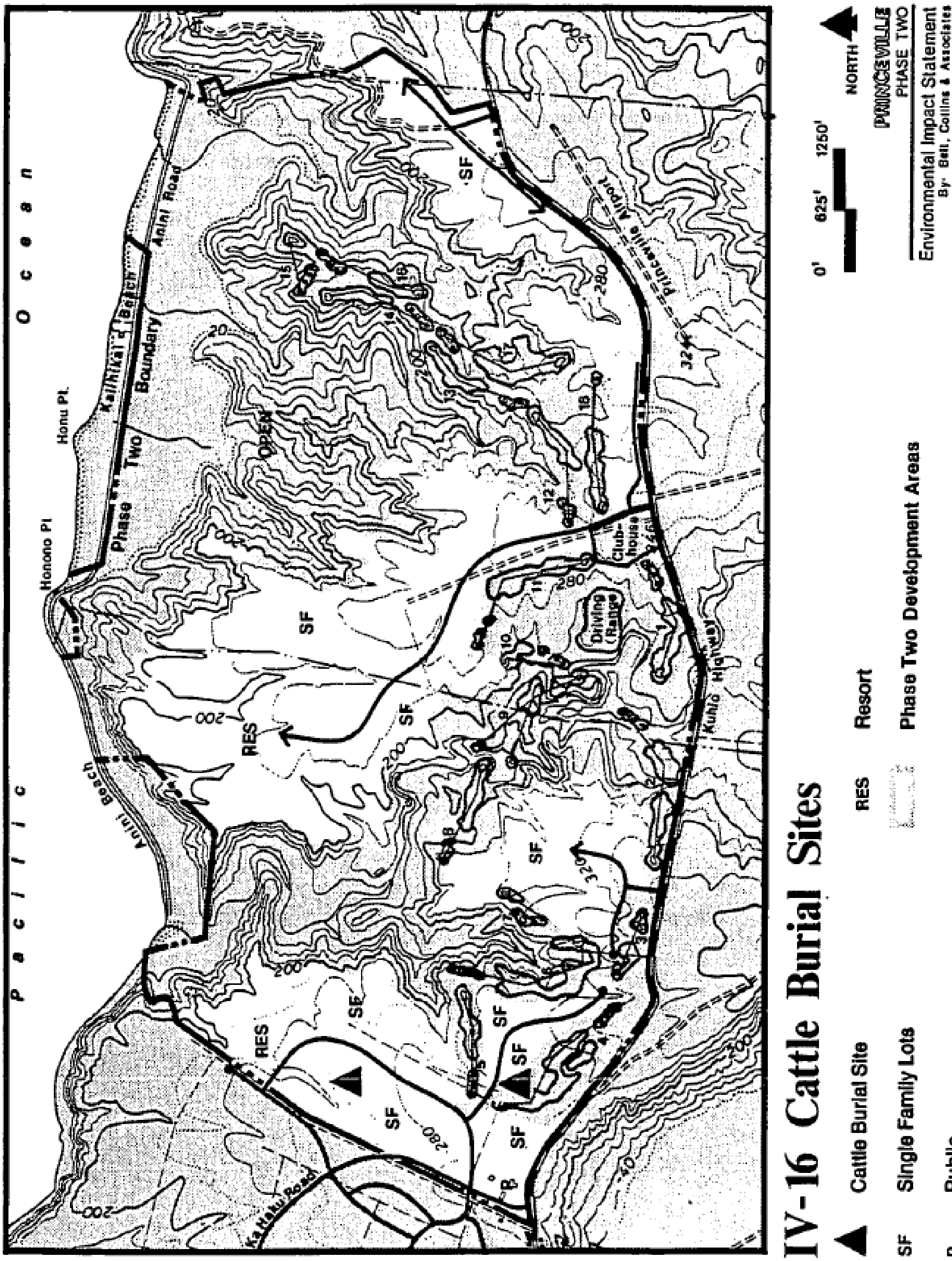


Figure 10: Topographic map identifying cattle burial sites in Princeville (EIS, 1983).

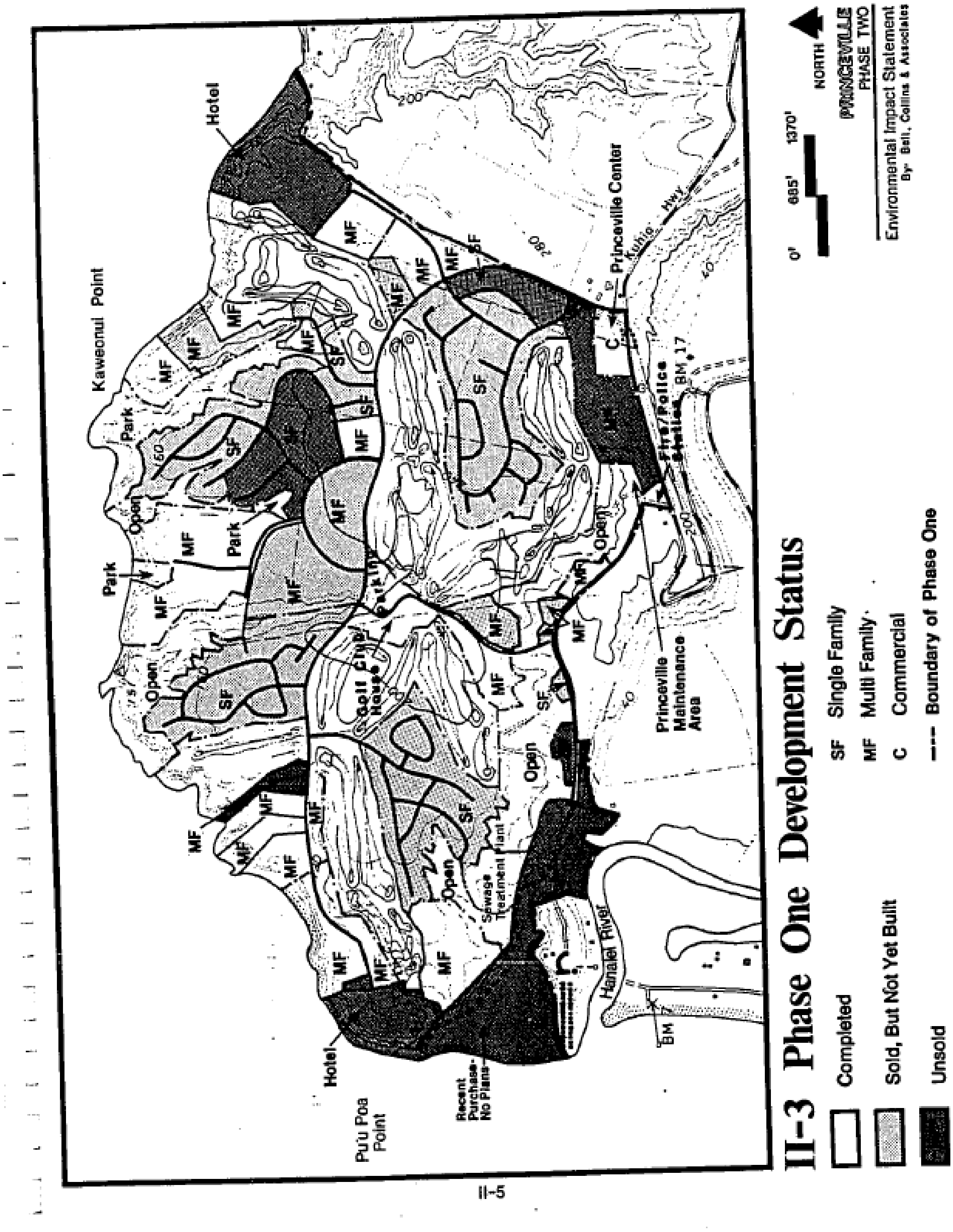


Figure 11: The development states of Princeville in the 1980s (EIS, 1983).

2.4 WATER DIVERSIONS

Virtually all water withdrawals directly or indirectly affect stream flow, with the most obvious form being stream diversions. Many historical diversions, such as those used by sugar plantations, removed so much flow that streambeds below the diversions were completely dry during periods of low precipitation. By 1920, 800 million gallons of water each day was being diverted from over a hundred streams across the state of Hawaiʻi (Wilcox, 1999). No streams within the watersheds of the Anini area appear to have been diverted for sugar.

2.41 SUGAR PLANTATION

Sugarcane requires large and continuous amounts of water to grow. Sugar plantations across the state have a history of manipulating water flows and creating diversions to irrigate their crops. This is significant to the Anini area because the Kilauea Sugar Plantation, operated by C. Brewer & Company, existed adjacent to the area for nearly a hundred years. To irrigate their sugarcane crops, Kilauea Sugar Plantation had a system of four ditches built circa 1880-1900: Mill, Koʻolau, Puʻu Ka Ele, and the combined Kaloko and Moloaʻa ditch. These connected six reservoirs: Kalihiwai, Stone Dam, Puʻu Ka Ele, Morita, Waiakalua, and Ka loko. Ka loko reservoir was the largest with a 408,856 gallon capacity. The total capacity of the irrigation system was over 730 million gallons. Other than Kalihiwai, the reservoirs were all constructed in 1911 (Wilcox, 1999). When the Kilauea Sugar Plantation closed in 1971, connections between reservoirs and the delivery systems started to become degraded and destroyed by roads, pastures, developments, and from neglectful maintenance. For example, the Hanalei Ditch (which fed Kalihiwai Reservoir) was abandoned; the connection between Kalihiwai Reservoir and Stone Dam was destroyed, as was the connection between Puʻu Ka Ele and Morita reservoirs. The delivery systems from Puʻu Ka ele and Ka loko reservoirs were also destroyed (Wilcox, 1999).

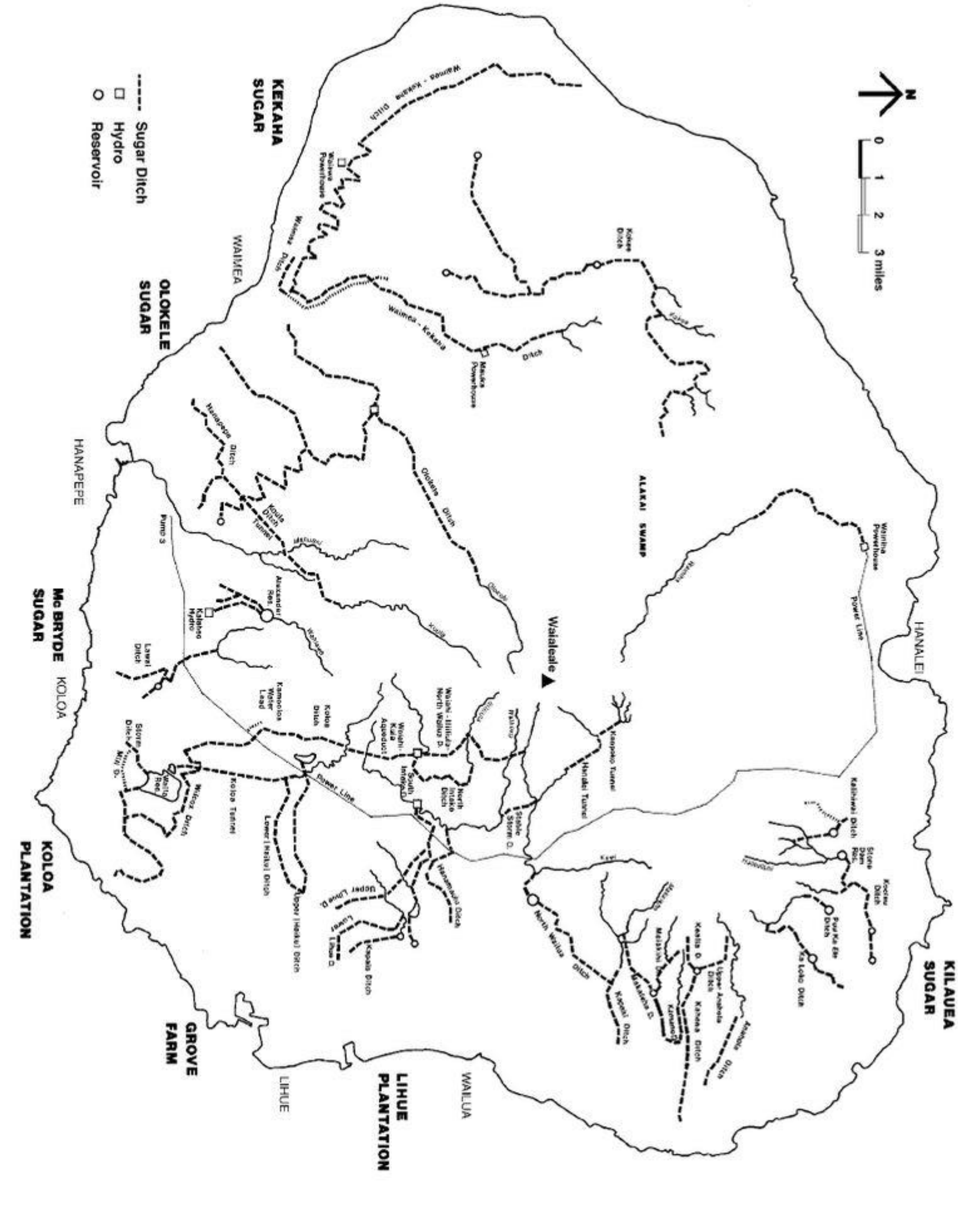


Figure 12: Major sugar plantations and ditches, Island of Kauaʻi (Wilcox, 1999).

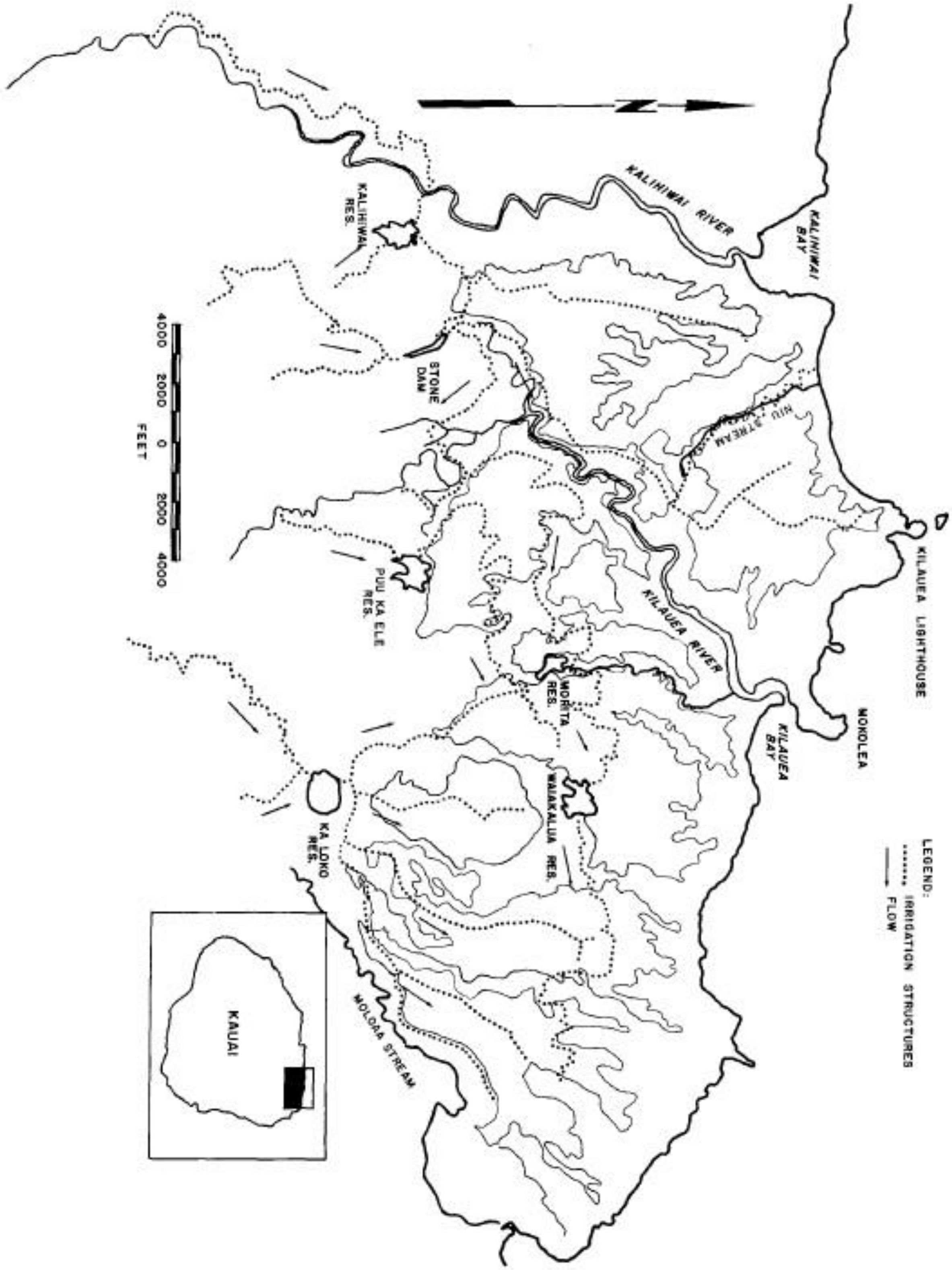


Figure 13: Irrigation system for Kilauea Sugar Plantation (Lau, 1972).

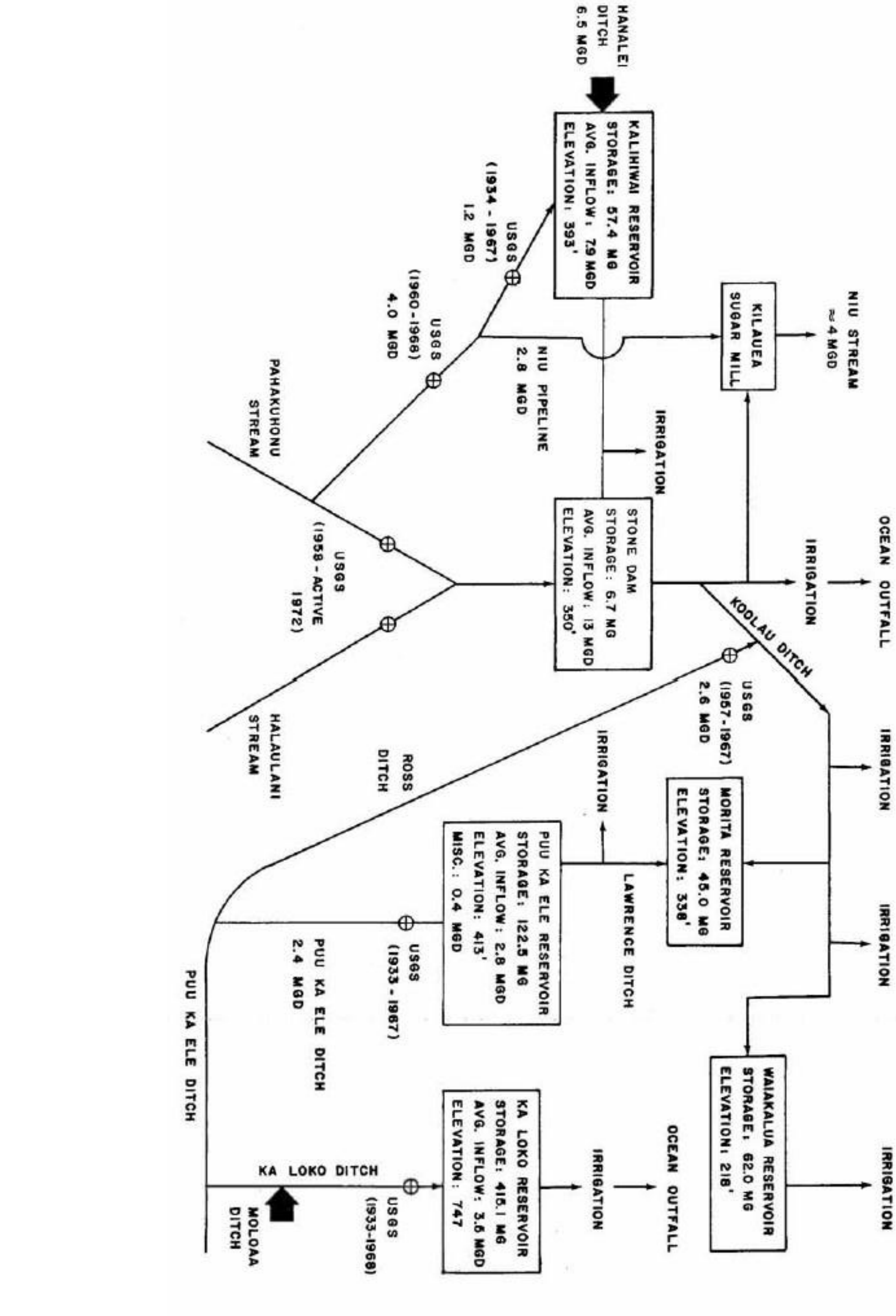


Figure 14: Irrigation Schematic for Kilauea Plantation. Inflow from USGS records, 1961-1966 Kilauea Plantation Records (Lau, 1972).

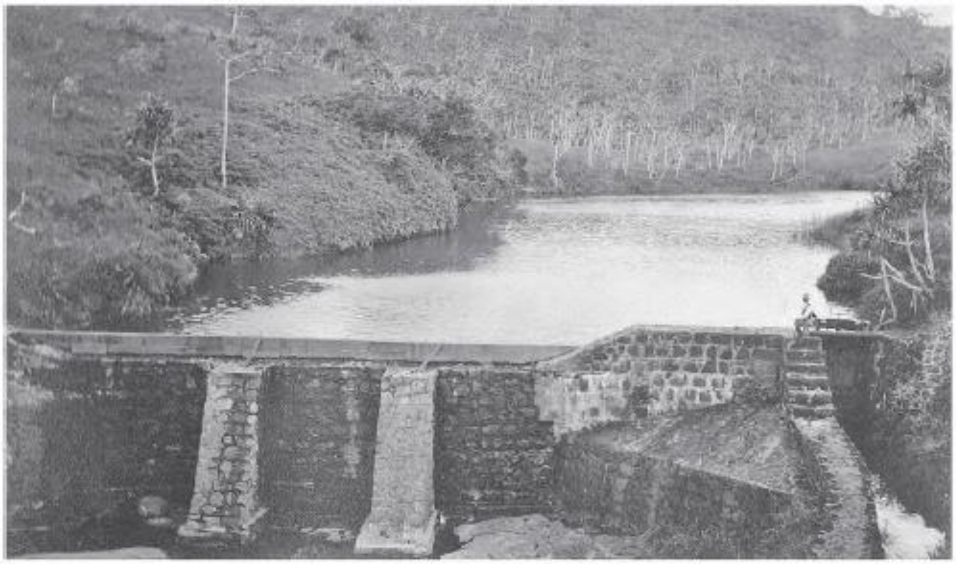


Figure 15: Stone Dam in 1912 (MacLennan, 2007).

Figure 16: A diversion ditch for Kilauea Sugar Plantation in 1912 (MacLennan, 2007).

2.42 KALIHIWAI RESERVOIR

Constructed in 1920, the Kalihiwai Reservoir is a privately owned facility serving the community of Kalihiwai Ridge. The reservoir was originally designed to serve the Kilauea Sugar Plantation (KalihiwaiReservoir.info, 2011). Water from Kalihiwai reservoir flowed to Stone Dam (Wilcox, 1999). After the plantation closed in 1971, the reservoir was used to feed prawn lagoons and the Guava Kai Plantation. The reservoir now serves as a wetland habitat and as an emergency fire suppression supply, in addition to being a source of drinking water for the Kalihiwai Ridge community. It is a federally recognized wetland habitat and is home year-round to three of the five endangered Hawaiian waterbirds (KalihiwaiReservoir.info, 2011).

The reservoir is located to the East of Anini, and is estimated to have a maximum storage between 80 and 140 million gallons. There are several communities existing in the possible drainage and flooding pathways of the reservoir, which prompted a study in 2006 by FlowSimulation, LLC to estimate different outcomes of the reservoir dam breaking. According to the report, under the “worst case scenario”, no residential structures would be inundated with flooding, and only two non-residential structures, characterized as a “boat storage structure” and “small illegal structure” would be inundated by as much as 0.7 ft. of water (FlowSimulation, 2006).

2.43 KALIHIWAI RIVER

In 1922 the Hanalei ditch was constructed to supplement Kilauea Sugar Plantation’s irrigation, and diverted water from Kalihiwai River. It was 3.8 miles long, the longest in the Plantation’s system, and had a capacity between 10 and 15 million gallons per day. The ditch was destroyed after the plantation closed (Wilcox, 1999). Other diversions from Kalihiwai River have existed in the past and may still exist today.

2.44 ANINI STREAM

Anini Stream is one of the smallest systems used by the Department of Water (DOW) in terms of water consumption. Only 63 metered users, including Kalihikai Park, a polo field, and residence on Anini Road utilize this water. In addition, customers along Anini Road are also serviced by the Princeville water system with a 4-inch PVC waterline. This pipe crosses Anini stream and then follows it to the terminus (DOW, 2011). These systems were created in the 1970’s and are now in need of repair.

The 1983 EIS notes five irrigated agricultural systems or lo‘I kalo 300 meters inland from the mouth of Anini stream, four on the east side and one on the west side of the stream. They were noted in 1983 to be in good condition and have separate ‘auwai systems, which were traced to man-made dams in Anini Stream. Although areas further upstream were not explored at the time, additional agricultural systems may have existed and may still exist (EIS, 1983).

In the area around Anini Stream Gulch, the topography is very steep and thick with vegetation of guava, panadanas, and guava plum. Bulldozing is evident in the gulch. The gulch was investigated for archeological and historic features for the determination of road widening in 1962 of the main “Belt Road” of Kuhio Highway. The Archeological Research Center Hawai‘i, Inc. found no evidence of historic sites (Proby, 1980).

There are 8 smaller erosional gullies in the Kalihikai plateau. Soils in this area are subject to severe erosion because of steep slopes (not because of soil composition as seen in Figure 2). The Anini stream is 4 miles long covering a 1,244 acre stream basin.

PDC was aware of development runoff like roadway contaminants, pesticides, fertilizers, fuel, lubricants, hydraulic fluids and coolants. However, they noted that already by the 1980’s the stream was in poor health because of the pollutants of the landfill next to Anini Stream, however no data could be found on when the landfill was established and stopped (EIS 1983, IV-30). Water quality was also poor due to the landfill and the addition of further development. The lease on the landfill came to a close around 1983

(EIS, 1983). Today, there is a refuse transfer station mauka of Kuhio Highway located adjacent to Anini Stream. Princeville itself has a private refuse collection company to transfer solid wastes (EIS, 1983).

The Hawaiʻi Commission on Water Resource Management maintains a database of all registered surface water diversions. This database is based upon self-reported information and does not include all the diversions throughout the state. Furthermore, registered diversions may or may not currently still exist, or may not be in their original condition.

Figure 17 shows a map of all registered diversions in the area including three on Anini stream and five on Kalihiwai River. One diversion is noted to be near the mouth of Anini Stream, which is consistent with the diversion for loʻi kalo in this area as described above. Kilauea River and nearby surface waters also show multiple diversions. All diversions, whether they are shown in the figure above and whether or not they exist today, have, or have had an impact on surface water through reductions of flow.

Water quantity in streams can be substantially reduced due to multiple factors including diversions, deforestation, and wells which reduce ground water levels and thus base flow of streams. Maintaining healthy streamflow is important for local biota such as the oʻopu and hīhīwai, and is also important for recharging groundwater and maintaining wetlands. Historical and current diversions located in Anini are likely to contribute to the decline in freshwater biota.

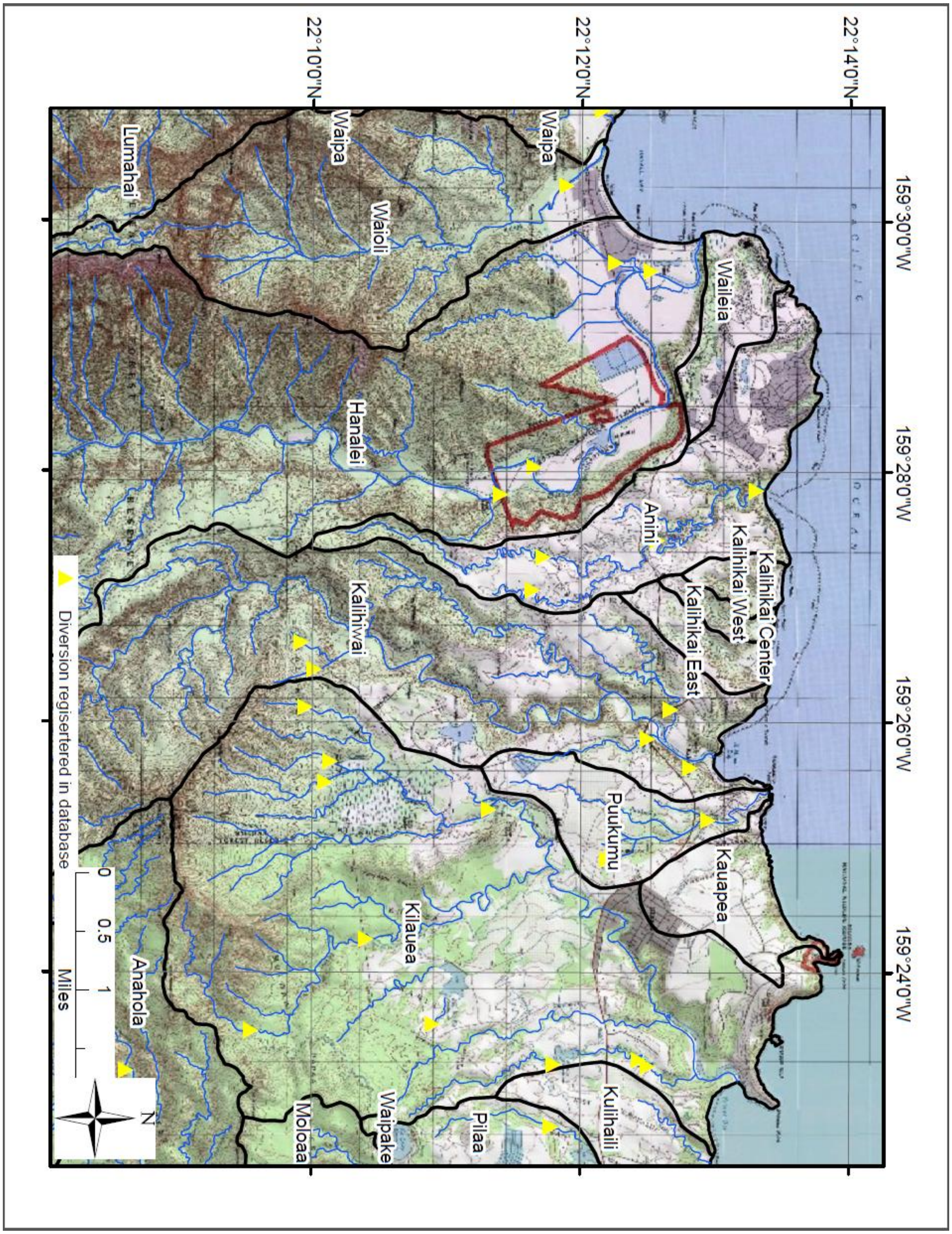


Figure 17: Registered surface water diversions as of 1991 (Hawaiʻi Commission on Water Resource Management, 2015).

2.5 BIODIVERSITY

2.51 FRESH WATER STREAM LIFE

An Environmental Impact Statement was published in 1983 for the Phase II Princeville development (EIS, 1985). This is the first known government document that conducted scientific surveys from Kalihiwai to Princeville. Besides personal communications with aquatic biologists who have worked extensively in the area, this study is the first documentation of biota, both terrestrial and marine, in these areas. Specifically, the EIS included a survey done on Anini Stream in November 1982 by Dr. Don Heacock and Dr. Amadeo Timbol. The survey investigated four sites along Anini Stream, in which fish, prawns, crabs, snails, and frogs were documented (Figure 19). Endemic and indigenous species of fish that are important to the stream ecosystem were still present at this time. Furthermore, the survey described Anini Stream as having good water quality both in the estuary and throughout the stream, to the extent that the stream bottom could be seen even in the deepest pools. The stream bottom consisted of rocks and boulders with a thin layer of algae that was free of sediment. The native oʻopu and ʻōpae were noted to be abundant in certain areas (Timbol, 1982; Heacock, 1989).

Table IV-12. Aquatic Macrofauna in Anini Stream, Kaua'i.[1]

Scientific Name	Local Name	Origin[2]	Distribution and Relative Abundance[3] Stn. 1	Stn. 2	Stn. 3	Stn. 4
FISH						
1. Awaous stamineus	'o'opu-nakea	endemic	A	U	U	O
2. Eleotris sandwicensis	'o'opu-akupa, 'o'opu-okuhe	endemic	C	O	O	O
3. Kuhlia sandvicensis	aholehole	endemic	A	O	O	O
4. Mugil cephalus	'ama'ama, mullet	indigenous	A	O	O	O
5. sphyraena barracuda	kaku	indigenous	C	O	O	O
6. Tilapia (=Sarotherodon) mossainbica[4]	tilapia	introduced	C	O	O	O
7. Xiphophorus helleri	swordtail	introduced	O	C	A	C
PRAWNS						
1. Macrobrachium grandimanus	'opae-'oeha'a	endemic	A	O	O	O
2. Macrobrachium lar	Tahitian prawn	introduced	A	A	A	U
CRABS						
1. Metopograpsus messor	thukuhar	indigenous	C	O	O	O
SNAILS						
1. Neritina granosa[5]	hihi-wai	endemic	U	O	O	O
2. Theodoxus vespertinus	brown wi	endemic	C	O	O	O
FROGS						
1. Rana catesbeina	bullfrog	undetermined	C	C	C	C

[1] Field observations of fauna on November 11, 13, and 20. Physical damage to the stream and its vegetation was surveyed post-hurricane Iwa on November 24 and 30.

[2] Endemic - occurring naturally in Hawai'i only; Indigenous - occurring naturally in Hawai'i and elsewhere; Introduced - brought to Hawai'i either intentionally or accidentally.

[3] A - Abundant (more than 5 individuals)
C - Common (between 2 and 5 individuals)
U - Uncommon (only one individual seen)
O - Absent (neither sighted nor collected)

[4] Tilapia was not seen by Timbol but resident living near Station 1 confirmed presence of this species.

[5] Maciolek (1978) states that this snail is depleted, "apparently...from habitat degradation and exploitation."

Source: Timbol (December 1982).

Figure 21: List of species observed in Anini in 1983 (EIS, 1983).

Comparatively, Heacock surveyed Anini Stream again in 1989 and found it to have deteriorated significantly since his last survey. Particularly, the water quality in the estuary was noted to be very turbid and have significant sedimentation to the extent that the entire bottom in the lower reaches was covered with mud and soil aggregates. The water quality in other parts of the stream had also deteriorated to the point where the entire bottom had layers of soil and soil aggregates ranging from a 1/8 inch to 18 inches in deeper pools. Additionally, no ʻōpae were found and very few oʻopu were seen. Golf balls with the Princeville insignia were also mentioned to be "abundant" in the lower reaches of the stream (Heacock, 1989).

Heacock also describes a conversation with a nearby resident, who had concerns over the health of the stream and the possible impacts to the marine ecosystem. According to Heacock, the resident had noticed heavy sedimentation of the stream, increased storm water runoff, and erosion of adjacent hills. Furthermore, this resident and others had noticed the sedimentation started to increase approximately two years prior, and many attributed it to the expansion of the Princeville Prince Golf Course and other developments (Heacock, 1989).

Additional biotic sampling has been conducted across the Anini area and has consisted mostly of damselfly surveys, but stream sampling was also done. An additional survey was performed in 1990 which investigated one site along the middle reach of Anini Stream (Hawaiʻi Division, 2008). The table below depicts native species observed during surveys on Anini Stream in 1982, 1989, and 1990. The 1982 survey listed additional species (both native and introduced) however the list has been condensed to include those considered more scientifically, biologically, economically, and/or culturally valuable (Heacock, 1989). No surveys of Anini Stream post-1990 were found.

Table 3: List of native aquatic species noted to have scientific, biological, economic, and/or cultural value, and their surveyed presence in Anini Stream (Division, 2008; Heacock, 1989; Timbol, 1982).

Species	Survey Year		
	1982	1989	1990
Brown Wī (Theodoxus vespertinus)	Observed		
Hīhīwai/Wī (Neritina granosa)	Observed		Observed
ʻOʻopu nākea (*Awaous gaumensis*)	Observed	Observed	Observed
ʻOʻopu akupa/okuhe (*Eleotris sandwicensis*)	Observed		
ʻŌpae kala'ole (Atyoida bisulcata)	**	**	Observed
ʻŌpae ʻOeha'a (Macrobrachium grandimanus)	Observed		Observed

Tahitian prawn (Macrobrachium lar)	Observed		
Tilapia (Tilapia mossambica)	Observed*		
Thukuhar (Metopograspsus messor)	Observed		

*Tilapia was not observed by the surveyors, but a resident was noted to be absolutely sure that one had been seen in the estuary.

**This species of native shrimp was observed in a 1978 survey by Heacock. Heackcock notes that since the 1982 and 1989 surveys used a visual survey method, which is less efficient than the electroshocker used in the 1978 survey, the absence of this species from Anini Stream could not be determined with complete confidence.

The freshwater biota recorded in these sampling efforts indicates the presence of many different species remaining in some part of these streams into the 1990s. Decreased stream flow has significant impacts on habitat availability and may interrupt the movement of native species along streams, which could help explain the loss in abundance of ’o’opu and hīhīwai. These are amphidromous species meaning that their lifecycle and reproduction utilize and require both ocean and fresh water. If streams do not flow to the ocean often enough, it may be impossible for these species to reproduce in these streams.

2.52 BIRD SPECIES

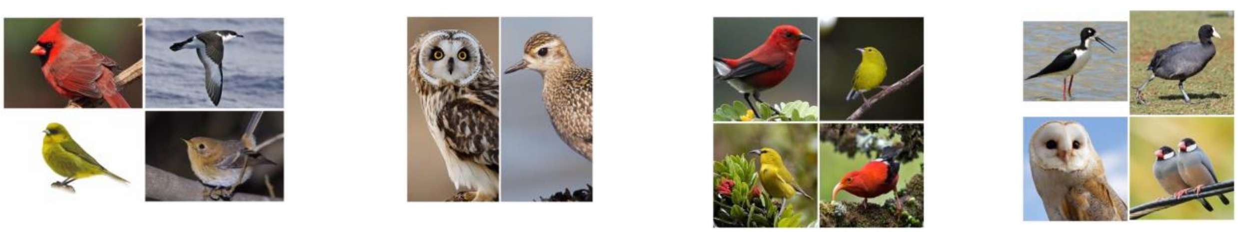


Figure 18: Birds species likely to be present in and around Anini. **Block 1** from left to right: Northern Cardinal, Newell’s Shearwater, ‘Akeke‘e, Kaua‘i ‘Elepaio **Block 2:** Short-eared Owl (Pueo), Lesser Yellowlegs. **Block 3:** ‘Apapane, ‘Anianiau, Kaua‘i ‘Amakihi, I‘iwi **Block 4:** Hawaiian Stilt, Hawaiian Coot, Barn Owl, Java Sparrow.

Anini has not been looked at specifically in terms of bird habitat. Of the endemic birds, the Hawaiian Coot, Hawaiian Stilt, Kaua‘i ‘Elapaio, Kaua‘i ‘Amakihi, ‘Anianiau, ‘Akeke‘e, ‘I‘iwi, Short-eared Owl (Pueo), and ‘Apapane are considered fairly common in Kaua‘i. Plovers and sanderlings are known to forage at the beach park of Anini(Griesemer, personal communication, 2015). A few of the other endemics are considered uncommon or have been listed as extinct. Closest to Anini, urban birds and open country birds are listed as more common than any other bird type, although the endemic Newell’s shearwater and Wedge-tailed shearwater colonies may visit along with Laysan Albatross (moli) and nene. In addition, species include Java Sparrows, House Sparrows, Red-crested Cardinal, Northern Cardinal, and Barn Owls, among others (Hawai‘i Audubon Society, 2005; KIUC HCP, 2010). The EIS from 1983 lists several other common species of songbirds found at and around Anini and can be found below with relative abundance included.

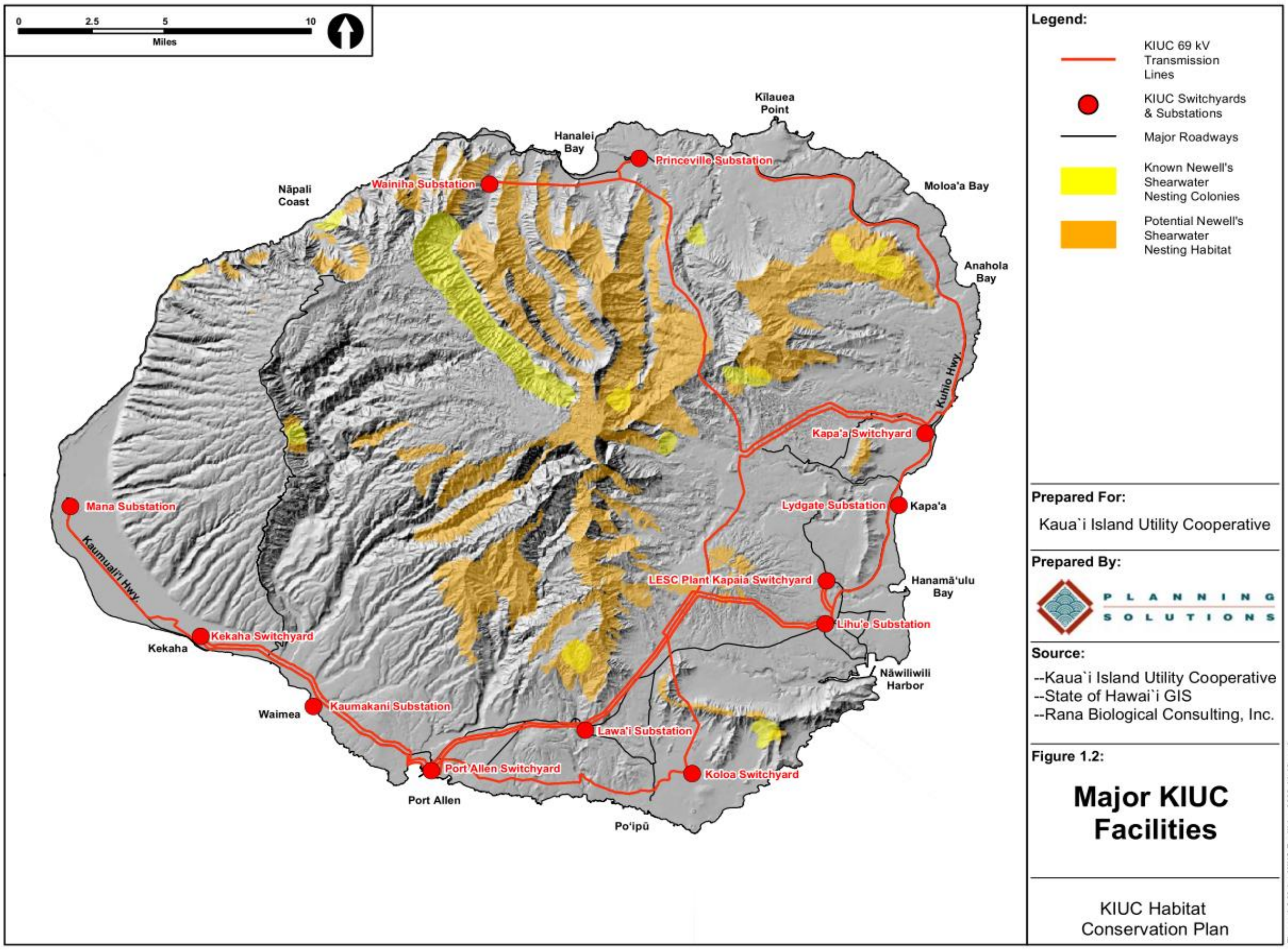


Figure 19: KIUC Facilities Map (KIUC HCP, 2010).

In terms of birds, Anini and its surroundings are mostly home to non-native songbirds and seabirds. The EIS survey in 1983 identified 20 birds common in the area as identified in Figure 11. During a visit to the site, the authors of this report walked along Anini road several times and identified the following species: Northern Cardinals, Nutmeg Manakin, Common Myna, Feral Chicken, and Japanese White-eye. Nutmeg Mannikins traveled in flocks, and a pair of Northern Cardinals could be heard singing every morning, using a different song-type than what is common on Oahu Interviews with kupuna from the area suggested increased abundance of Cattle Egrets. While non-native birds have certainly made use of the beach park and surrounding area, native birds, such as Newells shearwaters, Hawaiian petrels, and albatross are documented nearby in the forest and on cliffs, so they may be using the area more indirectly. A more in-depth survey would be needed to be able to review relative abundances and richness numbers.

By the 1980's a large mix of introduced birds were present along the Anini Stream as identified in Figure 20 (EIS 1983, IV-43). These four sites listed 20 species surveyed: the Cattle Egret, Melodious Laughing-

Thrush, Common Myna, Northern Cardinal, Japanese White-eye, and Golden Plover are most abundant, with an average of over 10 birds counted during an 8-minute count. The Ring-necked Pheasant, Barred Dove, Western Meadowlark, were considered common with a count number between 5 and 10 in an 8-minute count.

Table IV-11. Relative Abundance and Habitat Preference of Birds at Princeville Phase Two, Kaua'i.

Common Name	Scientific Name	Habitat[1]	Abundance[2]	Category[3]
Cattle Egret	*Bubulcus ibis*	P,E,R	A	E
Ring-necked Pheasant	*Phasianus colchicus*	E,P,R	C	E
Erckel's Francolin	*Francolinus erckelii*	E,R	R=02	E
Feral Chicken	*Gallus gallus*	R,W	U	E
Barred Dove	*Geopelia striata*	R,W,E	C	E
Spotted Dove	*Streptopelia chinensis*	R,E	U	E
Barn Owl	*Tyto alba*	R,P,E	R=1	E
Shama Thrush	*Copsychus malabaricus*	R,W,E	A	E
Melodious Laughing-Thrush	*Garrulax canorus*	R,W	U	E
Common Mynah	*Acridotheres tristis*	E,P,W,R	A	E
Western Meadowlark	*Sturnella neglecta*	P,E	C	E
Japanese White-eye	*Zosterops japonica*	E,W,R,P	A	E
Northern Cardinal	*Cardinalis cardinalis*	R,W,E	A	E
House Sparrow	*Passer domesticus*	E	U	E
House Finch	*Carpodacus mexicanus*	E,W,R	U	E
Spotted Munia	*Lonchura punctulata*	P,E	R=10	E
Golden Plover	*Pluvialis dominica*	M,P	A	M[4]
Koloa (Hawaiian Duck)	*Anas wyvilliana*	R	R=1	N
Auku'u (Black-Crowned Night Heron)	*Nycticorax nycticorax*	R	R=2	N
Pueo (Hawaiian Owl)	*Asio flammeus sandwichensis*	E,P	R=2	N

1 Habitat - Area most frequented. Order of most preferred or utilized begins at left.

P = Pasture
R = River valley floor
W = Walls of river valley
E = Edge of pasture and forest
M = Mudflats

2 Abundance - Number of times observed during survey or frequency on eight minute counts.

A = Abundant (average number on 8 minute count > 10)
C = Common (average number on 8 minute count > 5 but < 10)
U = Uncommon (average number on 8 minute count < 5)
R = Recorded, but not on 8 minute count. Number that follows is the actual number seen.

3 Category - Provenance of species

E = Exotic (Introduced)
N = Native--Indigenous or Endemic
M = Migratory

4 Two other migratory species--Ruddy Turnstone (*Arenaria interpres*) and Bristle-thighed Curlew (*Numenius tahitienis*) could be expected to utilize the site.

Source: Phillip Bruner (May 1979:Table 1) and Hawai'i Audubon Society (1975).

IV-43

Figure 20: The identification of avian species at four sites along Anini Stream in 1982 (EIS, 1983).

Seabirds in Hawaiʻi depend entirely on active management strategies. Historically, three approaches have been taken to in regards to active management of birds: exploitation when population numbers were much higher (for food consumption, or use of feathers), remediation (taking into account human impact), and restoration (of habitat and ecosystem). In the past, seabirds were exploited culturally both for their feathers and for food. During World War II, many birds were killed purposefully (via bulldozer) so as to not conflict with the war effort (Duffy, 2010).

In 2010, Hui Hoʻomalu i Ka ʻAina, the Conservation Council for Hawaiʻi, the Center for Biological diversity, and the American Bird Conservancy gave notice to sue Kauaʻi Island Utility Cooperative (KIUC) for violating the Endangered Species Act by placing power lines within shearwater habitats, effectively killing 125 and injuring 55 birds a year. While these numbers do not appear very high, at $50,000 a bird, the potential fines KIUC would be facing are serious. The US Department of Justice indicted KIUC in May of 2010. In December 2010, KIUC released a short-term habitat conservation plan to protect the endangered birds. The map on the previous page (KIUC HCP, 2010) shows that while shearwaters nest east of Anini, the area south of the beach park could certainly also have served as shearwater habitat in the past or could serve in the future. The area would probably serve as current habitat if the substation were not there (Griesemer, personal communication, 2015). A plan exists to have a transmission line run straight across the forests above Anini Beach Park, along Kuhio Highway. KIUC maintains that this would be safer than the line proposed in 1994 because it would be attached to the side of the highway (KIUC HCP, 2010).

In 2011, KIUC procured an Endangered Species Act (ESA) incidental take permit, and contributed $400,000 a year to protect the shorebirds (EarthJustice, 2011). The effect of power lines is significant, especially considering that more are being added, and many of them are taller than 15.2 meters, which adds greater risk to the shearwater populations. Surveys of power line heights in Princeville and east of the Hanalei River have not yet been completed (Griesemer & Holmes, 2011).

The endangered Newell's shearwater is especially important here, as 90% of this species breeds on the island of Kauaʻi and feeds off-coast. The shearwater faces three main threats off of the coast of Anini: power lines, predation, and sensitivity to light pollution. Because these seabirds evolved on islands, they are not accustomed to any natural predators, which make them more susceptible to human impact (Griesemer and Holmes, 2011; Nettleship et al., 1994). The Newell's shearwater population has dropped nearly 75% since the 1980s, when their numbers were estimated to be about 84,000 total birds. Light pollution affects the most vulnerable of the shearwater population, the fledglings. Studies have shown that their first nocturnal flight towards the ocean has been disrupted and resulted in more collisions (Ainley et al., 2001; Griesemer and Holmes; 2011).

The changing landscape around Anini has also had a severe impact on shorebirds. Non-native plants change the vegetative structure of the landscape, reducing burrowing habitat for the Hawaiian Petrel, and inviting more opportunities for non-native mammals to move into the area, such as cats and owls (Griesemer and Holmes, 2011; Penniman, 2009). With the exception of the Hawaiian Monk Seal and the Hawaiian hoary bat, which are both endangered, all other mammals on the island of Kauaʻi are non-native. Among the non-native mammals, rats and cats are likely to be predators to look out for on the beach park, due to their proximity to shearwater and other vital bird habitats (KIUC HCP, 2010). Feral cats have been a large problem on nearly all of the Hawaiian Islands, and have been confirmed to be predating shearwater nests within the last year (KESRP, 2014).

2.53 CARELIA SNAIL

Of the various snails native to the Hawaiian Islands, Kauaʻi and Niʻihau are unique in being the only islands endemic to the genus of snail called Carelia, which includes 21 species. These are the largest native Hawaiian snails and they likely developed when the two islands were still connected, which would account for the distribution on both islands. Unfortunately, all remaining species of Carelia are thought to have become extinct between 1970 and 1990 (Hawaiʻi Biological Survey, 1997). Two particular species of Carelia, *pilsbryi* and *cochlea*, are noted to have historically inhabited Anini, including near the mouth of Anini stream and around Kalihikai beach (Cooke, 1952; Holocene Extinction, 2013). Most Carelia colonies found consisted of a single species, however colonies of both *pilsbryi* and *cochlea* species were found in the Anini-Kalihikai-Kalihiwai areas. The species *cochlea* was noted as being quite common, while *pilsbryi,* the largest of Carelia snails, was rarer (Cooke, Jr., 1931).

Overall there appears to be a declining trend in biodiversity in Anini, with native species being impacted the most. Bird species, including waterbirds, have declined over the past century and several are now extinct. The Carelia snail, native only to Kauaʻi and Niʻihau went extinct in the past century, and many freshwater organisms seem to be declining in numbers. While no single cause can be outlined, urban development, land use change, and surface water usage are commonly seen mechanisms for the decline in species diversity, and several known mechanisms such as power line construction and water diversions are occurring in the area. Furthermore, the introduction of non-native species can also play a role in the loss of native species through competition and habitat destruction.

2.6 POTABLE WATER

As with the other Hawaiian Islands, the majority of drinking water is supplied by groundwater aquifers, while agriculture is irrigated mostly by surface water reserves. The drinking water supplied to Anini is mostly sourced from Princeville Utility Company, wells 1, 2, and 4, located in the Kalihiwai Aquifer (aquifer code 20201), and is stored in two tanks (50,000 and 500,000 gallon capacities) (Princeville, 2013; Shade, 1995a). Some residents along Anini Road, in addition to Kalihikai Park, receive drinking water from Anini Stream (DOW, 2011). The Princeville wells are located mauka of Kuhio Highway in Princeville. Like most groundwater in Hawaiʻi, it is naturally purified, and the drinking water in the distribution lines is estimated to have a neutral pH of 7.0 and hardness between 60-190 ppm (parts per million), which complies with normal regulations and standards. Both the Kauaʻi Department of Water (County of Kauaʻi, 2014) and Princeville Utilities Company (Princeville, 2013) report no contaminant levels of concern in the drinking water and that the water meets or exceeds all regulations to be considered safe for drinking. In 1990 the groundwater recharge for Kalihiwai Aquifer was estimated to be 17 MGD, while the groundwater pumpage was estimated to be 1.22 MGD. For the island of Kauaʻi, groundwater recharge and pumpage were estimated to be 652 MGD and 46.28 MGD respectively (Shade, 1995a).

The US Geological Survey (USGS) has groundwater records for Princeville well 1, shown in the figure below. According to the figure, groundwater level at the well has been stable since the mid-1990s, hovering around 8 feet above mean sea level. The USGS does not have groundwater records for the other wells (National Water Information System, 2015). Two other Princeville utility wells (#3 and #5) iare not currently being utilized. If future development occurs in the area, these wells might be used to supply water. Two other options would be to drill additional wells or to use surface water such as from a nearby reservoir.

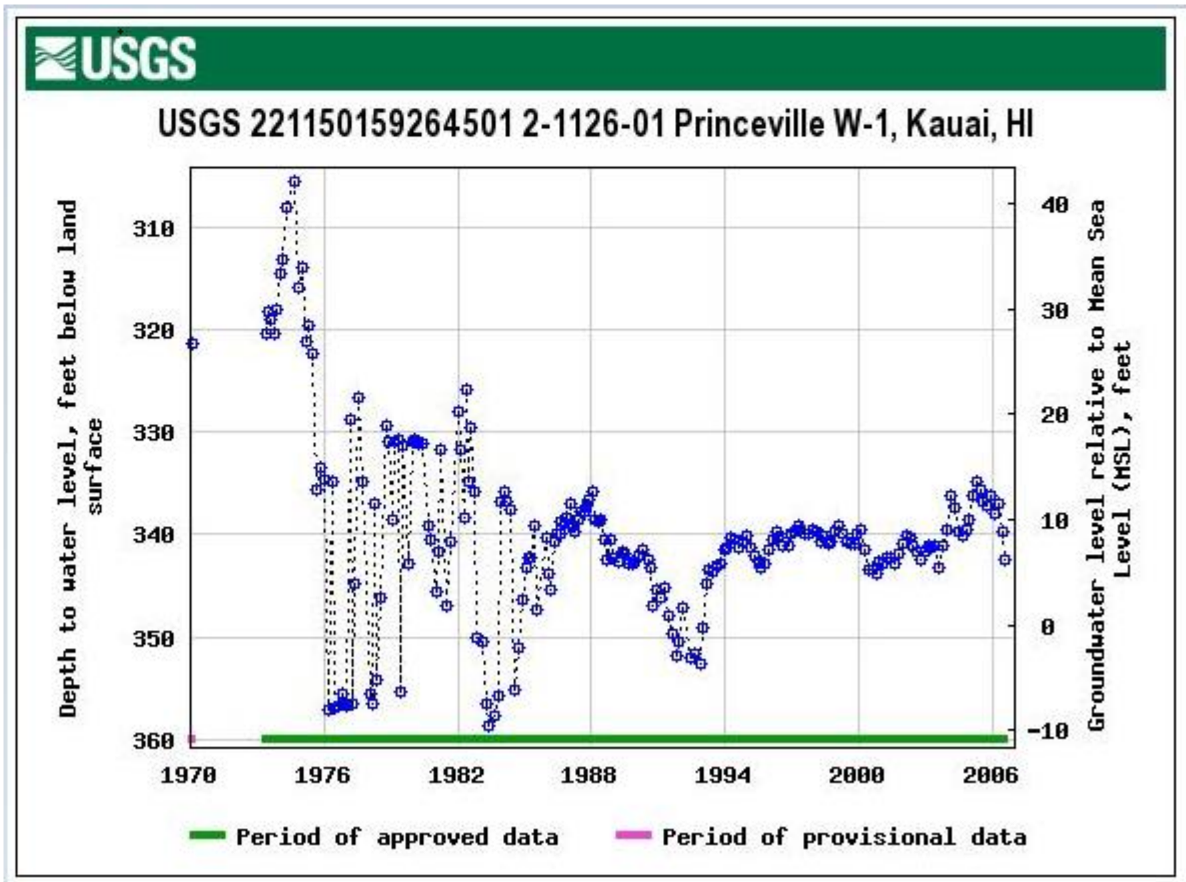


Figure 22: Historical groundwater levels for Princeville Well #1 (NWIS, 2015).

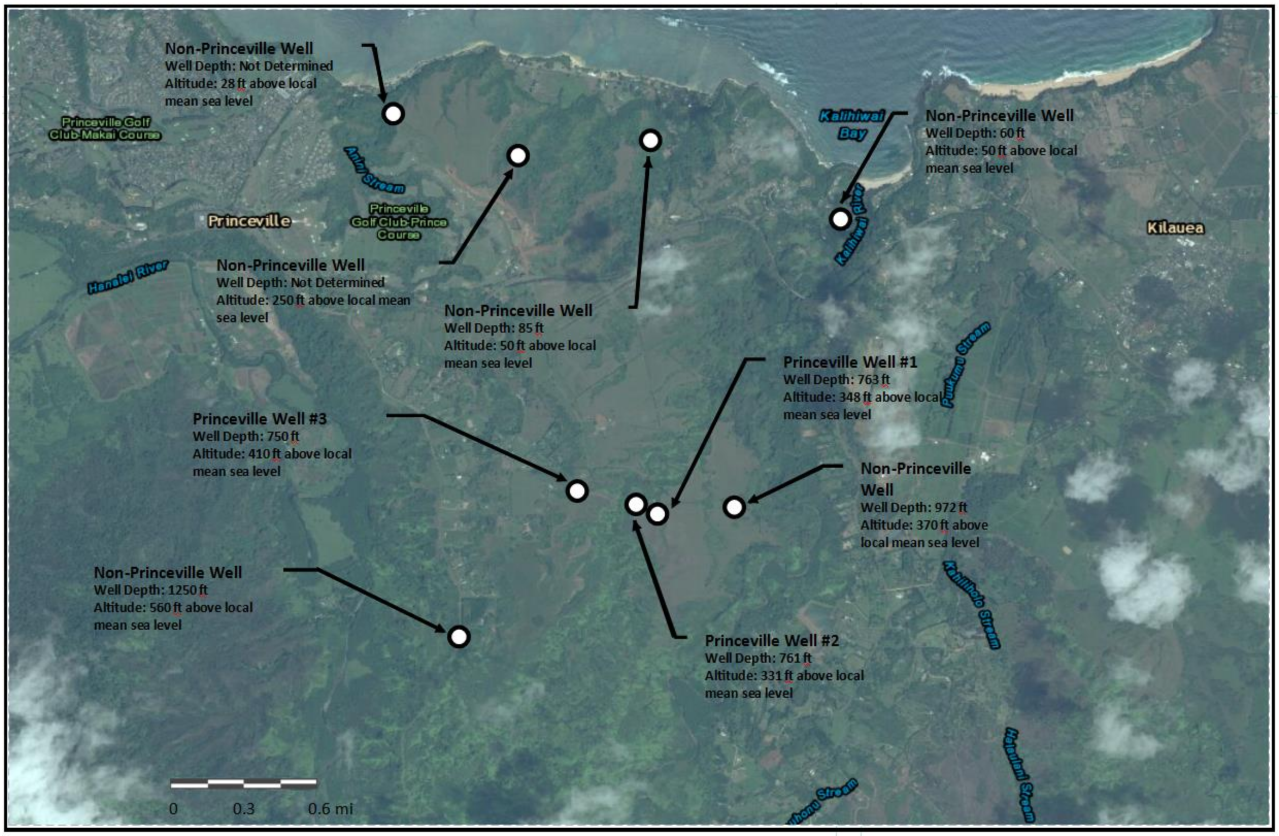


Figure 2318: Location of groundwater wells (NWIS, 2015).

On October 16, 2012 trace amounts of PCBs, organic chemicals formerly used in the US for industrial and commercial purposes, were found in one of Princeville Utilities' storage tanks. Further samples were taken at distribution points and sampling was done by both the Hawaiʻi Department of Health and a California based testing company. The results showed that the PCBs had not reached the distribution system and that the water was safe to drink. PCBs were not found in later sampling of the tanks (The Garden Island, 2012).

The drinking water supplied to Anini is distributed via a 4" water main that runs along Anini Road. According to the County of Kauaʻi Department of Water's Water Plan 2020, the fire flow capacity at one end of the pipeline system is deficient (County of Kauaʻi, 2001). There are current plans in development to replace the 4" water main with a 6" water main, which will supply water users of Anini and will provide sufficient fire flow protection. This project is on the Hawaiʻi Department of Health Priority List for funding in 2015. Additionally, this project will change the water supply from Princeville Utilities to Kauaʻi Department of Water (Hawaiʻi DOH, 2014).

2.7 WASTEWATER

The Anini and Princeville areas have historically treated wastewater through cesspools and septic tanks. Cesspools are still quite common in rural areas to treat domestic wastewater, and Hawaiʻi has the highest cesspool use in the nation. Of the 90,000 cesspools in the state, 14,000 are on Kauaʻi, according to the State Department of Health. Cesspools are technically dry wells: deep underground pits with seepage holes at the bottom for the discharge of wastewater, which is usually untreated. The wastewater filters through the soil and is slowly degraded biologically by bacteria and other microorganisms present in the soil. Since wastewater can contain harmful pathogens, excess nutrients, and synthetic chemicals, untreated wastewater discharge can have harmful effects on the environment. If seepage from cesspools reaches rivers, oceans, or groundwater, humans, animals, and plants can be directly exposed (EPA Region 9, 2013).

On-site disposal of wastewater can be a risk to human health and the environment. Kauaʻi has the highest density of on-site sewage disposal systems (OSDS) in the state, which include cesspools, septic systems, and systems that have some degree of wastewater treatment (soil treatment or aerobic treatment) (Whittier & El-Kadi, 2014). According to DOH records, the area between Anini Stream and Kalihiwai River and makai of Kuhio Highway contains 22 known cesspools and 84 septic tanks. Furthermore, according to the DOH, if there are no records of individual wastewater systems (cesspools and septic tanks) for a property that has a house on it, there is a "99.9%" change the property has a cesspool and the owners simply did not file paperwork or notify the DOH for inspection. This means there could be an additional 18 cesspools in the area. Therefore, out of roughly 99 lots with houses in the area, there could be as many as 40 cesspools (Vetter, 2015). Coral reef biologist, Jim Maragos, recommends changing cesspools to sewer wastewater systems, also stating that "septic tanks are not ok, unless you are away from the shoreline, it is not a problem…if you are, [and] it is all going out on the reef". Maragos equates most of the damage to nearby marine areas to "sewage and runoff from the (Princeville) golf course." He explains that leaching fields help to continue to decompose waste but there is still going to be nutrients, and "if you're going to do it right near the shoreline you are not going to kill everything with a septic tank". Maragos also points out that there is not much ability on the island to periodically fix the septic tanks or just to check them.

In 2014, the estimated discharge from OSDS on Kauaʻi was 12.5 MGD (Whittier & El-Kadi, 2014). Leaking of sewage and contamination of ground and surface water could pose a hazard to human and ecological health. Although the U.S. EPA is continuing to close and replace cesspools in rural Hawaiʻi, the remaining ones may still pose an ecological hazard, mainly if they leak (EPA Region 9, 2013). The constituents in wastewater that can pose a risk to human and ecological health include pathogens, nutrients, and unregulated/emerging contaminants. Nitrate (a nitrogen compound) is contaminant of particular concern with OSDS, because it can infiltrate into groundwater. Kauaʻi has the highest probability of drinking water impacted from OSDS, and nearly all groundwater wells on Kauaʻi located near coastal communities may have elevated levels of nitrogen. The discharge from OSDS has the potential to degrade streams and marine water quality through the introduction of pathogens and nutrients. Furthermore, Kauaʻi streams have been determined to be most at risk to degradation due to OSDS discharge.

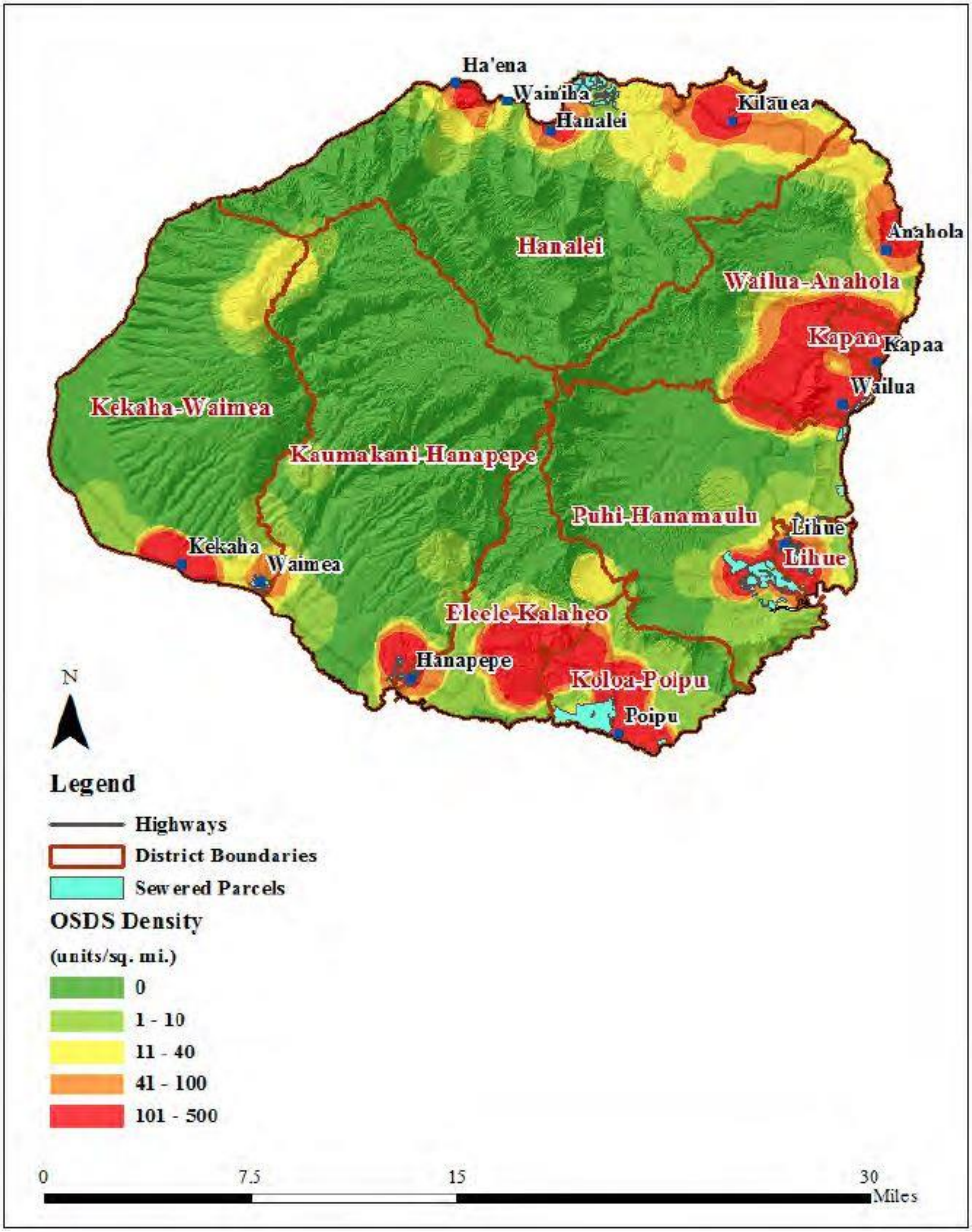


Figure 24: On-site Sewage Disposal System Density on Kauaʻi (Whittier & El-Kadi, 2014).

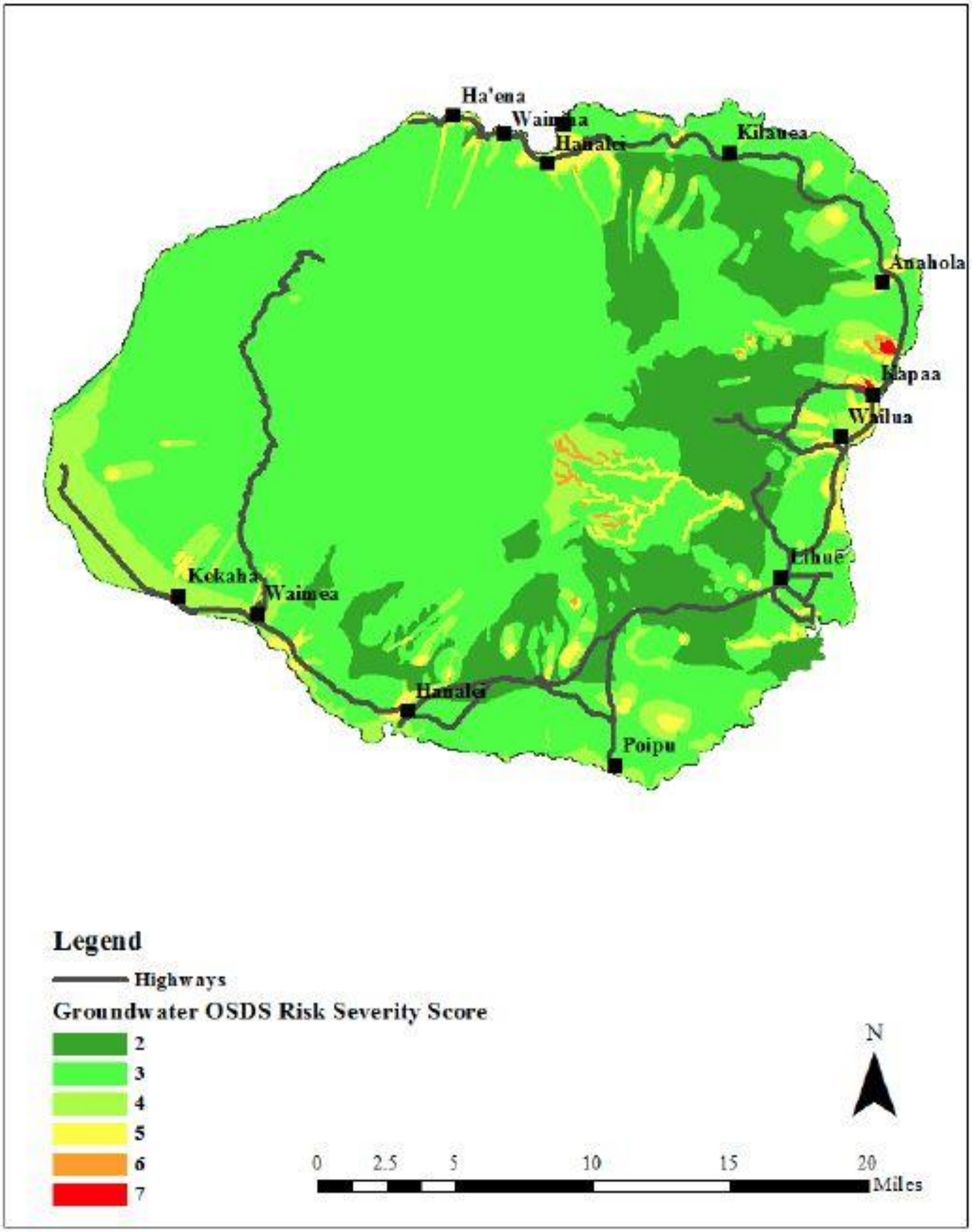


Figure 25: Map of susceptibility of groundwater and drinking water from OSDS contamination (Whittier & El-Kadi, 2014).

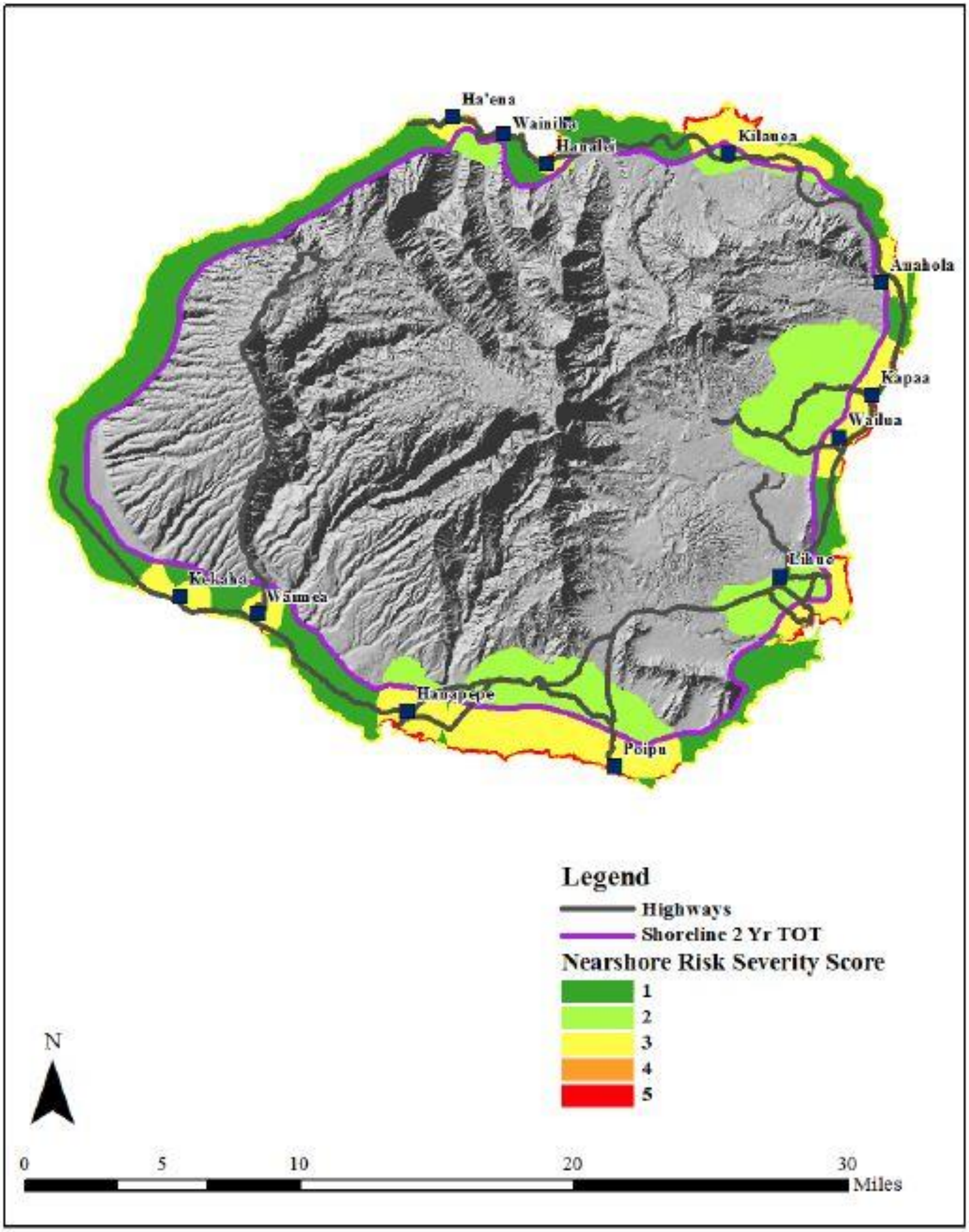


Figure 26: Map of OSDS risk to coastal surface waters (Whittier & El-Kadi, 2014).

The risk to human health and the environment from OSDS was estimated for Kaua'i and the distribution and ranking is shown in the figure below.

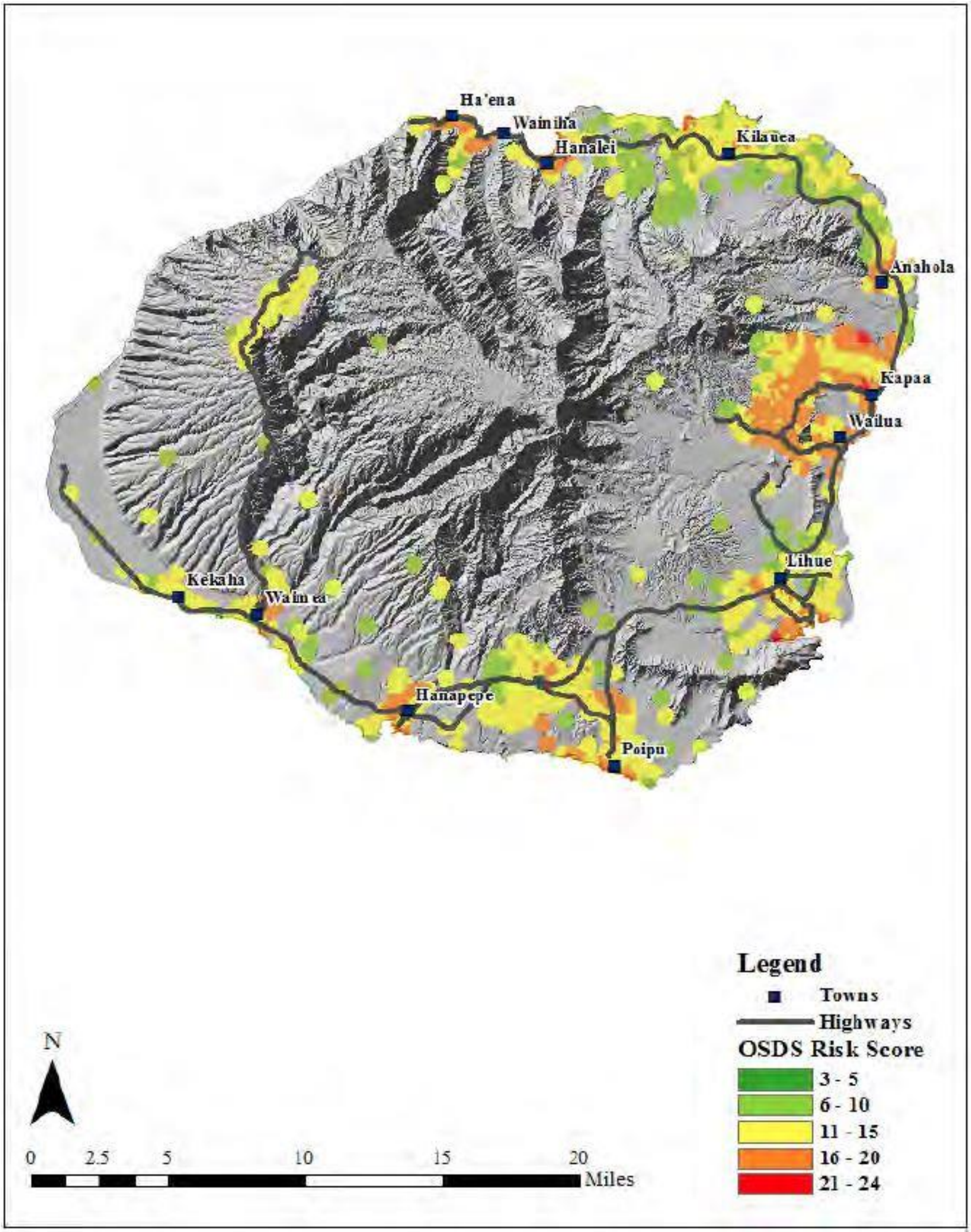


Figure 27: Distribution of OSDS risk ranking for Kaua'i (Whittier & El-Kadi, 2014).

Figures 24-27 indicate a medium to high OSDS density in and around Anini, and while the risk to coastal waters associated with OSDS is not severe, there seems to be a possible risk to groundwater contamination in the area, as well as a notable amount of risk to human health and the environment.

Currently, Princeville Utilities Company provides wastewater treatment services for the resort area through its own wastewater treatment plant. The treatment plant uses extended aeration to treat wastewater, and has a 1.0 MGD design capacity. As of 2014, the plant is operating at an average daily flow of 0.74 MGD. Princeville's wastewater treatment plant is also a reuse facility, where treated wastewater is used to irrigate the golf courses (County of Kauaʻi, 2014). However, many individual residences in the area still use individual wastewater systems such as septic tanks and cesspools. In addition, storm drainage was developed to flow naturally and in conjunction with the road system (EIS, 1985).

In some areas of the U.S. Mainland, Europe, and Australia there has been a link between the concentration of caffeine in ground and surface waters, and wastewater contamination. This is possible because humans excrete a small percentage of their caffeine intake, which can be used as a tracer for human wastewater (Knee et al., 2010).

In 2010, researchers analyzed the neighboring Hanalei watershed for caffeine concentrations in ground and surface water. No caffeine was found upstream of human development, however the majority of samples taken at marine and coastal water areas detected caffeine. This was in part due to terrestrial sources of caffeine that are synthesized naturally by plants, which, in Hawaiʻi, there are at least 14 plants that do so. However, it was noted during testing in February of 2007, that there was a positive correlation between caffeine and the fecal bacterial Enterococcus. This could be because of human wastewater contamination, but it is unclear at this point which source(s) the caffeine came from (Knee et al., 2010).

Anini Beach Park has its own wastewater facility, which was recently upgraded and expanded in 2014. The upgrades included the installation of additional leach field (soil) absorption beds. These are onsite wastewater treatment systems that use bacteria in the topsoil to biologically remove pathogens and decompose organic matter into nutrients. The total cost of improvements at Anini was $35,800 (County of Kauaʻi, Department of Public Works, 2014).

Wastewater treatment and discharge remains a threat to the environmental and ecological health of Anini. This is particularly the case due to the continued widespread use of cesspools that do not treat wastewater prior to discharge, and septic tanks that may leak if not properly maintained. The high density of OSDS in Anini is a concern (as many as 40 cesspools and 84 septic tanks). The infiltration of sewage into groundwater and the contamination of surface water in the area pose a specific risk to human health due to unknown levels of leaching into the ground water and marine system. Furthermore, the nutrients and chemicals found in wastewater have the potential to negatively impact the marine environment through increased algae growth, especially non-native algae, and through potential poisoning of marine creatures.

2.8 GOLF COURSE EFFECTS

There are two golf courses belonging to Princeville: one on the peninsula between Hanalei and Anini, and the other located just above Anini. Many long-time Anini residents point to the building of the Prince golf course above Anini in the mid-1980s as a turning point that may have caused changes in terrestrial, freshwater, and marine health (see interview analysis). Although golf course effects at Anini have not been studied in detail, many studies show that golf course construction significantly changes the landscape it is built on, as well as the hydrology, topography, and habitat surrounding it. Disturbances such as grading for golf courses can lead to destruction of wetlands (Klein, 1999), loss of tree cover, cause adjacent land to be more erosive, and increased nutrient runoff (Winter and Dillon, 2005). Additionally, fertilizers and chemicals find their way into nearby streams and the larger waterways connected to it. Pesticides also have been recorded to affect species diversity, especially those that ingest turf grass (Klein, 1999). These studies about golf courses in general support statements from community members describing a reduction in freshwater flow and biota, and a reduction in marine quality since the implementation of the golf courses.

Furthermore, nitrate levels are known to rise in creeks during golf course construction, and affect adjacent waterways in the long-term (Winter and Dillon, Mallin and Wheeler 2000). Several studies have reported excessive and unsafe amounts of pesticides in nearby streams (Klein, 1999). The treatment of lime on the course can change pH and alkalinity levels in streams (Winter and Dillon 2005). One study in Florida (Lewis et al, 2002) reported no difference in water quality between a golf course stream and the adjacent coastal area, but found atrazine (an herbicide), mercury, lead, and arsenic present. These same streams have seen 43% decreases in seagrass adjacent to the course. Additionally, lead and mercury were found in levels higher than what is allowable by the state of Florida (Lewis et al., 2002).

Several management practices can be utilized to reduce the impacts of golf course runoff. A vegetative buffer of 30 x 30 meters has been found to effectively reduce the amount of nitrate that enters the water (Winter and Dillon 2005). Very regular monitoring of nitrate and pesticide levels are needed to keep the freshwater stream, wetland, and adjacent coastal area healthy. At this point, restoration efforts may be needed in Anini, but more information needs to be collected. The problem with monitoring occasionally or annually has to do with the half-life of the chemicals; it may be too late to know exactly the extent of the chemicals that made it into the surrounding habitat from 1970.

2.81 GOLF BALL LITTER

The Princeville Golf Course overlooks Anini and the terrain tends to drop steeply at its borders. During heavy rains, golf balls have been witnessed washing down to the beach, particularly through Anini Stream, and into the ocean. Community members have taken thousands of golf balls out of the ocean over the years, and many are concerned about the impact on marine health. Golf ball litter in water bodies has recently become a global concern and research interest. While little research has been done, the Danish Gold Union has run tests to determine possible effects of golf balls on the aquatic environment. They found that it takes between 100 to 1,000 years for a golf ball to naturally decompose. Furthermore, during decomposition golf balls released high amounts of heavy metals. The rubber filling of golf balls contains high levels of Zinc, which may be hazardous if exposed to the environment. According to the research done by the Danish Golf Union, when submerged in water the zinc attached to sediment and poisoned the surrounding aquatic species. Future research is necessary to better understand the environmental effects of golf ball litter (Macfarlane, 2009). Some community members have communicated with the State DOH regarding this issue.

Figure 32: A golf ball with the Princeville insignia found in the ocean near the mouth of Anini Stream.

3.0 MARINE ECOSYSTEM

3.1 WATER QUALITY

Water quality of marine water bodies throughout the state is monitored by the Department of Health. According to the 2014 DOH Water Quality Report, the island of Kaua'i has the highest percentage of turbidity impairments in assessed marine water bodies (Hawai'i DOH, Clean Water Branch, 2014). Turbidity is one of the largest issues affecting Kaua'i's marine waters. Roadside erosion, agricultural runoff, and land development all increase soil and sediment transport and deposition into marine waters. The past large scale development of agriculture around Anini, and now the development of resorts and housing displaces natural plant species and changes the ecology of the area. This reduces the stability of the soil and increases sedimentation in the ocean through stormwater runoff. Further development in the area is very likely to increase sediment runoff and worsen turbidity issues (Kido, personal communication, 2015).

Within the Anini project area there are sampling sites at Kalihiwai Bay, Anini Beach Park boat ramp, and Anini Beach marine bodies. According to the 2014 water quality report, the turbidity (cloudiness) in Kalihiwai Bay has gotten worse since the previous 2012 report, and is now listed as a category 5 water body, which means external action may need to be taken to correct the pollution problem. Anini Beach Park is also listed as category 5 for turbidity (Hawai'i DOH, Clean Water Branch, 2014). The sampling station at Anini Beach (different from the beach park, see figure below) has not been sampled enough to obtain data, and Kalihikai is not listed in the report.

The 2014 water quality data for these marine bodies of interest is summarized in the table below.

Table 1: 2014 Water Quality data for 'Anini Beach, 'Anini Beach Park, and Kalihiwai Bay (DOH, 2014). Assessment listings: ? = insufficient data; A = attainment of water quality standards; N = non-attainment of water quality standards. Pollutant categories: 1 = all uses of the marine body regarding pollutant have been attained; 2 = some uses have been attained; 3 = not enough data to evaluate; 4 = at least one use not attained; 5 = at least one use not attained, and action may need to be taken for attainment. Source: State of Hawai'i DOH Water Quality Monitoring and Assessment Report 2014.

Marine Body Water Quality Data	**Assessed Marine Body**		
	Anini Beach	**Anini Beach Park**	**Kalihiwai Bay**
Geocode ID	HI338804	HI418744	HI264001
Enterococci	?	A	N

Total Nitrogen	?	?	?
NO3+NO2 (Nitrate + Nitrite)	?	?	?
NH4 (Ammonia/Ammoniu)	?	?	?
Total Phosphorous	?	?	?
Turbidity	?	N	N
Chlorophyll a	?	?	?
Pollutant Categories:	3	2, 3, and 5	3 and 5

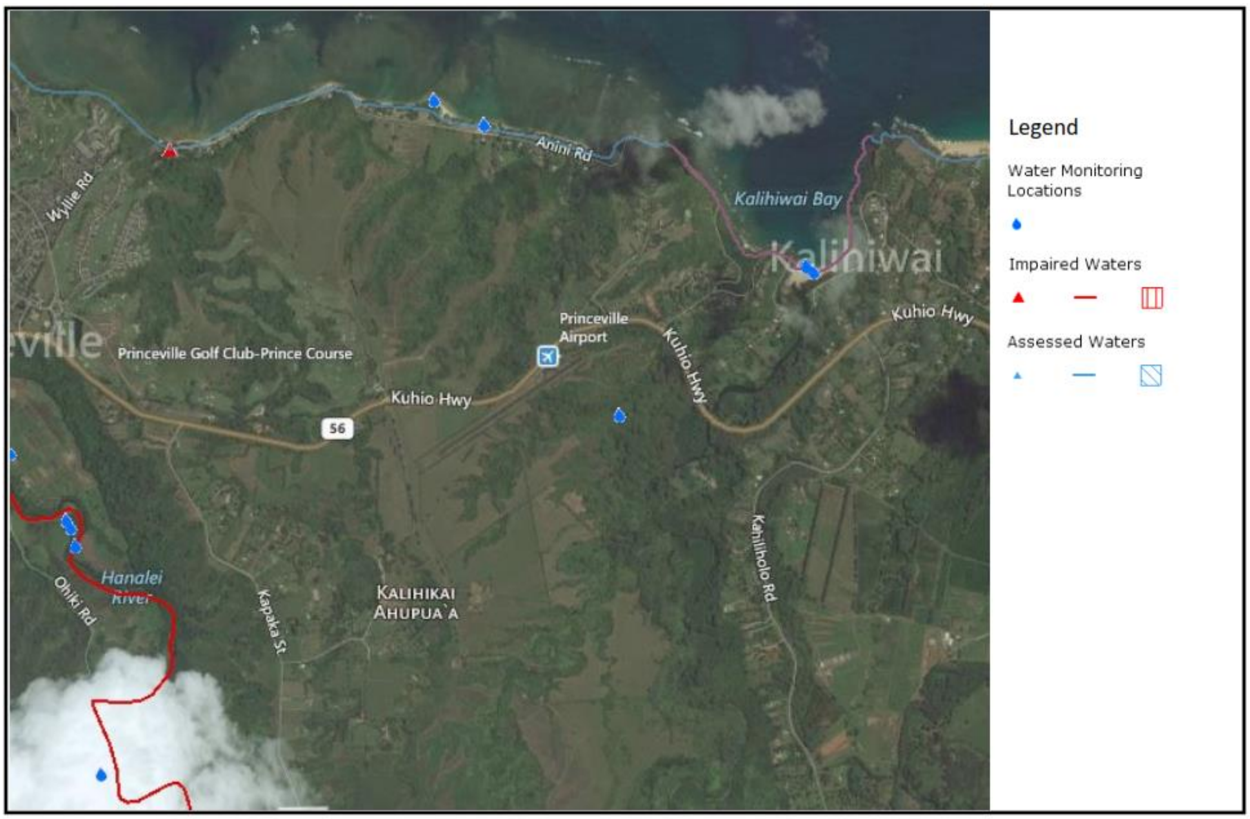


Figure 28: Map of water quality sampling locations (EPA, 2015).

Another common pollutant monitored is the bacteria *Enterococci*, which can be an indicator of fecal matter and possible sewage contamination. Kalihiwai Bay did not meet the water quality standards for *Enterococci* in 2014, however Anini Beach Park does meet the standards for *Enterococci*. There has not been enough sampling to acquire data for Anini Beach, for to the 2014 water quality report. *Enterococci*, like most contaminants, is measured through grab-samples, where the concentration of the bacteria is later measured by growing and counting bacterial colonies from the samples. A minimum of 10 samples is needed to evaluate for pollutants (H-DOH, Clean Water Branch, 2014). There are records of intermittent water quality sampling for fecal pathogens done at the Anini Beach Park station for marine water quality since the 1970s. The sampling was done by the Hawaiʻi DOH, however over time, different methods were used and different specific pathogens were monitored as sampling practices changed. The figure below provides the most recent sampling data for *Enterococcus* and C*lostridium* at Anini Beach Park (State of Hawaiʻi, Department of Health, Clean Water Branch, 2014).

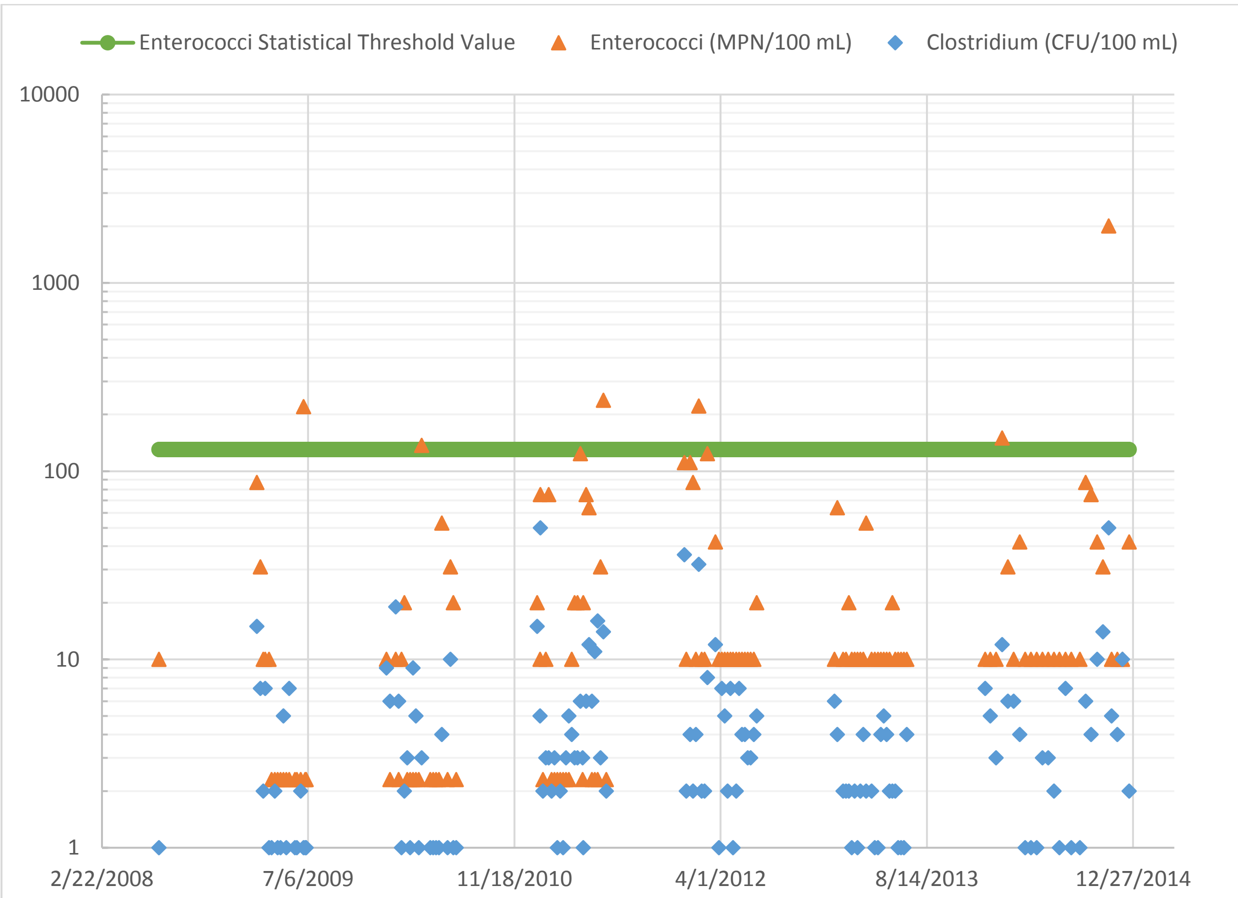


Figure 29: Anini Beach Park fecal pathogen water quality testing data (State of Hawaiʻi, Department of Health, Clean Water Branch, 2014).

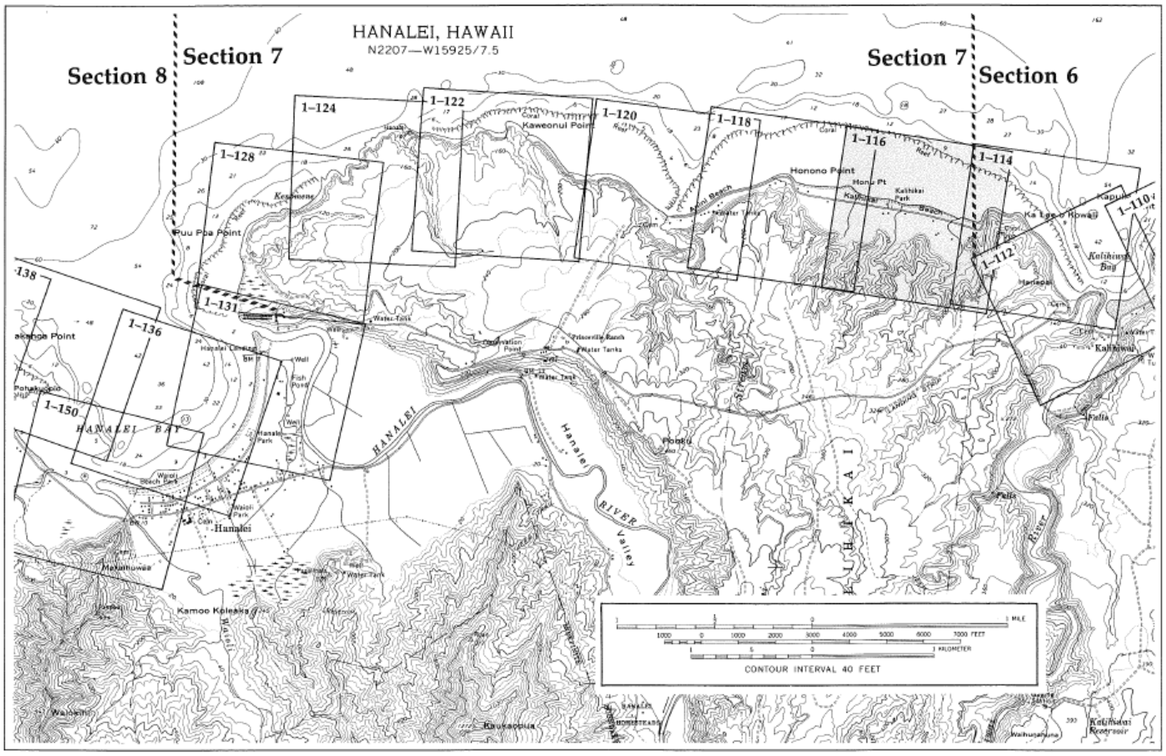
The Enterococci Statistical Threshold Value, equal to 130 CFU/100 mL and determined by state law, must not be exceeded by more than ten percent of samples taken in the same 30 day interval in which the geometric mean is calculated. If exceedance occurs, additional testing is required and beach warnings may be posted (Department of Health, 2014). The CFU metric stands for Colony Forming Unit, and comes from a method by which water samples are diluted and bacteria are allowed to grow on nutrient plates. If there are live cells, then “colonies” will form and the concentration of organisms (cells) in the original water sample can be estimated (Lindquist, n.d.). The MPN metric stands for Most Probable Number, and is the unit used in measuring *Enterococcus* levels in the method (Enterolert) used by the State of Hawaiʻi DOH. This method involves using fluorescent substrates to indicate the concentration of organisms. While not technically equivalent to CFU, both methods and their resulting units are acceptable for these monitoring purposes (State of Hawaiʻi, Department of Health, 2012).

Enterococci is a pathogenic bacteria commonly found in fecal matter and sewage, and is often used as a tracer to determine possible sewage leaks. *Enterococci* is also found in warm blooded animal fecal matter, and concentrations are often higher near cattle and areas of high animal population. The bacteria are known to naturally occur in tropical soils, making it difficult to identify the source (Ragosta et al., 2011). However, it's still applicable to test for Enterococci because it can be a good indicator of other pathogens. In addition to *Enterococcus*, the state uses the bacteria *Clostridium perfringens* as a secondary tracer, which has been suggested to be a better indicator of fecal and sewage pollution (Viau et al., 2011).

In summary, water sampling data shows that Anini Beach Park may have turbidity issues, but existing samples do not support a significant bacteria problem. Continued monitoring of water quality will provide further insight.

3.2 REEF HEALTH

The 1982 Kauaʻi Island Coastal Resource Inventory (KICRI) was lead and conducted by James Maragos for the U.S. Army Engineer Division in Hawaiʻi. Extensive research on marine ecosystems was undertaken on the island of Kauaʻi and at Anini, which provides a baseline for evaluating the current state of health. Anini reef is illustrated as ranging from Kalihiwai Bay to the high sea cliffs at Princeville. It's also stated as one of the longest, widest, and most extensive fringing reefs in the state. In the KICRI, the Anini section of coastline was described as being characterized by an exceptionally wide fringing reef bordering the long sand beach at Anini. The reefs off Anini Beach Park and the west Anini reef were characterized as consisting of sand-bottomed inner reef with isolated coral heads and limestone mounds. Deep channels also divided the reef, where "vertical walls were deeply incised with numerous overhangs, cuts, and caves". The 1982 report states that the Hawaiian monk seal (*Monachus schavinslandi)* was sighted at Anini beach, but was considered endangered during this period. Corals of the genus *Montipora* were most abundant and many sharks frequented the area. The report also indicated that visibility was excellent (up to 80 feet) on the reef slope where conditions were good for spear fishing and sport diving. However, where freshwater enters the shoreline, there was a noticeable effect on water quality, with plume evident. These details are noted in Table 5 and are illustrated through the aerial photographs and descriptions provided from the 1983 Atlas in Figures 30 through 37.



rcg – Consolidated reef
groove-and-spur sys
rsg – Sand predominates
conspicious groove-
rcs – Mostly consolidated
50%) sediment bott

SHORELINE
ba – Volcanic rock shorelines.
bal – Low basalt outcrops
meter high, includin
ba2 – Talus rocks at the
(clearly not rework
beach); sometimes
ba4 or ba5 cliffs.
ba3 – Low outcrops to l
high), shoreline acc
ba4 – Sea cliffs more than
difficult to dangerou
ba5 – Sea cliffs more than
dangerous to impos
bb – Man-made boulder shor
revetments, rip-rap, e
bc – Concrete/cement masonr
shorelines.
lm – Limestone rock shoreline
lm1 – Low outcrops, boul
cluding ramps.
lm2 – Limestone talus (pro
stone cliffs are not e
lm3 – 1–3 meter high lime
lm4 – Limestone cliffs 3–1
s – Sedimentary shoreline.
sa – Storm beach, deposit
inland and/or above
sb – White sand beaches
sb1 – Detrital sand beach.
sb2 – Black sand beach.
sbb – Boulder beach.
sbc – Cobble, pebble beac
sbr – Poorly sorted deposi
mouths, sometimes
of rubble or sand be
Special types.
br – Beachrock (a speciali
formed at the shore
tp – Tidepools, where t
feature at the shorel

Aerial Photograph Based Classification System

OFFSHORE

s – Sediment.
- **sc** – Sand bottom, including channels, in water depths less than 10 meters (especially common offshore from beaches).
- **sd** – Sand bottom, deeper than 10 meters (some possibility of error, such as white reflecting rock in deep water, not checked by dives).

Special types.
- **co** – Areas of greater than 50% live coral cover (spot checked for verification).
- **br** – Beachrock (offshore).

r – Rock.
- **rs** – Mostly sand bottom but with some rocky features; rock bottom covered by a veneer of sand.
- **rbs** – Hard bottom, but with conspicuous sediment up to 50% coverage.
- **rb** – "Other" hard bottom types (a catch-all for dark areas, not reefal or sedimentary; normally basalt with a thin veneer of marine life).
- **rbb** – Seaward extensions of talus boulder beaches, with definable rocks or boulders.
- **rbc** – Seaward extensions of cobble beaches (rocks smaller than boulders).

rc – Reef complex.
- **rc** – Shallow reef flats or structural reefs, normally (but not exclusively) in water depths less than 2 meters.
- **rcl** – Consolidated limestone; lacking sediment (also a catch-all for moderate to high relief areas).
- **rcp** – Consolidated smooth limestone pavement.

Offshore Bottom T

Categories	% San
rbc, br, s, sb, sc, sd	100
rs	less than
rbs, rcs, rsg	25 – 5
r, rc, co	less than
rbb, rb, rcl, rcp, rcg	—

Figure 30. Aerial photograph of topography and marine and terrestrial substrates categorized for the area of East (1-112 & 1-114), Central (1-116 & 1-118), and West Anini (1-120, 1-122, & 1-124) (KICRI 1982).

Table 2: Description of coastal and nearshore environments in and around Anini as of 1982 (KICRI, 1982).

	Corals	Algae	Fish life
Offshore, East Anini Reef (Kalihiwai bay to just past Koali point)	Flat reef, covered by fleshy algae such as Padina sp., Colpomenia sp., Sargassum sp. Corals cover approx.. 50% of the reef slope. Common species include: Leptastrea purpurea, Pavona varians, Porites lobata, P. brighami, Pocillipora meandrina, Poc. Eydouxi, Montipora flabellate, M. patula, M. verrucosa, and Pavona duerdeni. Large numbers of dead coral heads have been observed at depths of 30 feet.	Coralline algae, including Porolithon onkodes, P. gardineri, Lithophyllum kotschyanum and Sporolithon sp., grows entangled with other species such as Pterocladia caerulescans and Laurencia nidifica. Liagora spp. are also common.	Fish are abundant on the reef slope. All major reef fish families are well represented. Most common species are nenue, uhu, surgeonfishes (Acanthurus olivaveus, manini, kole, maiko, palani), goatfishes (white weke, red weke, moano), ta'ape, wrasses, and hawkfishes.
Off Anini Beach Park (From Koali to Honono point including "Jerry's Channel" and Ka Lae Honu (Honu Point)	Corals are rare in the inner reef and are concentrated on isolated limestone mounds, which project about the sandy bottom. Dead Porites evermanni are a major component of the mounds. Montipora verrucosa and Pocillopora damicornis are the principal living corals. Coral cover increases somewhat on the out reef flat.	Algae are abundant and diverse, with at least 26 species represented. Inshore, Dictyota acutiloba, Spyridia sp., and Hypnea sp. are very common. The sea grass, Halophila ovalis grows in patches. Dictyota divaricate, Neomeris annulate, Halimeda discoidea and Hormothamnion enteromorphoides are less abundant. Amansia sp. Are Galaxaura sp. Grow on mounds projecting above the inner reef flat. Sargassum polyphyllum and Porolithon sp. Inhabit the shallow outer reef flat. Dictyosphaeria versluyasii is common on the outer reef flat, where the prized limu huluhuluwaena, Gracilaria filicina is also present.	The sea hare, Aplysia parvula, is conspicuous on the sandy inner reef. The sea cucumbers, Holothuria atra and Actinopyga sp., and the sea urchin, Echinometra mathaei, also occur. Fishes are sparse.
West Anini Reef (From reef flat East of Anini river mouth to Keone-mene bay below Prince-ville)	Live coral on the inner reef flat is limited to isolated limestone mounds and coral heads. Montipora verrucosa and Pocillopora damicornis are most conspicuous. Coral cover increase to 1% to 5% on the outer reef flat and along the upper walls of a channel which bisects the reef. Montipora flabellate, M. patula, Pocillopora meandrina, P. ligulata, Porites brighami and P. evermanni are common. Coral growth in the vicinity of the channel may be affected by freshwater discharges from the ligulata, Porites brighami and P.	Patches of sea grass, Halophila sp., are common on the inner sand flats. Fleshy algae are abundant on both the inner and outer reef flat. Lyngbya sp. Occurs across the entire reef flat. Hypnea cervicornis, Dictyota bartayressi, Lyngbya sp. And Acanthophora spicifera inhabit the sandy moat, whereas Jania sp., Padina Australia, Halimedia opunti, and Pterocladia sp. Has been reported near the reef margin. Dense growths of Padina sp. Have also been reported at a depth of Anini reef. reported near the reef margin. reported near the reef margin.	Most fishes are juveniles. Dadcyllus sp., triggerfishes, boxfishes, and schools of surgeonfished (kala, manini) and palani are evident. Some small papi'o are present, but the only large fish are uhu. Fishes are abundant on the reef slope. The sea urchin Echinometra mathaei and E. oblonga occur in pockets on the reef flat, with wana at the reef margin. Various sea cucumbers live on the sand flats.

	evermanni are common. Coral growth in the vicinity of the channel may be affected by freshwater discharges from the stream. Large number of coral heads have been reported at a depth of 30 feet.stream. Large number of coral heads have been reported at a depth of 30 feet.	Dense growths of Padina sp. Have also been reported at a depth of Anini reef. .

3.21 ALGAE (LIMU) HEALTH

Two signs of a healthy reef ecosystem are the health of corals and coralline algae. Algae, (seaweed) also known as limu, are essential to the health of reef ecosystems because they produce oxygen, provide habitat, and act as a food source for marine animals Limu kohu, found offshore Kaua‘, is a valuable food source today and was used in the past by Native Hawaiians (Walker, 1998). Fleshy algae are also an important food source for a range of invertebrates and herbivorous fish and play an important role in the food chain. The introduction of excessive nutrients into marine ecosystems can result in abundant and unwanted algae growth. Fertilizers in storm water runoff and sewage contamination are potential sources of these nutrients. Given high amounts of nutrients, invasive algae are often able to outcompete native species, which may alter the ecosystem through a loss in biodiversity. . Since the 1950s, it has been reported that 18 different species of limu have been introduced to O‘ahu (See Table 7); some were intentional and others were accidental (Russel, 1992). Some of these species have been introduced to Kaua‘i, including, *Acanthophora spicifera*, *Gracilaria salicornia*, *Kappaphycus spp*., *Hypnea musciformis*, and *Avrainvillea amadelpha* (Smith, 2002). Another factor that contributes to the growth of invasive species of algae and to a decline in reef health is overfishing. Overfishing of herbivorous fish that eat plants such as invasive algae can lead to algal outbreaks on coral reefs (Smith, 2007). Invasive species compete with corals for space, oxygen, sunlight, and nutrients which can lead to declines in coral abundance and diversity, or even phase shifts where coral beds transition to algae flats (Stimson et al., 2002).

Table 6: Historical data and new records of invasive algal species in the Hawaiian Islands. *Source: This table was compiled by Jennifer Smith, PhD, Department of Botany & Ecology, Evolution and Conservation Biology as part of the Hawaiʻi Coral Reef Initiative Research Program.*

Species	Date of Introduction	Island 1st Found	Number of Islands	New Island Records – 2000
Acanthophora spicifera	After 1950	Oʻahu	Hawaiʻi, Maui, Molokaʻi, Lanaʻi, Kahoʻolawe, Oʻahu, Kauaʻi	None[1]
Eucheuma denticulatum	1970	Oʻahu	Oʻahu	None
Kappaphycus striatum	1970	Oʻahu	Oʻahu	None
Gracilaria salicornia	1971	Oʻahu	Oʻahu, Hawaiʻi, Molokaʻi	Molokaʻi
Hypnea musciformis	1974	Oʻahu	Maui, Molokaʻi, Lanaʻi, Oʻahu, Kauaʻi, Necker, Maro Reef	Kauaʻi
Kappaphycus alvarezii	1974	Oʻahu	Oʻahu	None
Avrainvillea amadelpha	1981	Oʻahu	Oʻahu	Kauaʻi

[1] Note, that Acantophora (and possibly Kappaphycus) has since been identified on Kauaʻi, including at Hāʻena (Unpublished data, Hāʼena community limu surveys 2011 & 2015).

3.22 KILAUEA SUGAR COMPANY MILL AND RESEARCH, 1971

The Kilauea Sugar Plantation began in 1877 with its first planting as well as its purchasing of mill equipment (Maclennan, 2007). Kīlauea neighbors the project site to the East, and possible implications of the sugar plantation will be addressed in following sections. In 1880 the plantation was incorporated and crystallized its first sugar (Wilcox, 1999). When the plantation first opened it relied solely on rainfall, but began constructing reservoirs and ditches in the late 1880s, with the first being the Ka loko reservoir. Plantations required extensive acreage for crops in order to make the investment worthwhile, which led to increased deforestation in Kīlauea and around Kalihiwai River. Forest lines diminished and rainfall declined creating a greater need for irrigation systems, even in rainy areas, for protection against periods of drought (Maclennan, 2007). At its largest, Kilauea Sugar Plantation cultivated 4,688 acres of land. During World War II, the shortage of labor led to mechanized harvesting, irrigation, and milling. While this increased yields and decreased costs, it also increased soil erosion and loss of fertility (Lau, 1972). The intensive agricultural practices, including fertilization and pest control, along with the creation of large amounts of waste has been a concern due to the belief that the culmination of these factors has had damaging effects on the ecosystem, particularly the marine environment. The plantation closed in 1971.

In 1971, a project was undertaken by the Water Resources Research Center of the University of Hawaiʻi to "identify, develop, and evaluate physical and biological" limits of being able to implement a system to protect coastal waters around the Hawaiian Islands (Russo, 1971). Studies looked at the effects of the discharge into offshore waters coming from the Kilauea Sugar Company Mill. Niu Stream in Kauapea beach (see map below) was the single point at which the sugar company discharged all mill waste. In addition to mill waste, storm water runoff from the plantation may have carried fertilizers, herbicides, and rodenticides into Niu Stream and nearby bodies of water. This suggests that the ocean itself may be the long-term indicator of the effect of sugarcane wastes and their potential to alter water quality (Lau, 1972).

In 1971, the year the sugar plantation closed, Ultramar Chemical Water Laboratory analyzed mill influent and mill waste streams for chemicals and organisms. Most notably, the mill influent (which came from the same source as the field irrigation water) contained 600 MPN of fecal coliforms, while the mill waste stream contained 100,000 MPN of fecal coliforms (Lau, 1972). MPN stands for Most Probably Number, and is an estimation, or probability, of the amount of fecal coliform colony forming units (CFU) in the sample. The DOH states that samples containing greater than 130 CFU per 100 mL may be cause for High Indicator Bacteria advisories in beaches. Nothing can be definitively concluded since the samples were taken directly from the sugar mill streams and not from the marine waters, however the difference between the influent and waste streams suggests the sugar mill was discharging high amounts of potential pathogens directly into the ocean, which may negatively impact the marine environment as well as pose a risk to human health. The waste stream is noted to have higher content of fecal coliforms due to the discharge of plantation factory restroom waste directly into the mill discharge stream. Furthermore, a comparison between samples taken at the shoreline, where wastes had presumably mixed with other waters, showed that Niu Stream, on that occasion, was comprised mostly of mill wastes with only minor dilution from Niu Stream itself (Lau, 1972).

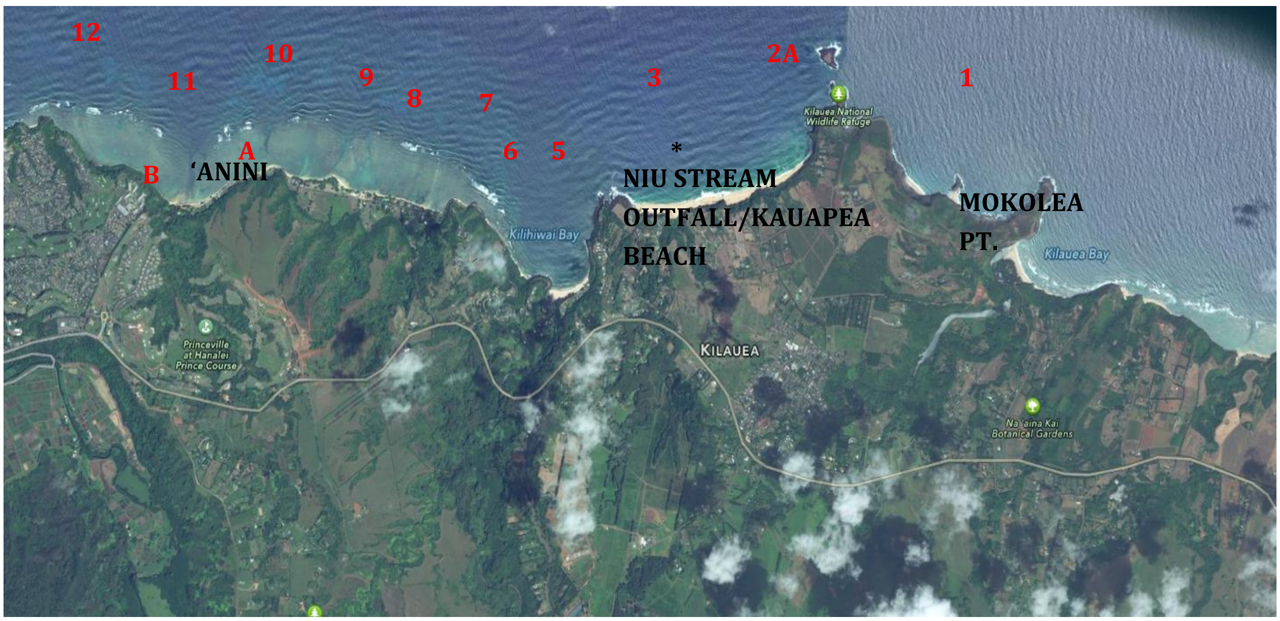
According to the 1971 Russo report, the areas most impacted by the runoff of the sugar mill were within 900 yards from the outfall. Little flora and fauna growth was observed, and there were large amounts of bagasse (the fibrous matter that remains after sugar cane has been crushed). Even though certain areas of the reef became clearer two to three miles from the outfall, debris was carried as far as five miles to the west of the outfall (Russo, 1971). In fact, the plume of sediments originating in the milling operation often drifted to the west from the Niu Stream discharge point, towards Anini (Lau, 1972), observable from land as a brown plume of ocean stretching wet past Kalihiwai bay (Akana, personal communication, 2014). At Anini (points 8 – 12 on map below), there was less evidence of bagasse and cane stalks, and the coral and fish life described as abundant. Coral growth appeared to be affected by the accumulation of silt and by turbidity closer to the outfall (Niu Stream). The percentage of coral coverage was observed to be above 80 percent at Anini, dropping to between 50-80 percent near Kalihiwai Bay. However, as pointed out, "sparse coral growth does not necessarily mean an unhealthy reef condition" (Russo, 1971). Anini reef however was in the direct path of the discharge plume and large amounts of bagasse and mill trash were deposited on the beach. Overall, there was a noticeable decline and/or absence of sea urchin from Kīlauea to Anini (Russo, 1971).

It is important to note that there are discrepancies in the data made available in the Russo report. The evidence in the table below indicates that no samples were taken from Anini at point 10 and 11, which were located offshore. Yet points A and B (in-shore data) reported a reef in poor condition and evidence of mill discharge was visibly apparent. Taking all of this into consideration, it would be fair to say that the impacts were less significant on the outer Anini reef due to regular flushing compared to the inner reef.

Table 7: Description of major offshore stations (Russo, 1971).

STATION	LOCATION AND GENERAL DESCRIPTION
1	1 mile east of outfall: No benthic fauna. No bagasse.
2	½ mile east of outfall: Plume evident, water very unclear. No bagasse.
2A	½ mile east of discharge, below Kilauea lighthouse: Medium presence of coral. No bagasse. Some silt present.
3	900 yards seaward of Niu Stream outfall: Some algal growth, some bagasse observed 50 yards long floating on surface. No fauna present on bottom.
4	½ mile west of outfall: No flora or fauna seen. Large amounts of bagasse and cane stalks.
5	East side of Kalihiwai Bay: Reef flat covered in mud, silt, bagasse and cane stalks. Large amount of burrows of mud shrimp.
6	West side of Kalihiwai Bay: abundant coral. Little bagasse.

7	700 yards west of Kalihiwai Bay: Abundant coral, bagasse and cane stalks seen, 2-3 m plume thickness, clarity of water increased sharply below this layer of suspended solids
8	1 ½ mile from the outfall/900 yards off the coast, west of Kalihiwai Bay: Bagasse and cane stalks seen. 2-3 meters plume thickness.
9	2 miles west of mill discharge, 900 yards offshore: No bagasse, abundant coral, abundant fish
10	Anini: no data
11	Anini: no data
12	3.5 miles west of outfall: Abundant coral and fish, sea urchin seen in large number. At 22 meters a large amount of bagasse piled along reef cliff base. Turbid Water at this depth.
13	5 miles west of outfall: Abundant coral, some cane stalks seen.



Points A and B: Both reefs showed little or no coral coverage, numerous dead coral heads, large amounts of bagasse and other cane debris strewn on reef, scum collected in shallow static pools, 18 out of 20 quadrats sampled showed extensive silt laden algal growth. Sea urchins and other invertebrates were scarce (Russo, 1971).

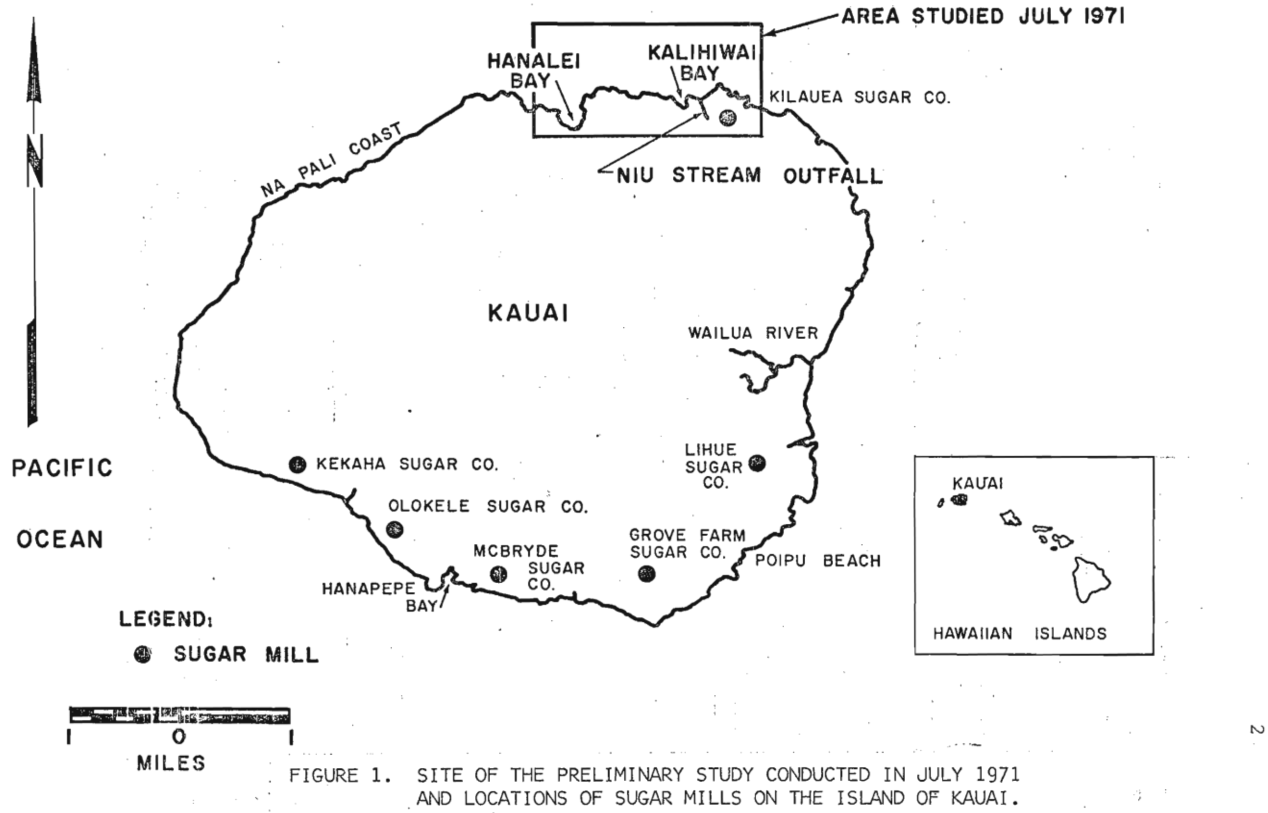


Figure 39: Location map of the sugar plantation study conducted in 1971 (Russo, 1971).

3.23 COASTAL USES

Closer to Kalihiwai Bay, Anini reef was a favorite octopus fishing ground of local families. The local Akana family held the konohiki fishing rights for octopus in this area (community interviews, 2015). After the konohiki system was abolished, fishing and other recreation became increasingly popular among isle residents and visitors. The KICRI study in 1982 described coastal recreation at Anini as including regular shore casters, throw net fishermen, gillnet fishermen, trap fishermen, divers, seaweed harvesters and torch fishers. Commercial fisherman netting was infrequent (KICRI, 1982). Anini Beach Park is a popular camping area. Inshore waters are safe, except in reef channels, where dangerous rip currents flow. The KICRI report also stated that the reef in and around Anini Beach Park was frequently visited by school children who would walk on the reef during low tides. Boats were also launched directly across the sand beach; smaller boats were poled while larger ones were motored. Scuba divers also frequented the area, exploring outside the reef where there are a number of underwater caves and cliffs (KICRI, 1982). All of the above uses still occur at Anini today, along with higher numbers of snorkelers, swimmers, and sun-bathers than were present in 1982, most of whom are visitors. The area also continues to be used by many local residents, and is popular with families who have small children, particularly on weekends (preliminary data from human use counts conducted by class in summer of 2015).

3.3 CORAL DISEASE

Surveys of coral mortality in Anini conducted in 2012 (USGS, 2012), revealed a severely degraded reef with sedimentation and algal turf overgrowth, along with large numbers of corals manifesting varying degrees of tissue loss. Greta Aeby, a coral biologist at the Hawaiʻi Institute of Marine Biology (HIMB), has spent significant time investigating coral disease, and carried out a field investigation to determine what may be causing the mortality. The 2012 report states that the waters on the reef were laden with particulates, and that throughout the reef, corals (mainly *Montipora capitata* or Rice Coral) were encroached by sediments and turf algae. Sedimentation on reefs occurs naturally to some extent, mostly due to runoff from heavy rainfall events, but can be exacerbated by grading, clearing, and development. Aeby found live coral cover to be unusually low in comparison to what would be expected from a healthy reef. The overall picture of Anini was one of a severely degraded reef impacted by sediments and turf algae (USGS, 2012).

In 2014, Aeby completed another study on Black Band Disease (BBD) in Hanalei Bay. BBD was first identified in 2004 at Hanalei Bay and has since spread to different coral communities in the Haleleʻa region of KauaʻI, including Anini, where there is a similar climate and some of the same stressors (Aeby et al. 2014). According to Aeby et al., "BBD is caused by a microbial consortium, visually dominated by filamentous cyanobacteria, that creates the characteristic black band" (Aeby et al. 2015). BBD can be caused by human stressors such as land degradation, nutrient loading, and pollution. The survey found that the outbreak affected 6-7% of corals from the past decade. Furthermore, the researchers were able to use a treatment epoxy to slow down tissue loss and heal coral species affected by the disease (Aeby et al., 2015).. Aeby explains as well that this particular coral disease is only found on the north shore of Kauaʻi, not in other main Hawaiian islands (Aeby, personal communication, 2015).

The vast spread of BBD affecting large coral communities on the North Shore of Kauaʻi is seen to be directly linked to the presence of specific cyanobacteria and fungi that cause the gross lesions. Because of this direct relationship, BBD is noted as a coral epidemic. The 2014 study by Aeby was the first time a cyanobacterial/fungal disease at this level had been documented in Hawaiʻi . Aeby concluded that understanding what drives this phenomenon and how to mitigate it would be critical in the recovery process of the reefs in the area of Haleleʻa (USGS, 2012). A specific focus on Anini would be a critical target area since BBD has become a noticeable issue here.

Figure 40: Map showing marine monitoring sites. Yellow: UH Manoa PhD candidate survey sites, Ms. Christina Runyon. Red: Site of 1st Black Band Disease (BBD) outbreak in 2012. (DOH, 2014).
Source: USGS 2012

Since the first sighting of Black Band Like Disease (BBLD) within Hanalei bay in 2004 by University of Hawai'i researchers Greta Aeby and Alan Friedlander (Aeby et al., 2015), a UH PhD candidate, Christina Runyon, has advanced the research by quantifying spread of the disease on the North shore of Kaua'i (including Anini) and attempting to identify causes. Preliminary findings from Runyon's dissertation and her colleagues are as follows:

1. A total of 12 diseases affect the corals of Hawai'i (Aeby et al., 2011), of which four are known to be on Kaua'i (including Anini).
2. In 2012, Black Band Disease (BBD) affected three rice corals belonging to the genus *Montipora*, on Anini reefs. Unlike the BBLD infection of 2004 which affected around one percent of corals, the 2012 BBD outbreak affected six to seven percent of corals.
3. Runyon's six stations at Anini are shown in Figure 34 below, with the inset showing position of Anini on Kaua'i Island.
4. Figure 35 shows that algae and other substrate (including rubble and sand) are the dominant feature of reef surfaces on Anini and that coral cover is generally very low at all sites.
5. There is a relationship between high Sea Surface Temperature (SST) and the prevalence of Black Band Disease as shown in Figures 36a and Figure 36b. With climate change and continuing sea surface warming, it is expected that coral diseases may become more prevalent as time goes by.

Figure 41: Map showing Runyon's six survey sites at Anini. Insert: Location of Anini on Kauaʻi.

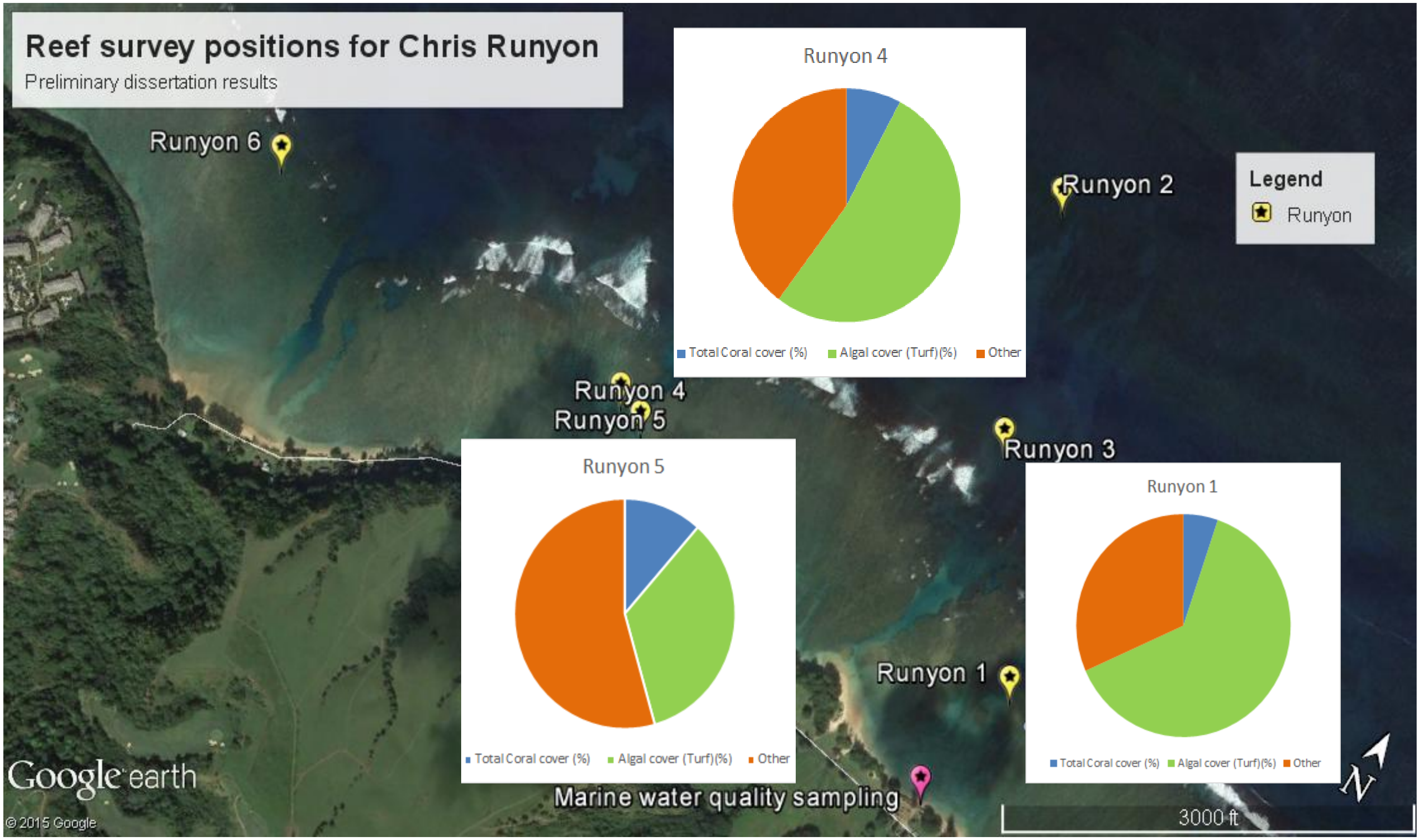


Figure 4219: Breakdown of substrate cover on three of the six sites surveyed by Christina Runyon.

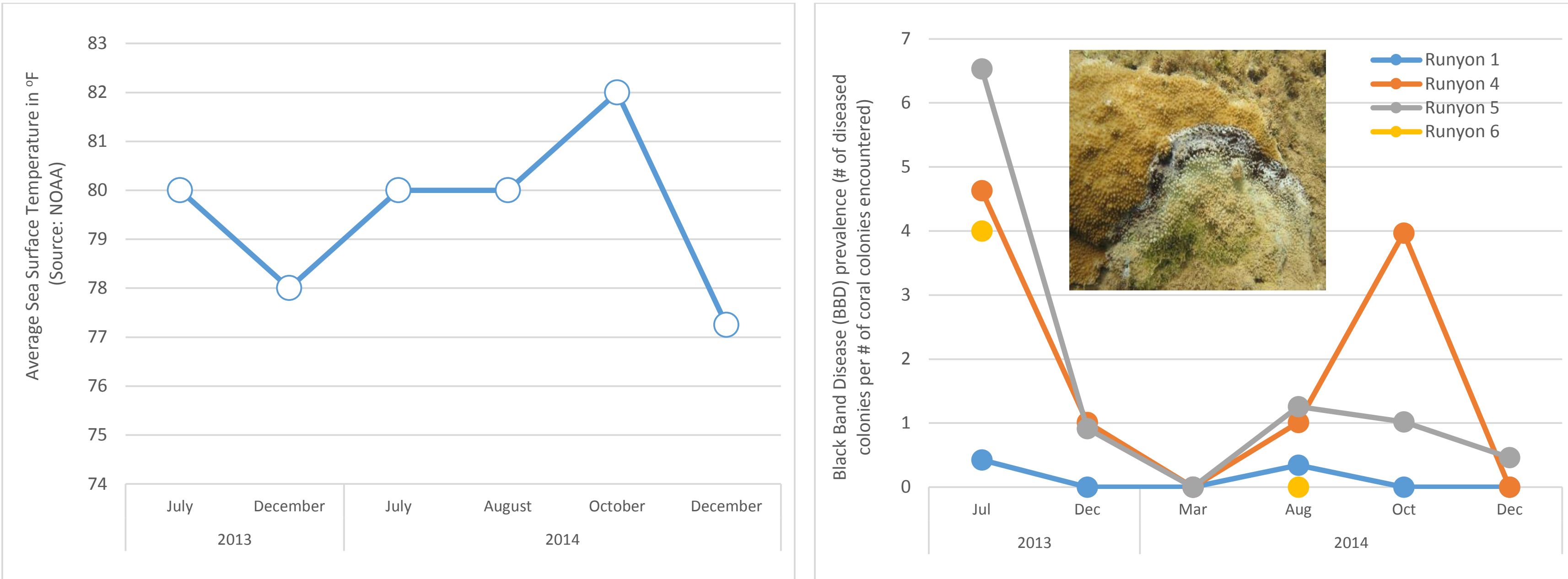


Figure 4320: Graph A (left) shows changes in Sea Surface Temperature (SST) over time. Graph B (right) shows the number of corals surveyed at each station that showed signs of Black Band Disease (BBD). From the two graphs, it can be seen that periods of high sea surface temperatures (July 2013 and leading up to October 2014) correspond to higher occurrences of Black Band Disease.

3.4 CORAL BLEACHING

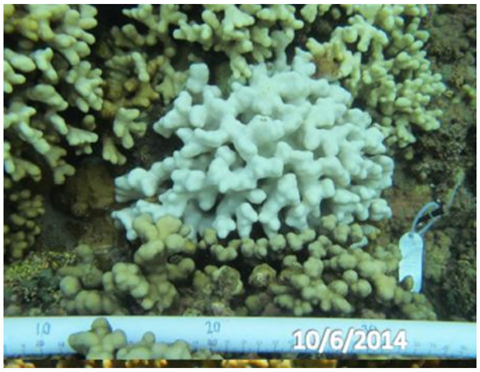
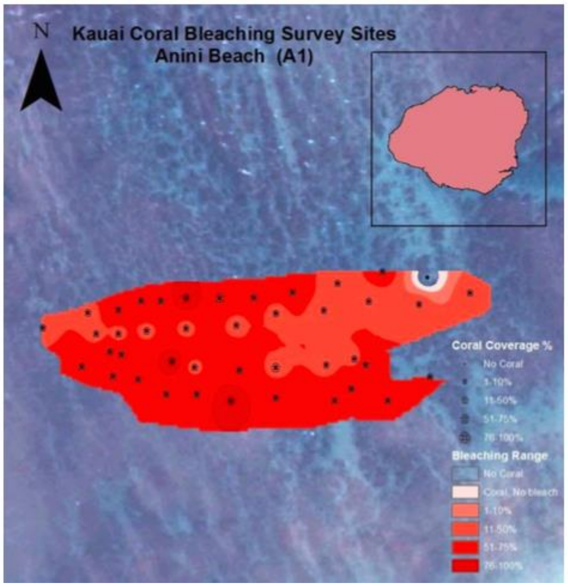


Figure 44: Coral Bleaching at Anini (Neilson, 2014).

Coral bleaching in its simplest explanation is white, bleached out coral reefs, rather than the colorful array we would normally expect to see. The image on the left shows a bleached *Porites compressa* colony a week after bleaching started (Neilson, 2014). Corals get their vibrant colors from tiny algae that live in their tissues. Corals and algae benefit from each other through symbiosis. The coral provides the algae with a protected environment and facilitates their need for photosynthesis. In return, the algae produce oxygen and help the coral to remove wastes (NOAA, 2015). Coral bleaching typically occurs when water temperature increases 1.8^{o} to 3.6^{o} F above normal levels and persists for at least three weeks. The consistent above normal temperatures cause the coral to eject algae, turning them white (Keener et al., 2012). If the algae do not return to the coral in a short period of time, the coral dies. Coral bleaching can result from disease, pollution from urban or agricultural run-off, changes in salinity, sedimentation from undersea activities such as dredging, and very bright sunlight particularly when combined with extra-warm sea water (Douglas, 2003). A 2011 report titled *Reefs at Risk Revisited* predicts that by 2050 many pacific reefs will bleach annually (Keener et al., 2015).Coral reefs are essential to human survival and are some of the most valuable ecosystems on earth, making management of marine ecosystems critical. Over 1 billion people depend on food from coral reefs, providing goods and services worth $375 billion each year (Costanza et al., 1997). Coral reefs protect land by dissipating wave energy from storms and tsunamis, therefore significantly reducing the damage to land.

The Division of Aquatic Resources (DAR) of the Department of Land and Natural Resources (DLNR) surveyed select reefs on Oahu and Kaua‘i during the September to October 2014 bleaching event (Neilson, 2014). Two of the sites surveyed on Kaua‘i were at Anini, on the east and west end of Anini beach. Results showed greater bleaching occurrence in the west compared to the east. Spatial extent of bleaching in the two locations in relation to coral cover is shown below.



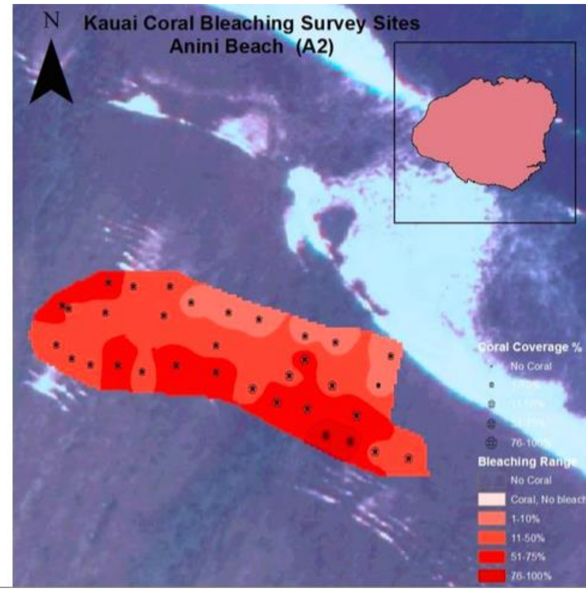


Figure 45: Color-coded images of West Anini Reef (left) and East Anini Reef (right) showing coral cover (size of black circles) and degree of bleaching (intensity of red band with darker red colors indicating higher percentage of bleaching) (Neilson, 2014).

3.5 FISH ABUNDANCE

Fish abundance data was also collected by Christina Runyon as part of her PhD research. Six sites (see map of sites on Figure 37) in Anini reef were monitored between June 2013 and November 2014. Data was collected at the species level where possible, using the belt transect method, which involves surveying a volume of ocean measuring 25 meters in, at a length, 4 meters in width, and 2 meters in height, totaling a volume of 200 cubic meters. Fish observed along the transect lines were later classified as being “food fish” or “non-food fish.” Food fish, as the name implies, include species that are known to be consumed for food. These can range from small to large sized fish and over hundreds of species. Runyon’s dissertation data indicates that fish abundances are so low that the highest average abundance (in a 200m^3 area surveyed) of food and non-food fish, is below two individuals. However, at the species level, the most abundant food and non-food fish are present up to 10 individuals per 200m^3 area. Additionally, it’s worth noting Runyon’s observation that many of the fish present at Anini reef are small in size.

Table 8 below shows the change in abundance of both food and non-food fish during the survey period. Figure 37 shows the top 2-3 most abundant, food and non-food fish, and their change in abundance over time.

Table 8: Runyon’s data showing the change in abundance of the most abundant food and non-food fish over time.

		2009		**2010**			
Food fish type	**English common name (fish type)**	**Jun**	**Nov**	**Feb**	**Jul**	**Nov**	**Sept**

Non-food fish	Surgeonfish	2.31	1.86	1.28	1.44	0.83	1.67
	Wrasse	1.64	1.14	1.04	2.89	1.33	3.04
Non-food fish Average Abundance		**2.02**	**1.55**	**1.17**	**2.06**	**1.05**	**2.25**
Food fish	Goat fish	0.25	0.33	0.00	0.08	0.17	0.06
	Surgeonfish	0.00	0.35	0.06	0.21	0.00	0.28
	Wrasse	4.61	0.85	1.15	2.61	1.59	1.70
	Parrot fish (adult)	0.33	4.56	2.22	0.00	0.00	0.00
Food fish Average Abundance		**1.83**	**1.06**	**0.72**	**1.05**	**0.64**	**0.72**

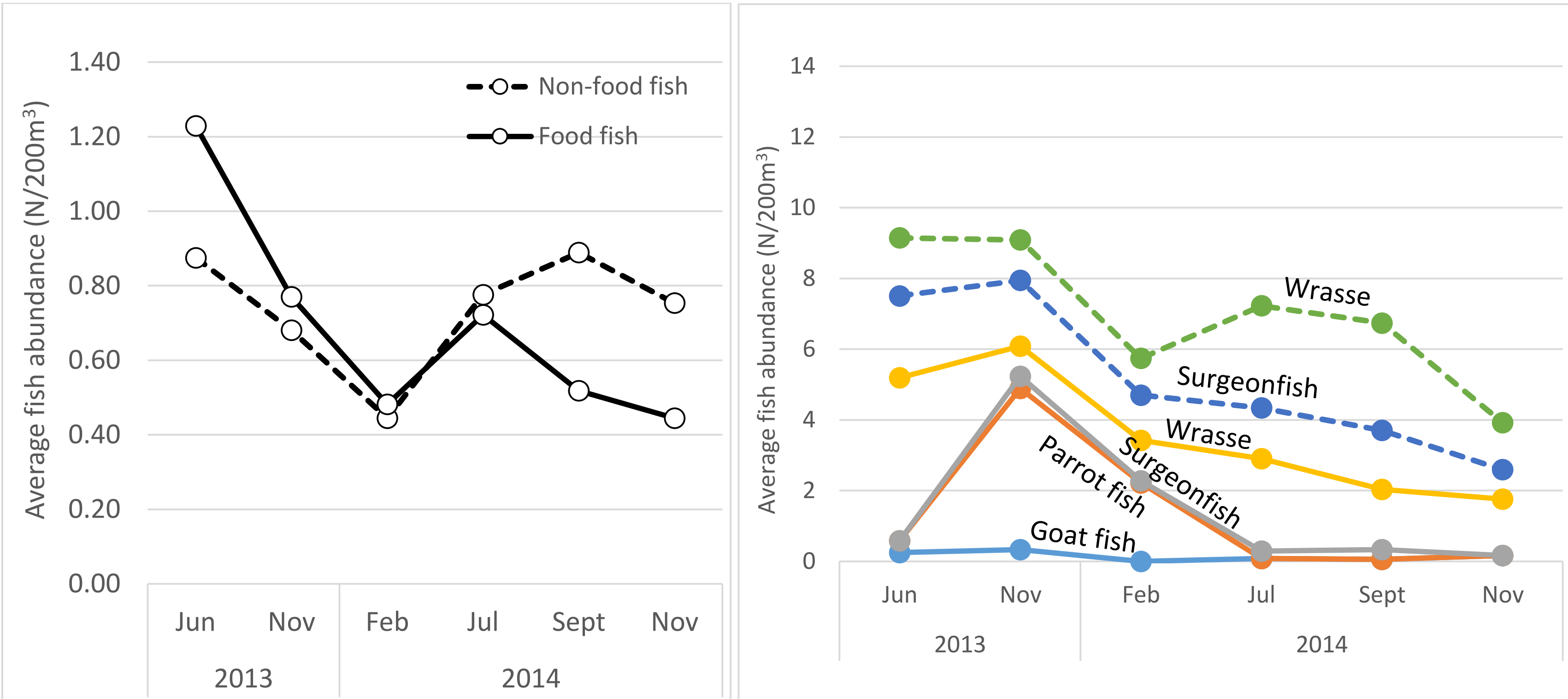


Figure 46: Graph A (left) shows the change in food and non-food fish abundance over time. Graph B (right) shows the change in abundance of the two non-food fish (in dashed lines) and top three food fish, over time. In Graph B, it should be noted that although surgeonfish and wrasse appear in both the food and non-food fish, the species that comprise each category.

Graph A shows that food fish were more abundant than non-food fish at the start of the surveys (June 2013). However, the abundance of both types of fish declined over time.. By the end of the survey (November 2014), non-food fish were twice as abundant as the food fish. Despite the abundances being lower than at the start of the surveys, the change was more prominent in food fish in comparison to the non-food fish. Graph B also showed decline in abundances of all fish graphed here.

Several marine invasive species exist in the Hawaiian islands, and Anini reef is no exception. These species include the peacock grouper locally known as roi (*Cephalopholis argus*), blacktail snapper locally known as to'au (*Lutjanus fulvus*), and the blue striped snapper locally known as ta'ape (*Lutjanus kasmira*). To date, such invasive species are being controlled through organized spearfishing tournaments (Eagle 2010). One such fishing tournament took place in 2010 at Anini beach, where 60 freedivers took 244 invasive roi or peacock grouper off the reefs in one morning. Scientist Terry Lilley estimated that 170,000 native fish survived because of this event (Eagle, 2010).

3.6 CLIMATE CHANGE, SEA LEVEL RISE & IMPACTS

Climate change has become the forefront of scientific research and debate in the last decade. Climate change can be seen throughout the main Hawaiian Islands and the Pacific in terms of rising sea levels, increasing ocean acidity, changing rainfall patterns, decreasing base flow in streams, changing wind and wave patterns, and changing habitats and species distribution (Keener, 2012). Marine inundation, the flooding of the immediate coastal area, terrestrial flooding (flooding of land), coastal erosion, hurricanes, and tsunamis are some of the coastal hazards facing the island of Kaua'i. Specifically, coastal flooding, marine inundation, and coastal erosion are predicted to be exacerbated by climate change related sea-level rise (Figure 38).

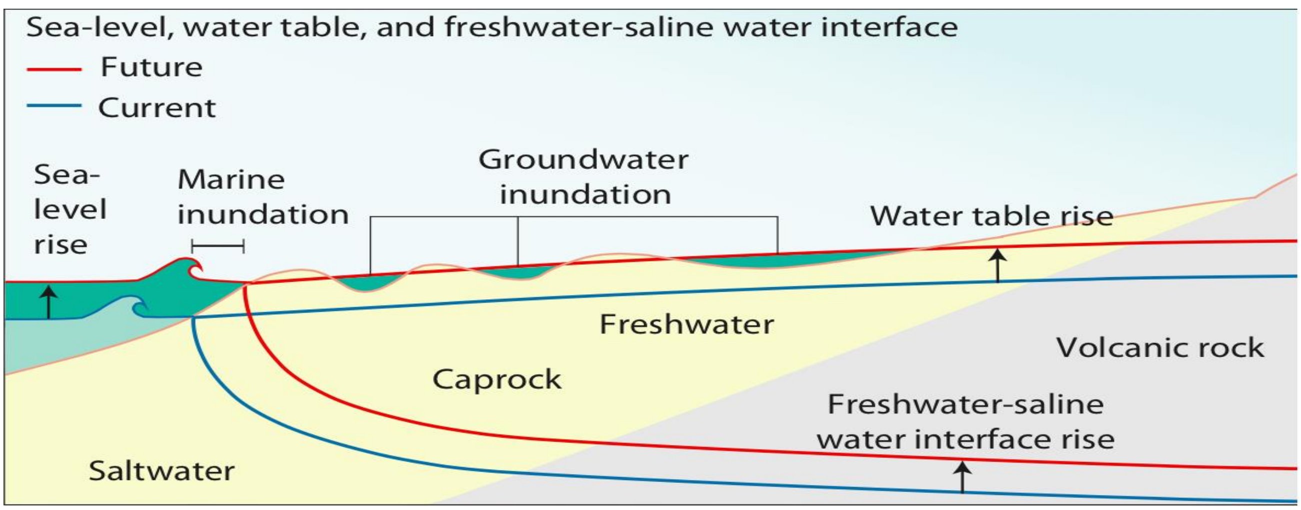


Figure 47: Diagram of a freshwater lens, and marine and groundwater inundation under sea level rise (Rotzoll, 2012).

Extreme water levels will occur when sea level rise, , combines with certain conditions including seasonal high tides, yearly and decadal sea-level variations, tide surges, and high water rise associated with storms and tsunamis (KCCCHA, 2014). Records indicate that sea level has been rising globally for the last century or longer. On the island of Kaua'i, sea level has risen about six inches over the past century (NOAA, 2014). Sea level rise leads to shoreline retreat through two processes: 1) by moving the water line up the coastal slope and 2) by increasing erosional effects of waves on the upper beach, dune, or cliff (KCCCHA, 2104). USGS and NOAA have predicted that sea levels around Hawaii will rise by one foot by 2050 and three feet by 2100 (Parris, 2012). This will significantly impact Anini beach and those that reside close to the shoreline, due to the low lying landscape of the area (Figures 39-44).

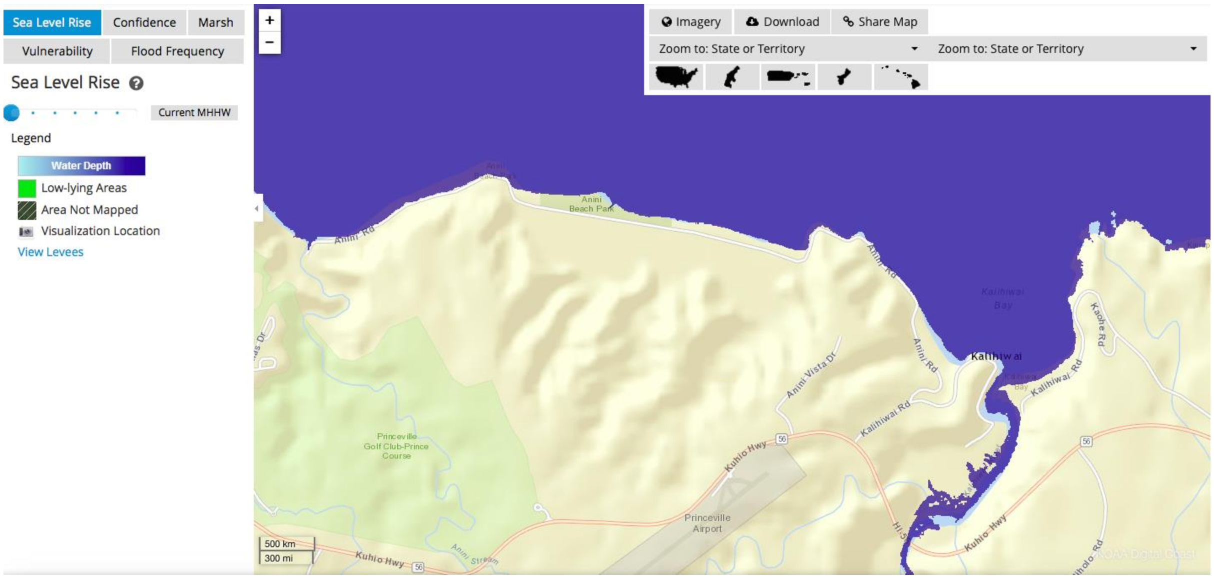


Figure 48: Map indicating current sea levels at Anini (NOAA, 2015).

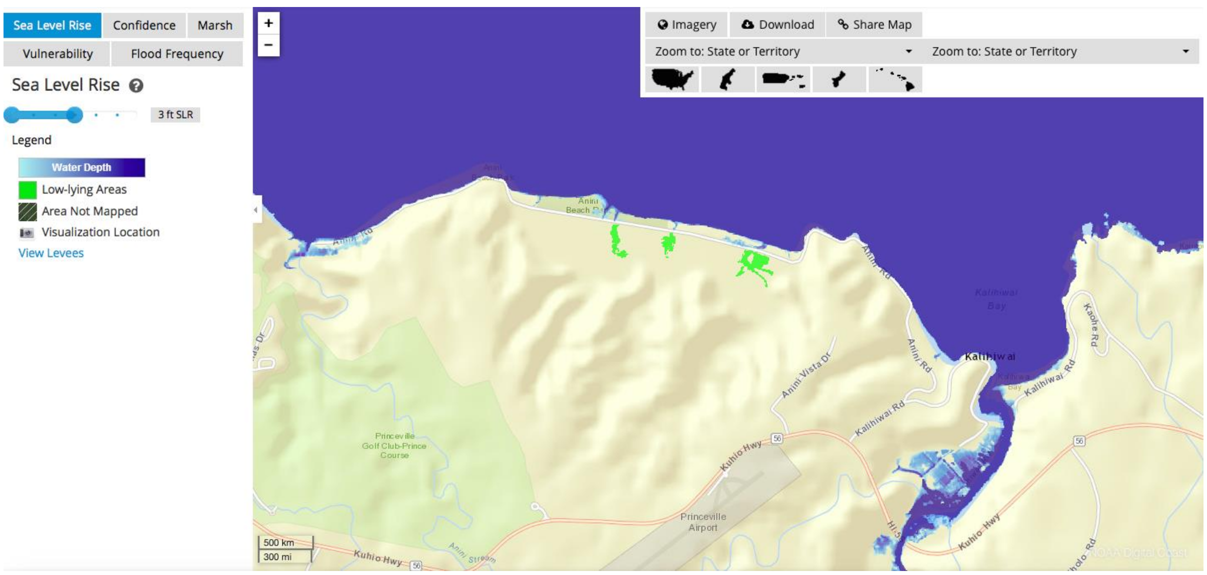


Figure 49: Map indicating a sea level rise of 3 feet at Anini (NOAA, 2015).

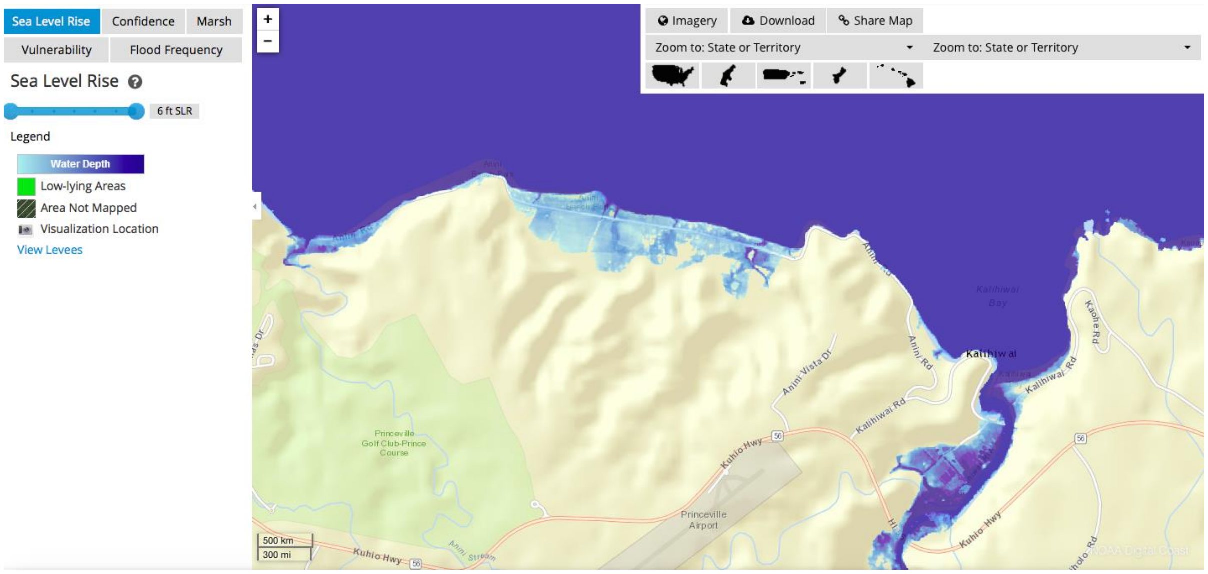


Figure 50: Map indicating sea level rise. At 6 feett, a significant portion of the coastal area around Anini will be submerged, including Anini Road (NOAA, 2015).

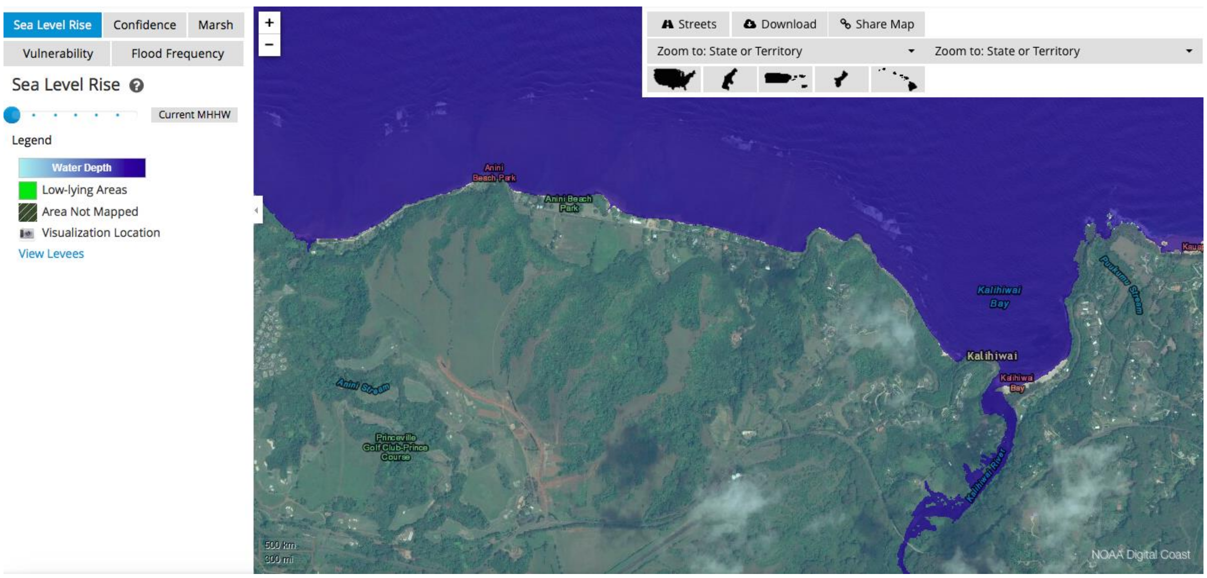


Figure 51: Satellite image indicating current sea levels at Anini, see Figure 35 (NOAA, 2015

Figure 52: Satellite image indicating a sea level rise of 3 feet at Anini, see Figure 36 (NOAA, 2015

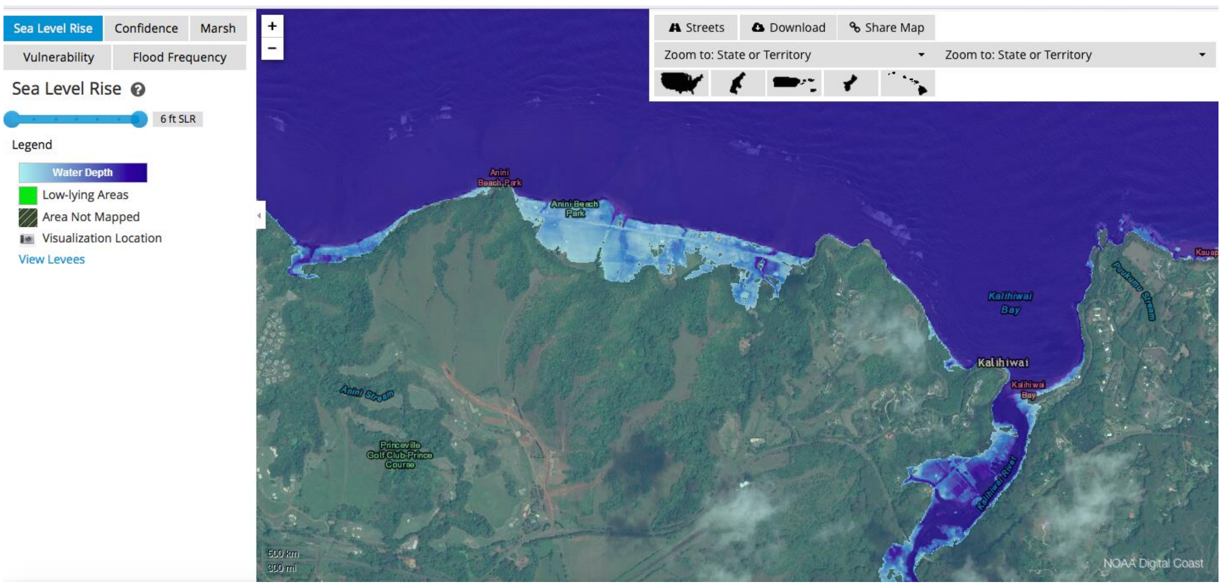


Figure 53: Satellite indicating sea level rise. At 6 feet, a significant portion of the coastal area around Anini will be submerged, including Anini Road. See Figure 37 (NOAA, 2015)

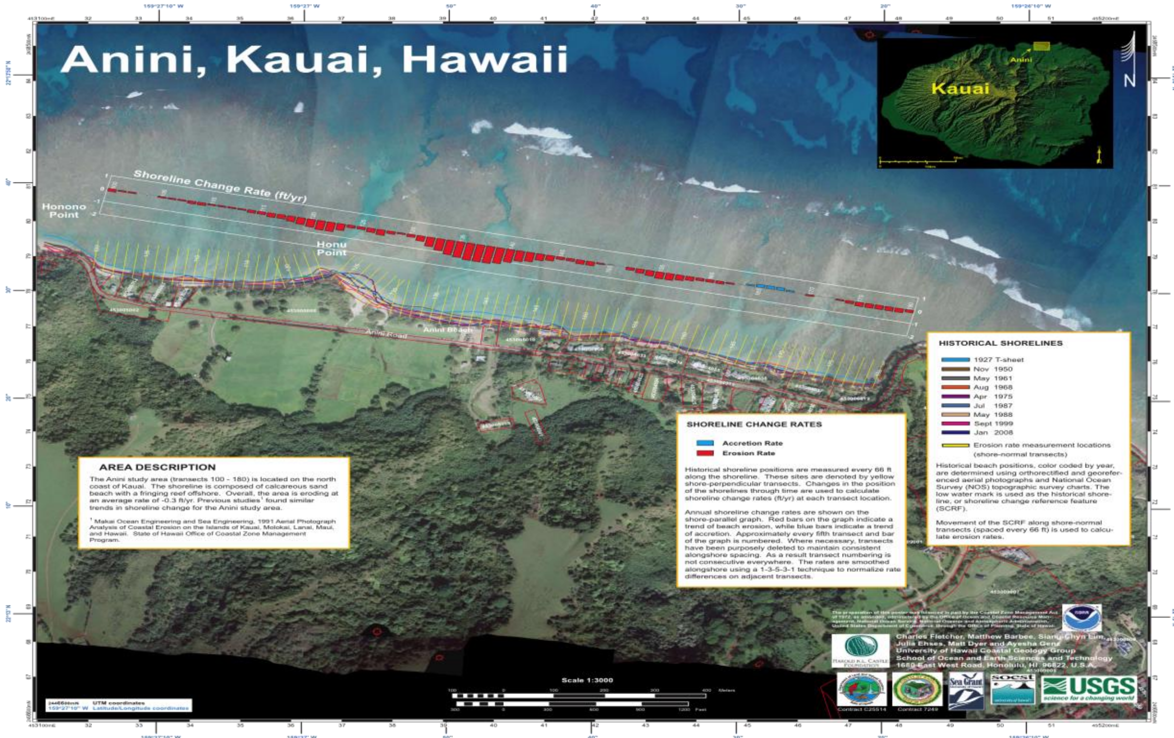


Figure 54: Shoreline erosion at Anini. Anini is eroding at an average rate of 0.3 feet/year. The red bars on the map indicate an area that is subject to high rates of erosion and therefore classified as moderately high (USGS, 2014)

Figure 55: Anini Beach/Road erosion (http://www.forKauaionline.com/how-will-your-community-adapt-to-climate-change/)

Sea level rise can cause the water table to rise. If the water table breaks the land surface, the effects can include expanding wetlands, changing drainage patterns, soil saturation, and increased flooding (KCCCHA, 2014). Wetlands are critical in filtering pollutants from water, recharging groundwater, protecting shorelines and providing habitat for wildlife. If an area has an adequate amount of land, rising ground waters may create additional wetlands. However, if adequate land is not available, sea level rise could cause saltwater intrusion (the movement of saline water into freshwater underground wells), which can lead to contamination of drinking water sources. Approximately 70% of Kaua'i's beaches have already experienced shoreline erosion due to sea level rise, which is expected to increase with the projected future levels (UH CGG, 2013). Figure 45 indicates areas in Anini that have a potential high level of erosion rate due to tidal patterns. These sections of beach front should be of specific concern for long term issues of flooding and pollutants in the ground water. Anini has already seen erosion issues in the street connecting the area (Figure 46). Sand has begun to recede from where the road is built, indicating long term slow erosion occurring, a pattern that the community of Anini should note as a progressing issue.

According to the 2012 Pacific Islands Regional Climate Assessment, "Threats to traditional lifestyles of indigenous communities in the region (including destruction of coastal artifacts and structures, reduced availability of traditional food sources and subsistence fisheries, and the loss of the land base that supports Pacific Island cultures) will make it increasingly difficult for Pacific Island cultures to sustain their connection with a defined place and their unique set of customs, beliefs, and languages." (Keener 2012). It is therefore necessary that effective mitigation and adaptation is achieved for the entire island of Kaua'i in order to sustain the full value of Hawaiian culture. Sea-level rise will also impact intertidal areas, beaches, wetlands, estuaries, lagoons, tidal marshes and tidal flats. Inundation and erosion from sea-level rise will reduce habitats and/or convert habitats from one type to another. Fish species that depend on shallow water plant communities will be at risk of habitat loss whilst changing water depths are likely to affect species types and quantities (KCCCHA, 2014).

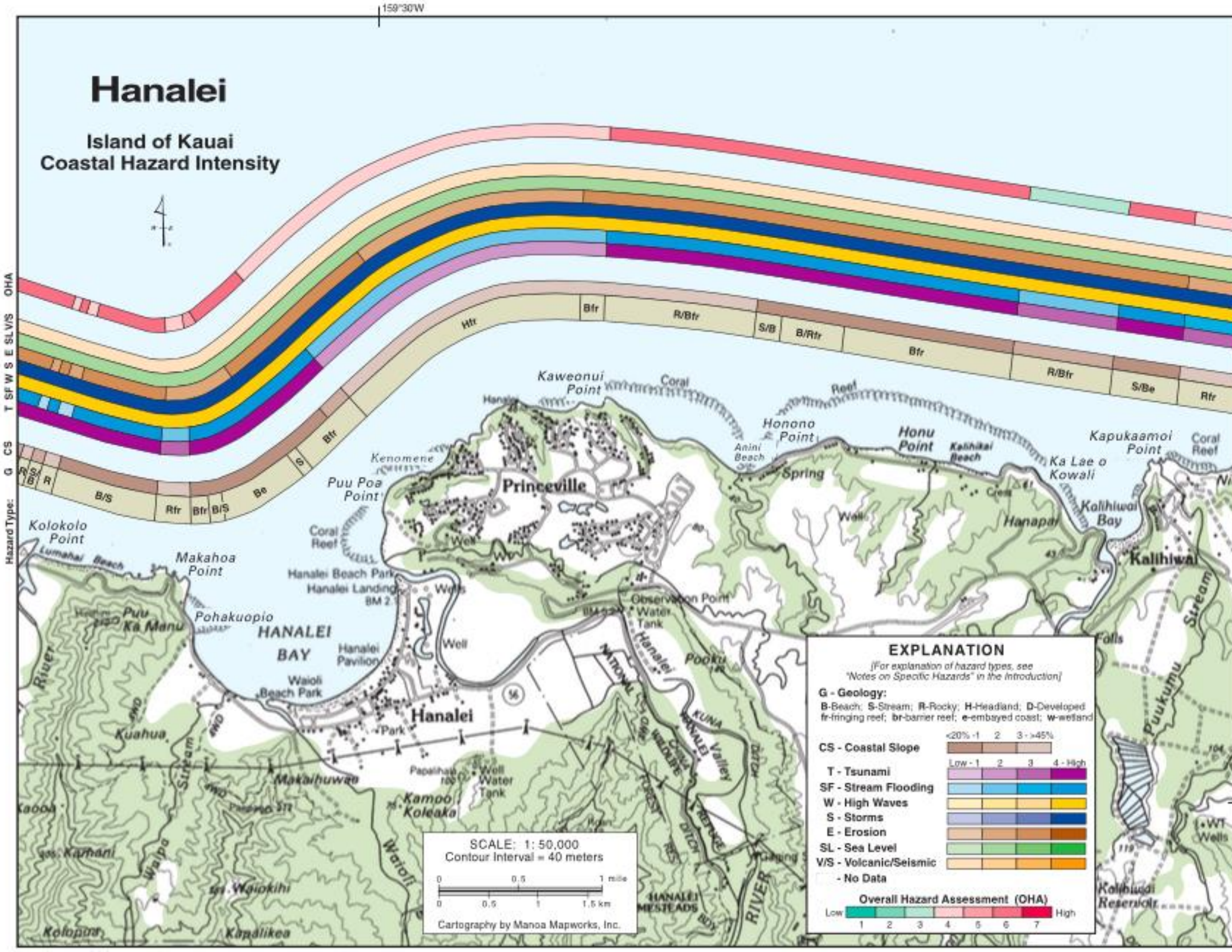


Figure 56: Coastal Hazards Intensity map indicating that Anini is highly susceptible to erosion, whilst susceptibility to sea-level rise is moderately low (USGS).

4.0 SUMMARY

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1. Visitor and residential population increases have led to development of new homes and vacation rentals along the coastline.
2. Land clearing and development are common mechanisms for watershed deterioration. Since the early 1980s, Princeville has developed as a resort area with two golf courses. The Prince golf course situated just above Anini was constructed in the mid-1980s. Kilauea Sugar Plantation closed in 1971, however it operated for nearly 100 years with extensive sugarcane cultivation and the use of fertilizers and pesticides. Both of these land uses possibly have or have had negative impacts on the environment.

3. The quantity of fresh water reaching the marine environment through springs and from streams appears to have decreased. Kalihiwai River located near the site has historically been diverted for sugarcane irrigation as well as for small-scale agriculture. Smaller diversions, manily for agriculture use, may also have impacted Anini stream. Some of these diversions have been destroyed while a few appear to still be present. Water diversions are considered to be a mechanism for stream and wetland deterioration. Ground water and stream base flow in the Anini area may also have been affected by multiple wells.
4. Anini Stream degraded significantly between 1982 and 1989. In 1982 the water quality was described as good, with relatively abundant ʻōpae and ʻoʻopu. In 1989 the water was noted to be turbid with significant sedimentation, and very few native species were found.
5. The biodiversity of native species shows a declining trend, with several species reaching extinction in the past 100 years. The native Newell's Shearwater is especially at risk from developments in the area that could interfere with its habitat, and increase light pollution.
6. Wastewater contamination is a concern in the area due to the high density of on-site disposal systems, particularly cesspools, which discharge untreated wastewater, containing pollutants toxic to the environment and human health.
7. However, existing marine water quality data at Anini shows high levels of sediment and turbidity issue, but not high bacterial counts.
8. The reef at Anini has extensive dead coral, and is being affected by black band coral disease which appears to be affected by water temperature. Sedimentation and coral bleaching are also degrading the reef.
9. The abundance of native fish populations has declined, while invasive introduced fish populations thrive. Commonly consumed species are also less abundant than non-food fish.
10. Climate change and sea level rise are expected to inundate parts of coastal areas within the next century. Coastal erosion is also expected to increase at Anini.

5.0 CONCLUSION

5.1 CONCLUDING RESPONSES TO KEY QUESTIONS

5.11 TERRESTRIAL

1. What are the underlying geological and hydrological characteristics of Anini?

Anini is characterized by large plateaus surrounded by higher cliffs, potentially making the area more susceptible to landslides and flooding. The soil is predominantly of the Makapili series, which is characterized as being well-drained silty clay and clay loam soils, having low fertility. The site includes five watersheds: Anini, Honu (Kalihikai West), Kalihikai (Kalihikai Center), Kowali (Kalihikai East), and Kalihiwai River. Anini and Kalihiwai River watersheds have perennial streams while the other three have ephemeral streams, all of which begin as fresh water springs makai of the highway.

2. What terrestrial developments or changes have occurred and what are the effects of these changes?

The clearing of land for agriculture and cattle ranching likely changed the hydrology at Anini. The cultivation of agricultural crops, can erode soils and make it easier for them to be transported and deposited in nearby surface waters, negatively impacting aquatic and marine organisms. Cattle grazing compresses soils reducing infiltration, and can negatively impact streams which are not fenced off. The watersheds have been further altered by the construction of an airport, dump, new highway, golf course and increased resort and residential housing.

Recent resort and residential development in Anini likely increased erosion, storm water runoff, sediment deposition, along with point sources of pollution. Twenty-two residences along the coast still use cesspools as wastewater systems, which discharge untreated sewage containing pathogens, excess nutrients, and chemicals. These may infiltrate through the soil and reach groundwater. Contaminants may also leach into surface waters such as streams and the nearby ocean. The Princeville golf courses utilize fertilizers and pesticides that can reach surface waters through runoff, and can also infiltrate through soils to groundwater. The old refuse dump on the ma kai side of the highway, through which Anini Stream flowed, was a noted point source for pollution. Today, the refuse transfer station mauka of Kuhio Highway, is located adjacent to and uphill from Anini Stream. Hazardous substances such as petroleum products can be seen draining towards the stream, which may also receive contaminants from plastic and metal leaching. Stream diversions and wells could decrease stream health by reducing flows and impacting freshwater biota, as well as impacting local wetlands. Another side effect of development is interference with native species such as shearwaters, which are vulnerable to habitat disruption, power line placement, noise and light pollution.

3. What species are present within the site, especially with regards to invasive and non-native species?

Extensive data and survey results on biodiversity at Anini are not available. This report contains information from decades-old surveys of damselflies, birds, and aquatic macrofauna, as well as eye witness accounts and personal communication. However, there does appear to be a decline in abundance and diversity of stream and marine native species, while introduced species persist. Anini Stream specifically is noted to have declined in terms of native species.

4. What are the historic and current conditions of surface water and groundwater reserves and are there identifiable threats to these sources?

There are two perennial streams: Anini Stream, which borders the project site on the west, and Kalihiwai River on the east. Both Anini Stream and Kalihiwai River have been diverted at different points, mostly for agricultural purposes. Kalihiwai River was diverted to serve the Kilauea Sugar Plantation and Anini Stream has had several small diversions to serve agricultural purposes, with five diversions being noted within 300 meters of the mouth of the stream in 1983. Other diversions are known to have occurred further up in the watershed. It is unknown at this point the extent to which diversions currently exist and if they still serve their original purpose. While there has not been enough data collected to provide a firm conclusion about the health and quality of surface waters in the area, stream scientists familiar with the area assess them as not in very good condition. Groundwater quality does not seem to be a concern. There are several wells in Anini, however there is relatively little data available about their usage, and current aquifer conditions are not readily known at this time.

There are currently several identifiable threats to freshwater sources, as well as possible future threats. Fertilizers and pesticides applied to the nearby golf course and landscaping areas above Anini potentially run into surface waters. Golf balls and other debris also wash down into streams and the ocean presenting a risk to water quality and aquatic organisms. Current water diversions are unlikely to cause increased negative impacts, however additional diversions would likely affect stream flow and possibly stream health. Furthermore, twenty-two known cesspools in the area pose a risk to groundwater through infiltration of untreated sewage. These may also affect surface waters including the ocean. As sea level rise begins to increase, cesspools and septic tanks could pose a more substantial threat to the health of groundwater quality in Anini.

If future developments, such as the proposed Princeville expansion occur, surface water is likely to be impacted by sedimentation through erosion from construction and land clearing. Continued large scale use of fertilizer and chemicals on golf courses coule also contaminate surface waters. Additionally, increased residential or resort development in upper watershed areas would pose a threat.

5.12 MARINE

1. How has marine life changed on Anini reefs? What were the causes of these changes and how widespread are the effects?

The most significant and noticeable changes in Anini‘s marine ecosystem have been in the health of the reef, including the decline in abundance and health of coral, fish, and algae (limu). Coral cover is unusually low with turf algae and sediment now covering expansive sections. Black band coral disease and coral bleaching have recently been detected on the reef, and fish size and abundance appear to have declined. Native species of fish and algae have also been reduced through competition with invasives. DAR reports a significant decrease in the abundance of inshore marine resources over the past three decades in Anini, which is supported by comparisons of studies from 1972-2014. Diversity of marine species present in 1982 is summarized in Table 5 with presence of certain coral species noted in Table 7.

Causes appear to include, but are not limited to: introduction of invasive species, land clearing and development, overfishing, climate change, pollution and sedimentation. The clearing of land for cattle, agricultural activities, and increased development has increased erosion and runoff, causing sedimentation of the ocean and reef. Additionally, Kilauea Sugar Company's mill discharged bagasse and according to one report, raw sewage, into the ocean at Kauapea beach where it drifted to Anini.

One possible cause for changes in marine health is pollution. The old refuse dump and the current refuse transfer station, pesticides, fertilizers, and cesspools are all potential sources of chemical pollution, located in close proximity to Anini stream or the ocean. The coastline west of Anini stream is strewn with discarded plastic and trash left from derelict campers. Corroding golf balls from the Prince course litter the mouth of Anini stream. Studies from other locales document leaching of heavy metals from golf ball cores. Marine debris, discarded either directly into the ocean or indirectly washed out in storm drains or streams, can be carried many miles from its source, and contain multiple potential contaminants.

Some of the major causes associated with degradation of Anini's freshwater and marine ecosystems are displayed in the visual timeline below (Figure 58). These issues, are not unique to Anini, but are prevalent in coastal communities throughout the main Hawaiian islands. All result from human activities. No single event or action should be blamed for degradation of Anini's marine environment, which is likely the outcome of many interacting factors causing a magnified, or cascading effect. The key issue is how to best manage and minimize the environmental impacts of future human activities and development on Anini's unique ecosystem.

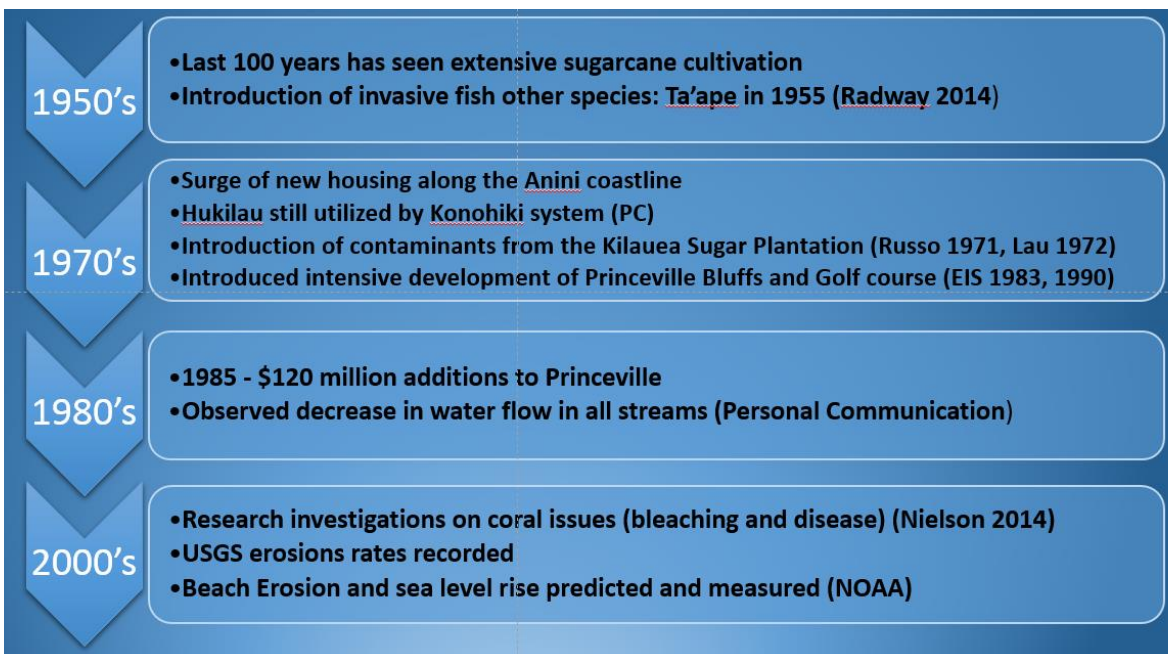

Figure 58. Timeline of some key events that changed Anini to a degraded state.

2. How will sea level rising impact Anini? Can we anticipate significant changes in the shoreline?

Although a precise timeframe and scale of sea-level rise cannot be accurately stated, the types of impacts it will have on the coastline can. Sea-level rise will ultimately result in increased frequency and severity of wave inundation, coastal erosion and flooding (areas infrequent to flooding will become more permanently flooded). The SOEST erosion map shown earlier in this report (Figure 54) is based on erosion rates taking into account historical trends over the last century. However, it does not reflect projected increases in sea-level rise in the decades to come. Coastal infrastructure including roads, homes, water supply, wastewater systems, and ecosystems will be threatened. Beaches that are already eroding due to modern environmental conditions will see extensive erosion and shoreline retreat. The potential for damage is exacerbated by high wave events, hurricanes, tsunamis and extreme tidal events, expected to occur more frequently with sea-level rise. Coastal erosion rates on Kaua'i and other Hawaiian Islands are also expected to increase.

The Pipeline Replacement from Kilauea to Anini, Final Environmental Assessment, 2011 provides an accurate description of the Anini shoreline in relation to Anini road: The majority of Anini road is along the coast, with elevations varying from 7 to 30 feet. The roadway was constructed essentially traversing the cliff, and the grade slopes steeply, sometimes near vertical, off the side of the roadway. The shoreline, in several locations, is at the base of the cliff on the down slope side of the roadway. The section of Anini Road adjacent to Kalihikai Park is flat, straight, and relatively open. The west end of Anini Road, adjacent to Anini Beach is a few feet above sea level abutting the shoreline. The coastal flooding maps (Figures 48-53) above indicate that at a sea-level rise of 3 feet, some residential properties in Anini more than likely will be submerged. At 6 feet of sea level rise most homes in Anini and Anini road will be submerged. Clear evidence of erosion such as that depicted in the image above (Figure 55), suggests that the threats are imminent.

3. How have terrestrial changes and development affected the marine environment at Anini?

As noted in Section 5.11 Question 2, and 5.12 Question 1, developments on land over the past century have likely contributed to the loss in endemic and indigenous species of both fish and invertebrates in fresh water and marine ecosystems. First, the Kilauea Sugar Plantation likely contributed to the degradation of reef health and native fish populations by discharging sugarcane bagasse from the mill which washed up on area reefs. Second, cesspools and septic tanks, mainly of vacation rentals along Anini beach have increased. Tanks located in proximity to the ocean can seep during floods, leading to increases in turf growth and bleaching events. The third major land development was the transformation of the Princeville area. Multiple land use changes and extensive grading likely caused erosion and sedimentation in the ocean. Furthermore, continued pesticide and fertilizer treatments on the Prince golf course continue to run off into Anini stream and the ocean, along with deteriorating golf balls. These are three of the major contributing factors to decreased resilience and health of Anini's marine environment. Impacts include nitrification, sedimentation, decreased survival rates of endemic species (both fresh and marine), increased invasive vegetation, and loss of endemic limu which in turn alters marine food chains. Some indirect impacts may include cases of ciguatera reported during personal communication with past residents and fishermen of the area from eating akule that had fed on high nutrient bagasse contaminated with dinoflagellates. In addition, the increase in development is related to an increase in visitors and fishermen to the area. This may lead to disruption of fish cycles and overharvesting of resources . Although other anthropogenic pressures have likely contributed to depleted marine ecosystem health, these were cited in both scientific studies and the 40 interviews this class conducted with community experts. Many community experts also pointed to decreases in the quantity of fresh water entering the marine environment as another key factor.

4. To what extent does community livelihood depend on the reef?

Because the community dynamics have transitioned drastically from its past states to a highly visited site for recreational and tourist visitation, the needs of the reef have changed. Prior to tourists utilizing the reef, the marine resources were needed for the everyday survival and subsitence lifestyle of the immediate community for food, shelter, and other uses (Sproat interview, Personal Communication, 3/6/2015). Please view the coding analysis of the cultural and ecological group for further examples of how the community thrived off the reef. However, today, there are only a handful of community members that live in Anini full time whilethe rest are transient rental visitors, as seen in the policy group document. Although they are less permanent of a community, they still utilize the reef resources through snorkeling, fishing, types of surfing, and boating. Fisherman still use the Anini Boat Ramp to access the ocean and fish in nearby areas (Jerry Kaialoa, Personal Communication, 3/5/2015). The reef is used more for recreational needs and for the pleasure of diving and catching food, but not for a subsistence lifestyle in most cases. Therefore, the livelihood of the community may be less dependent on the reefs today than it was 30 years ago, when people were living off of the land. But the livelihood of the community now depends on the reef for aesthetic needs and recreational needs. Without the Anini reef, the community will not be able to utilize this area for use, driving the community to other beach sites to practice recreational use on the reefs. Further studies are needed to understand how important this reef is to the transient community that visits Anini.

5. How do fishing practices impact the reef ecosystem?

Declines in the abundance of Aniniʻs marine fish, coral, and native algal species were noted by both researchers and community members. One study, depicting lower abundance of fish used for consumption, suggests fishing may be a contributing factor (Runyon, preliminary study, 2015). Interviewees asserted that new gears that make fishing easier contribute to overharvest. Overfishing can lead to invasion of certain algae species and loss of coral by disrupting ecosystem balance. Corals depend on fish to eat algae. Without the fish to clean them, corals can decline and be replaced by algal systems (Rasher and Hay, 2009). Goggles, snorkels, and scuba gear all allow divers to stay under water longer to hunt for fish, while motorized boats provide easy access to outer reefs. Fishing can also contribute to marine ecosystem health through harvest of invasive species.

5.2 RESEARCH CHALLENGES

Much of the literature used and referenced in this report was specific to areas surrounding Anini. Technical sampling and data was sparse. Furthermore, finding resources was initially slow due to lack of knowledge of the area. This data collection and assessment was based only on publicly available documents and personal interviews conducted by the authors of this report. Private company data was not collected and if it is possible to obtain, would enhance future studies as well. This report offers a starting point and base line gathering of the best information students were able to access during the time constraint of a semester long course. The next section outlines questions for further research.

5.3 FURTHER QUESTIONS TO BE ANSWERED

1. What is the composition of species diversity at Anini?

2. What is the magnitude of the human impact on the beach park?
    - How many people visit the park on a daily basis and for what purpose(s)?

3. What is the quality and composition of soils on the cliffs of Anini?
    How stable are they to withstand intense erosion (landslides)?
    - Collect soil samples and analyze for data.
    - Collect state data on soil erosion levels.

4. How many surface water diversions currently exist?
    - Where are they located?
    - What purpose do they serve?
    - How much water do they divert?

5. How many cesspools actually exist in the area?
    - What condition are they in?

6. What percent of the reef consists of healthy coral?
    - What types of coral are present?

7. What types of native and invasive algae (limu) are present?
    - What is their respective abundance?

8. How much fish is typically caught at Anini?
    - What species are being caught and how big are they?

5.4 RESILIENCY OF ANINI BASED ON FINDINGS (HUMAN DEGRADATION CHANGES)

Anini previously had extensive plant and animal biodiversity in both marine and terrestrial environments. Over time, humans have utilized the local ecosystem for food, shelter, and recreation. Increasing intensity of use and development of the area have fueled concerns for the health of Anini's environment. Resilience can be defined as the ability and capacity of a system to recover from shocks or stress (Folke 2006). The more stress applied to the environment, the harder it is for natural systems to sustain their health and growth. Ecological data collected in this report may assist in predicting Anini's ecosystem resilience and planning for the future. Based on our collected research, Anini is in a state of declining resilience. There are seven major causes to degradation in the Anini area, seen in the figure below (Figure 60): Residential development, overfishing, Princeville development and golf course runoff, Kilauea Sugar Plantation history, invasive species, water diversions from streams, and global warming. These were just a few of the issues touched on in this literature collection. Together, these multiple factors have interacted to decrease the health and resilience of Anini‘s terrestrial, freshwater, and marine ecosystems. If trends in human impacts on the area continue, Anini‘s ecosystems will not be able to restore themselves naturally. While in the marine ecosystem, for example, we saw multiple indicators of decreased resilience including coral bleaching and disease events, we also see pockets of health and resilience which could provide a foundation for future ecological restoration, both necessitated and assisted by humans.

Figure 60: Major contributing factors that cause degradation to Anini ecosystem based on research findings. However, these may change and have more factors over time.

5.5 RECOMMENDATIONS FOR THE FUTURE

- Continue and support local fishing competitions that target the removal of invasive species such as roi, ta'ape and to'au.
- Many scientific studies have been conducted in and around Anini and the reefs around Kaua'i. Most of the data collected is unpublished grey literature and not easily accessible. We recommend that this information be made widely available to members of coastal communities like Anini and Kalihiwai. Creating a database that is open to the public, which holds research data and documents, would facilitate access. Such a database would support informed decisions making in planning for the future of Anini and other coastal communities.
- Nurture relationships between community members, government agencies, researchers, extension agents, and other stakeholders. Collaboration in managing natural resources can be a very powerful tool, but requires extensive communication and respect for all perspectives.
- Initiate consistent water quality testing at Anini, Anini Stream, and Kalihiwai River, particularly for turbidity and pathogenic bacteria.
- Work with State (DOH) and Federal (EPA) agencies as well as the County of Kaua'i to confirm the number of cesspools (22 known, possibly 18 more unaccounted for) and replace them with septic tanks.
- Consistently survey terrestrial, stream, and marine species diversity.
- Update and inform the public regarding current wells installed in Anini, possibly through an online database system for enhanced transparency.
- Begin discussion of mitigation strategies for dealing with sediment runoff into the water systems. Solutions should include increased monitoring of watershed and hydrological changes.
- Obtain increased transparency from the Resort Group and owners of Princeville, especially with regards to their golf course maintenance regimes and development plans.
- Establish codes of conduct, non-regulatory informal social controls that can complement an adaptive approach to resource management. In Anini's case it would be extremely beneficial for the community to draft a fishing code of conduct for both residents and visitors. Figure 61 shows an example from Hui Malama O Mo'omomi that is utilized in a subsistence fishing area in Molokai.
- Investigate possibilities for long term monitoring of resources, especially from a marine/reef stand point. Consistent and long term data collection can be helpful in forming management strategies.
- Coordinate between studies on land, freshwater and marine ecosystems, to allow for mauka to makai connections between cause and effect.

Figure 61: Hui Malama O Mo'omomi draft fishing code of conduct for shore fishing in Mo'omomi Bay: Source: http://www.ahamoku.org/wp-content/uploads/2011/09/Final-Report-12-18-081.pdf

6.0 REFERENCES

AECOS Inc. 1982 . Kaua'i Island Coastal Resource Inventory (KICRI)

Aeby, G. S., Williams, G. J., Franklin, E. C., Kenyon, J., Cox, E. F., Coles, S., & Work, T. M. (2011). Patterns of Coral Disease across the Hawaiian Archipelago: Relating Disease to Environment. *PLoS ONE, 6*(5), e20370. doi: 10.1371/journal.pone.0020370

Aeby, G. S., Work, T. M., Runyon, C. M., Shore-Maggio, A., Ushijima, B., Videau, P., . . . Voolstra, C. R. (2015). First Record of Black Band Disease in the Hawaiian Archipelago: Response, Outbreak Status, Virulence, and a Method of Treatment. *PLoS ONE, 10*(3). doi: 10.1371/journal.pone.0120853

Ainley DG, Podolsky R, Deforest L, Spencer G, Nur N. 2001. The status and population trends of the Newell's Shearwater on Kaua'i: Insights from modeling. Studies in Avian Biology No 22 Evolution, Ecology, Conservation, and Management of Hawaiian Birds: A Vanishing Avifauna:108-123

Anini to Kalihiwai to the Kilauea Lighthouse, JANUARY 2, 2013 / SAVEOURSEAS Save Our Seas, 2013. https://saveourseas.wordpress.com/2013/01/02/Anini/

Bassiouni, M., & Oki, D. S. (2012). Trends and shifts in streamflow in Hawaiʻi, 1913-2008. *Hydrological Processes*, *27*(10), 1484–1500. http://doi.org/10.1002/hyp.9298

Bernado, R. 2012. Sick Kauaʻi coral tied to puffers. Star Advertiser newspaper. 28 Nov 2012.

Blay, C. T. (2011). Drowning deaths in the nearshore marine waters of Kauaʻi, Hawaiʻi 1970-2009. *International Journal of Aquatic Research and Education*,*5*(3), 284-324.

Byrd, G. V., Moriarty, D. I., & Brady, B. G. (1983). Breeding biology of Wedge-tailed Shearwaters at Kilauea Point, Hawaiʻi. *The Condor*, *85*, 292–296.

Calhoun, R. S., & Fletcher III, C. H. (1996). Late Holocene coastal plain stratigraphy and sea-level history at Hanalei, Kauaʻi, Hawaiian Islands. *Quaternary Research*, *45*(1), 47-58.Ainley, D. G., Walker, W. a., Spencer, G. C., & Holmes, N. D. (2014). The prey of Newell's shearwater Puffinus newelli in Hawaiian waters. *Marine Ornithology*, *42*(1), 69–72.

Carter & Burgess Inc. 2002. Planning for Sustainable Tourism in Hawaiʻi, Infrastructure & Environmental Overview Study, Volume IV: County of Kauaʻi.

Cleghorn, P. 1979. Archeological Reconnaissance Survey of Princeville Lands Hanalei, Kauaʻi. Department of Anthropology. Bernice P. Bishop Museum.

Cooke, Jr., C. M. & Kondo, Y. 1952. New Fossil Forms of Carelia and Partulina (Pulmonata) from Hawaiian Islands. Occasional Papers of Bernice P. Bishop Museum, 20, 329-346.

Cooke, Jr., C. M. (1931). The Land Snail Genus Carelia.*Bernice P. Bishop Museum*, *Bulletin 85*.

Conrow, Joan. 2010. Powerlines killing endemic species of birds on Kauaʻi. The Hawaiʻi Independent. 21 January 2010.

County of Kauaʻi, Department of Public works. (2014). Park wastewater facilities receive upgrades.

County of Kauaʻi: Department of Water. "Pipeline Replacement from Kilauea to Anini." (2011). Fukunaga and Associates, Inc. Retrieved from http://oeqc.doh.Hawaiʻi.gov/Shared%20Documents/EA_and_EIS_Online_Library/Kauaʻi/2010s/2011-07-08-DEA-Kilauea-to-Anini-Pipeline-Replacement.pdf

County of Kauaʻi, Department of Water. 2014. Water Quality Report for Anini Water System for 2013.

County of Kauaʻi. (2014, August 5). Reclaimed Wastewater Use in Kauaʻi County. Retrieved 26 April 2015, from http://health.Hawaiʻi.gov/sdwb/files/2014/09/SessionA-02.20140805-2nd-Joint-Water-Conference.pdf

County of Kauaʻi, Department of Water. (2001). *Water Plan 2020*.

Costanza, R., D'Agre, R., De Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, R., Paruelo, J., Raskin, R., Sutton, P. & Ven Den Belt, M. 1997. The value of the world's ecosystem services and natural capital. Nature 387: 253-260.

D'Angelo, J. 2013. Lilley: Reef has 'coral AIDS'. The Garden Island. 25 March 2013.

Department of Health. Amendment and Compilation of Chapter 11-54, Hawaii Administrative Rules (2014).

Department of Land and Natural Resources, Division of Aquatic Resources (DLNR/DAR). 2005. Marine Protected Areas In Hawai'i. A supplement published by the Custom Publishing Group of the Honolulu Advertiser. March 9, 2005. Honolulu, HI

Douglas, A.E. (2003). Coral Bleaching – How and Why?. *Marine Pollution Bulletin, 46.*

Ducks Unlimited. 2012. Hawaiʻi Conservation - More Information. Retrieved 23 February 2015 from http://www.ducks.org/printPage.aspx?documentID=45

Duffy, D. C. (2010). Changing Seabird Management in Hawai'i: from Exploitation through Management to Restoration. *Waterbirds*, *33*, 193–207. doi:10.1675/063.033.0208

Duffy, D. C., & Capece, P. I. (2014). Depredation of Endangered Burrowing Seabirds in Hawai'i: Management Priorities. *Marine Ornithology*, *152*, 149–152.

Eagle, N. 2010. Spearfishing challenge helps Anini reefs. The Garden island e-edition. 25 July 2010.

EarthJustice. 2011. Conservation Groups Succeed in Efforts to Protect Imperiled Seabird. EarthJustice.org. 26 September 2011.

Environmental Impact Statement. (1983). PDC Phase II Environmental Impact Statement. Belt, Collins and Associates, Ltd. Honolulu, Hi.

Environmental Impact Statement. (1990). Kalihiwai Ridge Phase II Subdivision (DLNR). PBR Hawai'i. Honolulu, HI.

Environmental Impact Statement. (2011). Pipeline Replacement from Kilauea to Anini (County of Kaua'i). Lihue, HI: Department of Water.

Environmental Protection Agency. 2013. My WATERS Mapper. Retrieved 23 February 2015 from http://watersgeo.epa.gov/mwm/?layer=LEGACY_WBD&feature=20070000&extraLayers=null

EPA Region 9. Cesspools in Hawai'i. 2013. Retrieved from http://www.epa.gov/region9/water/groundwater/uic-hicesspools.html

EPA, U. (n.d.). STORET Data Warehouses, STORET/WQX System for EPA, Office of Water. Retrieved from http://www.epa.gov/storet/dbtop.html

FlowSimulation, LLC. 2006. Final Report: Simulation of Kalihiwai Reservoir Dam-Break Flooding. 17 October 2006.

Folke, C. (2006). Resilience: the emergence of a perspective for social–ecological systems analyses. *Global environmental change*, *16*(3), 253-267.

Griesemer, A.M. and N.D. Holmes. 2011. Newell's shearwater population modeling for Habitat Conservation Plan and Recovery Planning. Technical Report No. 176. The Hawai`i-Pacific Islands Cooperative Ecosystem Studies Unit & Pacific Cooperative Studies Unit, University of Hawai`i, Honolulu, Hawai`i. 68 pp.

Hackler, R. E. (1982). Princeville Plantation Papers.

Hammond, R. L., Crampton, L. H., & Foster, J. T. (2015). Breeding biology of two endangered forest birds on the island of Kauaʻi, Hawaiʻi, *117*, 31–40. doi:10.1650/CONDOR-14-75.1

Hawaiʻi Audubon Society. (2005). Hawaiʻi's Birds, 5th edition.

Hawaiʻi Biological Survey. 1997. Hawaiʻi's Extinct Species - Snails. http://hbs.bishopmuseum.org/endangered/ext-snails.html

Hawaiʻi Division of Aquatic Resources and Bishop Museum. 2008. Atlas of Hawaiian Watersheds and their Aquatic Resources. http://www.Hawaiʻiwatershedatlas.com/index.html

Hawaiʻi DOH. (2014). *DWSRF Priority List of Projects for SFY 2015*.

Hawaiʻi DOH, Clean Water Branch. 2014. 2014 State of Hawaiʻi Water Quality Monitoring and Assesssment Report. 2 September 2014.

Heacock, D. (1989). *Survey of Anini Stream: the impact of shoreline developments on the water quality of the stream and nearshore reef ecosystems*.

IPCC, 2013. IPCC, 2013: Summary for Policymakers. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker,T.F., D. Qin, G.-K. Plattner, M. Tignor, S. K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. http://www.climate2013.org/spm Last Accessed November 14, 2013)(U.S. National Academy of Sciences, 2012. Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future.)(Parris, A., P. Bromirski, V. Burkett, D. Cayan, M. Culver, J. Hall, R. Horton, K. Knuuti, R. Moss, J. Obeysekera, A. Sallenger, and J. Weiss. 2012. Global Sea Level Rise Scenarios for the US National Climate Assessment. NOAA Tech Memo OAR CPO-1. 37 pp.

Jokiel, P.L. and E.K. Brown. 2004. Reef coral communities at Pila'a reef: Results of the 2004 resurvey. Hawaiʻi Coral Reef Assessment and Monitoring Program (CRAMP) report

Kalihikai to Hanalei, Kauaʻi. 1962. Belt, Collins and Associates Ltd.

KalihiwaiReservoir.info. 2011. History. Retrieved 24 February 2015 from http://kalihiwaireservoir.info/history.html

Katz et al. 1993. Ciguatera on Kauaʻi: Investigation of factors associated with severity of illness. *Am. J. Trop. Med. Hyg*.

Kauaʻi Climate Change and Coastal Hazards Assessment(2014).

Kauaʻi Endangered Seabird Recovery Project:: - June 26, 2014: Feral Cats Caught on Camera Killing Endangered Seabirds. (n.d.). Retrieved 25 February 2015, from http://Kauaʻiseabirdproject.org/index.php/media/kesrp-press-releases/june-26-2014-feral-cats-caught-on-camera-killing-endangered-seabirds

Keener, V. W., Marra, J. J., Finucane, M. L., Spooner, D., & Smith, M. H. (Eds.). (2012). Climate Change and Pacific Islands: Indicators and Impacts. Report for The 2012 Pacific Islands Regional Climate Assessment. Washington, DC: Island Press.

KIUC. (2010). Short-term Seabird Habitat Conservation Plan http://Hawaiʻi.gov/dlnr/chair/meeting/submittals/110225/C-FW-Submittals-C2a.pdf

Klein, R. D. (1999). Protecting the aquatic environment from the effects of golf courses, *21117*(November), 1–42.

Knee et al. 2010. Caffeine and agricultural pesticide concentrations in surface water and groundwater on the north shore of Kauaʻi (Hawaiʻi, USA). Marine Pollution Bulletin, 60, 1376-1382.

Koethe, F. 2014. Resurveying of the marine environment of Kaua'i: Views from the perspective of locals and kupuna. Senior honors thesis. University of Hawaiʻi at Manoa. 86pp.

Lau, S. (1972). *Quality of Coastal Waters: First Annual Progress Report*

Lewis, M.A., Boustany, R.G., Dantin, D.D., Quarles, R.L., Moore, J.C., Stanley, R.S., 2002. Effects of a coastal golf complex on water quality, periphyton and seagrass. Ecotoxicology and Environmen-tal Safety 53, 154–162.

Lindquist, J. (n.d.). Microbiology 102: The CFU Page. Retrieved from http://www.jlindquist.net/microbiology102/cfupage.html

Lipskey, E.A. 2001. Hair mineral analysis of children living on Kauaʻi's North Shore. PhD dissertation. 222pp.

Macfarlane, C. (2009, November 10). Golf balls: 'Humanity's signature litter'. *CNN*.

Maclennan, C. (2007). Kilauea Sugar Plantation in 1912: A Snapshot. *The Hawaiian Journal of History*, *41*.

Mallin, M., Wheeler, T., 2000. Nutrient and fecal coliform discharge from coastal North Carolina golf courses. Journal of Environmen-tal Quality 29 (3), 979–986.

Murakami, H., Wang, B., Li, T., Kitoh, A., 2013. Projected increase in tropical cyclones near Hawaiʻi. Nature Climate Change 3, 749-754.

National Oceanic and Atmospheric Administration (NOAA) Center for Operational Oceanographic Products and Services (CO-OPS), Silver Spring, MD. http://tidesandcurrents.noaa.gov/sltrends/index.shtml.

National Oceanic and Atmospheric Administration, DigitalCoast Office For Coastal Management, http://coast.noaa.gov/digitalcoast/tools/slr

National Oceanic and Atmospheric Administration. Warm ocean temperatures may mean major coral bleaching. 2015. http://www.noaanews.noaa.gov/stories2015/20170211-noaa-warm-ocean-temperatures-may-mean-major-coral-bleaching.html

National Water Information System, US Geological Survey.. 2015. Mapper. Retrieved 24 February 2015 from http://maps.waterdata.usgs.gov/mapper/index.html

National Water Information System, US Geological Survey. 2015. Groundwater for USA: Water Levels.

Neilson, B. 2014. Coral Bleaching Rapid Response Surveys: September-October 2014. [PowerPoint slides]. Department of Land & Natural Resources (Division of Aquatic Resources).

Nettleship DN, Burger J, Gochfeld M. 1994. Seabird on islands. Threats, case studies and action plans. Cambridge: Birdlife International.

Pacific Coast Joint Venture. 2006. Strategic Plan for Wetland Conservation in Hawaiʻi.

Parris, A., P. Bromirski, V. Burkett, D. Cayan, M. Culver, J. Hall, R. Horton, K. Knuuti, R. Moss, J. Obeysekera, A. Sallenger, and J. Weiss. 2012. Global Sea Level Rise Scenarios for the US National Climate Assessment. NOAA Tech Memo OAR CPO-1. 37 pp.

Penniman J. 2010. Hawaiian Petrel (Pterodroma sandwichensis) endangered seabird management on the Island of Lānaʻi. Poster paper. World Seabird Conference, Victoria, Canada.

Princeville Utilities Company, LLC. 2013. 2013 Water Quality Report.

The Garden Island. 2012. PCBs found in Princeville water tank official say water does not pose a threat.

Proby, Fred. 1980. "Letter Report: Archeological Reconnaissance of Portions of Hawaiʻi Belt Road form Kalihiwai to Princeville, Kauaʻi Island. ARCH 14-59. Archeological Research Center Hawaiʻi, Inc.

Pipeline Replacement From Kilauea to Anini: Draft Environmental Assessment, July 2011, from http://oeqc.doh.Hawaiʻi.gov/Shared%20Documents/EA_and_EIS_Online_Library/Kauaʻi/2010s/2011-07-08-DEA-Kilauea-to-Anini-Pipeline-Replacement.pdf

Posts about Carelia on Holocene Extinction. (n.d.). Retrieved 25 February 2015, from https://theholoceneextinctionevent.wordpress.com/tag/carelia/

Ragosta et al. 2011. Risk Factors for elevated Enterococcus concentrations in a rural tropical island watershed. Journal of Environmental Management, 92, 1910-1915.

Rasher, D. and Hay, M. 2009. Chemically rich seaweeds poison corals when not controlled by herbivores, *Proceedings of the National Academy of Sciences of the United States of America.*

Reiners, P. W., Nelson, B. K., & Izuka, S. K. (1999). Structural and petrologic evolution of the Lihue basin and eastern Kauaʻi, Hawaiʻi. *Geological Society of America Bulletin*, *111*(5), 674-685.

Rotzoll, Kolja and Charles H. Fletcher. November 11, 2012. Assessment of Groundwater Inundation as a Consequence of SLR. Nature Climate Change Letters. http://www.nature.com/doifinder/10.1038/nclimate1725

Russ, David, J. The Complete Kauaʻi Guidebook. 1995. Indian Chief Publishing House. California

Russell, Dennis J. 1992. The Ecological Invasion of Hawaiian Reefs by Two Marine Red Algae, Acanthophora spicifera (Vahl) Boerg. and Hypnea musciformis (Wulfen) J. Ag., and their association with two native Laurencia nidifica J. Ag. and Hypnea cervicornis J. Ag. ICES Marine Science Symposia.. Copenhagen. 194: 110-125

Russo, A. 1971. A preliminary study of some ecological effects of sugar mill waste discharge on water quality and marine life , Kilauea, Kauaʻi. Technical report No. 31. 45pp.

School of Ocean and Earth Science and Technology, University of Hawaiʻi, Mānoa, http://www.soest.Hawaiʻi.edu/coasts/Kauaʻicounty/poster/Anini_STposter_tmks.pdf]

Scott, J. M., Kepler, C. B., Iii, C. V. R., & Fefer, S. I. (2011). Conservation of Hawaiʻi's Vanishing Avifauna. *Evolution*, *38*(4), 238–253.

Shade, P. (1995a). *Estimated Water Use in 1990, Island of Kauaʻi, Hawaiʻi*.

Shade, P. (1995b). *Water Budget for the Island of Kauaʻi, Hawaiʻi*.

Sileo, L., Sievert, P. R., Samuel, M. D., & Fefer, S. I. (1989). Prevalence and Characteristics of Plastic Ingested By Hawaiian Seabirds. *Proceedings of the Second International Conference on Marine Debris*, (200 cc), 665–681.

Smith, Jennifer and Eric Co. Alien Marine Algae in the Hawaiian Islands. 2002. Hawaiʻi Coral Reef Initiative Research Program. University of Hawaiʻi at Mānoa, Department of Botany from www.botany.Hawaiʻi.edu/GradStud/smith/invasive/BROCHURE.htm

State of Hawaii, Department of Health, Clean Water Branch. (2014). Water Quality - Microbiology. Retrieved 20 September 2015, from http://emdweb.doh.hawaii.gov/CleanWaterBranch/WaterQualityData/Default.aspx

State of Hawaii, Department of Health. (2012). *Beach Monitoring Quality Assurance Project Plan*.

Timbol, A.S., and Maciolek, J. A. 1978. Stream channel modification in Hawaiʻi. Part A: Statewide Inventory of streams. Habitat factors and associated biota. Prepared for Stream Alteration Project, Office of Biological Services, Fish and Wildlife Services, U.S. Department of Interior. 157p.

Timbol, A.S. (1982). *Aquatic Macrofauna in Anini Stream, Kauaʻi*.

University of Hawai'i Sea Grant Program. June 2014. Kaua'i Climate Change and Coastal Hazards Assessment.

UH Coastal Geology Group. 2013. SLR Hawaiʻi. Accessed at http://www.soest.Hawaiʻi.edu/coasts/sealevel/

U.S. Fish and Wildlife Service. 2015. National Wetlands Inventory. Retrieved 17 February 2015 from http://www.fws.gov/wetlands/Data/Mapper.html

USGS. 2015. StreamStats Interactive Map. 3 Febuary 2015.

Viau, E. J., Goodwin, K. D., Yamahara, K. M., Layton, B. A., Sassoubre, L. M., Burns, S. L., … Boehm, A. B. (2011). Bacterial pathogens in Hawaiian coastal streams—Associations with fecal indicators, land cover, and water quality. *Water Research*, *45*(11), 3279–3290.

Vetter, L. (2015, May 4). Anini Cesspool and Septic Tank List. (State of Hawaiʻi Department of Health, Wastewater Branch)*Department of Health Public Records*.

Walker, H., Food From The Waters, 1997. Prospects Books. England.

White. 2002. Ciguatera on the Island of Hawaiʻi: Windward vs Leeward shore.

White, P, J. Revised EIS for the proposed Princevile Phase two development. Belt, Collins and Associates. 1983

Whittier, R. B., & El-Kadi, A. I. (2014). *Human Health and Environmental Risk Ranking of On-Site Sewage Disposal Systems for the Hawaiian Islands of Kauaʻi, Molokai, Maui, and Hawaiʻi*.

Wilcox, C. (1999). *Sugar Water: Hawaiʻi's Plantation Ditches*. United States: University of Hawaiʻi Press.

Winter, J. G., & Dillon, P. J. (2005). Effects of golf course construction and operation on water chemistry of headwater streams on the Precambrian Shield. *Environmental Pollution*, *133*(2), 243–253. doi:10.1016/j.envpol.2004.05.037

Work, T. 2012. Diagnostic Case Report (US Geological Survey-Biological Resource Division) - Case Number 21830