

**Assessment of Land Based Threats to Coastal Resources at
Kaloko-Honokōhau National Historical Park**
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Introduction

Kaloko-Honokōhau National Historical Park is located in the North Kona district on the west coast of the Island of Hawaii. The 469-hectare/1160-acre park was established in 1978 primarily to preserve and protect native Hawaiian culture and cultural sites. Within the park are a diverse and unique array of water resources such as the Kaloko and 'Aimakapa Fishponds and surrounding wetlands, and an abundance of anchialine pools. The fishponds, anchialine pools, and associated wetlands are all hydrologically connected to both the ocean and the groundwater system.

The wetlands, classified by the US Fish and Wildlife Service as either emergent or open water estuarine wetlands (USFS, 1991 and Cowardian, 1979), are a significant natural resource at Kaloko-Honokohau. The wetlands provide habitat for native and migratory birds such as the endangered Hawaiian black-necked stilt and the Hawaiian coot as well as resident waterbirds like the pied-billed grebe (*Podilymbus podiceps*) and black-crowned night heron (*Nycticorax nycticorax*) (Morin 1996; Pratt 1993). Growing among the dominantly non-native vegetation are a number of native species such as 'ākulikuli, 'ōhelo kai (*Lycium sandwicense*) and *makaloa* sedge (*Cyperus laevigatus*) and occasionally 'ahu'awa (*Mariscus javanicus*) and 'ae'ae or water hyssop (Pratt). The wetlands also provide habitat for native insect fauna such as the orange-black damselfly (*Megalagrion xanthomelas*) (Cooper et al., 2005).

Various existing and proposed development activities adjacent to and upslope of Kaloko-Honokohau National Historical Park (KAHO) have created concern over potential effects of these developments on the quality and quantity of groundwater flowing into the coastal water resources. Land use changes such as increases in the density of roads, houses and industries threaten the health of coastal waters, benthic marine habitat and wetland ecosystems. Urban encroachment directly adjacent to the Park is also of particular concern to park managers at Kaloko-Honokohau National Park.

The drainage basin of Kaloko-Honokōhau extends from the rift zone of Hualalai at about 7,000 ft elevation down to the coast (Figure 1). The average annual rainfall ranges from about 1000 mm (39.4 inches) in the upper reaches of the watershed to about 500 mm (19.6 inches) down along the coast. Due to high temperatures and porous substrates, the small amount of precipitation is either released into the atmosphere as evapotranspiration or percolates through the lavas to become groundwater. The groundwater in this area generally flows from the mountainous interior down towards coastal discharge areas such as the ponds and anchialine pools within the Park (Oki).

This project analyzes changes in population, land cover, and land use (between 1980 and 2000) and evaluates how these changes may be impacting the water quality of the ponds and anchialine pools within the Park.

Figure 1. Map of North Kona District and Kaloko-Honokōhau Watershed (outlined in black) on the Island of Hawai‘i.

Methods

The drainage basin of Kaloko-Honokōhau was defined using the Basin tool in ArcGIS. The Basin tool uses a digital elevation model to identify ridge lines between basins. In this case the 30m x 30m National Elevation Data (USGS, 1999) were used, because the 10m x 10m elevation data contain data gaps within the drainage basin of Kaloko-Honokohau.

The outline of the drainage basin was then used to “clip” GIS layers of land cover and land use, shown in table 1. Census data for 1980 were only available at the district level, limiting estimates of population change to the entire district of North Kona.

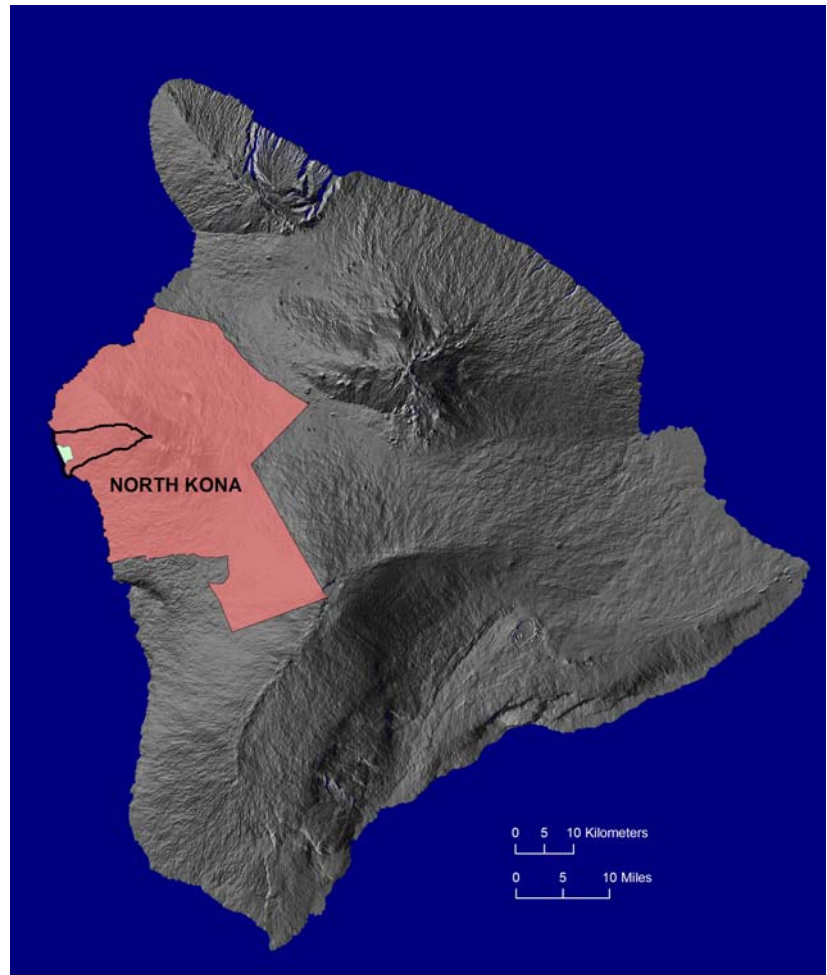


Table 1: GIS layers for change detection analysis

Name of GIS Layer	Source	Date(s)	Information Provided
Landcover/Landuse	USGS	1976	Anderson Level II classes
Landcover/Landuse	NOAA-CCAP	2000	Anderson Level II classes, more detailed
Landcover	Hawaii GAP	2005	National Vegetation Standard, Alliance Level
TMK Parcel Data	Geosight/County of HI	1999-2006	Land Ownership, Bldg. Value, Pitt Code
Roads (Digital Line Graphs)	USGS	1976, 1995	Roads, coded by type

The USGS park water quality database (Wolff, unpublished) contains water quality data collected by EPA (STORage and RETrieval database), the USGS, and NPS, and includes geographic coordinates (in lat/long format). The geographic data were used to create point features in an ArcGIS geodatabase. The water quality sampling data were then clipped to the watershed boundary for further analysis. It should be noted, however, that limited water quality data exists for this study area and the database currently excludes water quality sampling data collected by USGS-WRD (2003) and NPS (2005).

Data Preparation Steps:

- 1) Use a 10m Digital Elevation Model and GIS hydrological tools to define the drainage area for coastal water resources at Kaloko-Honokohau, realizing that the ground water drainage area may differ from surface water runoff.
- 2) “Clip” GIS layers of interest (Table 1) using Watershed Boundary
- 3) Use GIS to analyze changes over time for Roads, Housing, Urban Development, and Land Cover
- 4) Create a GIS layer of Water Quality sampling sites from EPA, USGS, and NPS data

Key Results

According to Census data, the population more than doubled between 1980 and the year 2000. Most of the increase, from 13,748 to 22,284 people, occurred between 1980 and 1990. By the year 2000 there were 28,543 people living in the North Kona District (US Census 1980, 1990, and 2000).

<u>Year</u>	<u>Population</u>	<u>Change</u>
1980	13,748	-----
1990	22,284	62%
2000	28,543	28%

The land use and land cover classes mapped within the watershed of Kaloko-Honokohau in 1976 and 2000 are provided in Table 2 below.

Table 2. Original land cover classes mapped in 1976 and 2000.

Land Use Level II (1976)	Acres	Percent of Total
Cropland/Pasture	500.3716	2.98%
Other	88.6633	0.53%
Bare Rock	373.4262	2.23%
StripMine/Quarry/GravelPit	33.2075	0.20%
Transitional	282.4481	1.68%
Evergreen	5593.5650	33.37%
Mixed (Grassland)	2577.1515	15.37%
Shrub and Brush	6993.3403	41.72%
Industrial	40.9152	0.24%
Residential	259.3718	1.55%
Trans/Comm/Utils	21.7349	0.13%
Land Use (2000)	Acres	Percent of Total
Bare Land	3012.3288	17.97%
Cultivated Land	1.2579	0.01%
Evergreen Forest	3131.0217	18.68%
Grassland	5552.5489	33.12%
High Intensity Developed	343.7919	2.05%
Low Intensity Developed	1036.9022	6.19%
Scrub/Shrub	3669.0724	21.89%
Unconsolidated Shore	4.4864	0.03%
Water	12.1188	0.07%

For comparative purposes the classes were aggregated, using information available on a USGS web site (<http://landcover.usgs.gov/classes.php#similar>), which describes how to crosswalk the Anderson classes with the National Land Cover Data classes. See Appendix A for a description of the land cover and land use classes used in this analysis.

Table 3. Aggregated classes for GIS analysis of change.

Land Cover Class	Acres (1976)	Acres (2000)	Percent Change
Barren	689	3,012	77%
Agriculture	589	1	-46727%
Forest (Evergreen)	5,594	3,131	-79%
Rangeland (Shrub/Brush)	6,993	3,669	-91%
Rangeland (Mixed, Grassland)	2,577	5,553	54%
Urban Built	322	1,381	77%

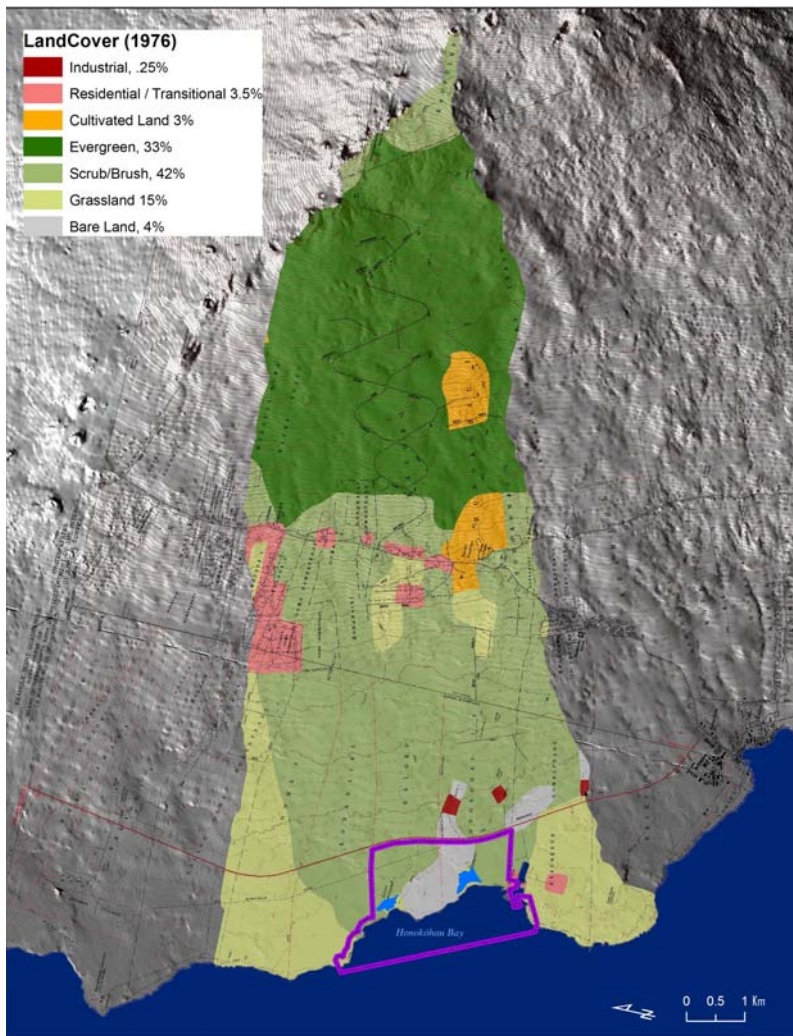


Figure 2. Land cover in 1976.

The 1976 land cover map (from the USGS) indicates that approximately 75% of the area upslope and adjacent to Kaloiko-Honokohau was either evergreen forest or shrubland while 3% of the watershed (or 582 acres) was agriculture. In the year 2000, the forest and shrubland areas comprised only 41% of the area, while only 1% of the area was mapped as agriculture. The combined area of industrial and residential categories went from nearly 4% in 1976 to 8% of the watershed in the year 2000.

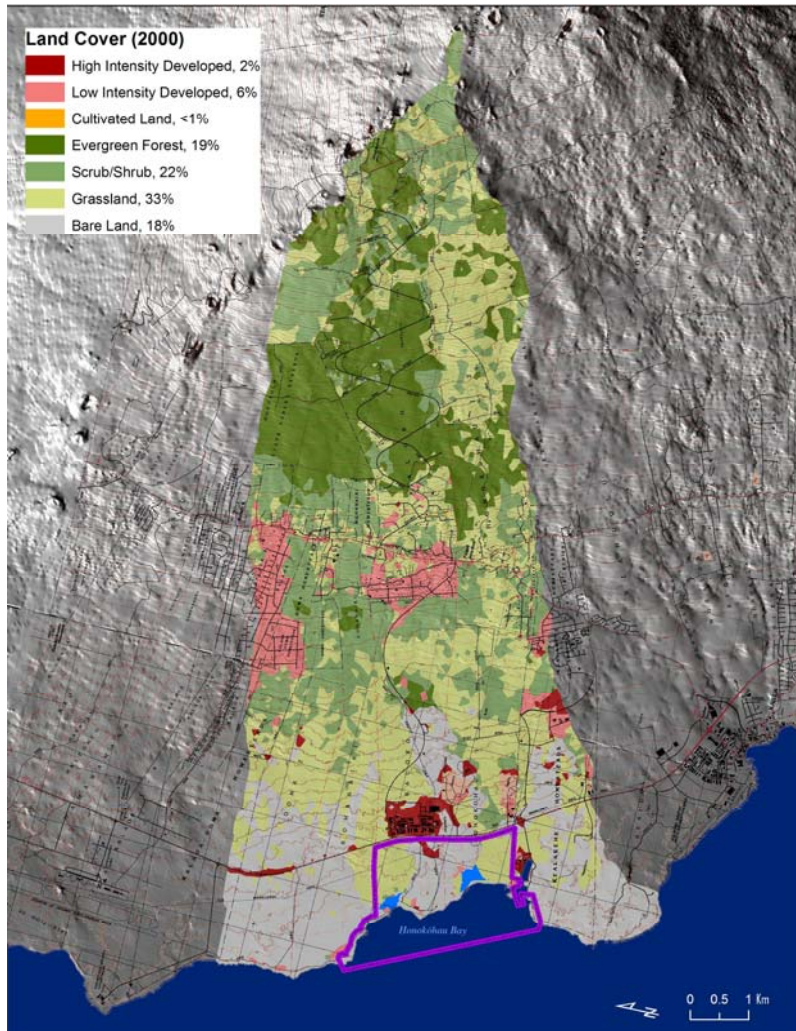


Figure 3. Land cover in 2000.

Between 1976 and 1997 the total linear miles of roads within the watershed went from 58 to 101 miles, about a 43% increase (USGS, DLGs). These figures include all roads, both paved and unpaved. Table 4 shows the length of roads by type as mapped by the USGS in 1976 and 1997.

Table 4. Total length of roads in 1976 and 1997.

Road Type (1976)	Length (Miles)
Cane	0.01
Dirt	19.44
Primary	7.33
Residential/Commercial	30.51
Secondary	0.77
Road Type (1997)	Length (Miles)
Dirt	25.79
Light Duty	45.37
Primary	4.00
Residential/Commercial	20.80
Secondary	4.95

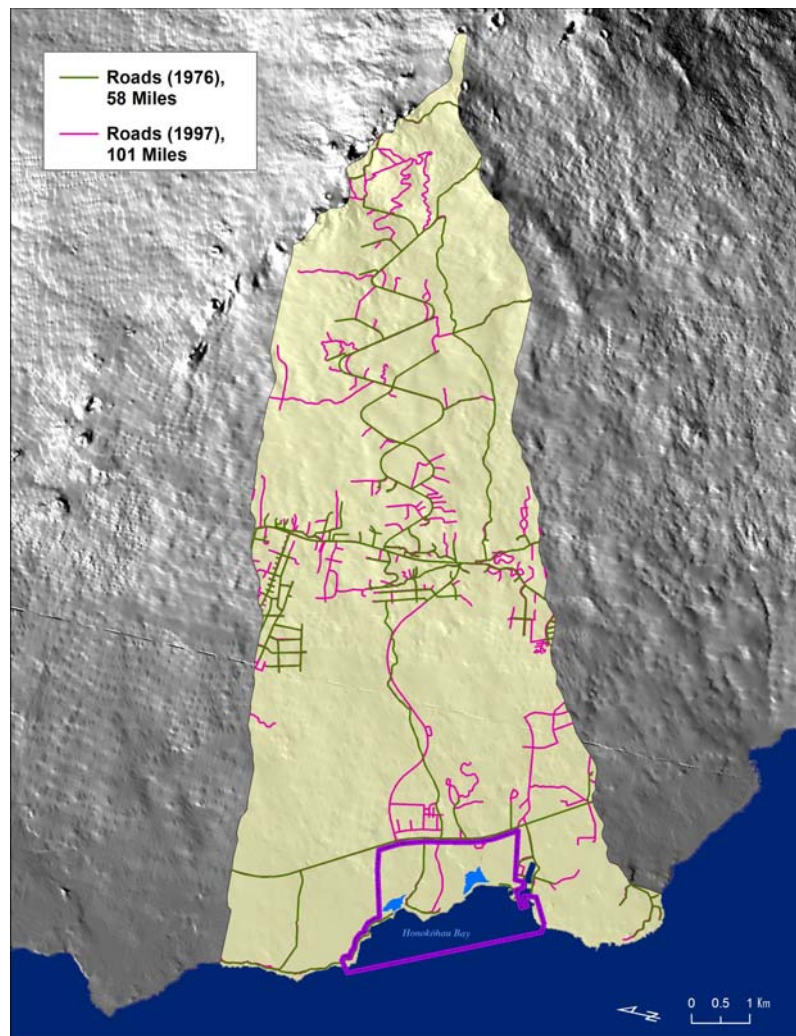


Figure 4. Map of roads in 1976 and 1997. The green lines represent roads present in 1976. The pink lines show roads added between 1976 and 1997.

Water quality data from EPA STORET and the USGS National Water Information System (NWIS) were compiled in a relational database by the USGS in 2005. The database includes water quality measurements for 150 sites within the Kaloko-Honokōhau watershed, but currently excludes data collected by Marine Research Consultants (2000), USGS-WRD (2002), Tribble (2003), and NPS (2005). The map below shows sampling sites, by type, within Kaloko-Honokohau National Park and adjacent coastal areas.

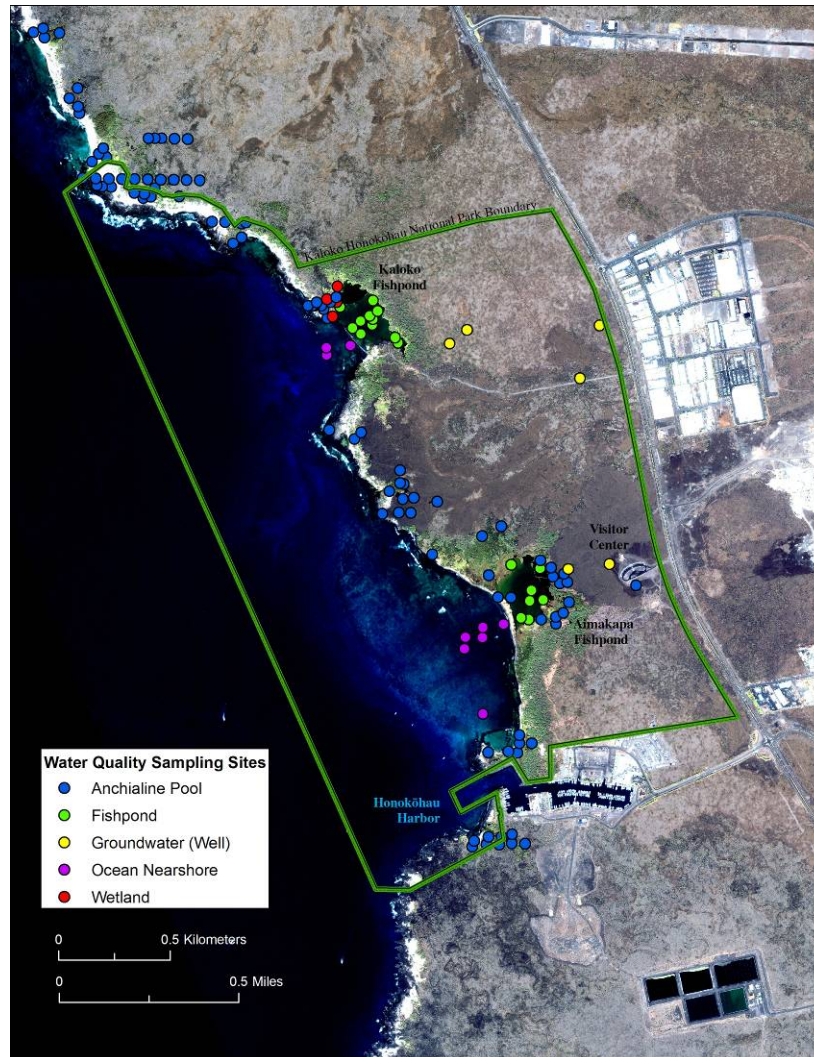


Figure 5. Water quality sampling sites compiled in a relational database by the USGS, 2005. Background image is an IKONOS satellite image taken in 2006.

The points in yellow show the locations of wells used in testing the quality of the groundwater flowing through the park. A water quality survey sampled three of these wells in 2005 and results showed significant increases in total nitrogen and phosphorus as well as dissolved organic nitrogen and phosphorus (Hoover and Gold, 2005).

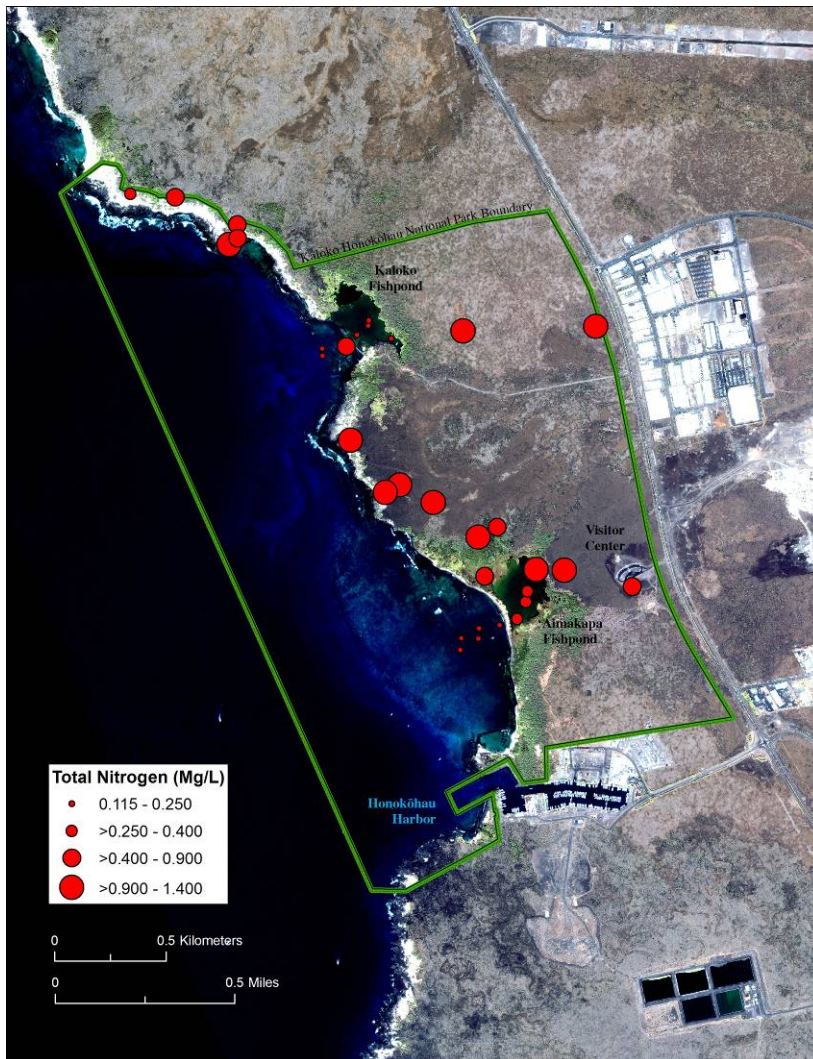


Figure 6. Total nitrogen measured within the ponds, pools and wetlands on June 4, 1996.

In general higher nitrogen levels are found in coastal waters that are more hydrologically connected to groundwater sources. Water bodies with higher concentrations of groundwater have higher concentrations of total nitrogen, phosphorus, orthophosphorus, and silica. The reverse is true for salinity and temperature. On the other hand, water bodies that are directly connected to the ocean generally have higher salinities and temperatures.

Discussion

Between 1980 and 2000 the population in North Kona more than doubled. During a similar time period (between 1976 and 1997) the total length of roads within the watershed of Kaloko-Honokohau nearly doubled as well (from 58 to 101 miles). Furthermore GIS analysis between land cover maps of the watershed show a decline in forest, shrubland, and agriculture and an increase in residential and urban development. Thus the landscape of the watershed has become more fragmented due to the expansion of roads, and residential and commercial developments.

Degradation of water quality can result from either point or non-point source pollutants in the form of toxic chemicals or excess nutrients (especially nitrogen and phosphorus). The increase in impervious surfaces such as roads and urban developments accelerates surface runoff and increases the potential of oil, gas, and industrial toxins contaminating groundwater. Furthermore, the use of fertilizers in residential areas can be as high as or higher than agricultural areas, which can lead to increased concentrations of nitrogen and phosphorus in the groundwater. Potential point source pollutants within the watershed of Kaloko-Honokōhau include cesspools and septic leach fields, the now abandoned landfill, and the Kealakehe wastewater treatment plant south of the park.

Although the scarcity of water quality data does not permit a direct comparison with State water quality standards, the available data do provide insights in the overall water quality of the coastal resources within the Park. For instance, a recent study of water quality in Honokōhau harbor entrance found that nitrate concentrations in brackish water discharge were higher than earlier studies, possibly due to increased sewage (Hoover and Gold, 2005).

Furthermore, increases in total and dissolved organic Nitrogen and Phosphorus were measured in 2005 in three groundwater test wells within the Park. Increases in nutrients, especially nitrogen and phosphorus pose serious concerns, since these nutrients usually limit primary production within coastal waters and wetlands. An increase in these nutrients will likely increase the primary production of algae (such as *Acanthophora spicifera*), leading to a decrease in available light and dissolved oxygen within ponds. In addition, increased levels of nitrogen and phosphorus within wetlands often results in the expansion of aggressive non-native plants (Mitsch and Gosselink, 2000).

The quantity of groundwater flowing into the Park also impacts the quality of coastal water resources. According to groundwater models by Oki et al., approximately 6.48 Mgal/d of groundwater is discharged along the coast within Kaloko-Honokōhau. The model predicts a 47 percent reduction in freshwater coastal discharge and a subsequent 0.6 ft decline of water-levels within the Park if ground-water withdrawal rates increase by 56.8 Mgal/day relative to 1978 rates. Withdrawal rates in 1978 were estimated to be 3.853 Mgal/day and by 1997 average withdrawal rates were 11.5 Mgal/d (Oki, 1999), an increase of 66%. Long term salinity and temperature studies (1971-2000) suggest that salinities in both Kaloko and 'Aimakapa are increasing due to either a decrease groundwater or an increase in marine water flow (Hoover and Gold, 2005).

In order to gain a better understanding of current water quality conditions and how they are changing over time, the National Park Service's Inventory and Monitoring program will be annually monitoring the water quality of the ponds and fishponds within the Park. Furthermore, the Inventory and Monitoring program will use advancements in remote sensing and GIS mapping technologies to monitor changes in land use and land cover within the watershed of Kaloko-Honokōhau (Haysmith et al., 2006). Ideally, these monitoring programs will help alert Park Managers of changing conditions and their potential impacts to the coastal water resources within the Park.

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