University of Hawaii at Manoa
Water Resources Research Center
2540 Dole Street, Holmes Hall 283
Honolulu, Hawaii 96822 USA

WRRC-2002-02

Assessment and Protection Plan for the Nawiliwili Watershed: Phase 1–Validation and Documentation of Existing Environmental Data

Monika Furness
Aly I. El-Kadi
Roger S. Fujioka
Philip S. Moravcik

October 2002

PREPARED FOR
State of Hawai'i
Department of Health
Clean Water Branch

Project Report
for
"Assessment and Protection Plan for the Nawiliwili Watershed"
ASO Log No. 02-104

Project Period: 1 September 2001 – 30 November 2003

Principal Investigator: Aly I. El-Kadi

Co-Principal Investigtors: Roger Babcock, Roger S. Fujioka
Clark C.K. Liu, Jacquelin N. Miller, James E.T. Moncur,
and Philip Moravcik

WATER RESOURCES RESEARCH CENTER
University of Hawai'i at Mānoa
Honolulu, Hawai'i 96822

CONTENTS

FIGURES

TABLES

APPENDIX FIGURES

ABSTRACT

This report documents the findings for Phase 1 of a three-phase study that is aimed at assessing the status of the Nawiliwili Watershed on Kaua'i and developing a plan for its future protection. The objectives of this phase include utilizing sources of existing information to assess current land use in the area and identifying sources and levels of pollutants believed to be present in the watershed based on past studies relevant to the project area. Sources of information included available documents, persons who are familiar with the area, and questionnaires mailed to concerned individuals. Letters mailed to landowners and operators in the watershed area asked for their input. Information was also obtained at community meetings. The study also benefited from a local advisory committee that included government individuals and environmental groups. Data concurrently collected by the Nawiliwili Bay Watershed Council are also used here.

The study concluded that little hard scientific data exist for the Nawiliwili Watershed, especially baseline data. The Hawai'i Department of Health's current Total Maximum Daily Load (TDML) studies may provide public information that could be useful in assessing the health of the watershed. Since more baseline data are being made available, there is a chance to systemically define changes and trends in the watershed.

The study identified sediment, nutrient, and bacterial-contamination problems in the Nawiliwili watershed and bay. Sediment sources include agricultural lands, construction sites, channel alteration, stream erosion, a quarry, and urban runoff. Nutrients originate from agriculture practices, golf courses, cesspools, frosted areas, urban runoff, and wastewater treatment spills. Bacterial contamination originates from cesspools, frosted areas, urban runoff, and wastewater treatment spills. There is, however, a chance that chemicals from other sources are also present. The absence of data has created great uncertainties regarding quantification and assessment of such contaminants. Only the levels of bacterial contamination are defined based on available measurements. Additional studies are needed to assess the existence of other chemicals in the watershed and their respective concentrations. There is also a need to assess the various sources of bacterial contamination to define the level of contaminant caused by each.

A fairly extensive list of potential sources of pollution has been identified which can provide a base for choosing sites for data collection and for sampling-scheme design. There is a need for new data to confirm these findings.

The study used the state of Hawai'i's web site on the Internet to identify relevant geographic information system maps of the area. There is a need, however, to update land-use information, which has changed in recent years.

Finally, there is a need to increase or improve on the availability of public and private information about the watershed and to maintain strong ties and full cooperation between environmental groups and landowners/operators. With availability of information and full cooperation of all parties involved, a better understanding of the

various processes will be gained. Developing sound approaches to remediate and protect the watershed is a goal that should be easy to reach. Scientific research can provide methods and approaches to maximize economic benefits from the watershed without negatively affecting the environmental quality.

ACKNOWLEDGMENTS

This report documents results of Phase 1 of the project "Assessment and Protection Plan for the Nawiliwili Watershed," principal investigator Aly I. El-Kadi, and co-principal investigators Roger Babcock, Roger S. Fujioka, Clark C.K. Liu, Jacquelin N. Miller, James E.T. Moncur, and Philip Moravcik—all with Water Resources Research Center, University of Hawai'i. El-Kadi is also with the UH Department of Geology and Geophysics. Monika Furness was the project's on-site research associate.

This project is jointly funded by the U.S. Environmental Protection Agency, under Section 319(h) of the Clean Water Act, and the Hawai'i State Department of Health, Clean Water Branch. The project officer is Denis Lau and the project coordinator is Jessica Peppler, both of the Clean Water Branch.

The research team acknowledges the help and continuous support of the project's Nawiliwili Watershed Community Advisory Committee:

- Jon Schlegel — U.S. Department of Agriculture, National Resources Conservation Service
- Cheryl Lovell–Obatake — Nawiliwili Bay Watershed Council
- Don Heacock — State of Hawai'i, Department of Land and Natural Resources, Division of Aquatic Resources, Pacific Island Sustainable Community Eco Systems
- David Martin — Nawiliwili Bay Watershed Council/Pacific Island Sustainables Community Eco System
- Adam Asquith — University of Hawai'i Sea Grant College Program
- Ted Inouye — East Kauai Soil and Water Conservation District
- Gary Ueunten — State of Hawai'i, Department of Heath, Clean Water Branch
- Mike Kido — University of Hawai'i, Hawai'i Stream Research Center
- Pat Cockett — Kaua'i High School

In addition, we would like to acknowledge individuals and businesses for their help in locating documents, sharing information, pointing us in the right direction, and donating time and resources. Among them are members of the advisory committee—Don Heacock, Gary Ueunten, Jon Schlegel, and Cheryl Lovell–Obatake, and Mike Kido—as well as the following:

- Thomas Kaiakapu — State of Hawai'i, Department of Land and Natural Resources, Division of Forestry and Wildlife
- Vaughan Tyndzic — State of Hawai'i, Department of Land and Natural Resources, Division of Boating and Ocean Recreation
- Outfitter's Kauai (donated kayaks)
- Anne Brasher — U.S. Geological Survey
- Carl Berg — Hanalei Heritage River Program
- Joanna Seto — State of Hawai'i, Department of Health, Environmental Management Division, Clean Water Branch
- Jude Schwarze — State of Hawai'i, Department of Health, Safe Drinking Water Branch

- Kaupena Kinimaka and Simon Yongert — Kauai Marriott Hotel
- Bob Kaden — County of Kaua'i, Fire Department
- Dave Penn — State of Hawai'i, Department of Health, Environmental Planning Office
- Katina Henderson — State of Hawai'i, Department of Health, Environmental Planning Office

1. INTRODUCTION

This study is aimed at assessing the status of the Nawiliwili Watershed on Kaua'i and developing a plan for its future protection. The study is divided into three phases. Phase 1 deals with validating and documenting existing environmental data. Phase 2 is aimed at identifying current sources of pollution and contamination in the watershed. Finally, Phase 3 deals with the development of a restoration and protection plan for the watershed. This report documents the findings for the first phase of the project.

Major changes have occurred in the Nawiliwili Watershed throughout geologic and historical time, including uses of land, harbor construction, industrialization, and development. We were not able to identify maps that document historical changes. However, pictures showing some of the historical features are available from a number of sources, including the Kauai Historical Society, the Bishop Museum, and the National Resources Conservation Service (NRCS). Table 1 provides a list of the pictures and the respective web sites where they can be accessed.

Several hundred years ago the flood plain of the Hulē'ia River was simply used for growing taro. Water that was diverted to flood the taro patches returned to the same watershed. Hulē'ia is also the home of the Alekoko Fishpond (Figure 1), which was culturally significant to the Hawaiian population living in Niumalu at the time. In *Native Planters in Old Hawaii* (Handy and Handy, 1991), Nawiliwili Stream in the 1930s was described as having terraces 3 miles inland from its mouth. Land in Nawiliwili at this time was planted with taro, cotton, and fruit trees or was used as garden patches. Above the mill the land was still terraced for half a mile and was being used for pasture and ranching. Above and below the mill were plantation camps (Handy and Handy, 1991).

Niumalu was considered one of the most important and undoubtedly most productive fishing areas on Kaua'i. Fairly large loi (taro fields) were present on the fertile banks of Niumalu's Puali and Halehaka Streams (Handy and Handy, 1991). Many loi in Niumalu were eventually converted to rice cultivation around 1860 (Cockett, 2000). Soon after, the sugar plantations came in and land use changed again. After the Second World War, the sugarcane fields on the Rice property were converted to ranches. More drastic changes took place when Nawiliwili Bay was dredged and the land was reclaimed, or filled in, to build the harbor and the breakwater around the 1930s (Cockett, 2000; Figure 2). Before Nawiliwili Harbor and the breakwater were built, Nawiliwili Bay was much larger. Water that flowed from the many streams that feed into the bay may have had a greater chance of "flushing" the bay without so many structures interfering with the natural mixing phenomenon.

Nawiliwili Bay is fed by at least four streams: Hulē'ia Stream, Papakōlea Stream (which actually feeds Hulē'ia Stream), Puali Stream, and Nawiliwili Stream. Papalinahoa Stream and "Kalapaki Stream" (herein called this but actual stream name is unknown) also feed into Nawiliwili Bay, but they are rarely referenced in modern times. However, Papalinahoa Stream may have been culturally significant as it is said to have petroglyphs near its mouth (Don Heacock, personal communication, 2002).

As time passed, Līhu'e developed into a commercial district. The Kauai Surf Hotel was built for visitors to come and enjoy the beach at Kalapaki. Since then, the hotel has grown, evolved, and changed to the Westin Hotel, and then to the Marriott Hotel. During the hotel expansion, two streams that flowed into Kalapaki Bay were diverted under the hotel, and now they discharge into Nawiliwili Stream. A sewage treatment facility and golf course were placed near the hotel at Kauai Lagoons. The future of the Nawiliwili Watershed will see more changes, including further development in Puhi and Līhu'e and a new power plant that adds some 14.5 acres of impervious surfaces to the neighboring watersheds.

2. OBJECTIVES

The objective of this phase of the study is to utilize sources of existing information to assess current land use in the area. Data sources include the State of Hawai'i's geographic information system (GIS). Factors to be included are physical features, basemap layers, political boundaries, administration layers, location of features of biological and cultural significance, and other layers. Another objective is to assess sources and levels of pollutants believed to be present in the watershed based on past studies relevant to the project area.

3. SCOPE, APPROACH, AND LIMITATIONS

As stated earlier, this phase of the study deals in part with validating and documenting existing environmental data, as a first step toward the development of a restoration and protection plan for the Nawiliwili Watershed. The approach we adopted includes identifying available documents and interviewing persons who are familiar with the area. We used a questionnaire (Appendix A) to collect information about the watershed from concerned individuals. Letters were also mailed to landowners and operators in the watershed to inform them of our research effort and the need for their input in our endeavor. We also organized and participated in community meetings and formed an advisory committee that includes government individuals and environmental groups. We also benefited from current projects in progress, including those by the Nawiliwili Bay Watershed Council (NBWC). The lead author of this report, Monika Furness, is a long time resident of the watershed; and information here depended in many instances on her familiarity with the region and knowledge of many of the people in the area. She also participated in data collection for NBWC and for Phase 2 of this project.

Search for information was hindered by the lack of comprehensive studies and by the difficulties in accessing information. A review of available data and reports has indicated that very little research has been done on the Nawiliwili Watershed, apart from that driven by development proposals and zoning changes for such development. Therefore, many of the reports reviewed here provided incomplete information and forecasted no environmental impacts. In many instances no baseline data were gathered. Although quite a few reports were identified, it was very difficult to access this type of information. Many reports with relevant information are kept in Honolulu offices away from the geographic region where the information is most needed. In some cases, reports for studies done on neighbor islands were even discarded or misplaced. Studies conducted to complement environment impact statements (EIS) were designed to assess the impact of a specific project, so they may not have addressed the cumulative impacts of overall development and urbanization in the watershed. Additionally, the scientific element of many of these types of studies is often limited due to the size of the data sets, which sometimes included only one datapoint.

A large portion of the land located within the Nawiliwili Watershed is privately owned by a small number of landowners. Public access to streams located on private property is very limited. There are very few locations where the public can access Puali, Nawiliwili, Papakōlea, and Hulē'ia Streams upstream of the estuaries at the mouth. This makes it difficult to assess the quality of the water and the stream channel itself. It also makes it difficult to identify nonpoint sources located in an inaccessible reach. Limited access can hinder public education and outreach by restricting activities such as volunteer monitoring. Since these areas do not fall under the jurisdiction of state and county agencies, little data have been collected there. Although landowners may be required to conduct monitoring for a permit or zoning change, the results of such studies are the property of the landowner and may not be made available to the public.

As much as possible, we documented our findings, which includes a listing of the sources of information and whether they were obtained from written documents or through personal communications. Pictures were used to support some of our findings. In identifying potential contaminant sources, sometimes we were faced with a difficult task when data or previous studies were lacking. In such cases, our rationale for including certain sites was based on studies and reports off Kaua'i. The word *potential* is specifically used here to stress the absence of hard evidence as to the source of pollutants in the watershed. Identifying a potential source can provide a starting point for future studies at locations where data gaps exist.

4. PREVIOUS STUDIES AND AVAILABLE DATA

4.1. General Watershed Description

General descriptive information on the Nawiliwili Watershed is readily available. Hydrologic data available from the U.S. Geological Survey (USGS) include peak flow data for Hulē'ia, aquifer and groundwater characteristics, and correlations between groundwater recharge and stream flow. Hulē'ia is the only stream that is gaged in the Nawiliwili Watershed. A USGS crest stage gage records peak flows at a site under Kipu Bridge. Peak flow in this stream over the last 40 years ranged from 463 cfs in 1998 to 26,800 cfs in 1971 (Matsuoka, 1982; USGS staff, personal communication, 2002), when the gage was actually destroyed by the flow. Stream flow in this area is highly influenced by groundwater seepage; in fact, base flow in many streams is maintained by groundwater seepage (Izuka and Gingerich, 1998). Between 1968 and 1970 an average base flow of 33.4 cfs was calculated for Hulē'ia where average stream flow was 73.4 cfs (Izuka and Gingerich, 1998).

4.2. Water Use and Availability

Water use and availability in the watershed, and in Kaua'i in general, are covered by a limited number of studies. Among these are a study by Shade (1990), who estimated water use on Kaua'i in 1990. The total freshwater withdrawal amounted to about 370 mgd, of which about 46 mgd were from groundwater sources and the rest was from surface-water sources. Water use for domestic purposes was mostly from groundwater sources (6.84 mgd) as compared to surface-water sources (0.32 mgd). The largest water use in 1990 was for irrigation. The total use of groundwater for irrigation was 19.22 mgd, of which withdrawals by plantations totaled 16.62 mgd and that by the Department of Water totaled 0.45 mgd. Most of the surface-water withdrawals (194 mgd) were by plantations for irrigation. About 94 mgd were used for hydroelectric power; of this amount, 29 mgd were recycled and 65 mgd were discharged back to streams.

The study by Izuka and Gingerich (1998) was prompted by an increased demand for water in the Līhu'e area and a decrease in water production by some Līhu'e wells. They investigated groundwater resources using well-drilling data, aquifer tests, groundwater discharge, and a numerical model of groundwater movement. The results indicated that the permeability of the rocks in the southern Līhu'e Basin is lower than in other areas and that a greater portion of the groundwater from this area discharges to the streams rather than to the ocean. The study estimated groundwater withdrawal on Kaua'i in 1990 at 40 mgd islandwide and 5 mgd for wells near Līhu'e. Recharge was estimated at 981 mgd in January and 454 mgd in June. Average recharge for southern Līhu'e was estimated at 30 mgd. The study also provided estimates for stream discharges and groundwater flow to the ocean and streams.

Izuka and Oki (2002) also used numerical simulations to study groundwater withdrawals in the southern Līhu'e Basin. The simulations indicate that groundwater withdrawals from the Hanamā'ulu and Puhi areas of the southern Līhu'e Basin will result in a decline in water levels and reductions in base flows of streams near proposed supply wells. Base flow reductions are discussed for both Hulē'ia and Nawiliwili Streams. Several different withdrawal amounts at different locations were simulated. Four new wells in Hanamā'ulu and two in Puhi are proposed to meet projected increased demand for the Līhu'e area. The wells have been drilled, but not all have pumps in them (S. Izuka, personal communication, 2002).

4.3. Stream Alteration

Timbol and Maciolek (1978) were the first to report on stream channel modification in Hawai'i. They reported that 12 of Kaua'i's streams had altered channels. Of those streams, 51% were cleared and realigned, 35% were of the revetment type, and 14% contained elevated culverts. Hulē'ia was listed as having 0.1 km modified (elevated culvert) in 1937 at a distance 12 km upstream from the mouth at an elevation of 122 m.

A portion of the statewide study by Timbol and Maciolek focused on stream fish and crustacean species richness, abundance, and proportions of native and non-native species present at certain sites. Of the 16 species found in Kaua'i streams, 7 (47%) were native. On O'ahu, no native species were found in areas with lined channels. At the time of this study, Kaua'i had no lined channels. Timbol and Maciolek's study also found that on O'ahu more exotic species were found in altered streams, whereas native species were predominant in unaltered streams. At the time of their study, Kaua'i streams did not seem to exhibit this pattern, but urban activity and additional channel modifications have changed the landscape of Kaua'i over the 25 years that have passed since that study was completed.

Timbol and Maciolek's (1978), inventory listed 68% of Kaua'i streams as having road crossings and 45% as having diversions. Kido (1999) studied the impact of road crossings and reported that streams with such crossings were physically and biologically degraded in the reaches where they intersected the highway and that nearly all of these locations exhibited excessive sedimentation and bank erosion. Further, he reported that in these locations, no native macrofaunal species were observed or collected and alien species were present in very low abundances. Additionally, NBWC staff noted that more rubbish is present at bridge crossings than at inaccessible reaches (unpublished field notes). Pig carcasses have also been found at bridge sites on Hulē'ia Stream.

Timbol and Maciolek (1978) defined four ecological-quality ratings for streams. Twenty percent of Kaua'i's streams were rated "pristine/high" quality, 37% "moderate/high," 39% "moderate low," and 4% "low." However, Kaua'i streams were rated second behind O'ahu streams in highest dissolved solids. The mean for dissolved ions for Kaua'i streams is given in Table 2. It is expected, however, that physiochemical parameters can be highly variable because temperature, pH, dissolved oxygen, and conductivity are significantly affected by channel modification (Hathaway, 1978).

Norton et al. (1978) noted that an immediate effect of almost any type of channel alteration is a reduction in the heterogeneity of the habitat, particularly the substrate. Channel modifications can also interfere with the diadromous lifecycle of native stream fauna. Elevated culverts, such as the one near the Marriott Hotel, may act as a barrier to prevent the migration of post-larval species, especially poorer climbers such as *Eleotris sandwicensis* (Parrish et al., 1978). Finally, lined channels reduce flow to a thin sheet. This type of flow during the dry season does not have enough depth to allow for fish movement between estuarine reaches and upper reaches (KRP Information Services, 1993).

A biological survey of Hanamā'ulu Stream was conducted by Timbol to accompany an EIS for the Hanamaulu-Ahukini cutoff road in 1978. The survey covered the distribution and abundance of macrofauna and fishes in Hanamā'ulu Stream. The survey also identified the 100-year flood of 22,800 cfs at a water level of 22 ft. The only recorded flow (average of 13.7 cfs) was at Kapaia Bridge between 1912 and 1914. The study listed physiochemical parameters, including the nature of flow and bottom type, as well as a classification of fresh- and brackish-water locations. Included in the EIS were comments from agencies and community members. One comment was related to missing species as a consequence of stream degradation. A decline in a sensitive species such as ‘o‘opu nōpili is used as an indicator of stream degradation in Kido’s (2002a) report on bioassessment protocol. Another comment in the EIS stated that the average coliform, phosphorus, and nitrogen levels in Hanamā‘ulu Bay all exceeded state standards for Class A waters. The poor water quality was attributed to surface runoff from canefields and pastures.

In another survey of Hanamā‘ulu Stream and its tributaries, which accompanied an EIS for the Lihue/Hanamaulu Master Plan, it was found that the watershed was heavily impacted from past and current land use (Environmental Technologies International, 1994). Low diversity and low numbers of native fish species were found in these streams. The reaches of highest quality were found above the Kapaia Reservoir (built by putting an earthen dam across Hanamā‘ulu Stream), but the reservoir blocks the native species from reaching other segments. Only bluegills and guppies were present. Major diversions were present at elevations of 350 ft, 400 ft, and 540 ft. Below the 200-ft elevation, the stream is partially channelized, receiving input from storm drainage. Native fish do not seem to be recruiting, due to these factors and due to the introduction of alien predatory species (Environmental Technologies International, 1994). The EIS concluded that no impact is expected from future development, due to the heavily disturbed nature of the watershed (PBR Hawaii, 1995).

4.4. Water Quality Data

4.4.1. Chemical Data

Tables 3 through 7 contain water quality data collected at various locations by the Department of Health in 1997. The measurements are considered baseline for a clean period. However, due to expected variability under hydraulic and other conditions, no conclusions can be drawn from such data.

Table 8 summarizes water-quality data available for the Nawiliwili Watershed; the data were obtained from the STORET database of the U.S. Environmental Protection Agency (USEPA) (http://www.epa.gov/storpubl/legacy/gateway.htm). The table contains 17 sampling points in the Nawiliwili Watershed, all of which are Hawai‘i Department of Health (DOH) stations (Figure 3). There is only one currently active DOH sampling point (Kalapaki 809). This point is sampled for *Clostridium perfringens*, temperature, dissolved oxygen (DO), and salinity four times a month.

Two other points, Nawiliwili 881 and 817, were monitored for fairly extensive periods: 881 for nutrients and physicochemical parameters and 817 for a variety of parameters, including bacteria. Both stations are located in the harbor, away from most recreational activities. Another sampling site, Kalapaki 810, was monitored on a monthly basis between January 1973 and November 1975 for fecal and total coliform and fecal streptococcus.

At Nawiliwili #01 to #12, sampling was done from one to three times each for nutrients, metals, or pesticides. Nawiliwili #03 to #06 and #08 to #12 are sites for sediment sampling only. Although the data available at these sites are useful, there are no regulatory standards available to assess the contamination level.

With the exception of Kalapaki 809, for which there has been regular monitoring, the existing data sets do not represent consistent monitoring. Most of the standards are expressed in terms of geometric means and averages of observations over time. The data in the STORET database, on the other hand, is not reported in this way. Based on analysis of data in Table 8, Table 9 outlines the exceedances of the standards recorded on the database for each of the sampling sites.

4.4.2. Biological Data

4.4.2.1. Strategy for Assessment

Experimental results obtained on O'ahu, Hawai'i, have shown that the EPA-recommended fecal indicator bacteria are consistently found in all types of soils (Hardina and Fujioka, 1991; Fujioka and Byappanahalli, 1998). Moreover, the three EPA-approved fecal indicator bacteria (fecal coliform, *E. coli*, enterococci) have been shown to persist and to multiply in soils. The latter finding is significant because in the application of recreational water quality standards for all states, EPA assumes that fecal indicator bacteria will not persist and will not multiply under environmental conditions. Thus, when such bacteria are found in high concentrations in environmental waters, EPA assumes that these fecal bacteria originate from sewage and concludes that there is an unacceptable risk for people who may become infected with sewage-borne pathogens. In Hawai'i the assumption used by EPA is not valid because Hawaiian soils are a significant environmental source of these fecal indicator bacteria, which can multiply under local soil conditions. This conclusion is also supported by the fact that most of the documented sewage-borne pathogens, such as the protozoans (*Giardia*, *Cryptosporidium*), and all human enteric viruses cannot multiply under environmental conditions.

In assessing the true hygienic quality of streams and coastal waters of Hawai'i, officials from the Hawai'i State Department of Health with the assistance of scientists from the University of Hawaii have developed an alternative measurement system to determine when the streams and beaches of Hawai'i are reliably contaminated with sewage. Studies primarily conducted on O'ahu have identified two alternative microbial fecal indicators, namely *Clostridium perfringens* and FRNA coliphages, because they are consistently present in sewage but cannot multiply in the soil environment. Additional studies on the use of *C. perfringens* as an indicator have provided recreational water quality standards of 50 and 5 *C. perfringens*/100 ml for streams and coastal marine waters, respectively (Fujioka and Shizumura, 1985; Fujioka et al., 1997).

The unsuitability of the EPA criteria for Hawaiian waters was based on assessing monitoring data obtained from the island of O'ahu. Factors specific to other islands are expected to affect the microbial quality of water for each. The first major factor to consider is the age of the island. The age of the island of Kaua'i is close to the island of O'ahu and therefore the surface and subsoil characteristics of these two islands are probably close. The second major factor is that rainfall is more prevalent on Kaua'i than on O'ahu. Soil environments on Kaua'i can be expected thus to better retain moisture than soil environments on O'ahu. This is significant because studies on O'ahu showed that the amount of moisture in the soil controls the ability of the EPA-approved fecal indicator bacteria to persist and to multiply. Thus, it can be anticipated that the soil on Kaua'i may represent a better environment than that on O'ahu for the effective colonization of fecal indicator bacteria. Another consequence of a larger amount of rainfall is the higher flows in streams and rivers, which can affect the transport and destination of bacteria. Finally, it is expected that rainfall will cause a greater subsurface flow contribution to surface water flow. Therefore, more emphases should be placed on the impact of groundwater flow into the sampling sites, which is generally ignored.

The third major factor is the widespread use of cesspools on Kaua'i by residences, businesses (restaurants, shops) and public parks. Many of these cesspools are located close to streams and beaches. The technology of cesspools is to simply collect fecal wastes into a shallow pit and to allow for natural degradation. Cesspool technology relies on the natural movement of sewage wastewater from this shallow pit to surrounding subsoil so more waste can be added without overflowing the pit. However, overflow of cesspools is a common occurrence and the subsurface flow of wastewater from cesspool pits cannot be easily traced. However, subsurface water flow is generally towards streams and coastal waters, and it can be safely concluded that wastewater from cesspools will contaminate such waters.

Contamination of stream and coastal waters from cesspools will greatly affect the interpretation of monitoring data because both surface soils and cesspool waste can contain elevated concentrations of the EPA-approved fecal indicator bacteria (fecal coliform, *E. coli*, enterorocci). Current methods cannot determine whether the source of sample bacteria is from sewage or cesspools. *C. perfringens* and FRNA coliphages are known to be present in high concentrations in sewage and can be expected to be present in high concentrations in cesspools as well. However, the expected movement of *C. perfringens* and FRNA coliphages in the subsoil may differ due to the differences in the size, charge characteristics and stability of these two fecal microorganisms. As mentioned earlier, these two alternative fecal indicators cannot multiply in the soil environments and therefore do not naturally exist in high concentrations in the soil environment of Kaua'i. As a result, monitoring for these two alternative fecal indicators should provide more reliable data to assess when the streams and coastal waters of Kaua'i are contaminated with sewage and cesspools than monitoring data obtained for the EPA-approved fecal indicator bacteria. The next section will assess the quality of stream and coastal waters in and near the Nawiliwili Watershed by using available data for *C. perfringens* as well as the required EPA-approved fecal indicators.

4.4.2.2. Results of Assessment

Tables 10 and 11 contain sampling data, collected by DOH, for Hanamā'ulu River and Hanamā'ulu Beach, respectively. These sites are shown in Figure 4. Although these sites are outside the Nawiliwili Watershed, their monitoring data are included here to attempt to relate bacterial contamination to land sources. Figures 5 through 7 are for the Hanamā'ulu River site, and Figures 8 through 11 are for the Hanamā'ulu Beach site. A total of 42 Hanamā'ulu River samples were analyzed for pH, dissolved oxygen, salinity, fecal coliform, enterococci, and *C. perfringens* during 1993, 1994, and 1995. During the same period, a total of 45 Hanamā'ulu Beach water samples were analyzed for the same parameters. In this assessment, the relevant parameters used include salinity, as well as concentrations of fecal coliform, enterococci, and *C. perfringens.*

The data for the Hanamā'ulu River site show that 41/42 samples were essentially freshwater with salinity readings of 0.1 to 0.2 ppt. Only 1 sample had a high salinity (17 ppt). Of these water samples, 29/42 (or 69%) exceeded the 200 fecal coliform/100 ml standard (Figure 5), 42/42 (or 100%), exceeded the 33 enterococci/100 ml standard (Figure 6), and 7/42 (or 17%) exceeded the proposed 5 *Clostridium perfringens*/100 ml standard (Figure 7). The high percentage of freshwater samples, which exceed the fecal coliform and enterococci standards, does not differ from results obtained on O'ahu and most probably reflects the growth of these bacteria in the soil environment of Hawai'i. However, the concentrations of *C. perfringens* in water from Hanamā'ulu River are higher than levels we have observed in water from streams on O'ahu. *C. perfringens* does not grow in soil, and since it is found in sewage, elevated concentrations of this bacteria in streams are taken as evidence of sewage contamination and increased health risk. The source of elevated concentrations of *C. perfringens* in Hanamā'ulu Stream has not been determined, but cesspools are suspected since they are used much more frequently on Kaua'i than on O'ahu.

The data for Hanamā'ulu Beach show that of the water samples taken there, only 3/45 (or 7%) had a salinity above 33 ppt. As for the rest of the samples, salinity for 42/45 (or 93%) ranged from 7 to 32 ppt, indicating that the beach water was a mixture of ocean water and freshwater from Hanamā'ulu River (Figure 8). These results indicate that water from Hanamā'ulu River is not effectively transported out of Hanamā'ulu Bay; rather, it is transported to the coastal waters of Hanamā'ulu Beach. Of these water samples, 7/45 (or 16%) exceeded the 200 fecal coliform/100 ml standard (Figure 9), while 41/45 (or 91%) exceeded state of Hawai'i standard of 7 enterococci/100 ml and 36/45 (or 80%) exceeded the USEPA standard of 35 enterococci/100 ml (Figure 10). Significantly, 22/45 (or 49%) exceeded the proposed standard of 5 *C. perfringens*/100 ml for beach water as established on O'ahu (Figure 11). These results indicate that beach water at Hanamā'ulu cannot be characterized as marine water because it represents a definite mixture of stream water and coastal waters. In summary, the public should be informed that the beach water at Hanamā'ulu does not circulate well with open-ocean water and generally contains a significant proportion of freshwater from Hanamā'ulu River. The river water contains elevated concentrations of all fecal indicator bacteria, including *C. perfringens*, which are transported to waters at the Hanamā'ulu Beach site. Beach water at Hanamā'ulu cannot reliably meet recreational water quality standards. Compared to the quality of water at other beaches, the quality of water at Hanamā'ulu Beach is poor and appears to be unacceptable for swimming.

During 1999, 2000, 2001, and three months of 2002, monthly samples from Kalapaki Beach Park were analyzed for salinity, turbidity, temperature, dissolved oxygen, and concentrations of fecal coliform, enterococci, and *C. perfringens* by DOH (Table 13). In this assessment, the relevant parameters used include salinity and concentrations of fecal coliform, enterococci, and *C. perfringens*. For 1999 and 2000, 50 water samples were analyzed, whereas for 2001, 46 water samples were analyzed. During January of 2002, a sewage spill entered Nawiliwili Stream near the culvert at the Marriott Hotel and then entered Kalapaki Beach.

During 1999, the salinity of the 50 water samples ranged from 29 to 35 ppt, indicating that the water was comprised primarily of ocean water with some mixture of freshwater, most likely from Nawiliwili Stream. Of these water samples, 17/50 (or 34%) exceeded the state of Hawai'i standard of 7 enterococci/100 ml, while 7/50 (or 14%) exceeded the USEPA standard of 35 enterococci/100 ml (Figure 12), and only 1/50 (or 2%) exceeded the proposed standard of 5 *C. perfringens*/100 ml (Figure 13). There were no reports of a sewage spill in 1999. These results indicate that water from Kalapaki Beach contains elevated levels of fecal indicator bacteria (Figure 14), which comes from Nawiliwili Stream. Thus, there does not appear to be sufficient water circulation within Nawiliwili Bay to effectively transport water from Nawiliwili Stream away from the Kalapaki Beach site. However, due to the low concentrations of *C. perfringens* recorded, water at Kalapaki Beach did not appear to be contaminated with sewage.

During 2000, the salinity of the 50 water samples ranged from 31.3 to 35.2 ppt, indicating that the water was comprised primarily of ocean water with some mixture of freshwater from Nawiliwili Stream. Of these water samples, 21/50 (or 42%) exceeded the state of Hawai'i standard of 7 enterococci/100 ml, while 6/50 (or 12%) exceeded the USEPA standard of 35 enterococci/100 ml (Figure 12) and only 1/50 (or 2%) exceeded the proposed standard of 5 *C. perfringens*/100 ml (Figure 13). There were no reports of a sewage spill in 2000. The water quality results for 2000 were similar to the water quality results for 1999.

During 2001, the salinity of the 46 water samples ranged from 22.8 to 35.3 ppt indicating that there was more mixture of freshwater in Kalapaki Beach during that year than during 1999 or 2000. Of these water samples, 23/46 (or 50%) exceeded the state of Hawai'i standard of 7 enterococci/100 ml, 7/46 (or 15%) exceeded the USEPA standard of 35 enterococci/100 ml (Figure 12), and 6/46 (or 13%) exceeded the proposed standard of 5 *C. perfringens*/100 ml (Figure 13). There was one report of a sewage spill on January 6, 2001. Water samples collected on January 7, 2001 revealed slightly elevated enterococci (33 CFU/100 ml) and very high concentrations of *C. perfringens* (29 CFU/100 ml). These counts returned to background levels on January 10. These results support the use of *C. perfringens* as a reliable marker of sewage. In summary, the concentrations of enterococci at Kalapaki Beach during 2001 were similar to those observed during 1999 and 2000. However, during 2001 more samples (13%) had elevated levels of *C. perfringens* than the 2% observed during 1999 and 2000. The elevated concentrations of *C. perfringens* in water samples from Kalapaki Beach in 2001 provide evidence that this beach site was contaminated with sewage for some period of time.

During 2002, a total of 11 samples collected during January, February, and March were analyzed. The salinity of 10/11 water samples ranged from 32.9 to 35.6 ppt, indicating that the water was primarily marine in origin. One sample had a lower salinity (27 ppt). Because of a significant sewage spill during January, samples were collected on January 8, 9, 14, 23, and 28; February 5, 12, and 19; and March 5 and 12. Of these water samples, 73% exceeded the state of Hawai'i standard of 7 enterococci/100 ml (Figure 12), 45% exceeded the USEPA standard of 35 enterococci/100 ml (Figure 12), and 82% exceeded the proposed standard of 5 *C. perfringens*/100 ml (Figure 13). Elevated *C. perfringens* concentrations such as 20, 50, 53, 60, and 400 CFU/100 ml were detected in water samples taken during and after the sewage spill. The sewage present in water at Kalapaki Beach represented a health risk to swimmers, so DOH closed the beach to swimming following the spill. In summary, these results support the two conclusions established earlier. The first conclusion is that concentrations of *C. perfringens* are a reliable indicator of sewage contamination in the environmental waters of Hawai'i. The second conclusion is that concentrations of USEPA-approved fecal indicator bacteria (enterococci, fecal coliform, *E. coli*) are unreliable indicators of sewage contamination in the environmental waters of Hawai'i.

Table 13 contains older (1990–1998) monitoring data for Kalapaki Beach Park and Nawiliwili Harbor. The data, collected by DOH, are presented in Figures 14 through 18. Fluctuations in enterococci concentrations are due to rain storms (Figure 15), unless they coincide with a rise in *C. perfringens* concentrations, which can be an indication of sewage spills or cesspool discharges. A number of spikes in *C. perfringens* at the beach site between 1993 and 1997 can be seen in Figure 16. The absence of similar increases at the harbor site (Figures 17 and 18) indicates that most likely the source is Nawiliwili Stream.

5. ASSESSMENT OF WATERSHED STATUS

As stated earlier, little research has been done on the Nawiliwili Watershed, that is, apart from that driven by development proposals and the need for zoning changes for such development. Therefore, many of the reports reviewed in the course of this study provide incomplete information and forecast no environmental impacts. No baseline data were gathered in most cases. Studies done to complement an EIS were designed to assess the impact of a specific project and thus may have failed to address the cumulative impacts of overall development and urbanization in the watershed. Additionally, the number of sample points surveyed may not have been sufficient for the study to be of scientific value.

Recently, several studies were conducted in response to 319 grants made available by the USEPA. These studies include baseline stream-monitoring data collected by

NBWC; fish tissue and bed sediment studies conducted by USGS; a biological assessment (in progress) by the University of Hawai'i, Hawai'i Stream Research Center (UH HSRC); and a study to identify the types and amounts of pollutants carried with urban storm-water runoff by installing catch basin inserts in storm drains, also conducted by NBWC. These studies were very useful in assessing the state of the watershed.

The Kauai General Plan (County of Kaua'i, 2000) confirms that nonpoint pollution (especially eroded soils and toxic chemicals) has the biggest impact on streams and coastal areas. The plan acknowledges Nawiliwili's status as an impaired water body and sets the priority for its restoration. However, the plan does not address short-term management concerns. A new drainage plan prepared by the Department of Public Works will be sent to us after final corrections are made. The department staff indicated that policies are also in place to protect areas that provide water quality benefits, especially wetlands, and to prevent disturbing natural drainage features and vegetation.

The plan states the demand of municipal water for Kaua'i as 10.6 mgd, with a maximum of 15.9 mgd in 1999. Līhu'e's demand was reported as 2.53 mgd, with a maximum of 3.8 mgd. There is increasing demand and thus a need to expand the water systems, especially in Līhu'e because Līhu'e and Hanamā'ulu facilities are running at capacity. The plan indicates that the water supply in Līhu'e is constrained by a lack of new groundwater sources, due to geologic reasons. One possibility for expansion that is under consideration is the use of surface water, which would require the construction and operation of water treatment plants.

5.1. Diversions

The large number of diversions and stream alterations present is the main reason for the difficulty in studying the watershed. About 45% of the streams on Kaua'i have diversions (Timbol, 1978). Unlike traditional taro diversions that return water to the same watershed, surface-water diversions for agriculture transfer water completely out of the source watershed into an entirely different drainage basin. According to some early Hawaiian water rights, no more than half of the flow from a stream can be diverted to a point. It is believed that if Kaua'i could only practice this one value and return half of the flow to dewatered streams, the majority of its water quality problems may be resolved (Don Heacock, personal communication, 2002). The Commission on Water Resource Management is responsible for administering some of the programs established by the Hawai'i State Water Code. Part VIII of the Hawai'i State Water Code requires the registration of existing stream diversion works. Permits are required for the construction, alteration, or abandonment of such diversion works. Documentation of registered stream diversion works and the respective permits is readily available from the Water Commission (Commission on Water Resource Management, 1992). The Commission created a database of this information and published two volumes of documentation (indexed by name of registrant and tax map key parcel number) in the 1990s, and it recently completed a new GIS-based version (David Penn, personal communication, 2002). The Commission also maintains the original files of registration forms, field verification, and other information. This type of information is critical for studies like this one and those done by the Department of Health's TMDL program. Identifying nonpoint sources depends on locating the pollutants' source, their destination, and the amount of water transporting them.

According to Carol Wilcox's 1996 book, *Sugar Water: Hawaii's Plantation Ditches*, nearly 18.3 mgd of water were diverted from Hulē'ia and Hanamā'ulu for sugarcane irrigation. Mink and Yuen's (1990) detailed flow chart shows even more water being diverted. It is estimated that an average of 10 mgd are diverted from Ku'ia Stream (tributary of Hulē'ia) to Waita Reservoir via the Koloa Tunnel (Mink and Yuen, 1990). The Koloa Tunnel is just one of four diversions present on Hulē'ia Stream. In 1990, islandwide surface-water withdrawals for irrigation were close to 194.5 mgd (Shade, 1990). Vann (1993) documented between 8 and 13 diversions or alterations to Puali Stream. Diversions and alterations were the only explanations for the inconsistencies in flow data from one end of the stream to the other. The diversion issue is not simple because the diversions are not gaged. The diversions can by turned on or off at the demand of the operator; otherwise, they may get damaged by a storm event unknown to the controller. The result is that measured flows in streams can change on a day-to-day basis: flows may be influenced by water entering from another watershed or by water being removed from a watershed.

5.2. Urban Impact

Nawiliwili is, by far, the most impacted stream in the watershed. This can be attributed to the urbanization of Līhu'e. Timbol (1978) gave Nawiliwili Stream a rating of "most polluted." Although little baseline data are available, many contamination events have occurred—including gas, chemical, and sewage spills in addition to urban storm-water runoff. NBWC conducted monitoring on this stream for a year (July 2001–July 2002). The monitoring data show the contrast between the lower Nawiliwili site (which is impacted by urbanization) and the upper Nawiliwili site (which is located upstream from any urban activity). The turbidity levels at the upper site meet state water quality standards, while the levels at the lower site consistently exceed the allowable limits (NBWC, 2002). By using Nawiliwili Stream as example of an impacted stream, it becomes clear that Puali and Papalinahoa Streams need to be protected as development continues in this watershed.

5.3. Stream Conditions

5.3.1. Puali Stream

In Timbol's 1978 study, Puali Stream was ranked only one class lower than "pristine." The Līhu'e/Puhi project has begun to urbanize the area that drains into this stream. If current practices continue, it is likely that Puali Stream will reach the same condition as Nawiliwili Stream. The Department of Public Works estimates that the area encompassed by the project is 55% of the total drainage watershed area, significantly impacting Puali Stream due to urbanization (Akinaka & Assoc., 1992). That study recommended that baseline data be collected prior to development. Subsequently, a seven-year (1995 to 2001) baseline study of Puali was conducted by AECOS, Inc. (2002). Four stations were monitored on Puali Stream, with two stations near golf course holes (one above reservoir Haiku 4B and the other right below) and two other stations at lower areas (one near the mouth of the stream and another upstream from a waterfall). Only the lowest station became more turbid in the last two years of the study. The other stations were unchanged or became even less turbid. The data were not reported as wet season or dry season, but the geometric mean from all the data did exceed wet season standards (the higher of the two) at two locations. Every total nitrogen sample exceeded both wet and dry season standards (AECOS, 2002). Golf course irrigation recharge and runoff may have been influencing nutrient levels. The AECOS field notes mentioned occasions when there was no flow or the stream channel had changed. This may have been the result of influence from the highly modified drainage and irrigation systems present in this area.

Many alterations have been made to Puali Stream. These include two culverted sections, one with a cement weir that crosses the channel. During a recent HSRC survey to identify monitoring sites, the survey team noted that the area near the culvert that crosses under Puhi Road was choked with vegetation. Excessive sedimentation and the overgrowth of hau were causing water stagnation. In the pool in front of the culvert, Tahitian prawns, crayfish, and poeciliids were noted. On the other side of the culvert, the stream has been fenced in. Farther downstream behind a residential housing development (Halelani Villages) in Puhi, Puali Stream's channel has been artificially realigned. The banks are nearly vertical and the stream channel looks like a ditch. Nearby, the construction of a residential development (Halemalu Village) is underway. This new development is located not far from the banks of Puali Stream. Drainage facilities for these developments can be the source of storm water into the stream (Don Heacock, personal communication, 2002).

Alterations to this stream go back to the building of a reservoir, Haiku 4B, right on the stream channel at the confluence of Puali and Halehaka around 1930. This reservoir might be the reason why Puali is not the most turbid stream in the watershed. There is also a chance that the reservoir is removing the natural bed load, not allowing it to continue downstream or filter out sediment (Don Heacock, personal communication, 2002). The substrate in the lower reaches is different from the substrate of any other stream in the area in that it consists of solidified clay (fine sediment that settled into mud some time ago), with little natural gravel, cobble, or boulder. In Kido's 1999 bioassessment of the stream, Puali was given a ranking of "very poor." This means that although native species were present, they were found in small quantities and were often outnumbered by alien species such as the Tahitian prawn *Macrobrachium lar.* The survey, which also looked into habitat availability, found Puali Stream to be severely degraded with excessive sedimentation and erosion.

Additional problems related to Puali Stream may be caused by operation of a sewage treatment plant uphill from the stream and a landfill site on one of its tributaries. The landfill operated between 1973 and 1991. Before solid waste was placed in the landfill, a 48-inch perforated pipe was placed in the valley to carry off groundwater (and leachate) from the site for eventual discharge into Puali Stream. A study done at the time of the landfill closure described the groundwater characteristics in the area. Groundwater testing showed that no dissolved metals or volatile organics were present (Mink and Yuen, 1993). However, some of the total metal concentration levels found in the gas probe series of tests conducted on the site itself exceeded the maximum contaminant levels (MCLs). The samples, however, included both dissolved metals and particulates which are expected be filtered out when passing through the aquifer, minimizing the chance of contamination. There may be a need to analyze fish tissues and sediments for the bioaccumulation of such toxins.

After the landfill was closed, it was covered with an impervious surface to prevent any further contamination. Additionally, monitoring equipment was installed to detect any potential contamination. However, the landfill could still be a potential source of pollutants. Although no toxic or hazardous waste was recorded as being accepted there, illegal dumping can happen. For example, car batteries could contribute to increased metal concentrations in the sediment.

Nutrient levels found in nearby groundwater samples were much higher than that for "pristine" groundwater, probably as a result of fertilizer residue being transported with surplus irrigation recharge from cane fields. Now that sugarcane operations have ceased, golf course irrigation may be the contributor of nutrients. Samples taken from the gas probe test series on the landfill site suggest the presence of a mixture of groundwater and leachate due to high sulfate and low nitrogen concentrations. One sample was excessively high in nitrogen, suggesting that it was primarily leachate. Samples taken from Puali Stream, both upstream and downstream of the landfill, were 0.769 mg N/l and 0.735 mg N/l, respectively (Mink and Yuen, 1993), suggesting that nutrients are contributed by irrigation recharge.

Puali Stream enters the ocean at Niumalu near a beach park and canoe club. This is near the small-boat harbor and is the launch point for three kayak tour companies. This area is highly used by boaters, paddlers, crabbers, and tourists. It is very shallow (1 to 4 ft) and the bottom is covered with fine silt. Cesspools are common in the area. Recently, Pat Cockett (a science teacher at Kaua'i High School) and Dr. Carl Berg led a group of students to this area to conduct bacterial monitoring. Although the data are from student test kits, the results made the front page of *The Garden Island* newspaper. Samples were collected from Niumalu near the mouth of Puali Stream on April 4, 2002. The geometric mean for enterococcus in this area was 400 CFU/100 ml. A hotspot near the kayak-launching ramp measured 2,602 CFU/100 ml (Carl Berg, personal communication, 2002). Section 8.3 below discusses cesspools as a potential source of contamination in the watershed.

5.3.2. Nawiliwili Stream

Nawiliwili Bay is subjected to accidental sewage, chemical, fertilizer, and oil/gasoline spills. The record shows that sewage and oil spills are regular occurrences there (see, e.g., *Honolulu Star-Bulletin*, June 29, 1993; June 30, 1993; August 14, 1996; August 15, 1996). Over the last five years, Kaua'i County has suffered as many as 14 spills islandwide in one year (Hawai'i State, DOH, 2002). Gasoline spills also occurred regularly, both from the facilities in the harbor as well as from the gas station in Anchor Cove. Other occurrences include chemical spills, like the one in 1993 which caused the closure of the beach as toxins dyed the water fluorescent green and fish floated to the surface (*Honolulu Star-Bulletin*, June 29, 1993). Another example is the fish kills due to spills of chlorinated effluent from the wastewater treatment plant (Don Heacock, personal communication, 2002).

The Nawiliwili Watershed is especially impacted by various sources of contaminants due to many factors. For example, much of the development that takes place in Līhu'e and Puhi relies on natural drainage ways to transport storm-water runoff, specifically through Kalapaki, Nawiliwili, and Puali Streams. In many instances culverts, storm drains, and other drainage facilities have been built to discharge storm water directly into these streams. One such facility is located about 150 m downstream of the lower NBWC monitoring site. Monitoring is not conducted below this facility because the sediment is so thick that it poses the threat of someone physically getting stuck. These types of drainage facilities are designed for "maximum efficiency of conveyance" (KRP Information Services, 1993). As a result, storm water and/or runoff from a chemical spill in Līhu'e, such as the one that occurred in the industrial area in 1993, will find its way to Nawiliwili Bay via these natural pathways. It is possible to trace the path of a spill or storm-water runoff from Līhu'e. Additional research, such as the use of watershed models combined with natural tracers, can define such paths by adopting a more physically based approach.

Farther downstream, near the mouth of Nawiliwili Stream, many pollutants appear to be concentrated in the box culvert by Duke's Restaurant. This culvert also acts as the confluence of two streams that are diverted under the Marriott Hotel. Below this elevated culvert is Nawiliwili Stream. Bacterial counts from the culvert are consistently some of the highest in the watershed (Carl Berg, personal communication, 2002; WRRC, 2002). The most recent spill of sewage effluent from the Līhu'e Wastewater Treatment Plant flowed into the stream on the golf course at Kauai Lagoons and then into the diversion under the Marriott Hotel, and finally it discharged through this culvert into Nawiliwili Stream (Kaupena Kinimaka, Kauai Marriott Hotel, personal communication, 2002; County of Kaua'i representative, personal communication, 2002). An estuary located at the mouth of Nawiliwili Stream and Kalapaki Bay acts as the final dumping ground for the pollutants listed thus far. Yet, this site is home to many endangered water birds including the Hawaiian gallinule. Native gobies have also been noted at this site (Don Heacock, personal communication, 2002).

A storm drain located in a parking lot above the culvert catches the runoff from activities in the lot. Residents have witnessed illegal cleaning activities in this area and in some cases reported such activities to the Department of Health (Cheryl Lovell–Obatake, personal communication, 2002). Recently (April, May, and July 2002), several small diesel spills near Nawiliwili Stream were responded to either by the fire department or hotel engineers. On April 23, 2002, a solenoid pump on the roof of the Marriott Hotel failed, causing a small diesel spill. The diesel (about 5 gallons) leaked into the roof drain and discharged into Nawiliwili Stream. Most of the diesel was removed with absorbent pads (Kaua'i County Fire Department, 2002). Earlier, when the hotel was still the Westin, an oil spill from an underground tank was recorded (Hawai'i State, DOH, 1993). The path of the diesel suggests that storm water from the roof of the hotel is also funneled into the culvert.

Another problem, more specific to the sewage issue, is that the wastewater treatment facilities are deteriorating and in much need of repair. Inspection ratings are more frequently becoming "unacceptable," but nothing is being done to fix these inadequacies (Hawai'i State, DOH, 2002). Furthermore, drainage manuals for county projects and for large landowners' development projects are out of date (Kaua'i County's drainage manuals are currently being updated). Until changes are made, streams remain the avenue for drainage. Finally, diversions, pumping, and channel alteration, as well as the increase in the surface area of impervious surfaces, affect the amount of water flowing into the bay via these drainage ways. Nutrients, petrochemicals, and sediments are potential contaminants that can be transported by the runoff. Preliminary results of a recent study in Līhu'e by NBWC (2002) showed a significant amount of sediment and trash transported by storm-water runoff. For their study, the NBWC staff installed catch basin inserts (wire baskets) in storm drains to document pollutants in the storm-water runoff, which can reach receiving waters (NBWC, 2002).

There is a concern about water use and potential contamination due to the construction and future operation of a new power plant near Ma'alo Road, Hanamā'ulu. This area is not part of the Nawiliwili Watershed, but due to diversions and interbasin transfer of water, water from one watershed has the potential to impact a different watershed. Like any typical construction site, it can be a source of sediment in runoff. A large amount of water will be needed to generate electricity, and the plant is already diverting water from Kapaia Reservoir via an 11,500-ft underground waterline. Diesel and naphtha will be stored on site in additional tanks (*The Garden Island*, March 14, 2002). This potential for contamination is due to the fact that the plant is located very near several natural drainages, including Hanamā'ulu and Nawiliwili Streams (Planning Solutions, 1998). Currently (July 2002), the power plant is in the application process for a National Pollution Discharge Elimination System (NPDES) permit (Gary Ueunten, Hawai'i State, DOH, personal communication, 2002). According to the EIS, processed water from the plant will be returned to the watershed via the Lower Līhu'e Ditch. The EIS states that if wastewater is returned to the ditch system, it would have slightly elevated total dissolved solids and sulfate concentrations and would include minute concentrations of chemicals such as RO antiscalent, RO bisulfate, boiler phosphate, boiler cyclohexylamine, and boiler hyroquinone. As described in Section 4.4, Hanamā'ulu Bay suffers from bacterial contamination. In addition, average coliform, phosphorus, and nitrogen levels in the bay all exceed state standards for Class A waters. This bay is highly impacted due to many years of receiving some 12,000 gallons per day of disposal cane wash water (Hawai'i State, DOT, 1978).

5.3.3. Hulē'ia Stream

Hulē'ia Stream undergoes the dynamics of dewatering from at least four diversions. The "main" diversion is located above Halfway Bridge. Under low-flow conditions, 100% of the water from Ku'ia Stream is diverted. However, depending on weather conditions, especially during heavy rains, that diversion may be turned off, returning the water to the stream channel (Alan Smith, Grove Farm, personal communication, 2002). Excess increased flows and tremendous spikes in turbidity have been recorded by NBWC after rain events. After a heavy rain in March 2002, NBWC recorded a reading of 83.7 nephelometric turbidity units (NTU), whereas the arithmetic mean for the year at the same site was 11.93 NTU. Turbidity measurements taken by Jon Schlegel of NRCS (personal communication, 2002) on the Rice Ranch in a reservoir just west of Hulē'ia Stream are 20 to 75 times the average measurements found in the stream. This area is now used for cattle ranching, and according to Schlegel, this activity can influence turbidity levels. Sediment that is causing the turbidity in this area undoubtedly finds its way into the stream during storm events.

The quarry near Nawiliwili Stream has been listed as a sediment contributor in a number of Hawai'i State Department of Health documents (e.g., Hawai'i State, DOH, 1990; KRP Information Services, 1993). The quarry referred to is actually located on Hulē'ia Stream at the confluence of Ku'ia and Kamo'oloa Streams. Mining activities expose rock and soil to the elements, exacerbating natural erosion processes. Sediment may contribute to the turbidity levels in the stream during rain events when it is transported by storm water. Although the quarry has an NPDES permit to discharge into Ku'ia Stream, actual discharges are intermittent. Recorded discharges have been the result of accidents such as a broken pipe or punched hole in the ditch system. A berm near the crushing facility collapsed and fell into the stream on one occasion after a heavy rain (Hawai'i State, DOH CWB, NPDES discharge monitoring reports, 1992–2002).

Crabbers, fishermen, and kayakers use Hulē'ia Stream. Tourists and locals extensively use tributaries to this stream for recreational purposes. An example is Kipu Falls. A June 2002 sample taken at Kipu Falls by WRRC showed coliform bacterial levels to be greater than 2,400 CFU/100 ml and entercoccus bacterial levels to exceed 1,040 CFU/100 ml (WRRC, 2002). The latter count is well in excess of the state water quality standard. The high bacterial counts may be linked to ranching activity in the vicinity. Additionally, hunters frequent the area inland in search of feral pigs. While sampling, NBWC staff often finds pig carcasses thrown from bridges built to cross over Hulē'ia Stream. Pigs are a suspected source of *Leptospirosis,* one of the public's biggest health concerns. Pigs are also known to cause erosion and can contribute to turbidity.

An assessment by Kido (1999) found Hulē'ia Stream to be biologically degraded, especially in areas where bridges cross the stream. Hulē'ia Stream, in general, was found to have the best biological integrity of the streams in the Nawiliwili Watershed, yet no native species were found near the bridge crossings. The rating of "best in the watershed" only means that multiple native species were found somewhere in the stream, some recruitment is taking place, and there is some habitat availability. However, when compared with reference streams, this stream ranked poorly (Kido, 1999).

Hulē'ia Stream is by far the biggest source of freshwater input into Nawiliwili Bay. This stream is culturally significant for being the location of Alekoko Fishpond as well as many other fishponds (now gone). Additionally, Hulē'ia Stream once was the water source for the staple food (taro) of the Hawaiian population. There is saltwater influence in this stream for over 2 miles upstream. The lower part of Hulē'ia is important as an estuarine environment and nursery ground for many marine fish and crustacean species. It is also important as a water bird habitat because many of our endangered water birds can be found in this portion of the stream. Unfortunately, 50 or so years ago the red mangrove was accidentally introduced and is thriving and is prolific along the banks as far up as the saltwater influence is present. The mangrove may contribute a significant amount of organic material to the stream, increasing turbidity and nutrient concentrations (KRP Information Services, 1993). Additionally, the massive amount of roots extendingfrom this plant into the stream may slow flows and trap sediment.

5.3.4. Papakōlea Stream

Papakōlea Stream winds its way through the Hulē'ia National Wildlife Refuge before discharging into Hulē'ia Stream. In the 1940s, Grove Farm built a power plant on Papakōlea Stream. Studies completed by the NBWC has indicated that Papakōlea is the most turbid stream in the watershed. It appears that the upper station is more turbid than the lower station (NBWC, 2002). This may be due to the presence of two waterfalls that separate the stations. Dissolved oxygen is found to be much higher at the lower station, as would be expected after aeration takes place at the falls. At the upper station, a spike in turbidity after a heavy rain in March 2002 measured 176 NTU (NBWC, 2002). This is twice the maximum turbidity measurement at Hulē'ia on the same day, yet the flow volume at Papakōlea Stream is nowhere near that of Hulē'ia.

Kido's (1999) assessment of Papakōlea Stream categorizes it as severely degraded. Preliminary results of a more recent study show that the sites assessed in the Nawiliwili Watershed (including Papakōlea) were impaired in terms of flow regimes, habitat structure, channel sedimentation, riparian characteristics, bank stability, and substrate availability (Kido, 2002b). The Hawai'i Stream Bioassessment Protocol was applied in this study. It was designed to evaluate the biological integrity of perennial Hawaiian streams, as well as its physical condition and habitat, as compared to reference streams considered "pristine" (Kido, 2002a).

HSRC and NBWC staff noted evidence of feral pigs at the lower Papakōlea site in the wildlife refuge during monitoring activities. The stream banks looked as if they had been "rototilled" by the pigs. Erosion from this type of activity can contribute to the already severe sedimentation problem at this site. At an upper station, the banks are steep and unstable. It is dangerous to sample this stream in some locations for fear of someone getting stuck in the deep sediment. An abandoned car can be found pushed over the banks at this site, and rubbish thrown from the bridge is often found. In July 2002, NBWC and

Hawai'i State Division of Aquatic Resources (DAR) staff encountered a 5-gallon bucket half full of used motor oil approximately 100 m uphill from the bridge site.

6. DOH'S STUDIES ABOUT TOTAL MAXIMUM DAILY LOADS

Under the federal Clean Water Act, the state of Hawai'i has identified 111 impaired water bodies and the pollutants causing impairments. Under this act, the state is required to either de-list each site or establish its TMDL. According to federal regulations, a TMDL sets the level of pollutant loading "necessary to attain and maintain the applicable narrative and numerical water quality standards with seasonal variations and a margin of safety which takes into account any lack of knowledge concerning the relationship between effluent limitations and water quality. Determination of TMDL's shall take into account critical conditions for stream flow, loading, and water quality parameters" (David Penn, personal communication, 2002).

The state Department of Health has listed Nawiliwili Bay and Nawiliwili and Hulē'ia Streams as impaired by turbidity and nutrients; thus both streams are being studied for TMDL (David Penn, personal communication, 2002). Papakōlea Stream is also being studied for TMDL because it is considered a major tributary of Hulē'ia.

Puali Stream is currently under consideration for potential listing as an impaired stream, because it has been identified as impaired through the Hawai'i Stream Bioassessment Protocol and because it flows into an impaired coastal water body (Nawiliwili). The DOH Clean Water Branch, Monitoring Section, is collecting water-column samples for laboratory analysis and conducting in situ measurements of stream discharge rate, pH, DO, temperature, conductivity, and turbidity. DOH may also consider other datasets (e.g., those collected by PISCES and UH's WRRC) in its listing decision.

TMDLs for nutrient and sediment loads in Puali Stream will be prepared only if study results suggest that implementation of TMDLs for Nawiliwili and Hulē'ia Streams are not likely to be sufficient to bring the bay back into compliance with state water quality standards for nutrients and sediments. DOH is hoping to continue sampling in Puali Stream during the TMDL study for other streams, but this has not yet been worked out with the contractor and DOH partners.

7. GROUNDWATER QUALITY DATA

Groundwater quality data were obtained from the DOH. Available data were for 1999, 2000, and 2001, with a few measurements at scattered times for 1992 through 1996. The data seem to be well documented with clear quality control procedures. For 2001, measurements were taken for volatile chemicals, including regulated and unregulated contaminants. The list includes a total of 24 of these. Measurements were also taken for carbamate pesticides, including two regulated and eight unregulated chemicals. Separate reporting was also done for EDB, DBCP, and TCP, as well as for chlorinated acids, synthetic organic chemicals, glyphsate, and inorganic chemicals (non-metals). Chlorinated acids include six regulated and one unregulated chemical, while synthetic organic chemicals include nineteen regulated and six unregulated ones. Finally, the list includes four inorganic chemicals.

In 2001, only on two occasions, the concentration of atrazine, a synthetic organic chemical (herbicide), exceeded the MCL of 0.05 µg/l. The well names are Kilohana B and Kilohana G, and the respective concentrations were 0.12 and 0.08 µg/l. Figure 19 shows the location of these wells. The sampling dates were June 4 and May 23, respectively. Other than that, most concentrations were below detection limits. Nitrate (as N), an inorganic chemical, did not exceed 1.7 mg/l, which is much lower than the MCL of 10 mg/l. The value of 1.7 mg/l was measured at Kilohana G on May 23.

Similar data were collected in previous years, with less frequency. However, none of the measurements indicate groundwater contamination problems. Phase 2 of this study will assess potential relationships of contaminant levels in streams and groundwater.

8. GENERAL LIST OF POTENTIAL POLLUTION SOURCES

Compiling an accurate and definite list of all potential pollution sources is difficult due to the absence of comprehensive studies and the lack of sufficient data. When this is the case, rationale from other studies and reports was used to justify why the potential source is included. The word *potential* is specifically used to reinforce the fact that we have very little hard evidence as to the source of pollutants in the watershed. The information regarding these sources can provide insight or a starting place as to where future studies may be focused. It is also intended to point out where the gaps exist that need to be filled.

The following are potential sources of pollution:

- Abandoned boats and vehicles
- Agricultural lands
- Cesspools
- Construction sites
- Channel alterations
- Chemical storage facilities
- Land and stream erosion
- Forested areas and feral ungulate-related problems
- Golf courses
- Halehaka landfill
- Quarry at Halfway Bridge
- Urban storm-water runoff
- Wastewater treatment facilities

It is clear from Sections 4 and 5 above that there are sediment, nutrient, and bacterial-contamination problems in the watershed and bay. Among those listed above, sediment sources include agricultural lands, construction sites, channel alteration, erosion, the quarry, and urban runoff. Nutrients originate from agricultural lands, golf courses, cesspools, frosted areas, urban runoff, and wastewater treatment spills. Bacterial contamination originates from cesspools, frosted areas, urban runoff, and wastewater treatment spills. There is, however, a chance that other chemicals exist due to the other sources listed above. There are great uncertainties regarding quantification and assessment of such contaminants due to the absence of data. Only the levels of bacterial contamination in a limited number of sites are defined based on old and new measurements, which have been collected during this study. Additional studies are needed to assess the existence of other chemicals in the watershed and their respective levels of contamination.

The following subsections detail known information about the potential sources listed above. The approximate locations of the potential sources are shown in Figure 20.

8.1. Abandoned Boats and Vehicles

Locations and fate of abandoned boats and vehicles are not documented as far as we know. Personal knowledge of our staff include the locations of three boats that have sunk or washed up against the rocks in the Nawiliwili Small Boat Harbor and Hulēʻia Estuary vicinity. Vaughan Tyndzic of the state Division of Boating and Ocean Recreation and personnel who manage the Nawiliwili Small Boat Harbor (Richard Watjen, manager, personal communication, 2002) both can verify that these vessels have sunk. According to Tyndzic (personal communication, 2002), a record is produced when an owner files an incident report, often for insurance purposes. However, if the boat has been abandoned, no report is filed. Figures 21 through 24 are photos of some boats that are damaged or may have sunk in the bay at a later time. There seems to be problems with jurisdiction in the Hulēʻia River, according to Tyndzic. Jurisdiction, lack of impounding authority, lack of resources, and the sheer number of problems (especially on Oʻahu) have lead to failure in resolving the junked or abandoned boat issue (Tyndzic, personal communication, 2002). There is a need to survey the bay for sunken vessels and to remove the wreckage.

Other boat-related pollution may involve litter (Figure 25), ballast discharge, petrochemicals, and sewage or wastewater discharge. Discharge from marine toilets into a small-boat harbor such as Nawiliwili is prohibited under section 19-63-8 of state Department of Transportation regulations (KRP Information Services, 1993). Federal regulations require vessels fitted with toilets to have marine sanitation devices. DOT personnel are permitted to inspect marine sanitations devices and issue citations to those vessels not meeting certain requirements. However, lack of manpower has made it difficult to enforce these regulations (KRP Information Services, 1993). Even those who comply with the above regulations may be in violation if no pump-out facilities are available.

For example, recreation activities can also be a source of contamination. The Norwegian Cruise Lines recently agreed to pay a $1.5 million fine for dumping oily wastewater into the ocean and keeping false records of discharges (*Honolulu Advertiser*, August 1, 2002). Although there was no evidence of dumping in Hawaiian waters, this cruiseline frequently calls at Nawiliwili Harbor. Several years ago Carl Berg (personal communication, 2002) reported another cruiseline, the American Hawaii Cruiselines, for discharging what appeared to be sewage into Nawiliwili Harbor.

Examples of pollution problems include an abandoned car, spotted by NBWC staff, that was pushed from the banks into Papakōlea Stream. In addition, on July 16, 2002, the staff also located and removed a leaky 5-gallon bucket half filled with used motor oil. The bucket was located at about 100 m up the road from the Hulemalu Bridge, which crosses Papakōlea Stream.

8.2. Agricultural Practices

Agriculture is a significant sediment generator. Additionally, pesticides and fertilizers from agricultural activity can become attached to sediment particles and thus be transported with storm-water runoff. Much of the agricultural land in the Nawiliwili Watershed was once used for sugarcane production, but that activity has recently ceased. The Rice Plantation is now used for cattle ranching. According to Jon Schlegel of NRCS (personal communication, 2002), cattle are a suspected source of bacteria and sediment. Excessively high turbidity levels (100+ NTU) have been recorded at nearby locations. Additionally, high fecal coliform and enterococcus counts (2,480 CFU/100 ml and 1,040 CFU/100 ml, respectively [WRRC, 2002]) found at nearby Kipu Pond are suspected to be cattle related. Additional data need to be collected before definite conclusions can be drawn, however.

The Nawiliwili Watershed is undergoing many land-use changes. Corn and papaya are grown in the area; however, no data have been made available on the acreage involved. NRCS seems to have limited information on this subject at this time. However, it has an erosion control program and a wildlife program that are designed to voluntarily address some of these questions. The state GIS site includes an agricultural land-use map dated 1978–1980 (Figure B7 in Appendix B). There is a need to update such critical information.

Bill Cowern of Hawaiian Mahogony has leased some 4,000 acres of private land for silviculture. Several hundred acres of this land is located within the Nawiliwili Watershed. Albizia, mahogony, and rosewood are currently being grown; however, there is a plan to grow up to a hundred different species of trees (*The Garden Island*, October 16, 2000). Data on the exact number of acres and species being grown have not been made available at this time. Most of this forestry project is taking place in the upper watershed.

8.3. Cesspools

A map from KRP Information Services (1993) documents existing cesspool areas on Kaua'i, including Hā'ena, Hanalei, Kīlauea, Anahola, Keālia, Kapa'a, Wailua, Hanamā'ulu, Līhu'e, Po'ipū, Kōloa, Lāwa'i, Hanapēpē, Waimea, and Kekaha. Private sewer treatment plants exist near Hanalei, Kapa'a, Līhu'e, and Po'ipū.

In Hanalei, after a septic tank malfunctioned last year, a community group (Hanalei Heritage River Program, led by Carl Berg) conducting bacterial monitoring near Hanalei River mouth and Black Pot found that the level of bacteria was exceeding state standards (*The Garden Island*, January 4, 2002). In response to the findings, Kaua'i County asked the state Department of Health to test the waters around the island to determine if they were safe for recreational use (*The Garden Island*, January 26, 2002). In March 2002, members of the USEPA, state Department of Health, and several community groups were present for a water quality workshop that was held in the County Council chambers. The main topic was bacterial counts in recreational waters around the island. The situation in Hanalei was addressed in the presentation by DOH staff. The presentation included a list of wastewater treatment plants in Hanalei, a tax map key of the area, and about 200 cesspools fronting the bay (Hawai'i State, DOH, 2002).

KRP Information Services (1993) mentions that there are problems associated with cesspools in high water-table areas such as Hanalei and Niumalu. These cesspools are susceptible to failure after a heavy rain (KRP Information Services, 1993). Recent developments in Līhu'e and Puhi have increased the amount of impervious surfaces adding to the volume of storm-water runoff (Akinaka & Assoc., 1992). This increased runoff could aggravate the problem of cesspool failure in high water-table areas.

As discussed earlier (Section 5.3.1), the results by Carl Berg and by Pat Cockett and his students showed high bacterial counts at Kalapaki Beach and Niumalu near Puali Stream. The geometric mean for the samples taken at Kalapaki Bay on April 3, 2002 was 40.66 CFU/100 ml. Some hotspots near Nawiliwili Stream measured 209 CFU/100 ml. Another group took samples from Niumalu on April 4, 2002. A hot spot near the kayak-launching area measured 2,602 CFU/100 ml. The geometric mean for the area was 400 CFU/100 ml (Carl Berg, personal communication, 2002).

Although the construction of cesspools has been restricted since August 1991, many older communities on Kaua'i, including many in the Nawiliwili Watershed, still use cesspools as their waste disposal method. In a 1993 report, it was estimated that the Kaua'i cesspool failure rate was between 2% and 8% islandwide. This number may be higher in areas with higher cesspool concentrations (KRP Information Services, 1993). Problems with cesspools may include, but are not limited to, failure due to improper operation and lack of maintenance, and seepage, which may contaminate coastal waters, streams, and perhaps even groundwater. Additionally, cesspools that are located in areas with nonporous soils can become clogged because of bacterial growth and fine solids buildup. This can lead to failure, especially during periods of high rainfall or storm runoff (KRP Information Services, 1993).

Groundwater contamination from cesspools may be of concern in areas with highly porous soils, which does not provide efficient treatment. Rapid percolation and a short distance to the water table are two factors that could increase the risk of groundwater contamination. The existence of a strong seaward flux of freshwater can increase the potential for the subsequent contamination of coastal waters (KRP Information Services, 1993).

Bacteria are not the only concern of contamination related to cesspools. As stated by KRP Information Services (1993), nutrients from waste in cesspools may also find their way into coastal waters. Potential eutrophication is even greater if nitrogen and phosphorus exist in waters with low circulation, such as embayments, estuaries, and tidal ponds. Nawiliwili is an embayment with potentially impaired circulation due to "flushing" barriers such as the breakwater and jetties contained within the harbor.

The potential seepage and failure of cesspools in the Nawiliwili Watershed, along with the limited amount of data currently available, have necessitated that a sanitary study be conducted in the future by Gary Ueunten of DOH and Carl Berg of the Hanalei Heritage River Program. In the first stage of the study, maps and documentation on existing sewer lines and sewered areas will be collected. A GIS layer will be created to include this information. Finally, a survey will be conducted to find out which properties are using cesspools vs. septic tanks. DOH's Clean Water Branch has obtained a fluorometer, and there is a contract pending to train staff in the use of dye tests, among other sanitary survey techniques.

8.4. Channel Alterations

As discussed in Section 4.3, the study by Timbol and Maciolek (1978) documented stream alterations and their effects on species abundance. Examples of alterations are shown in Figures 26 and 27. Urban activity and additional channel modifications have changed the landscape of Kaua'i since their study was completed. There is a need to initiate studies similar to that by Timbol and Maciolek to assess the current status of the streams.

As discussed earlier, Section 4.3, Hulē'ia and its tributaries have at least four stream diversions. Puali has been realigned behind Halelani Villages in Puhi and travels through a culvert where the road passes over it (Heacock, 1994). Near Niumalu Pavilion, another road-crossing bridge is located near the mouth of Puali Stream. Papakōlea Stream also has a road-crossing bridge on Hulemalu Road. Nawiliwili Stream travels through a culvert and is crossed by a small bridge. Two streams that run through Marriott Hotel and the Kauai Lagoons property are diverted under the hotel parking lot. They ultimately discharge through an elevated box culvert into Nawiliwili Stream.

Other problems include the large volumes of rubbish thrown from bridge crossings, as recorded by NBWC and UH HSRC staff. On more than two occasions, the staff encountered rotting pig carcasses at the Kipu Bridge site on Hulē'ia Stream. Kido (1999) reported that many streams were "physically and biologically degraded in the reaches where they intersect the highway." According to the study, "nearly all of these locations exhibited excessive sedimentation and bank erosion." Further, no native macrofaunal species were observed or collected in any of these locations, and even alien species were present in very low abundances.

Channel alteration and hydromodification have become the topic of a recent series of Hawai'i coastal zone management focus-group meetings. One important issue which has come about in these meetings is that an inventory of channel alterations, hydromodifications, and diversion works is lacking. The Hawai'i State Water Code requires that diversion works be registered by the Commission on Water Resource Management, but it is clear that the list is not complete. An inventory of channel alterations would be useful in assessing nonpoint-source pollution since we already know that hydromodifications have a direct impact on species, sediment load control, and other physical, chemical, and biological parameters associated with healthy streams.

8.5. Housing Developments and Construction

Before Hurricane Iniki, the construction industry was second to tourism in terms of dollar valuation (KRP Information Service, 1993). After the hurricane, construction activity increased dramatically but has since leveled off. Significant amounts of sediment can be generated by construction activities such as grading and grubbing. Additional pollutants that are commonly used at construction sites can bind to sediment and then be carried with storm runoff to receiving waters (KRP Information Services, 1993).

Best management practices (BMPs) are being used at many active construction sites in the Nawiliwili Watershed. Sediment traps at some locations may not be effective if they had not been properly installed or maintained. On a recent trip to locate sites for TMDL studies, DOH staff noted improperly installed sediment traps at a site near Aloha Church in Līhu'e. UH HSRC staff noted that sediment traps at the Halemalu site in Puhi had been knocked down by the sheer amount of sediment being generated. There is no evidence, however, to show that any improper or illegal activity is taking place. BMPs are being used, and permits have been issued for most construction activities taking place on Kaua'i.

8.6. Repair Shops and Chemical Storage

In 1993 a chemical spill occurred in the Līhu'e industrial area (*Honolulu Star-Bulletin*, June 29, 1993). The chemical, a fluorescent dye, traveled from a storm drain to Kalapaki Stream, where it was fed into an underground diversion and finally discharged into Nawiliwili Stream. Illegal dumping of toxins into storm drains is one method of contaminating receiving waters. However, even proper usage of chemicals can lead to contamination (Hawai'i State, DOH, 1990). The Kaua'i County Fire Department has responded to petrochemical spills in neighboring areas. Most spills involve a quart or two of oil. Others are more significant, like a 1,900-gallon diesel spill in an underground tank at the Līhu'e Power Plant in October 2001 (Kaua'i County, Fire Department, 2002).

At our study site, we have no evidence of any cases of spills. We are looking into DOH's records for a list of registered complaints, if any.

Below is a list of businesses that are present in the same industrial area as the company that housed the fluorescent dye. Many of them store petrochemicals, fertilizers, and pesticides. The list provided is for information only and does not imply any wrongdoing by any of these companies.

Līhu'e industrial area near headwaters of Kalapaki Stream:

Nawiliwili Machine Shop (galvanizing, welding and sheet metal)
UHS Fertilizer
Kauai Welding
Air Liquide (gasses)
Costa's Auto Repair
Kauai Toyota
Kuhio Motors
Kauai Automated Fuels Network (filling station and storage of refueling tanks)
D&W services (auto repair)
Terminex (pesticides)
Waynes Enterprises (auto repair)
Tire Warehouse
Thrifty Rental Car
Hawaiian Blade's (surfboard makers)

Other areas of the watershed:

Chevron
2 Shell Stations
2 76 Stations
Ohana Motors
Gas Pro
Midas
Napa (Pacific Service and Development Corp.)
Kauai Foreign Auto
Puhi Metals & Recycling (the company has BMPs in place, such as retention basins)
Brewer Environmental Industries (chemical storage facility for chlorine, pesticides, fertilizer)

8.7. Land and Stream Erosion

The pollutant listed by the Department of Health as having the greatest detrimental impact on water quality in Hawai'i is sediment. On Kaua'i alone, it is estimated that 294,300 tons/year of sediment are generated (Hawai'i State, DOH, 1990). Figures 28 through 31 show examples of sediment problems in the watershed.

Farming is one of the primary sediment generators. Construction sites, mining operations, feral ungulates, and natural erosion processes also contribute large quantities of sediment to streams every year. Some of the factors that affect the amount of sediment contributed include intensity of rainfall, erodibility of soil, amount and type of ground cover, and land management practices (USDA Soil Conservation Service, 1976, as cited in (Hawai'i State DOH, 1990). In East Kaua'i, 57,900 acres are eroding while only 24,900 acres are considered adequately protected from erosion. Some 33,000 acres with BMPs in place are still experiencing erosion problems (208 Water Quality Management Plan, 1980, as cited in KRP Information Services, 1993).

Sediment is responsible for destroying stream habitat, impacting reef environments, and increasing turbidity. In addition, the chemical and physical properties of sediment particles exacerbate problems by allowing other substance to be adsorbed onto their surfaces. The result is that these substances are transported with sediments in runoff generated by rain events. For example, pesticides used in agriculture tend to become strongly attached to sediment particles and are thus transported with eroded sediment and then carried with runoff into receiving waters. Nutrients and pesticides can also become entrained in water transported to streams via agricultural diversions (Hawai'i State, DOH, 1990). Toxic pesticides and other chemicals that have been found in the bed sediment and tissues of fish in Hawai'i streams include Dieldrin, Chlordane, DDT, PCBs, TBT (from treating wood), EDB, DBCP, and arsenic (Brasher and Anthony, 1998; Hawai'i State, DOH, 1990).

A recent study of fishes and bed sediment in Nawiliwili Stream was conducted by USGS (Brasher et al., 2002). Some semivolatile organochlorines and trace metals, such as mercury, found in the bed sediments exceeded probable effect levels for aquatic organisms. Levels of Dieldrin, a metabolized product of Aldrin (a common termaticide used in the 1970s), found in bed sediment exceeded New York State Department of Environmental Conservation guidelines. Dieldrin was also found in elevated levels in fish tissues. Concentrations of the compounds found in Nawiliwili Stream were similar to concentrations found in urban streams on O'ahu (Brasher et al., 2002).

An EIS for Kauai Electric Lihue Service Center stated that runoff from their project would unlikely affect the marine communities in the area (Hanamā'ulu) because a survey showed that there was low coral cover and poorly developed marine communities (Planning Solutions, 1998). Brock (1994) examined marine communities at Ahukini (Hanamā'ulu) and found them to be quite diverse in areas starting about 40 m offshore. Near the freshwater input from the stream and drainage outfalls from the airport, corals were notably absent and other benthic communities were less diverse than farther offshore. In another part of the study by Brock (1994), poorly developed communities (coral cover less than 1%) were found in Nawiliwili Bay. Existence of small coral communities suggest that wave force may be an important factor in community structure. Freshwater input from Nawiliwili Stream, however, also affects sensitive corals. In both locations (Nawiliwili and Hanamā'ulu), chlorophyll-a concentrations exceeded state standards (Brock, 1994). In an EIS for Līhu'e Wastewater Treatment Plant's effluent disposal, bottom characteristics and poorly developed marine and benthic communities were discussed for Nawiliwili Bay (Marine Research Consultants, 1998). It is possible that these communities are highly impacted by a variety of factors, such as the previous disposal of 12,000 gallons per day of cane wash water into Hanamā'ulu Bay (Hawai'i State, DOT, 1978). Sugarcane washings that were historically discharged into Nawiliwili Stream ended up in the bay (Hawai'i State, DOH, 1990). In a related matter, the, State

DOH (1990) cited a 1985 study by Grigg that shows the impacts of sediment on aquatic communities. Along the Hamakua Coast of the Big Island. Grigg identified sediment discharges from sugar mills as being responsible for biotic depletion in the area. Additionally, he stated that recurring sedimentation activities do not allow opportunities for recovery. Sediment from dredging and filling-in areas for harbor construction may have contributed to the impact on marine communities in Nawiliwili as far back as 1930.

Construction sites can also contribute a significant amount of sediment from a small area for short or intermittent intervals. BMPs such as the use of sediment traps may be used to retain the sediment within the site. As stated before, for maximum mitigative effect, the traps must be installed properly and then monitored. Additional pollutants often used at construction sites, including waste petroleum products, can bind to sediments and be transported with storm-water runoff to receiving waters (KRP Information Service, 1993).

Mining operations expose large areas of soil and rocks to wind, rain, and other eroding factors. Historically, many surface mines were placed near streams where soil and mined materials could be disposed of or washed (Hawai'i State, DBEDT, 1987, as cited in Hawai'i State, DOH, 1990). This is no longer allowed, but sediment can be transported with runoff from mines and quarries situated near streams where large areas of bare soil are exposed, like at the quarry located near Halfway Bridge on Hulē'ia Stream. Exposed soil can become disturbed after a heavy rain, causing erosive accidents such as the accidental collapse of a 200-yd^3 berm at the Halfway Bridge quarry in 1996 (Hawai'i State, DOH CWB, NPDES discharge monitoring reports, 1992–2002).

8.8. Forested Areas and Feral Ungulate-Related Problems

We have completed an extensive search of records of the Nature Conservancy, the Kauai Mountain Partnership, the Hawai'i State Department of Land and Natural Resources' Division of Forestry and Wildlife, and other organizations for studies on feral ungulates and related problems in the Nawiliwili Watershed. Unfortunately, it became clear that little is known beyond the common knowledge of those who frequent the area. One of the reasons studies may be lacking is that much of the land in this watershed is privately owned and therefore does not fall under the jurisdiction of agencies such as the Division of Forestry and Wildlife.

Some of the problems associated with feral ungulates include devegetation and destabilization of soils, causing the generation of pollutants (Tagawa, 1957, as cited in (Hawai'i State, DOH, 1990) and the facilitation of non-native plant establishment. The feral pig is said to be the most environmentally devastating animal in Hawai'i. Additionally, in areas with abundant animal populations, fecal matter may combine with runoff, further adding to stream pollution (Hawai'i State, DOH, 1990).

Pigs are present in large numbers in the Nawiliwili Watershed and are causing erosion problems. Pig populations have increased since the demise of sugarcane culture and the introduction of guinea grass (Thomas Kaiakapu, personal communication, 2002).

Guinea grass provides cover for the pigs, and thereby reduces the chance of being taken by hunters. Additionally, in recent times more gates have been installed to keep hunters and others out of privately owned land. According to Kaiakapu, recreational hunting may keep pig numbers in check. The Division of Forestry and Wildlife is concerned about pigs removing native vegetation because non-native plants tend to revegetate more aggressively, pushing out any native species. There is also concern that the pig population is increasing in the upper watershed area (Bill Cowern, Hawaiian Mahogony, personal communication, 2002). Cowern, who has several hundred acres of trees growing in the upper watershed, is concerned that the pigs will knock over small trees while rooting for bugs in the area (*The Garden Island*, October 16, 2000).

NBWC staff has observed the "rototilled" banks of many irrigation ditches and drainage ways in areas on Kilohana Crater as well as at monitoring sites in the Hulē'ia National Wildlife Refuge along Papakōlea Stream. Baby pigs have also been spotted at the NBWC Papakōlea monitoring site. NBWC staff identified pig carcasses and bones at the Kipu Bridge site on Hulē'ia Stream. Several pig families present on the Rice Ranch are an attraction for visitors lead by a local kayak tour company.

Since anecdotal evidence is all we have to go on at this point, a need exists to study feral ungulate populations in the watershed. In addition to erosion and devegetation issues, pigs also pose the risk of spreading *Leptospirosis*. There is a growing public health concern about *Leptospirosis*, which can be spread by the urine of infected animals. Contracting *Leptospirosis* seems to be correlated with pig hunting and other recreational activities such as prawning.

8.9. Golf Courses

According to "Hawai'i's Implementation Plan for Polluted Runoff Control" (Hawaii State, DBEDT OCZM and DOH CWB, 2000), golf courses have the potential to contribute significant amounts of polluted runoff to adjacent waters. Nutrients from lawns and golf courses located in urban areas can enter waters through runoff as well as infiltration (Hawai'i State, DOH, 1990). Issues related to irrigation and to nutrients and pesticides use on golf courses are also under consideration (Hawaii State, DBEDT OCZM and DOH CWB, 2000).

Golf courses located in the Nawiliwili Watershed include one at Puakea and two at Kauai Lagoons. At Kauai Lagoons, treated effluent from the adjacent Līhu'e Wastewater Treatment Plant is used to irrigate the courses. As discussed in Section 5.3.2, spills at the treatment plant may end up in Nawiliwili Stream (Kaupena Kinmaka, personal communication, 2002; Figure 32). Nutrient concentrations in the box culvert at Duke's Restaurant, the final discharge point for such spills, are usually about three to four times greater than those in Nawiliwili Stream (WRRC, 2002). Nutrient-rich runoff from the golf course may also follow the same path. Marine Research Consultants conducted a study in 1998 to complement an EIS for the discharge of effluent from the treatment plant through injection wells. It found that although nutrient concentrations were higher in nearshore areas than in exposed coastline areas, mixing analysis indicated that the nearshore concentrations were less than what would be expected from natural groundwater input. It seems thus that nutrients are removed from the golf course by turf uptake. Excess irrigation water can percolate into the groundwater and end up in nearshore waters. Based on data provided, there is no indication that excess nutrients are being contributed. However, it seems only one sample was taken. No mention was made of what portion of the irrigation water runs off into drainage ways and makes its way into the bay in this manner.

Puakea Golf Course has the potential to impact Puali Stream as well as Papalinahoa Stream. In a seven-year study conducted by AECOS, Inc. (2002), nutrient concentrations in Puali Stream always exceeded state standards. In a study done at the time of the Halehaka landfill closing, it was found that irrigation recharge from sugarcane agriculture influenced groundwater seepage into Puali Stream (Mink and Yuen, 1993). Fertilizers from sugarcane agriculture may have influenced nutrient concentrations in the groundwater and the stream. Golf courses that have replaced sugarcane fields in the same area also engage in irrigation and fertilization. Nutrient-rich runoff and irrigation recharge from golf courses may very well influence nutrient concentrations in Puali and Papalinahoa Streams. Higher average total nitrogen concentrations were found at sites near the golf course near Puali Stream than at the sites farther downstream (AECOS Inc., 2002). According to the 1998 Hawai'i Water Quality Assessment (305(b) Report) by the Hawai'i State DOH, storm water from a nearby residential development site as well as the shopping center is channeled to the golf course development site. The resulting reduction in sedimentation and turbidity levels is supposed to reduce the strain on Puali Stream and Nawiliwili Bay. Some concern has been raised, however, that this water is impacting Papalinahoa Stream. This concern may be addressed in the DOH TMDL studies or future studies by NBWC.

8.10. Halehaka Landfill

KRP Information Services (1993) states that solid waste disposal practices can cause harm to water resources, especially groundwater, if care is not practiced in the siting, design, and operation of disposal facilities. The leachate can be a source of excessive bacteria, high chemical oxygen demand, and a variety of heavy metals that can find their way from improperly designed and operated landfills into receiving surface water or groundwater. As a result, these facilities may be required to install and operate monitoring equipment to detect contamination resulting from their operation.

We have no evidence of contaminants emanating from the landfill. Problems could have been limited to the time the landfill was operational and briefly thereafter. More details on the types and amount of contamination are given in the section on Puali Stream. The location of the site (in a tributary of Puali Stream) and the discharge of leachate via a 48-inch pipe into Puali Stream were two main concerns when the facility was operational. Monitoring equipment was installed at the Halehaka landfill (Don Heacock, personal communication, 2002), but no data have been made available on what was recorded.

8.11. Quarry at Halfway Bridge

Mining operations such as the quarry at Halfway Bridge destabilize soil and rocks and expose them to the elements, causing accelerated erosion. Quarries do not fall under the county grading ordinance because they are considered mining operations. Historically, surface mining operations have been placed near streams so that excess soil could be disposed of and the product could be washed. This is no longer allowed. However, sediment particles from exposed soil, along with any chemicals that have attached to the particle surfaces, can be transported with storm-water runoff to receiving waters (Hawai'i State, DOH, 1990).

The Halfway Bridge rock quarry is located at the confluence of Ku'ia and Kamo'oloa Streams. Just below this location, these two streams converge to become Hulē'ia Stream. Since the quarry is so old, no environmental impact statement seems to have been prepared. Even Office of Environmental Quality Control is unaware of any study or EIS for the impact of this activity.

Grove Farm holds an industrial NPDES permit that allows the Halfway Bridge rock quarry (#0020851) to discharge process wash water and storm-water runoff into Ku'ia Stream (outfalls 001 and 002) and/or Waita Reservoir (outfall 003) from three different outfalls (KRP Information Services, 1993). The discharges are intermittent. Grove Farm operators are required to self-monitor their release of storm water. Records for 1992 to 2002 show two release instances in 1994 and a small number of accidental discharges from outfalls 001 and 002. In 1994, 800 gallons were discharged from outfall 001 (turbidity was 671 NTU and total suspended solids was 233 mg/l) and150 gallons from outfall 002 (turbidity was 711 NTU and total suspended solids was 449 mg/l). In 1995, approximately 4,000 gallons of non-process water entered the stream through a pipe break during pond repairs. Clean Water Branch personnel implemented corrective measures. In 1996, a contractor (Irrigation Technologies) opened a portion of a collection pond at the end of an irrigation ditch, sending 400 gallons of silty water into the stream (Hawai'i State, DOH CWB, NPDES discharge monitoring reports, 1992–2002). Also in 1996, after a heavy rain, a berm near the crushing plant collapsed, sending approximately 200 yd^3 of dirt into Kamo'oloa Stream. The berm was immediately repaired (Hawai'i State, DOH CWB, NPDES discharge monitoring reports, 1992–2002).

A number of state-generated documents mention that an unnamed quarry on Nawiliwili Stream is suspected of being a significant contributor of sediment (e.g., KRP Information Services, 1993; Hawai'i State, DOH, 1990; Hawaii State, DBEDT OCZM and DOH CWB, 2000). The quarry is actually not located on Nawiliwili Stream but within the Hulē'ia's Stream system. NRCS staff has also suggested a link between turbidity and sediment entrained in runoff from the quarry. It is uncertain, however, how much erosion is taking place or how much sediment is being contributed to the Nawiliwili Watershed.

8.12. Urban Storm-water Runoff

Urban storm-water runoff is a major source of contaminants and sediment. Urban runoff characteristics are described in the results of the National Urban Runoff Program study sponsored by USEPA. The results of this study are summarized in KRP Information Services (1993). The studies sampled 78 sites in 28 cities nationwide for a "year or two." The results showed that the metal concentrations found in urban runoff exceeded national water quality standards for copper, lead, zinc, and cadmium. Organic constituents consisted mostly of pesticides. The primary sources of the inorganic pollutants are from fossil fuel combustion, metal corrosion (a chronic problem in Hawai'i), and other automobile-related activities. There is a chance some of these contaminants exist in Nawiliwili Bay. In addition, coliform bacteria counts exceeded water quality criteria both during and after a rainfall event (Hawai'i State, DOH, 1993). For June 2002, the highest coliform bacteria count (2,640 CFU/100 ml) in the Nawiliwili Watershed was for samples taken from Nawiliwili Stream (WRRC, 2002). This stream receives urban runoff from numerous storm-drain facilities.

Water runoff from the streets of Līhu'e can pick up contaminants, such as sediment, nutrients, pesticides, heavy metals, and coliform bacteria that end up in Kaua'i's streams. According to the Water Quality Management Plan for the County of Kaua'i, drainage facilities are designed for "maximum efficiency of conveyance," which only exacerbates the problems associated with runoff. Such problems may include accelerated erosion of stream banks, as described in Kido's (1999) studies of the Nawiliwili Watershed. Additionally, "total pollutant loads during heavy runoff periods can often exceed the pollution load from a wastewater treatment plant" (KRP Information Services, 1993, p. XIII-I). In addition to the increased velocities created by designing drainage facilities to efficiently convey runoff, impervious surfaces found in urban areas like Līhu'e increase the volume of storm-water runoff by inhibiting it from percolating into the ground. Greater quantities of sediments are carried by high-velocity storm water and tend to accumulate at some point downstream (Hawai'i State, DOH, 1993). Some of these sediments may settle out in areas of slow-flowing water such as the deep-draft commercial harbor at Nawiliwili. As a result of this sediment accumulation, periodic dredging is required to maintain navigable depths (Hawaii State, DBEDT OCZM and DOH CWB, 2000). In 1990 alone, the U.S. Army Corps of Engineers planned to remove over a million cubic yards of sediment from several harbors and embayments around the state, including Nawiliwili Harbor (Esaki, 1989, as cited in Hawai'i State, DOH, 1990).

Sediment loads from urban runoff are also substantial. Additional pollutants from chemicals often found at constructions sites (such as Halemalu Village near Puali Stream) have the capability of binding themselves to the sediments before being washed into the streams along with storm-water runoff (KRP Information Services, 1993). In a study currently being conducted by NBWC, 25 storm drains in Līhu'e were fitted with catch basin inserts. The inserts consist of a basket that is approximately 6 inches wide × 6 inches deep and runs the length of the drain. After approximately seven months, the baskets were cleaned. More than 50 kitchen trash bags were filled with rubbish and sediment. Over 200,000 cm^3 of sediment alone were recovered. Sediment and decaying leaves accounted for approximately 75% of everything that was recovered from the baskets. The most common types of litter were cigarette butts and plastic wrappers from candy or cigarette packages.

8.13. Wastewater Treatment Spills

Pump failures from the Līhu'e Wastewater Treatment Plant have caused significant spills that have ended up in Kalapaki Bay. Possible bacterial contamination due to such spills is discussed in Section 4.4. Spills of this type are handled under point-source regulations. Private treatment facilities in the area include those located at Banyan Harbor Resorts (Nawiliwili), Kaua'i Community College (Puhi), and Kukui Grove Shopping Center (Līhu'e). Local residents have brought our attention to several problems that have occurred at the Banyan Harbor facility, although no documentation exists to support the claim. In 1994, Wasa Construction was excavating at the Līhu'e –Puhi Wastewater Plant at Halehaka and Nawiliwili Road when it accidentally punctured a sewage line. This caused a spill of 1,500 gallons that were then diverted into a depression in the construction area and treated with Chlorox (Hawai'i State, DOH CWB, NPDES discharge monitoring reports, 1992–2002). There is no evidence that this spill reached any stream or other receiving waters. As required, the operator of the facility reported this accident to DOH. There is no evidence that any unregulated activity is occurring in the Nawiliwili Watershed.

Information is available regarding Kaua'i County operation and maintenance inspection ratings of county wastewater treatment facilities. In the last five years the inspection ratings have gone from nearly all "acceptable" to more often "unacceptable" or "conditional," due to outdated, corroded equipment and inadequate backup effluent disposal, among other reasons (Hawai'i State, DOH, 2002).

At recent Water Quality Committee meetings, some concern has been raised about privately owned pump stations, such as the one located in the Anchor Cove Shopping Center in Nawiliwili. Local resident Cheryl Lovell–Obatake responded to an alarm that went off at the facility. At the meeting the Kaua'i County Public Works department representative declared that this was not a county-operated/regulated station. There was much confusion about who regulates this type of activity. One of the problems that we are faced with is that there is no central authority or mechanism at the state level to coordinate watershed management activities among government Hawaii State, DBEDT OCZM and DOH CWB, 2000).

9. GIS MAPS OF THE WATERSHED

Appendix B contains a number of GIS maps that show important and relevant features of the watershed. These were obtained from the Internet site of the State of Hawai'i. The site includes many layers which are compiled into four groups: physical features/basemap layers, political boundaries/administrative layers, natural resources/environmental layers, and hazard layers.

Appendix C contains information about GIS layers that are featured in this report. This information, obtained from the same web site, includes GIS attributes, sources of data and date collected, contact person, and other data. Aquifer-related definitions are given, starting on page 132. Additional information is added here for the aquifer status maps displayed in Figures B14 and B15. The aquifer status is defined by Mink and Lau (1990) using a 5-digit code describing the developmental stage, utility, salinity, uniqueness, and vulnerability to contamination. Tables 14, 15, and 16 list these status codes and their respective definitions for the high and low Hanamā'ulu aquifers, respectively. The hydrogeology of these aquifers is shown in Figures B12 and B13.

Figure B4 in Appendix B contains sites for rain gages in and around the Nawiliwili Watershed. Some information about the stations is listed in Table 17. We are currently contacting station operators to obtain available records for use in our modeling efforts.

Appendix B includes maps of political boundaries and administrative layers related to conservation district subzones, enterprise zones, parks, reserves, special management areas, and state land-use districts for 2000. Other layers—such as census tracts, school districts, and state senatorial districts—can be accessed from the web site.

GIS map deficiency includes biological and culturally significant features, as well as population demographics. Historical maps of land use before 1991 and after 2000 are also missing. Due to the dynamic nature of land use, especially after the demise of the sugar industry, annual or biannual updates should be made. Although the GIS maps show many rain gages existing in the watershed, we failed to get relevant data for any station.

10. CONCLUSIONS

Although little hard scientific data exist for the Nawiliwili Watershed at this time, fairly extensive potential sources of pollution have been identified. This type of information may provide guidelines for choosing data-collection sites and a strategy for sampling-scheme design. Absence of baseline data has been emphasized by the county Department of Public Works, state Department of Health, and state Department of Land and Natural Resources. The Department of Health's current TMDL study, although being conducted for a different purpose, may provide public information that could be useful in assessing the health of the watershed. Since more baseline data are being made available, we now have the opportunity to look at changes and trends in the watershed. With this base, we may be able to eliminate the rationale used in EISs that if the area is already highly impacted, new development cannot possibly affect the area any further.

The study identified sediment, nutrient, and bacterial-contamination problems in the watershed and bay. Sediment sources include agricultural practices, construction sites, channel alteration, erosion, the quarry, and urban runoff. Nutrients are originated from agricultural practices, golf courses, cesspools, frosted areas, urban runoff, and wastewater treatment spills. Bacterial contamination originates in cesspools, frosted areas, urban runoff, and wastewater treatment spills. There is, however, a chance that other chemicals exist due to the other sources listed in this report. The absence of data has created great uncertainties regarding quantification and assessment of such contaminants. Only the levels of bacterial contamination are defined, based on old and new measurements which have been collected in this study. Additional studies are needed to assess the existence of other chemicals in the watershed and the respective level of all contaminants, apart from bacterial contamination. There is also a need to assess various sources of bacterial contamination to identify the level of contamination caused by each source.

Although this study of available records provides only limited quantitative data, it can be used as a starting point for future areas of focus. Many potential sources of pollution have been identified. In addition to the studies and reports available in libraries, interviews of watershed users and residents were also conducted. Input from those who live and work in the watershed is an important component of this study. Concerned community members can provide valuable information regarding events that may not be recorded in scientific studies, which usually cover a limited time and space. If these events, such as minor but chronic spills or flooding, are recorded, they can provide insight into locating future potential pollutant sources. Of course, such information should be confirmed using of acceptable scientific research.

Finally, it is vital that public information on water resources be made available in the geographic region where it is relevant. State and county agencies need to maintain their own libraries and make it easier for researchers and also public to gain access to documents that have information which affects everyone on the island. Actions may be needed to allow access to water resource sites and information. There is a need to maintain strong ties and full cooperation among environmental groups, landowners, and land operators. In the absence of information and full cooperation, it is extremely difficult to assess the watershed status well in advance of contaminants reaching a receiving body, such as Kalapaki and Nawiliwili Bays. State and county agencies need accurate information to provide answers that alleviate the public's confusion and prevent misinformation.

11. REFERENCES

AECOS, Inc. 2002. Puali Stream monitoring data 1995–2001.

Akinaka & Associates, Ltd. 1992. Drainage master plan: Grove Farm's Lihue/Puhi project District Lihue, Kauai, Hawaii TMK: 3-3-03: POR 1. Prepared for Grove Farm Properties, Inc. Honolulu.

Belt Collins. 1993. Puakea Golf Course relocation, Honolulu, Hawai'i.

Berg, Carl and Cockett, Pat. April 3 & 4, 2002. Bacterial counts from Kalapaki and Niumalu. Unpublished data.

Brasher, Anne M. and Anthony, Stephen S. 1998. Occurrence of organochlorine pesticides in stream bed sediment and fish from selected streams on the island of Oahu, Hawai'i, 1998. Fact Sheet 140-00, U.S. Geological Survey, Honolulu, Hawai'i.

Brasher, Anne M., Anthony, Stephen S. and Wolff, Reuben. 2002. Results of bed sediment and fish tissue samples from Nawiliwili Stream. Presented at NBWC Water Quality Workshop, July 26, 2002. USGS, Water Resources Division. Oahu NAWQA Unit, Honolulu, Hawai'i.
Brock, R.E. 1994. Marine communities and water quality in the vicinity of three existing ocean discharges.
Cockett, Pat. 2000. 'Ainakumuwai web site. <http://www2.hawaii.edu/~pcockett/index.htm>
Commission on Water Resource Management. 1992. Declarations of water use. State of Hawaii Department of Land and Natural Resources Circular C-123 (Volume I — Declarations Summarized by File Reference and Volume II — Location Data Sorted by Tax Map Key), Honolulu, Hawaii.
County of Kaua'i. 2000. Kauai general -plan.
Environmental Technologies International, Ron Englund. 1994. Hanamaulu Stream biological survey Kauai, Hawai'i. Prepared for Amfac/JMB Hawai'i, Inc.
Fujioka, R.S. and Byappanahalli, M.N. 1998. Do fecal indicator bacteria multiply in the soil environments of Hawaii? Project completion report to U.S. Environmental Protection Agency. WRRC-98-04, Water Resources Research Center, University of Hawaii at Manoa.
Fujioka, R.S., Roll, B. and Byappanahalli, M. 1997. Appropriate recreational water quality standards for Hawaii and other tropical regions based on concentrations of *Clostridium perfringens*. *Proc. Water Environ. Fed.* 4:405–411.
Fujioka, R.S. and Shizumura, L.K. 1985. *Clostridium perfringens*, a reliable indicator of stream water quality. *J. Water Poll. Control Fed.* 57:986–992.
Fukunaga & Assoc., Inc. 2000. Final EA Lihue Wastewater Treatment Plant effluent disposal system. Prepared for Dept. of Public Works, Honolulu, Hawai'i.
The Garden Island. October 16, 2000. "Is forestry answer to sugar land question." Līhu'e, Hawai'i.
The Garden Island. January 26, 2002. "Kauai County has asked the state Department of Health to test recreational waters around the island to determine if they are safe to use." Līhu'e, Hawai'i.
The Garden Island. March 14, 2002. "KE's first new power plant in 11 years quietly being installed near Ma'alo Road." Līhu'e, Hawai'i.
The Garden Island. January 4, 2002. "Unsafe bacteria levels Reported at Hanalei Bay." Līhu'e, Hawai'i.
The Garden Island. May 5, 2002. "Students testing Kalapaki waters for pollution." Līhu'e, Hawai'i.
Grigg, Richard W. 1985. Hamakua coast sugar mill ocean discharges before and after EPA compliance. Sea Grant Technical Report UNIHI-SEAGRANT-TR-85-02, University of Hawai'i Sea Grant College Program, Honolulu, Hawai'i.
Handy, E.S. Craighill and Handy, Elizabeth Green. 1991. *Native Planters in Old Hawai'i: Their Life, Lore and Environment*, revised edition. Bernice P. Bishop Museum Bulletin 233, Bishop Museum Press, Honolulu, Hawai'i.
Hardina, C.M. and Fujioka, R.S. 1991. Soil: The environmental source of Escherichia coli and Enterococci in Hawaii's streams. *Environ. Tox. & Water Qual.* 6:185–195.

Hathaway, Charles B., Jr. 1978. Stream channel modification in Hawaii. Part C: Tolerance of native species to observed levels of environmental variability. Performed for Eastern Energy and Land Use Team Water Resource Analysis (formerly National Stream Alteration Team, Columbia, Missouri). FWS/OBS-78/18, U.S. Fish and Wildlife Services, Biological Services Program, Washington, D.C.
Hawai'i State, Department of Business and Economic Development (DBED). 1987. The state of Hawaii data book: A statistical abstract. Honolulu, Hawaii.
Hawai'i State, Department of Business, Economic Development and Tourism's Office of Coastal Zone Management (DBEDT OCZM) and Hawai'i State Department of Health's Clean Water Branch (DOH CWB). 2000. Hawaii's implementation plan for polluted runoff control. Honolulu, Hawai'i.
Hawai'i State, Department of Health (DOH). Bacterial counts from January, 2002 sewage spill at Kalapaki, Līhu'e, Hawai'i.
Hawai'i State, Department of Health (DOH). Bacterial sampling data for Nawiliwili (Gary Ueunten), Līhu'e, Hawai'i.
Hawai'i State, Department of Health (DOH). 1990. Hawaii's assessment of nonpoint source pollution water quality problems, Honolulu, Hawai'i.
Hawai'i State, Department of Health (DOH). 1991. Total metals in seawater, Honolulu, Hawai'i.
Hawai'i State, Department of Health (DOH). 1995. Turbidity data for Hule'ia Stream (Gary Ueunten), Līhu'e, Hawai'i.
Hawai'i State, Department of Health (DOH). 1997. Water quality data for Hule'ia, Papakōlea and Puali Streams, Līhu'e, Hawai'i.
Hawai'i State, Department of Health (DOH). 1998. 1998 Hawai'i water quality assessment (305(b) report), Honolulu, Hawai'i.
Hawai'i State, Department of Health (DOG). 2001. Water quality data for Hule'ia River, Līhu'e, Hawai'i.
Hawai'i State, Department of Health (DOH). March 2002. Presentation at Water Quality Workshop in County Council Chambers. Līhu'e, Hawai'i.
Hawai'i State, Department of Health, Clean Water Branch (DOH CWB). 1992-2002. NPDES discharge monitoring reports for permit # 0020842, Honolulu, Hawai'i.
Hawai'i State, Department of Transportation (DOT). 1978. Final EIS Hanamaulu–Ahukini cutoff road, Honolulu, Hawai'i.
Hawai'i State, Department of Transportation (DOT). 1983. Draft EIS Hule'ia Bridge replacement and approaches, Līhu'e, Hawai'i.
Heacock, Don. 1994. Written comments from intervenor status related to Grove Farm's Puhi/Lihue Project, Līhu'e, Hawai'i.
The Honolulu Advertiser. August 1, 2002. "Cruise firm to pay $1.5 million," Honolulu, Hawai'i.
Honolulu Star-Bulletin. June 29, 1993. "Chemical spill discovered in Nawiliwili Harbor," Honolulu, Hawai'i.
Honolulu Star-Bulletin. June 30, 1993. "Chemical spill keeps swimmers out," Honolulu, Hawai'i.
Honolulu Star-Bulletin. August 14, 1996. "Nawiliwili oil cleanup continues. . .beach closed," Honolulu, Hawai'i.

Honolulu Star-Bulletin. August 15, 1996. "15 chickens found dead near gas spill," Honolulu, Hawai'i.

Izuka, Scot K. and Gingerich, Stephen B. 1998. Groundwater in the southern Lihue Basin, Kauai, Hawaii. Water Resources Investigations Report 98-4031, U.S. Geological Survey, Honolulu, Hawai'i.

Izuka, Scot K. and Oki, Delwyn S. 2002. Numerical simulation of groundwater withdrawals in the southern Lihue Basin, Kauai, Hawaii. Water Resources Investigations Report 01-4200, U.S. Geological Survey, Honolulu, Hawai'i.

Kaua'i County, Fire Department. 2002. Incident reports, Līhu'e, Hawai'i.

Kido, Mike. 1995. An aquatic survey of Lower Hule'ia, Hanalei and Lumahai Streams and Papalihala Marsh, island of Kauai. For Wilson Okamoto & Assoc., Honolulu, Hawai'i.

Kido, Mike. 1999. Aquatic species survey and biological assessment of Lihue, Kauai streams intersected by Kaumualii Highway, Lihue to west of Maluhia Road (Koloa). Report to Park Engineering, Inc., Honolulu, Hawai'i.

Kido, M.H. 2002a. The Hawai'i Stream Bioassessment Protocol (Version 3.01): A manual for biological monitoring and assessment of Hawaiian streams. Report to the Hawai'i Department of Health, Environmental Planning Division and the U.S. Environmental Protection Agency, Region 9.

Kido, Mike. 2002b. Progress report—Nawiliwili Bay watershed restoration project bioassessment surveys of Nawiliwili Watershed streams.

KRP Information Services. 1993. Water quality management plan for the county of Kauai. Prepared for Hawai'i State Department of Health and the County of Kauai. Honolulu, Hawai'i.

Marine Research Consultants. 1998. Assessment of potential impacts to water quality and marine community structure from effluent disposal, Lihue Wastewater Treatment Plant, Lihue, Kauai, Hawaii. Prepared for Tom Nance Water Resource Engineering, Honolulu, Hawai'i.

Matsuoka, Iwao. 1982. Summary of available data on surface water, state of Hawai'i, Volume 1—Island of Kauai. Open-file Report 81-1056, U.S. Geological Survey, Honolulu, Hawai'i.

Mink and Yuen, Inc. 1993. Hydrogeological and geotechnical investigations: Halehaka Landfill closure, Lihue, Kauai, Hawai'i. Honolulu, Hawai'i.

Mink and Yuen, Inc. 1990. Water resources protection plan. Honolulu, Hawai'i.

Mink, John F. and Lau, L. Stephen. 1990. Aquifer identification and classification for O'ahu: Groundwater protection strategy for Hawai'i. Technical Report No. 179, Water Resources Research Center, University of Hawaii, Honolulu.

Nawiliwili Bay Watershed Restoration Project. Water quality data 2001–2002. Honolulu, Hawai'i.

Nawiliwili Bay Watershed Council (NBWC). 2002. Preliminary results of catch basin insert study, Līhu'e, Hawai'i.

Nawiliwili Bay Watershed Council (NBWC) and Hawaii State, Division of Aquatic Resources (DAR). 2002. Field notes. Līhu'e, Hawai'i.

Norton, S.E., Timbol, A.S. and Parrish, J.D. 1978. Stream channel modification in Hawaii. Part B: Effect of channelization on the distribution and abundance of fauna in selected streams. Performed for USFWS National Stream Alteration

Team, Columbia, Missouri. FWS/OBS-78/17. U.S. Fish and Wildlife Services, Biological Services Program, Washington, D.C.

Novotny, Vladimir and Chesters, Gordon. 1981. *Handbook of Nonpoint Pollution Sources and Management*. New York: Van Nostrand Reinhold Company.

Parrish, James. D., Maciolek, John A., Timbol, Amadeo S., Hathaway, Charles B., Jr. and Norton, Susan E. 1978. Stream channel modification in Hawai'i. Part D: Summary report. Performed for Eastern Energy and Land Use, Team Water Resource Analysis (formerly National Stream Alteration Team). FWS/OBS-78/19, U.S. Fish and Wildlife Services, Biological Services Program, Washington, D.C.

PBR Hawaii. 1995. Final EIS Lihue/Hanamaulu master plan. Prepared for AMFAC/JMB Hawaii, Inc. and Lihue Plantation Co., Ltd. Honolulu, Hawai'i.

Planning Solutions, Inc. 1998. Draft EIS Kauai Electric Lihue Energy Service Center. Prepared for Kauai Electric. Honolulu, Hawai'i.

Shade, Patricia J. 1990. Estimated water use in 1990, island of Kauai, Hawai'i. U.S. Geological Survey, Honolulu, Hawai'i.

Tagawa, Tom K. 1957. Forestry in Hawaii. Hawaii State Department of Land and Natural Resources, Honolulu, Hawai'i.

Technical Committee on Nonpoint Source Pollution Control. 1990. Nonpoint source pollution in Hawai'i: Assessment and recommendations. Prepared for Hawai'i State Department of Health, Honolulu, Hawai'i.

Timbol, Amadeo. 1978. Aquatic macrofauna in Hanamaulu Stream, Kauai, Lihue, Hawaii.

Timbol, Amadeo S. and Maciolek, John A. 1978. Stream channel modification in Hawai'i. Part A: Statewide inventory of streams, habitat factors and associated biota. Performed for Stream Alteration Project. FWS/OBS-78/16, U.S. Fish and Wildlife Services, Biological Services Program, Washington, D.C.

U.S. Geological Survey (USGS). 1973. Chemical quality of groundwater in Hawaii. Honolulu, Hawai'i.

U.S. Department of Agriculture, Soil Conservation Service. 1976. Erosion and sediment control guide for urbanizing areas in Hawaii. Honolulu.

Vann, Cheryl. 1993. Baseline study and discussion of potential impacts of urbanization on a small Hawaiian stream: Puali, Kauai, Hawai'i.

Wilcox, Carol. 1996. *Sugar Water: Hawaii's Plantation Ditches*. Honolulu: University of Hawaii Press.

Water Resources Research Center (WRRC). 2002. Coliform and *Enterococcus* bacteria counts. Laboratory analysis performed by the University of Hawai'i Water Resources Research Center, Honolulu, Hawai'i.

FIGURES

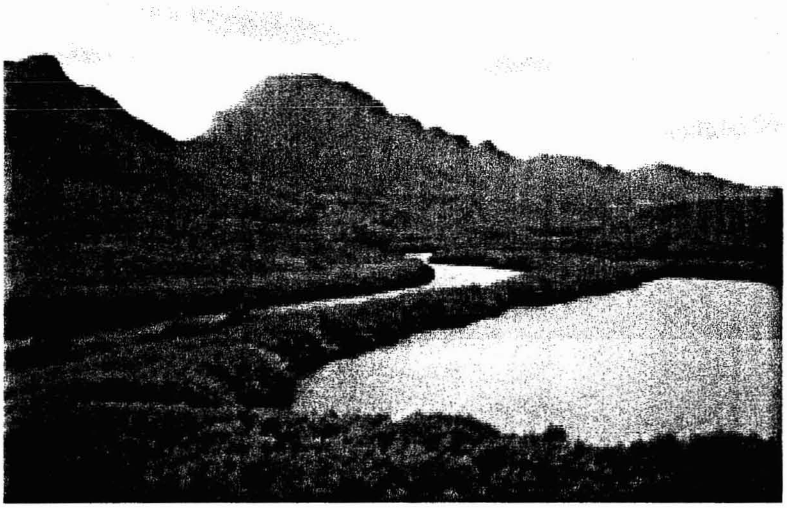

Figure 1. Alekoko Fish Pond on Hulē'ia River with significant growth of mangrove.

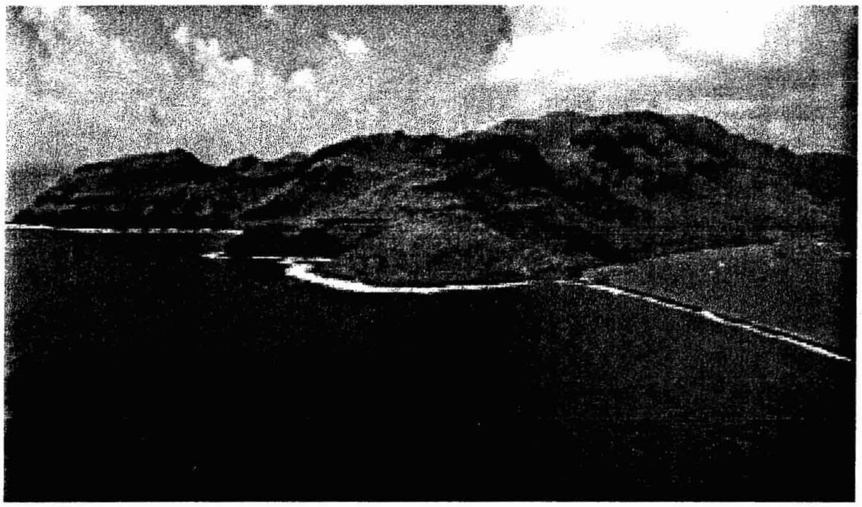

Figure 2*.The construction of the harbor at Nawiliwili has interrupted the flow of sediment out to sea, thus sediment is deposited in the harbor and on the reefs. When large surf arrives, this sediment is reintroduced into the water. Notice the difference in the color of the ocean and harbor water. Without the breakwater, the sediment would move out into the long shore flow. (Photo by David Boynton, Casey Riemer pilot - Jack Harter Helicopters.)

*Courtesy: 'Ainakumuwai: Ahupua'a of Nawiliwili Bay (http://www.hawaii.edu/environment/ainakumuwai/index.htm)

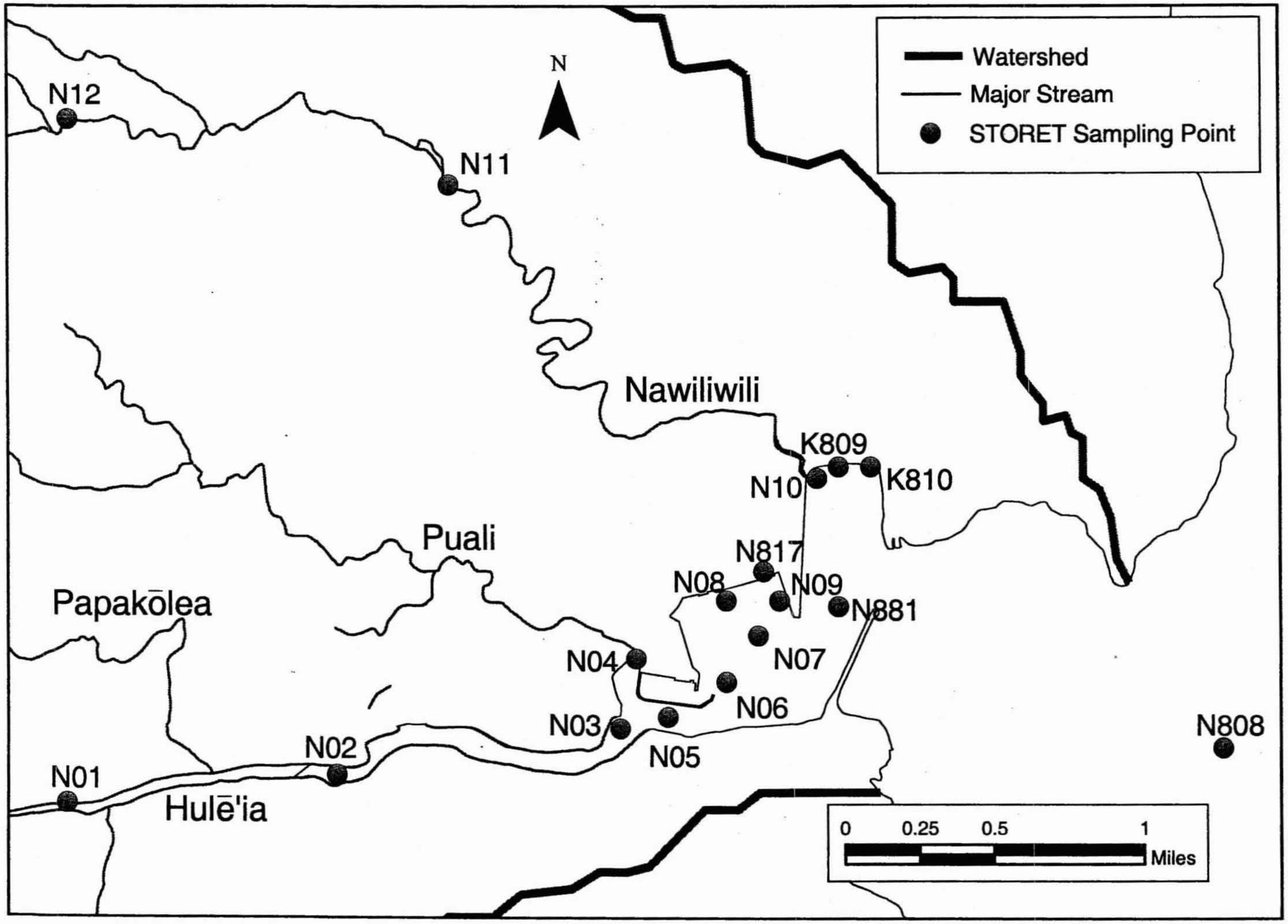

Figure 3. Location for STORET sampling points. Abreviated station names are shown. For example, N01 stands for NAWALIWILI#01 and K809 stands for KALAPAKI 809.(See Table 8 for information about the stations)

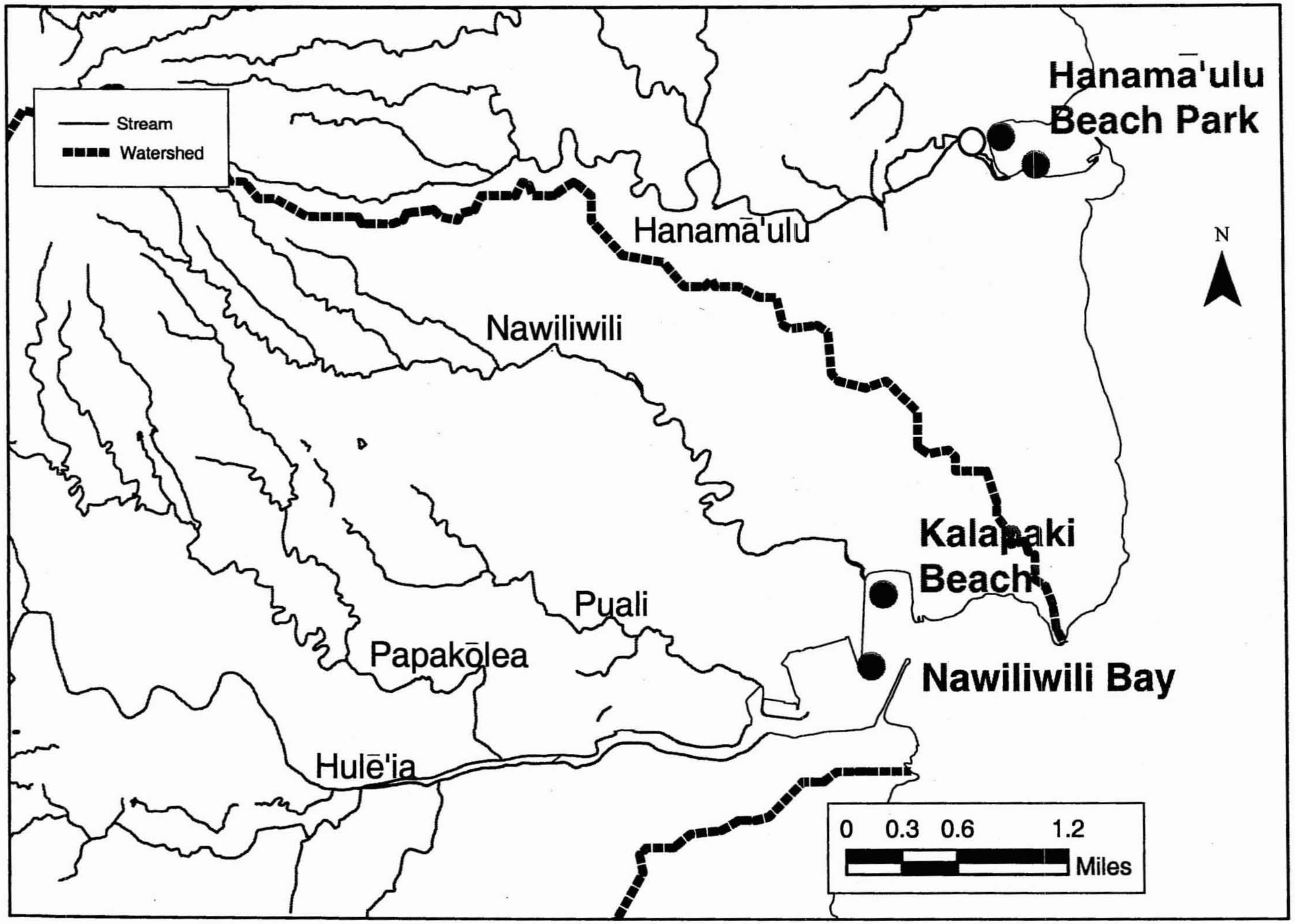

Figure 4. Location of monitoring sites for bacterial analysis for beach (closed circles), and Hanamā'ulu stream (open circle). The main streams are also shown.

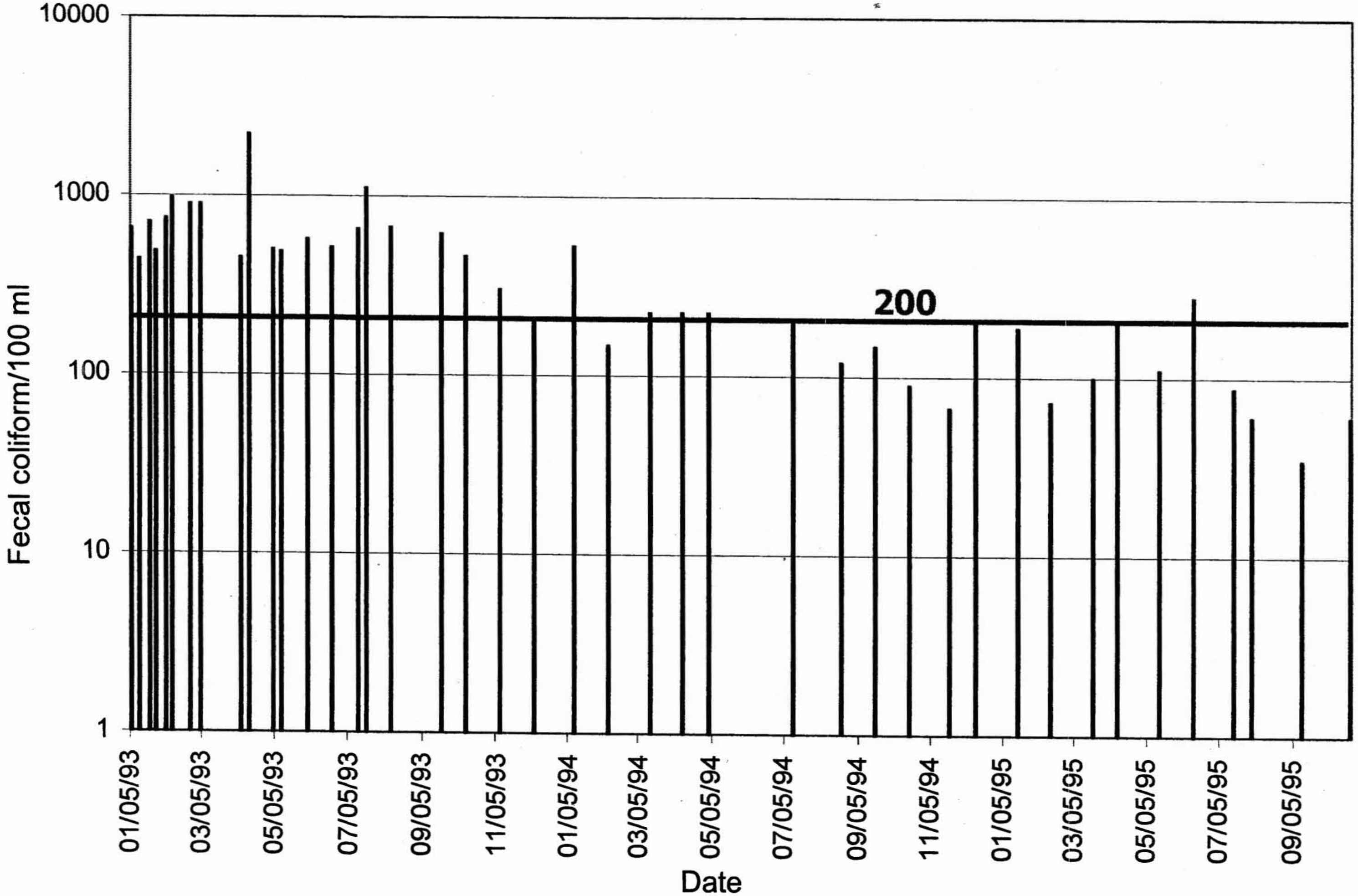

Figure 5. Fecal coliform at Hanamā'ulu River site. The heavy horizontal line indicates the fecal coliform standard for the State of Hawaii.

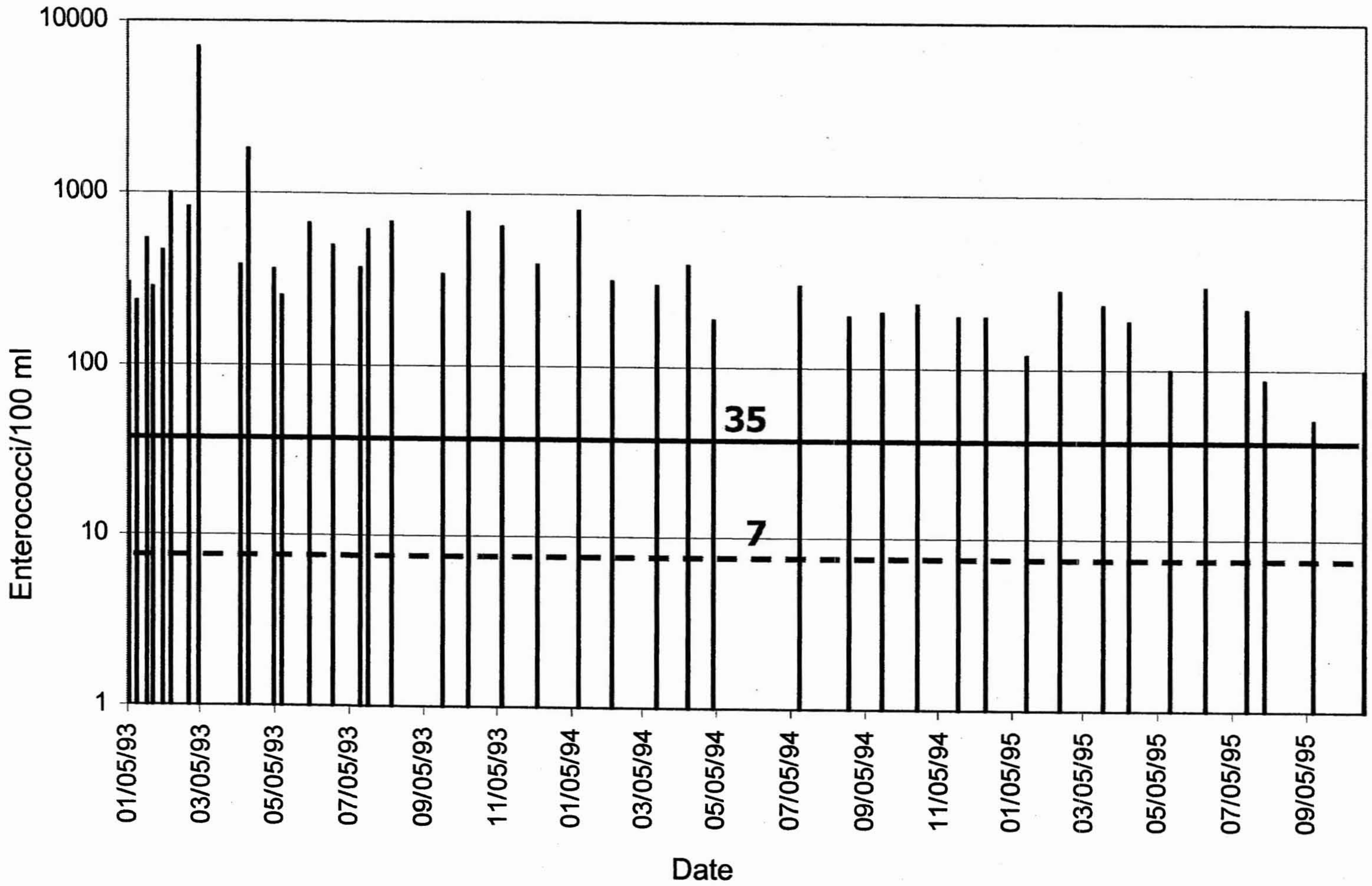

Figure 6. Entercococci in Hanamā'ulu River site. The heavy horizontal lines indicates the Federal (solid line) and State (dashed line) standards.

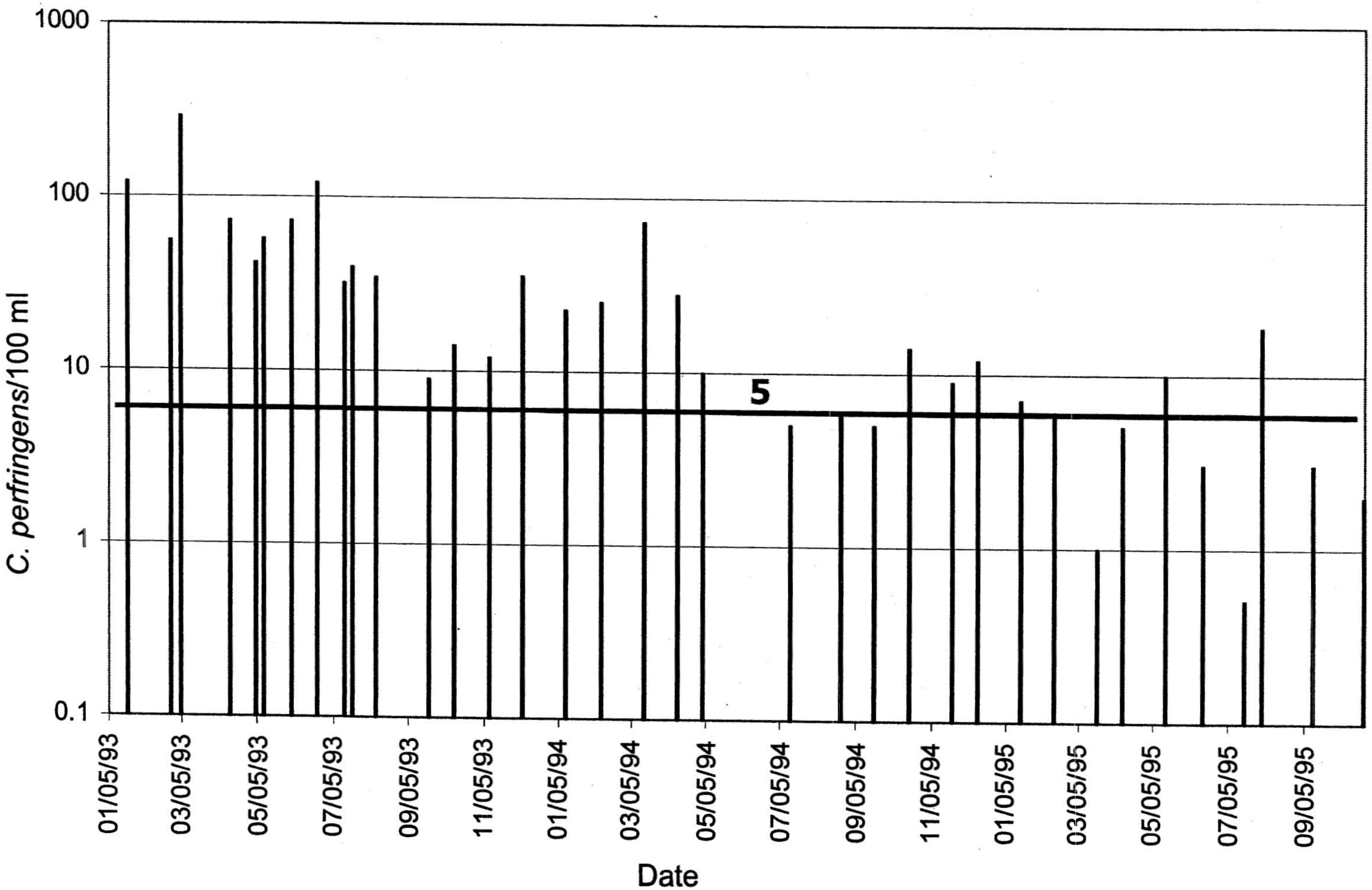

Figure 7. *C. perfringens* at Hanamā'ulu River site. The heavy horizontal line indicates the State's *C. perfringens* standard.

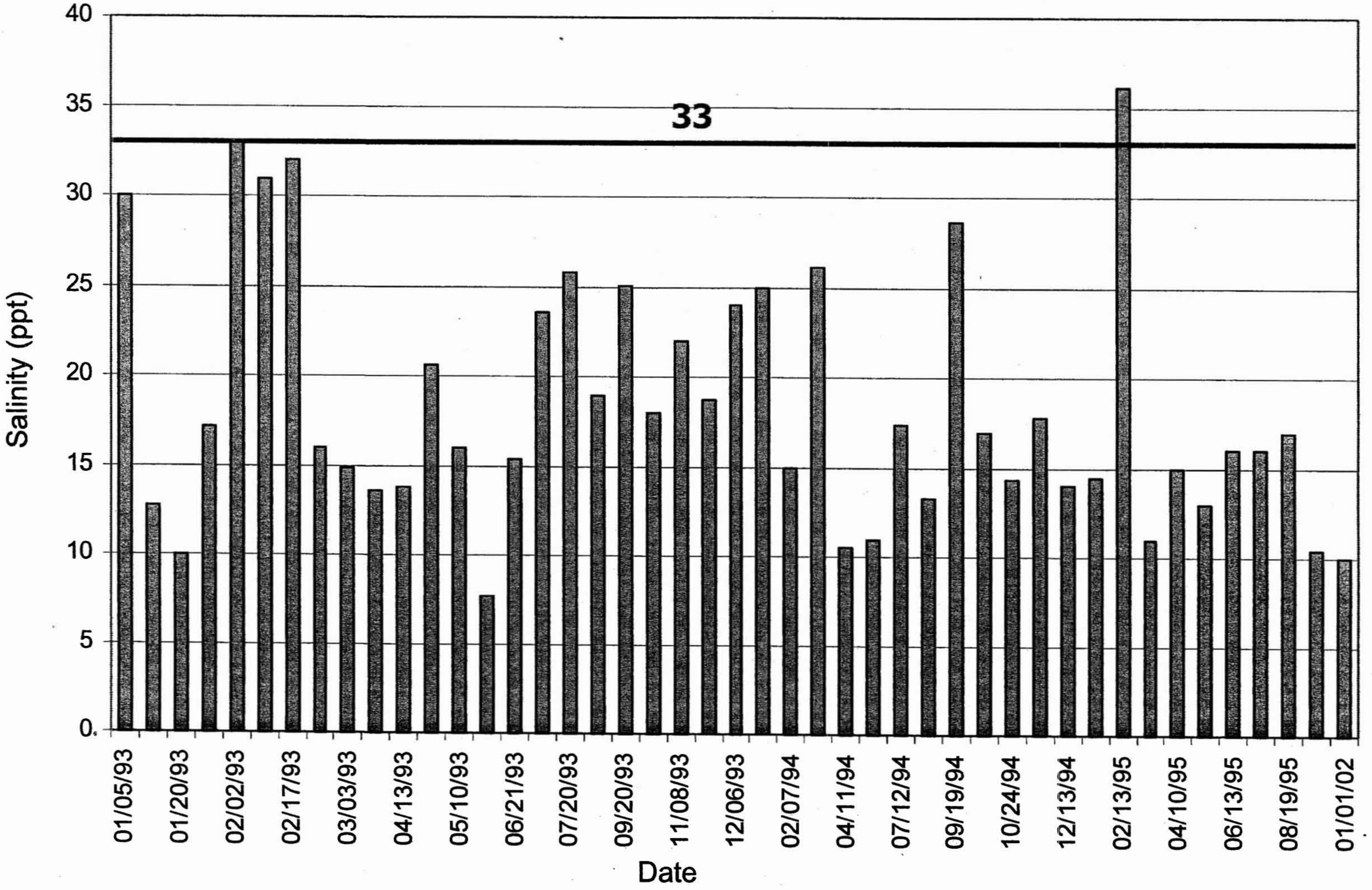

Figure 8. Salinity at Hanamā'ulu Beach site. The heavy horizontal line indicates the state's salinity standard.

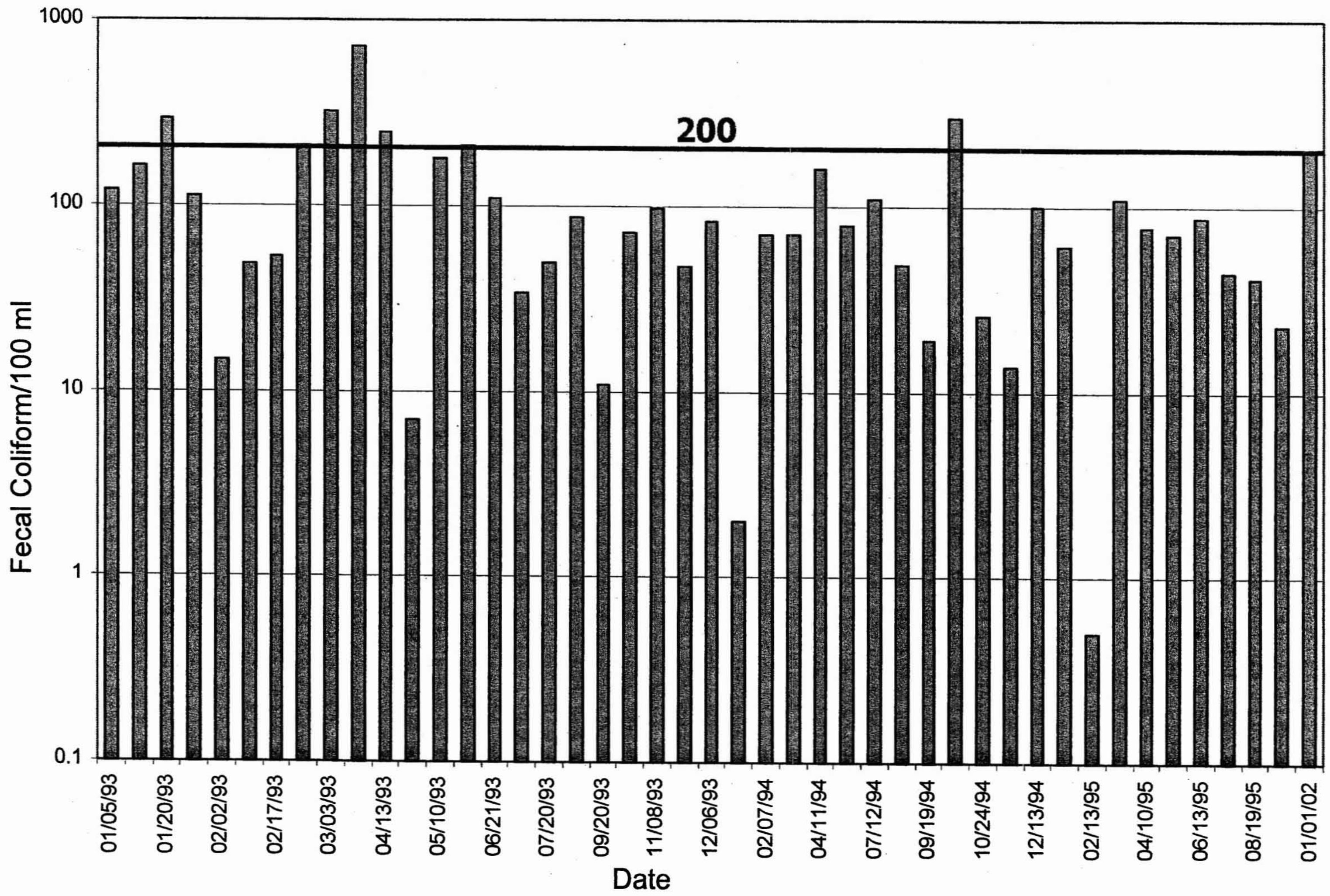

Figure 9. Fecal coliform at Hanamā'ulu Beach site. The heavy horizontal line indicates the State's fecal coliform standard.

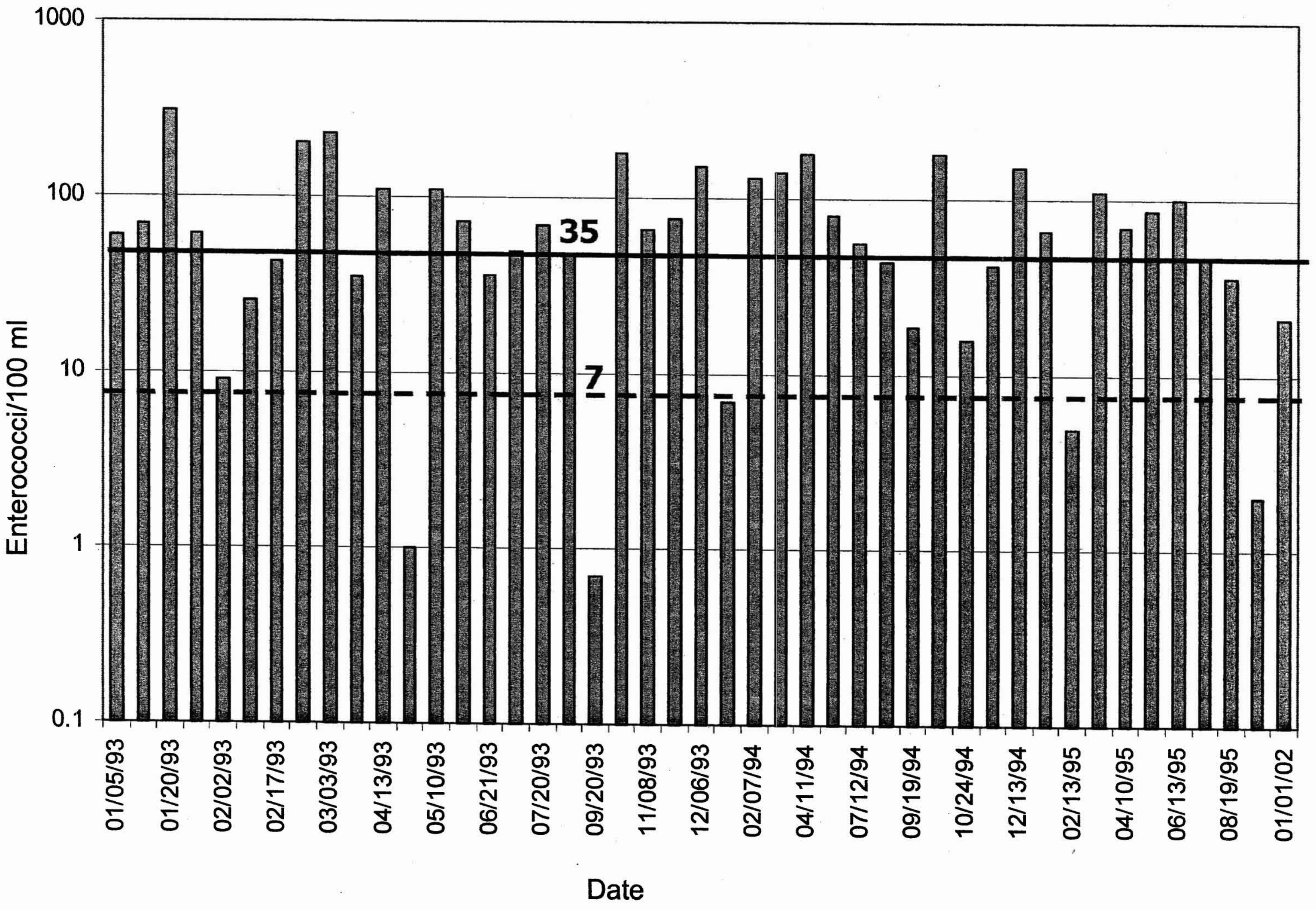

Figure 10. Entercococci at Hanamā'ulu Beach site. The heavy horizontal lines indicates the Federal (solid line) and State (dashed line) standards.

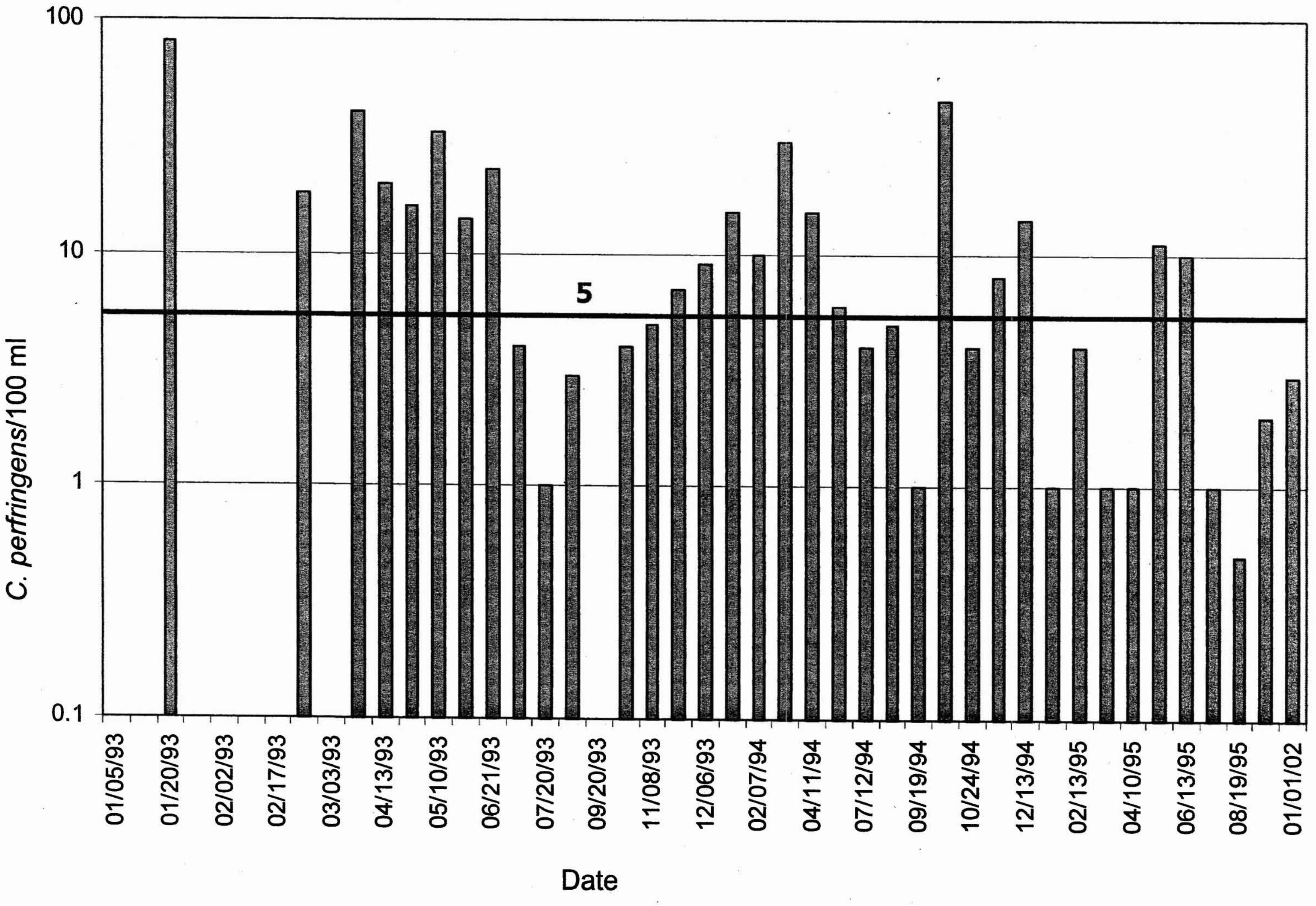

Figure 11. *C. perfringens* at Hanamā'ulu Beach site. The heavy horizontal line identifies the State's *C. perfringens* standard.

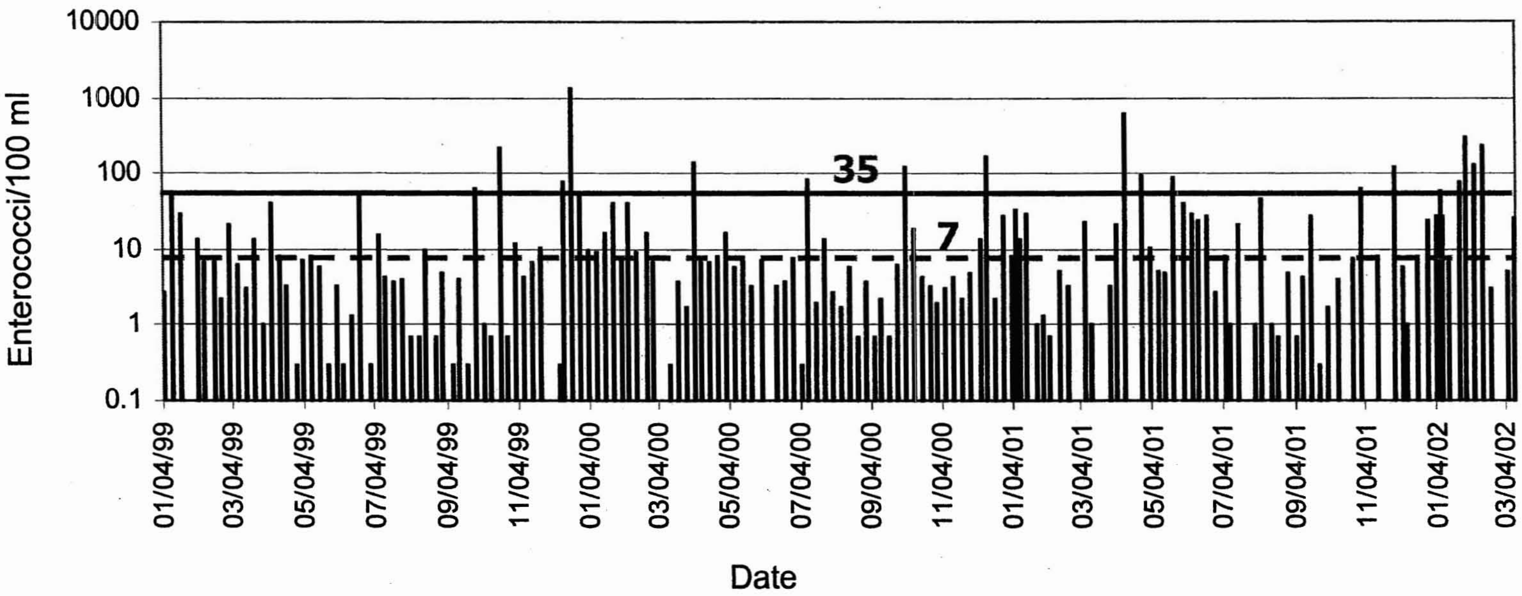

Figure 12. Enterococci at Kalapaki Beach site. The heavy horizontal lines indicate the Federal (solid line) and State (dashed line) standards.

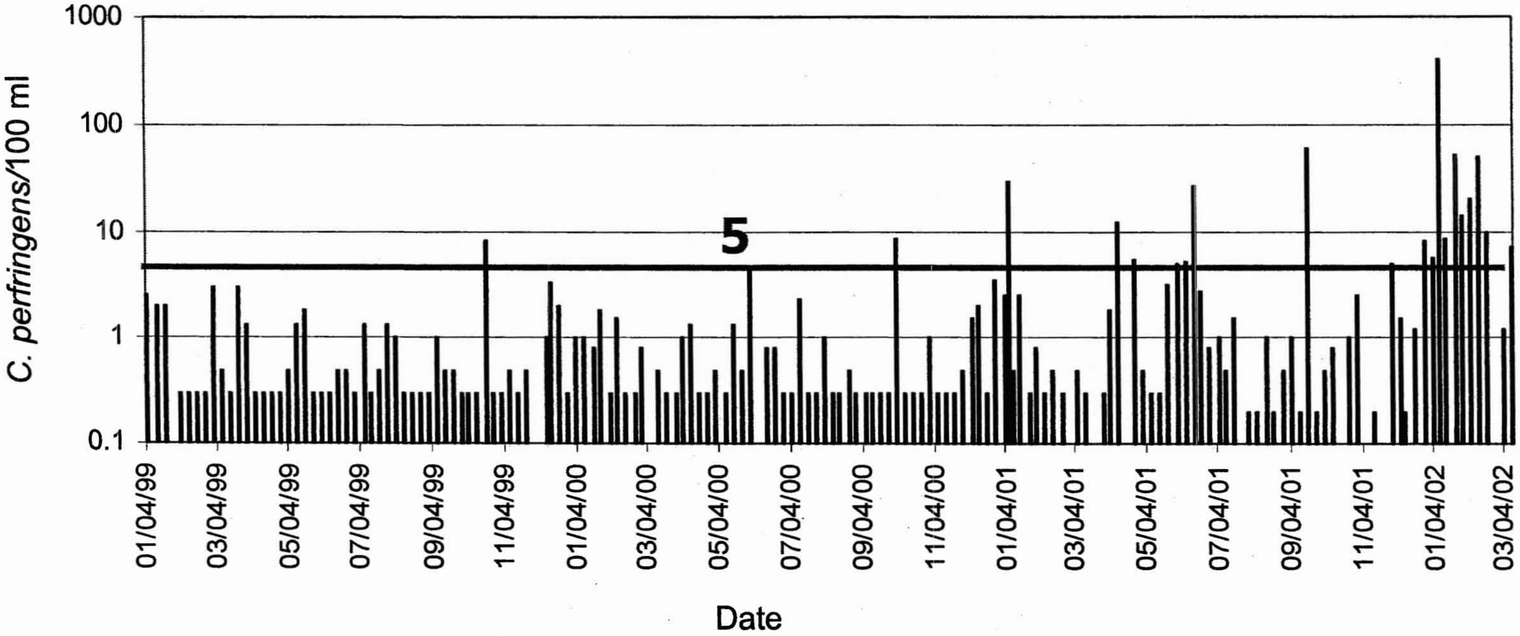

Figure 13. *C. perfringens* at Kalapaki Beach site. The heavy horizontal line indicates the State's *C. perfringens* standard.

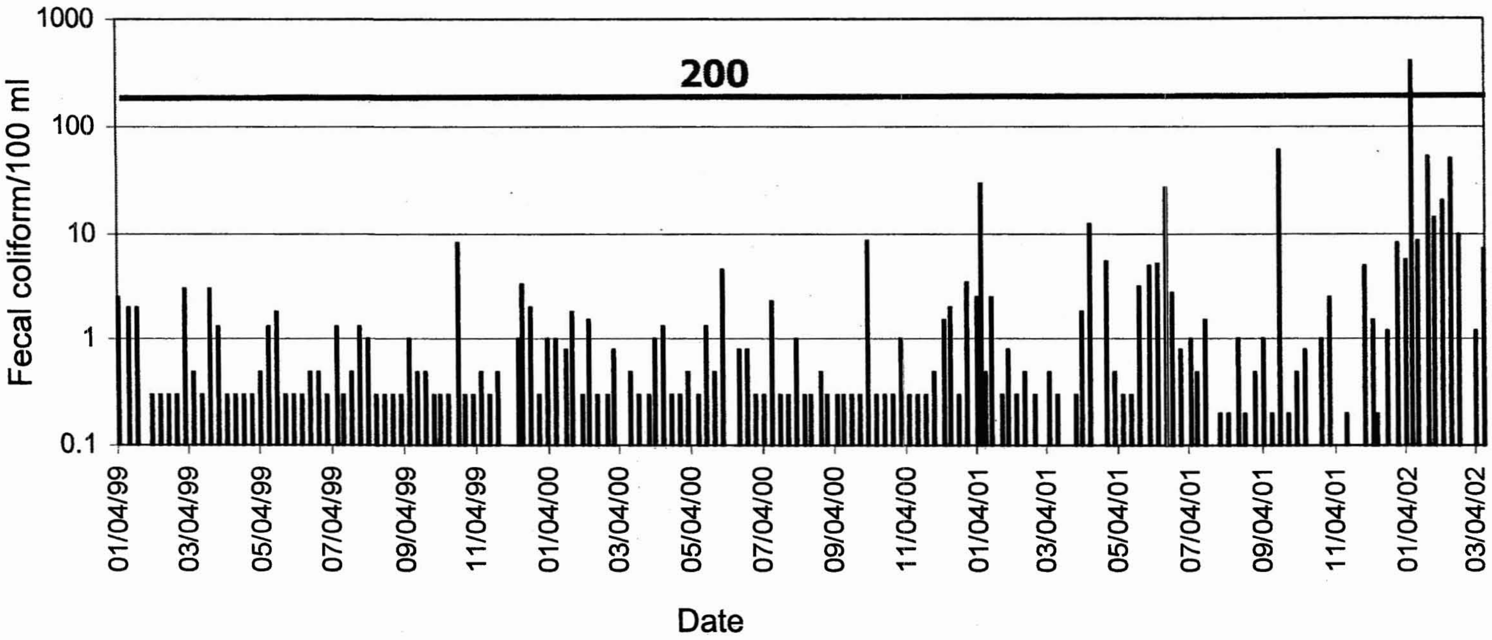

Figure 14. Fecal coliform at Kalapaki Beach site. The heavy horizontal line indicates the State's fecal coliform standard.

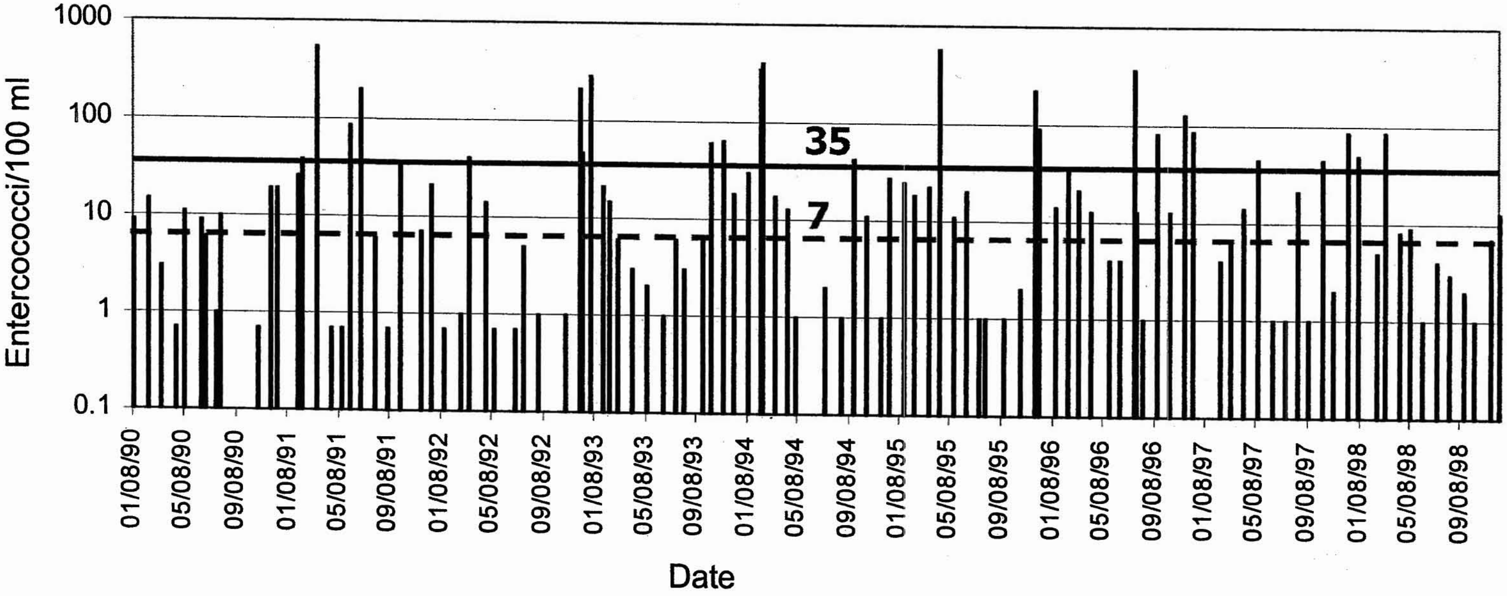

Figure 15. Enterococci at Kalapaki Beach site. The heavy horizontal lines identify the Federal (solid lines) and State (dashed line) standards.

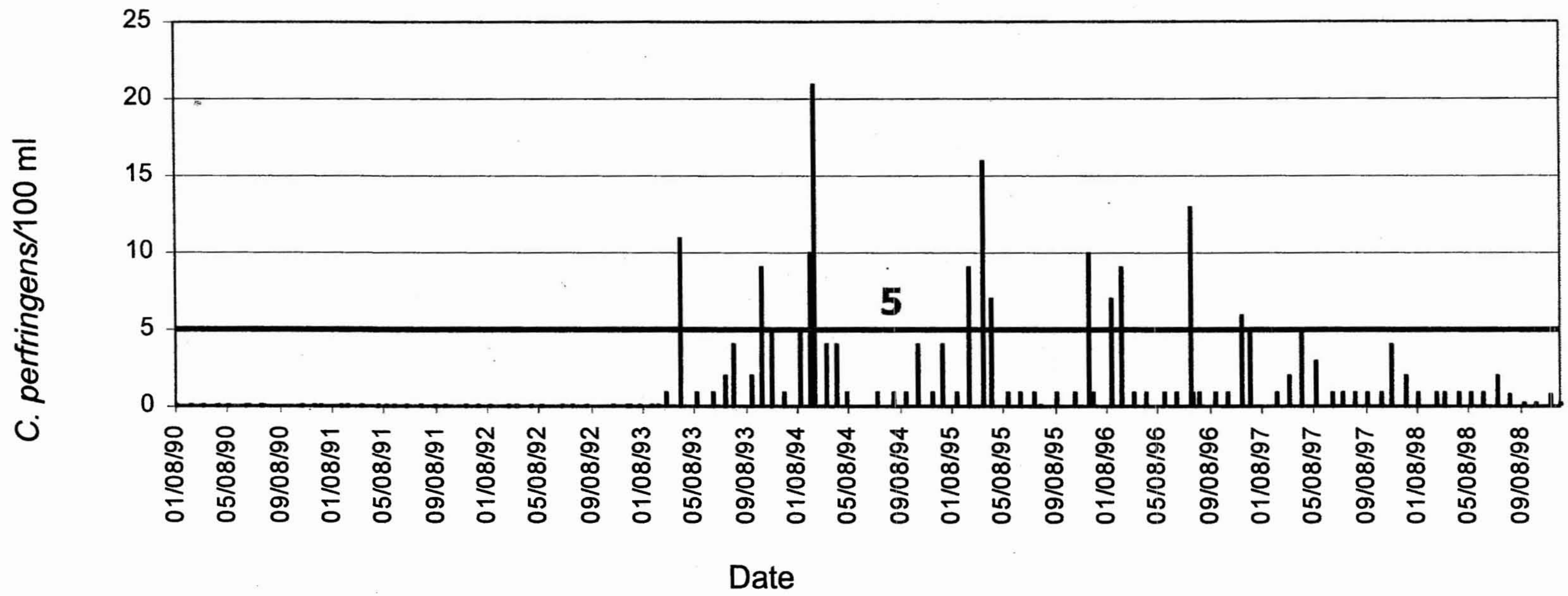

Figure 16. *C. perfringens* at Kalapaki Beach site. The heavy horizontal heavy line indicates the State's *C. perfringens* standard

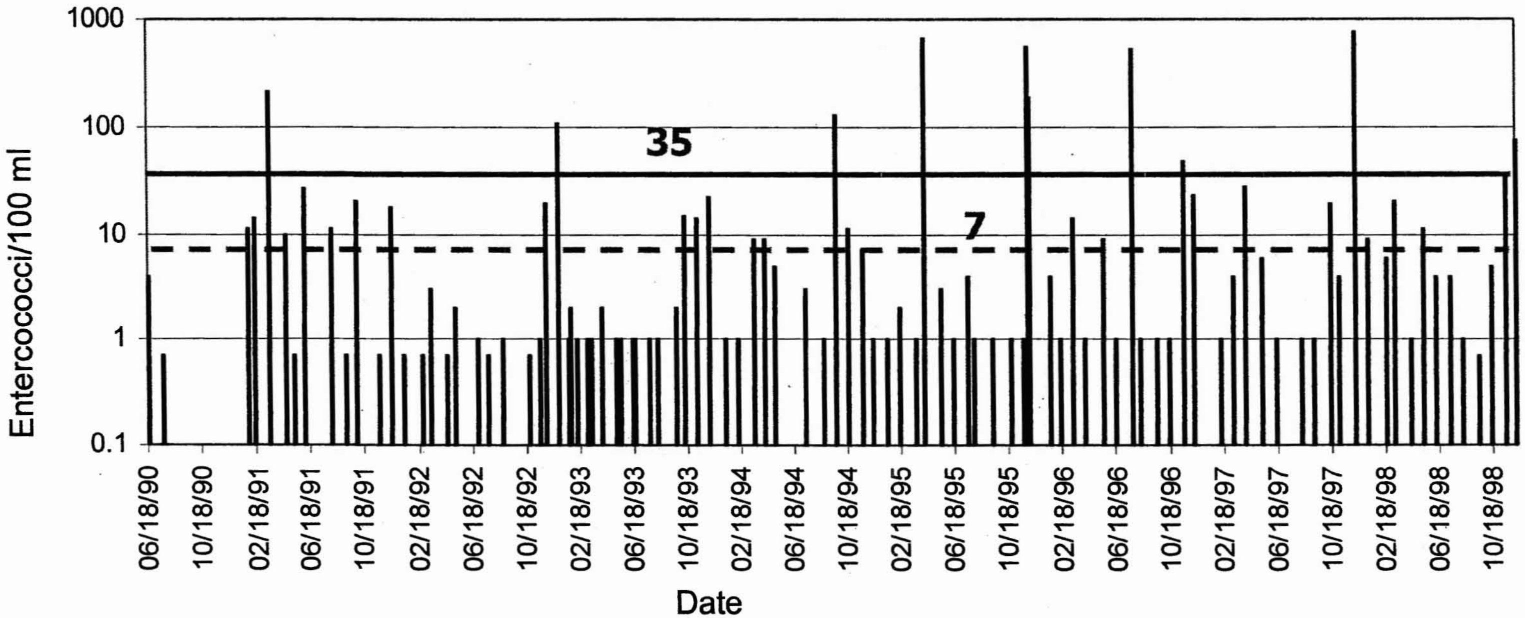

Figure 17. Entercococci at Nawiliwili Harbor site. The heavy horizontal lines indicates the Federal (solid line) and State (dashed line) standards.

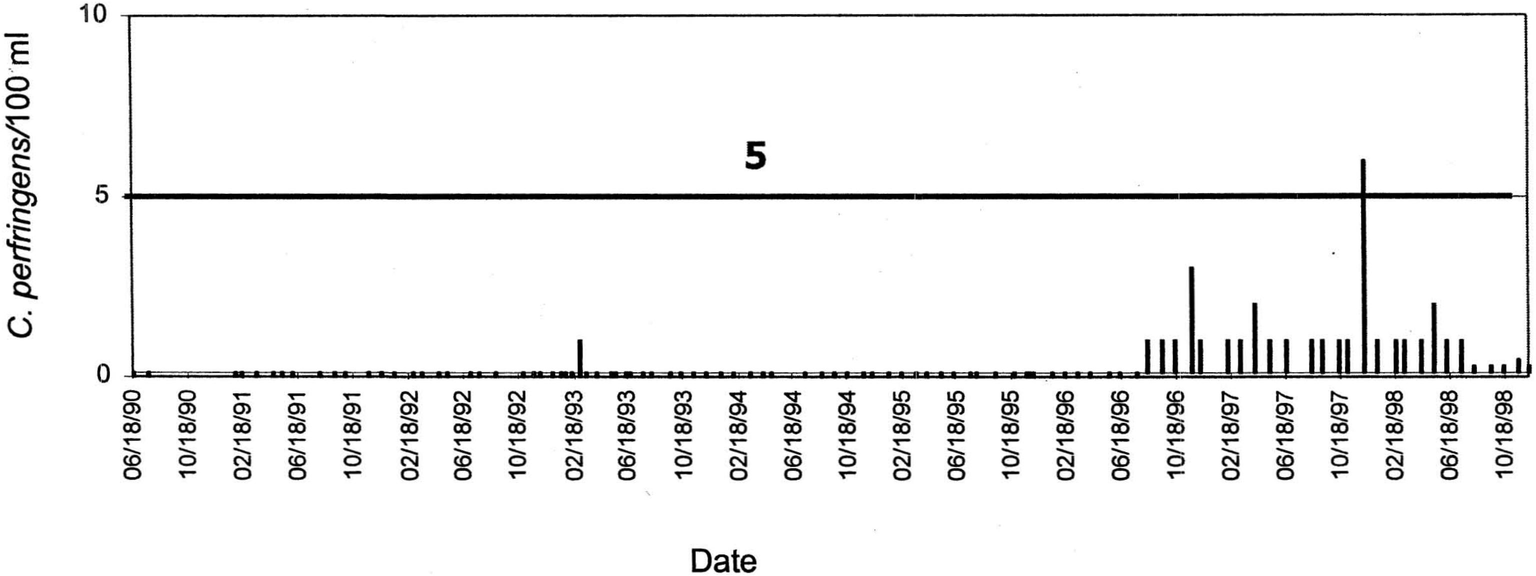

Figure 18. *C. perfringens* at Nawiliwili Harbor site. The heavy horizontal line indicates the *C. perfringens* standard.

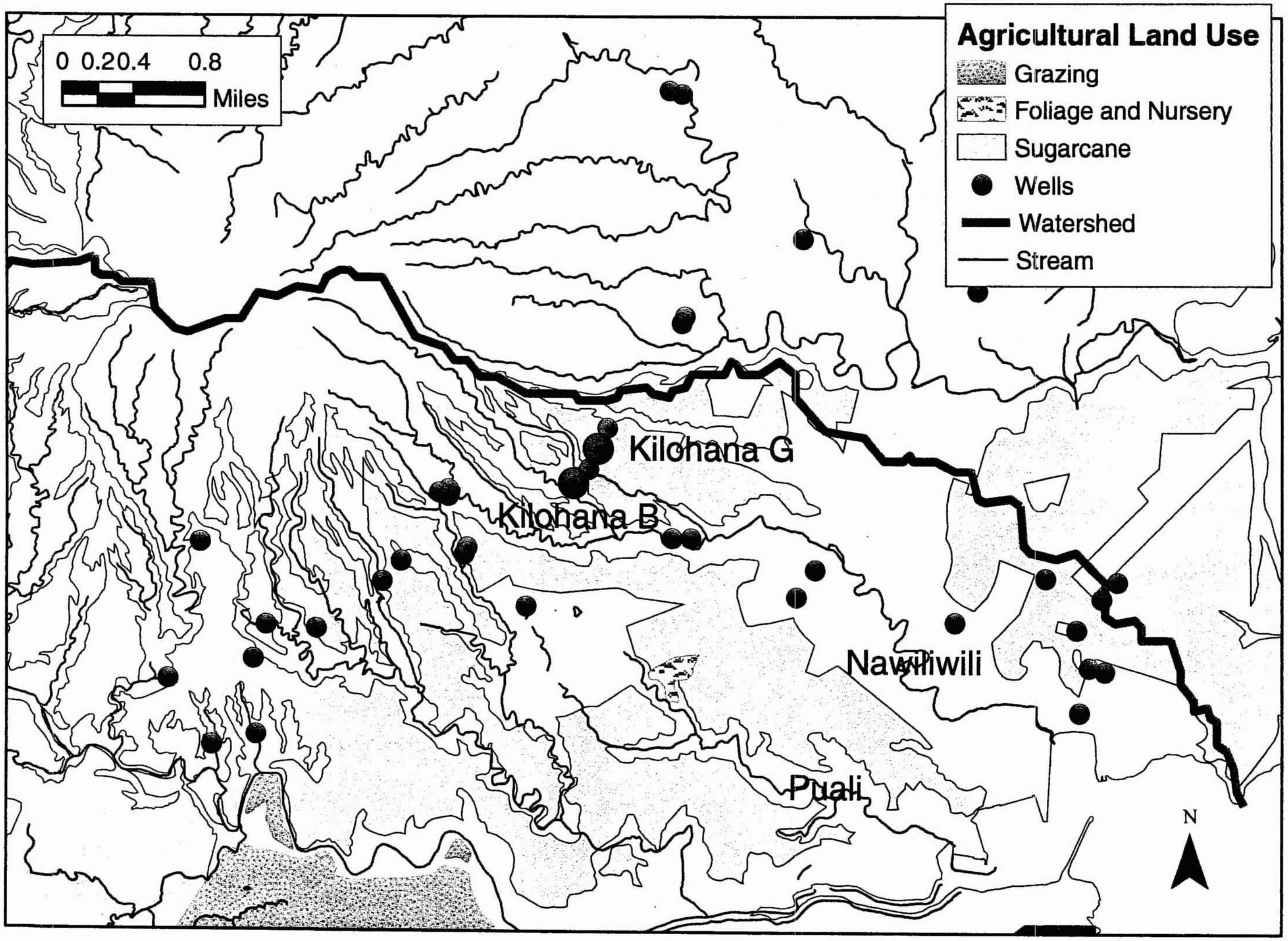

Figure 19. Wells with elevated atrazine (shown by red circles). The map also shows agricultural land use

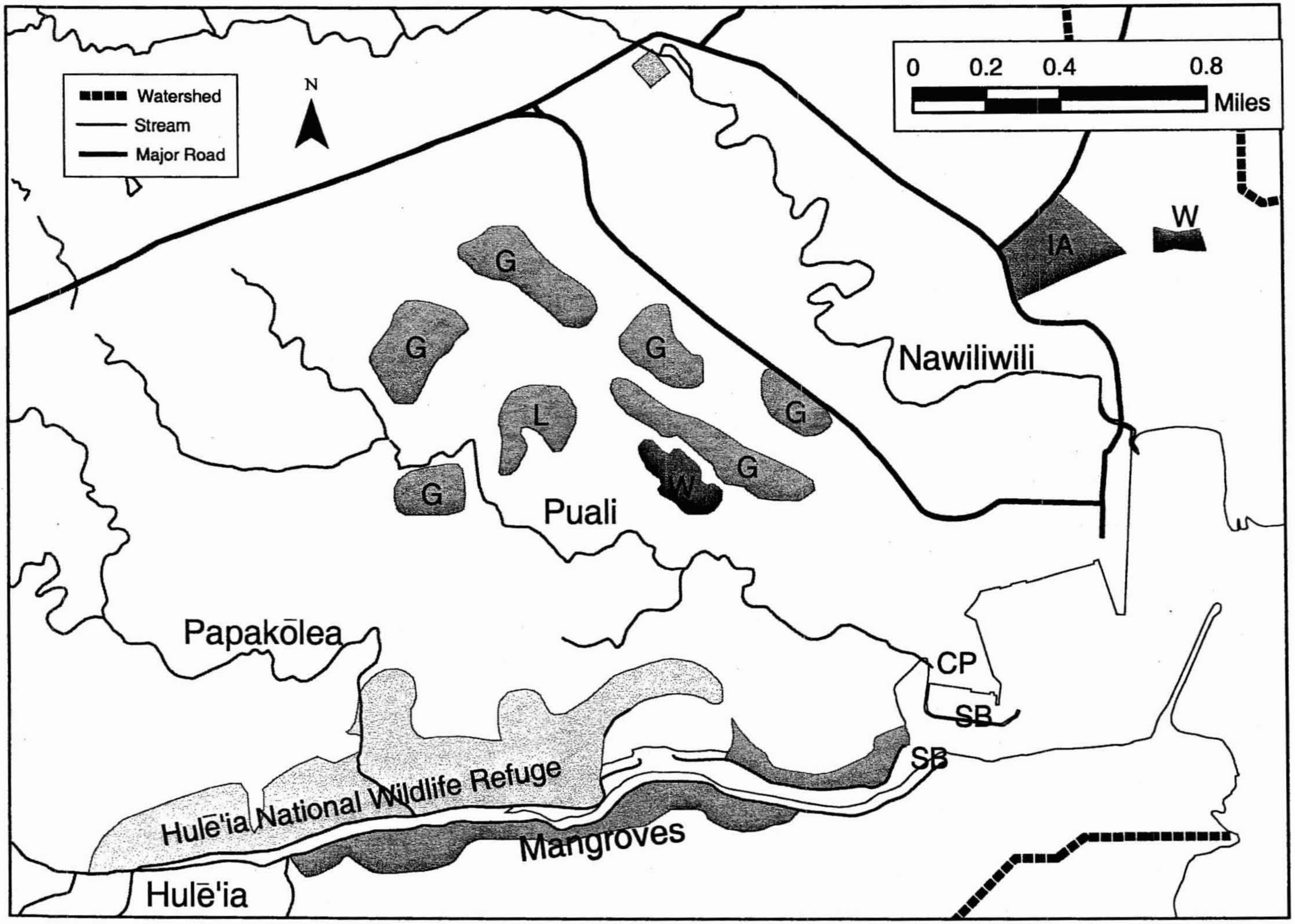

Figure 20. Potential sources of contamination in the Nawiliwili Watershed. G: Golf course, L: Landfill; W: Waste water treatment plant; IA: Industrial area; CP: Cesspools; SB: Sunken boat. The Kenai Spill occured in the industrial area (IA). (Sources location and configuration are approximate).

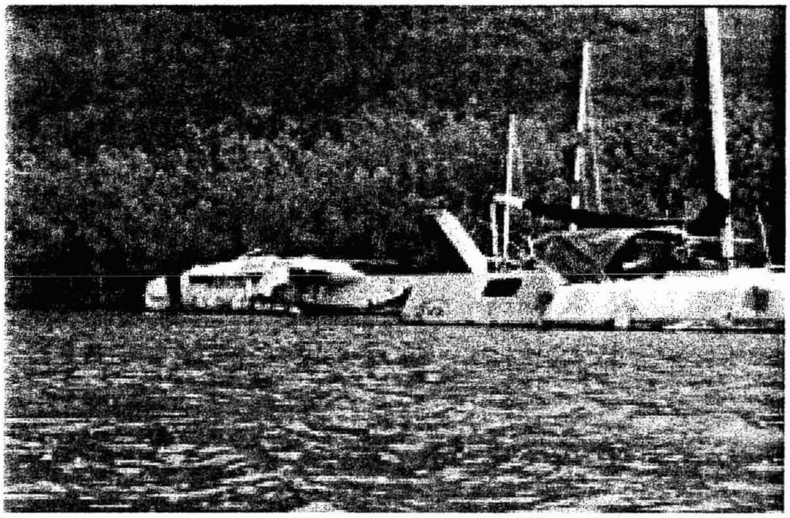

Figure 21. Termite damage and a big rain caused the hull of this boat to be sheered off, but it is still floating in the Hulē'ia Estuary.

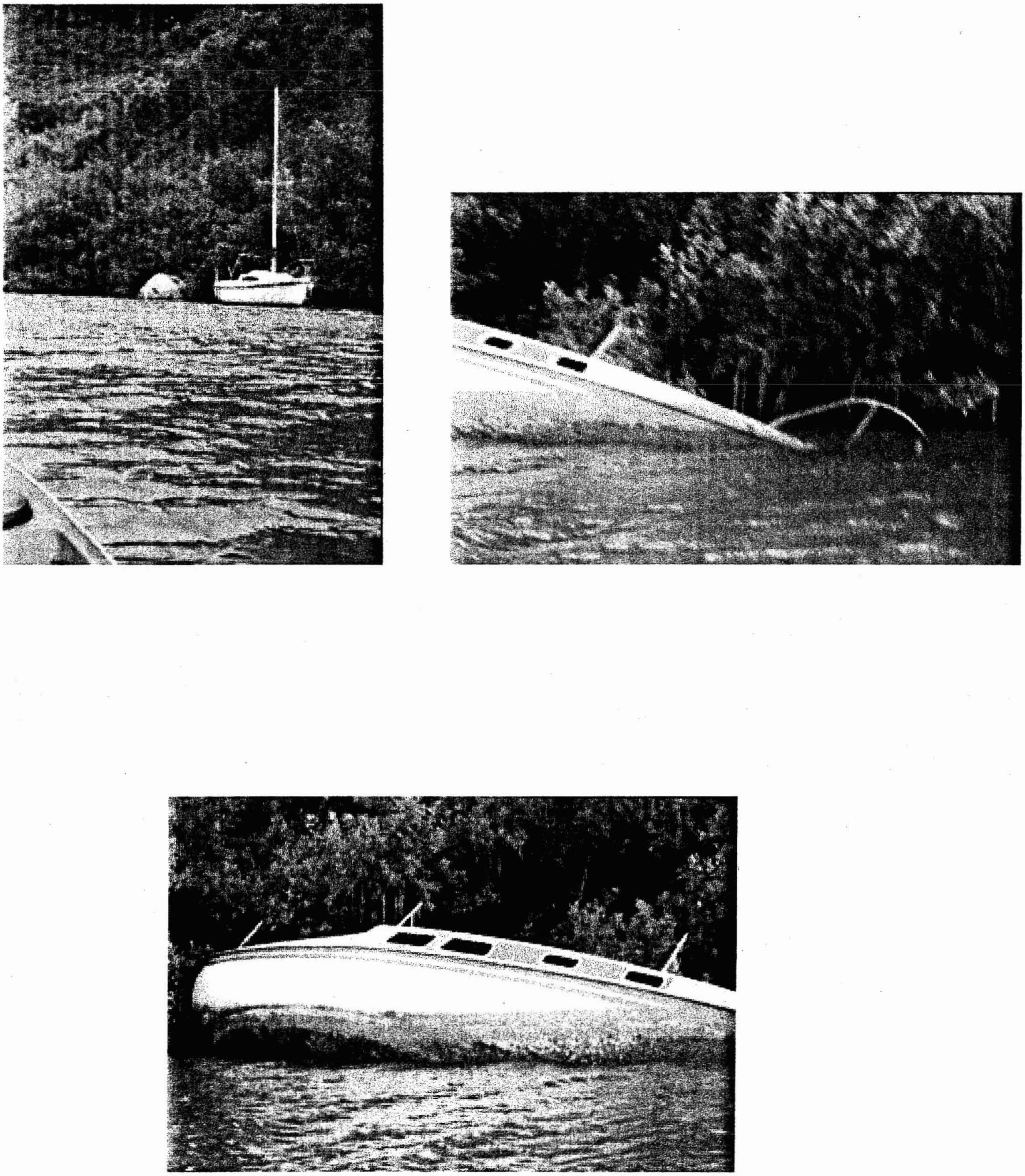

Figure 22. Views of a sailboat that sunk in Hulē'ia Estuary. Most of it is visible at a low tide.

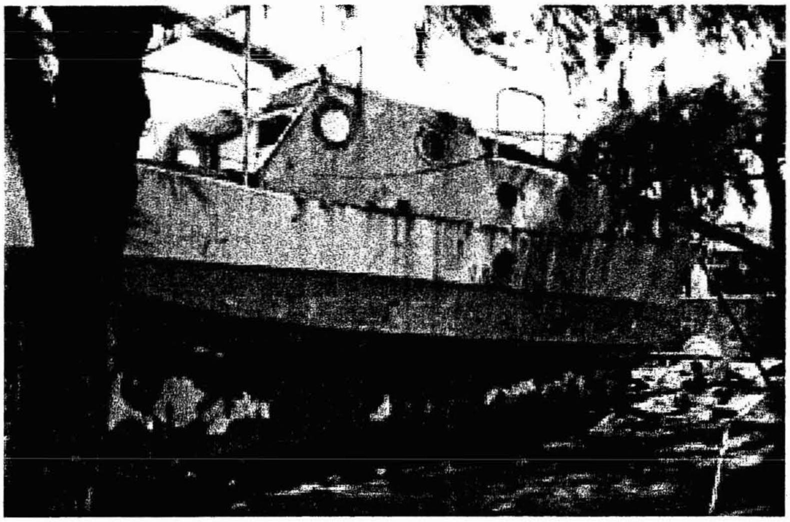

Figure 23. Two views of an abandoned vessel sunk in its slip in the Nawiliwili Small Boat Harbor

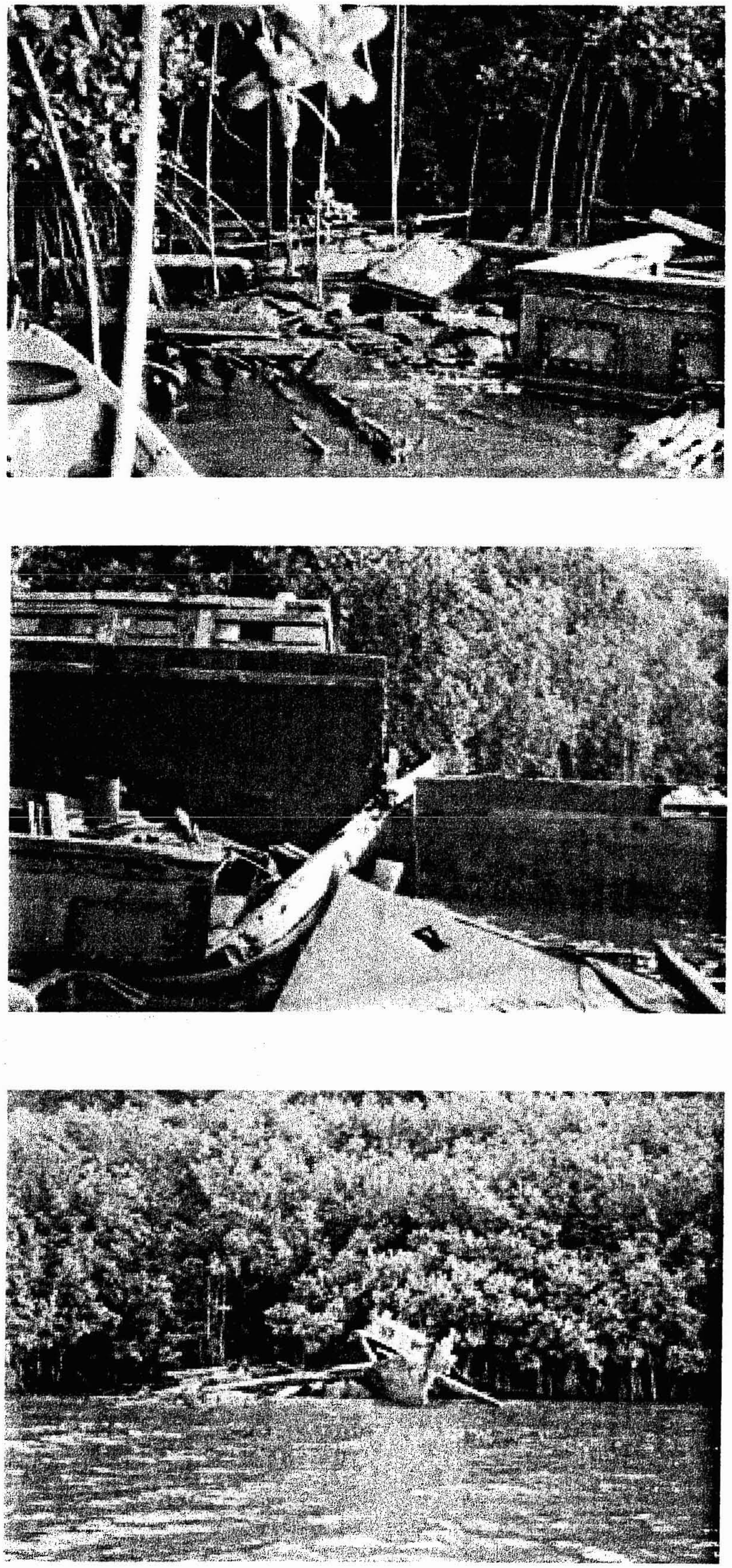

Figure 24. Views of a boat towed and parked in Hulē'ia Estuary, now busted up by human intervention and mangrove growth

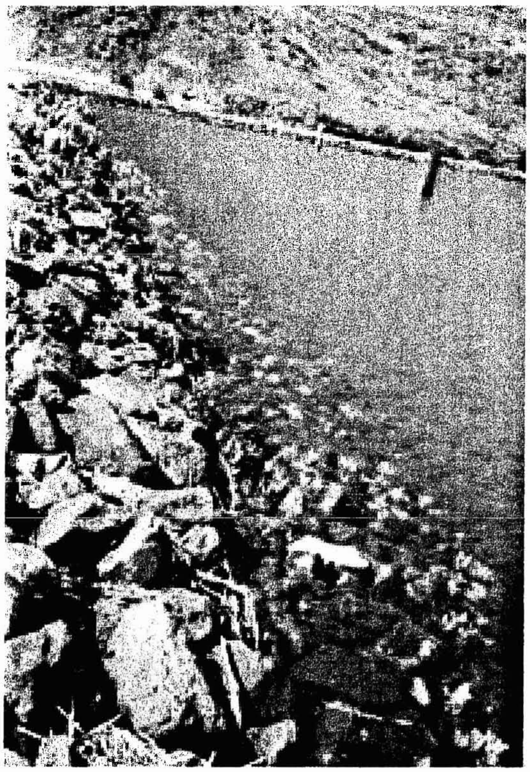

Figure 25. Rubbish generated by users of the Nawiliwili small Boat Harbor

Figure 26*. The streams of Nawiliwili are interrupted and diverted by reservoirs and ditches in their upper reaches (Photo by Adam Asquith)

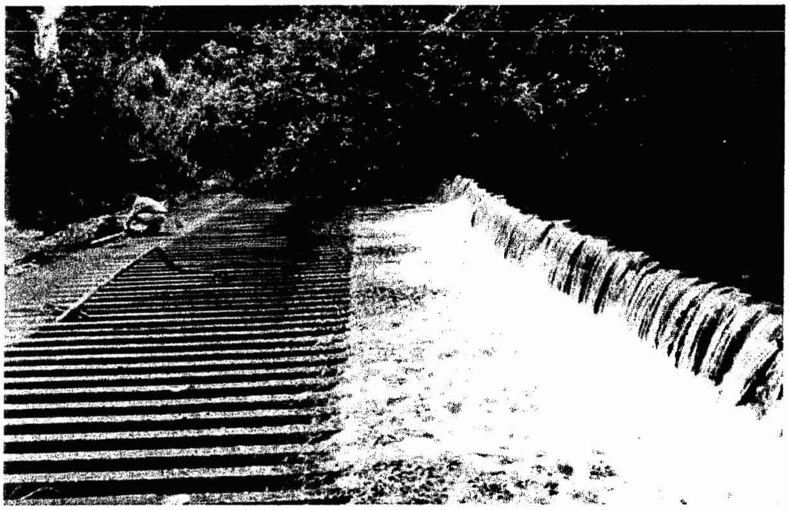

Figure 27*. Although the sugar industry is pau (ended), this diversion of 100% of Hulē'ia Stream's base flow continues to send water out of the watershed to Waita Reservoir. The streambed continues dry for a hundred yards, and then the groundwater begins to recharge the streamflow. (Photo by Adam Asquith)

*Courtesy : 'Ainakumuwai: Ahupua'a of Nawiliwili Bay (http://www.hawaii.edu/environment/ainakumuwai/index.htm)

Figure 28. Sediment accumulated at the bottom of stream, Hulē'ia National Wildlife Refuge

Figure 29. Sediment accumulated at bottom of lower Papakōlea site

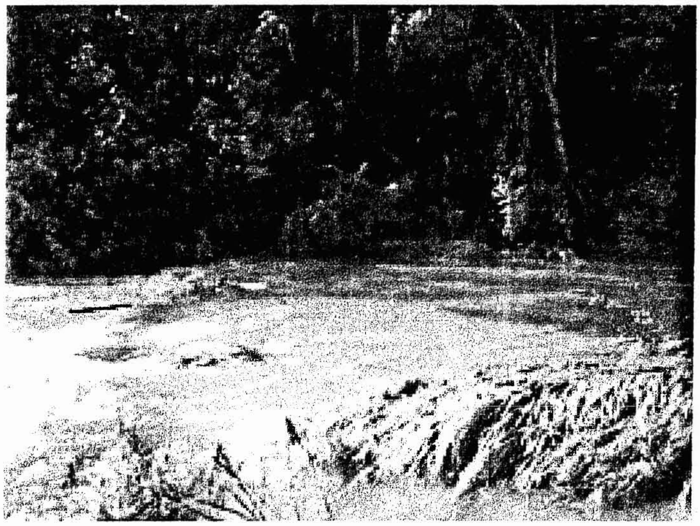

Figure 30. Hulē'ia Lower monitoring site turbid flow after a storm

Figure 31*. In some streams chronic sedimentation over a long period of time has produced clay bottoms from solidified mud.

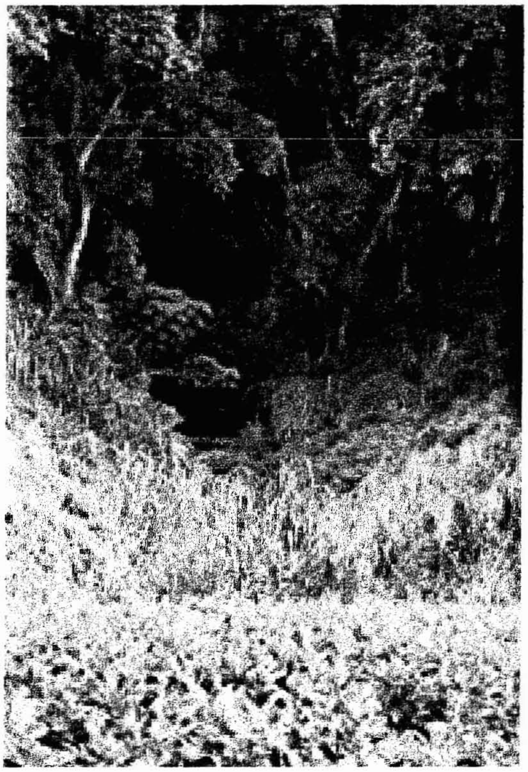

Figure 32. This stream runs through Kauai Lagoons Golf Course. The course is irrigated with effluent. When there is a spill, this stream catches the effluent and it is then diverted under the hotel to discharge at Duke's box culvert.

*Courtesy : 'Ainakumuwai: Ahupua'a of Nawiliwili Bay (http://www.hawaii.edu/environment/ainakumuwai/index.htm)

TABLES

Table 1. Web sites that include pictures of historical features of land use in the Nawiliwili Watershed

Web Site	Pictures
www2.Hawaii.edu/~pcockett/html/water.htm	1886 Nawiliwili Stream in taro 1905 Puali Stream in taro Fishponds and loi in Niumalu
www2.Hawaii.edu/~pcockett/html/plantationland.htm www2.Hawaii.edu/~pcockett/html/plantationsustainability.htm	Niumalu and Nawiliwili change to rice cultivation
www2.Hawaii.edu/~pcockett/html/ainakumuwaitour3.htm	Puali Stream and Papalinahoa Stream in 1928, with agriculture fields on both sides and the five streams of Kalapaki before any development
www2.Hawaii.edu/~pcockett/html/plantationwater.htm	A dam built on Nawiliwili Stream to run the mill
www2.Hawaii.edu/~pcockett/html/harbor.htm	Harbor and breakwater construction, including dredge and fill, and completion of the small-boat harbor in 1973
www2.Hawaii.edu/~pcockett/html/plantationsustainability.htm www2.Hawaii.edu/~pcockett/html/water.htm	Alekoko Fishpond before and after mangrove growth
www2.Hawaii.edu/~pcockett/html/todayland.htm	Current land uses such as the Rice Ranch in cattle, golf courses, hotel, harbor, airport, wildlife refuge, papaya farm, tree farm, quarry, and solid waste dump

Table 2. The mean for physiochemical parameters for Kaua'i streams (from Timbol and Maciolek (1978)

Ca (mg/l)	Mg (mg/l)	Na (mg/l)	K (mg/l)	Alk as CaCo3 (mg/l)	Sulfate (mg/l)	Chloride (mg/l)	Dissolved Solids (mg/l)	pH	Conductivity (umhos)
5.7	6.2	8.6	0.8	34.4	3.5	13.4	75.5	7.3	131

Table 3. Baseline water quality data collected by the Hawai‘i Department of Health, February 12, 1997

Sample Number	1	2	3	4	5	6	7	8	9	10	11	12
Location	Waimea Bridge Bottom	Waimea Bridge Surface	Waimea Crossing	Hanapepe Bridge Bottom	Hanapepe Bridge Surface	Hanapepe First Crossing	Hulē‘ia Zipu Bridge	Papakōlea Hulemalu Bridge	Puali Bridge Bottom	Puali Bridge Surface	Nawiliwili Double Bridge Bottom	Nawiliwili Double Bridge Surface
Temp. (°C)	22.88	21.51	20.59	25.27	25.03	22.47	22.41	22.2	23.62	23.2	23.26	23.45
DO (mg/l)	7.05	6.85	7.68	4.76	5.94	5.46	7.72	7.48	5.65	5.73	6.05	5.98
Depth (ft)	1.4	0.3	0.1	1.2	0.3	0.1	0.2	0.1	0.9	0.3	0.7	0.3
Conductivity (umhos)	6.48	0.441	0.191	49.1	39.4	0.716	0.191	0.21	10.69	3.58	0.317	0.314
pH / % Sat	7.72/83.7	8.02/77.6	7.91/85.3	7.98/70.2	7.94/83.6	7.6/63.0	8.09/88.8	7.51/85.7	7.32/69.2	7.36/67.8	7.45/70.7	7.39/70.2
Salinity (ppt)	83.6	0.2	0.1	32.1	25.1	0.4	0.1	0.1	6.1	1.9	0.2	0.2
Time	9:41	9:42	10:04	10:33	10:34	10:52	11:34	11:54	12:07	12:08	12:20	12:21
Turbidity (NTU)	2.3	2.3	2.6		9.3	4.5	2.1	4.6		2.6		5.6
Notes	River mouth open		Low flow		Kapanili Gulch flowing	Low flow	Low flow	Low flow				

Table 4. Baseline water quality data collected by the Hawai'i Department of Health, February 28, 1997

Sample Number	1	2	3	4	5	6	7	8
Location	Waimea Bridge	Waimea Crossing	Hanapepe Bridge	Hanapepe First Crossing	Hulē'ia Kipu Bridge	Papakōlea Hulemalu Bridge	Puali Bridge	Nawiliwili Bridge Foot
Temp. (°C)								
DO (mg/l)								
Depth (ft)								
Conductivity (umhos)								
pH / % Sat								
Salinity (ppt)	0		0				0	0
Time	1:57	2:07	2:24	2:30	2:59	3:09	3:17	3:22
Turbidity (NTU)	5.2	41	11	9.1	33	37	26	45
Notes	Red water present but not mixed throughout	Red water throughout	Water slightly turbid		Thoroughly mixed	Mixed	Mixed	Mixed

General notes: Rain off and on for past few days, heavy rain on 2/28/97. Isolated showers.

Table 5. Baseline water quality data collected by the Hawai'i Department of Health, March 3, 1997

Sample Number	1	2	3	4	5	6	7	8
Location	Waimea Bridge	Waimea Crossing	Hanapepe Bridge	Hanapepe First Crossing	Hulē'ia Kipu Bridge	Papakōlea Hulemalu Bridge	Puali Bridge	Nawiliwili Bridge Foot
Temp. (°C)								
DO (mg/l)								
Depth (ft)								
Conductivity (umhos)								
pH / % Sat								
Salinity (ppt)								
Time	2:04	2:14	2:29	2:39	3:08	3:19	3:25	3:31
Turbidity (NTU)	32	4	8.6	15	4.5	6.2	3.3	7.8

Table 6. Baseline water quality data collected by the Hawai'i Department of Health, March 13, 1997

Sample Number	1	2	3	4	5	6	7	8	9	10	11	12
Location	Hanalei Boat Ramp	Hanalei Bridge (along road)	Anini Stream Mouth	Kalihiwai Mouth	Anahola Mouth	Anahola Bridge (old ridge)	Kealia Mouth	Kealia Crossing	Wailua Canoe	Wailua Arboretum Crossing	Hanamā'ulu Mouth	Hanamā'ulu Swinging Bridge
Temp. (°C)												
DO (mg/l)												
Depth (ft)												
Conductivity (umhos)												
pH / % Sat												
Salinity (ppt)	5	0	0	0	0		0		2		0	
Time	10:12	10:23	10:59	11:12	11:36	11:43	11:52	12:02	12:20	12:38	13:06	13:19
Turbidity (NTU)	2.5	2.1	2.3	1.9	13	5.4	9.1	4.3	3.6	0.8	8.7	7.3

Table 7. Baseline water quality data collected by the Hawai'i Department of Health, April 7, 1997

Sample Number	1	2	3	4	5	6	7	8	9	10
Location	Waimea Bridge	Waimea Crossing	Hanapepe Bridge	Hanapepe First Crossing	Hulē'ia Kipu Bridge	Papakōlea Hulemalu Bridge	Puali Bridge	Nawiliwili Bridge Foot	Hanamā'ulu Swinging Bridge	Hanamā'ulu Mouth
Temp. (°C)										
DO (mg/l)										
Depth (ft)										
Conductivity (umhos)										
pH / % Sat										
Salinity (ppt)										
Time	9:30	9:38	9:54	10:02	10:33	10:45	10:54	11:00	11:11	11:21
Turbidity (NTU)	7.1	6.2	16	6.5	15	16	7.4	16	13	16
Notes	Low tide, mouth open	High flow		High flow	High flow					

General notes: Heavy rains over two-day period (4/5 and 4/6). Minus tides on 4/7 at approximately 10:00 am.

Table 8. Summary of water quality data available for Nawiliwili Watershed at EPA's STORET database

No.	Station	Latitude	Longitude	Location	What Data
1	KALAPAKI 809	21 deg. 57 min. 48 sec. N (21.96333)	159 deg. 21 min. 12 sec. W (159.353333)	middled of Kalapaki Beach	physical & bact. (18 parameters) 1973–1998. Monthly EC & FC data entire period, other bact. data in the 1970s, nutrients and other parameters sporadically. 1/99 – present *C. perfringens*, salinity, DO, and temp.
2	KALAPAKI 810	21 deg. 57 min. 48 sec. N (21.963333 N)	159 deg. 21 min. 6 sec. W (159.351667)	N.E. end of Kalapaki Beach	Bact. only. Total (90) and fecal coliform (87), fecal strep (36). 1973–1975.
3	NAWILIWILI #01	21 deg. 56 min. 50 sec. N (21.947222)	159 deg. 23 min. 36 sec. W (159.393333)	in Hulē‘ia Stream approximately 6,000 feet upstream from the Menehune fishpond	3 samples; 12/05/77, 7/13/79, 2/09/83 metals and pesticides in sediment.
4	NAWILIWILI #02	21 deg. 56 min. 55 sec. N (21.948611)	159 deg. 22 min. 46 sec. W (159.379444)	in Hulē‘ia Stream approximately 1,200 feet upstream from the Menehune fishpond	3 samples 12/5/77, 2/9/83 (metals & pesticides), 2/9/83 (metals) in sediment.
5	NAWILIWILI #03	21 deg. 57 min. 3 sec. N (21.950833)	159 deg. 21 min. 53 sec. W (159.364722)	in Hulē‘ia Stream approximately 600 feet upstream from where the mouth of the stream meets Nawiliwili Bay	2 samples 12/5/77, 2/9/83 metals and pesticides.
6	NAWILIWILI #04	21 deg. 57 min. 15 sec. N (21.954167)	159 deg. 21 min. 50 sec. W (159.363889)	mouth of Puali Stream	1 sample 12/5/77 metals and pesticides in sediment only.
7	NAWILIWILI #05	21 deg. 57 min. 5 sec. N (21.951389)	159 deg. 21 min. 44 sec. W (159.362222)	in Nawiliwili Bay outside of the south breakwater of the small-boat harbor and approximately 200 feet from the entrance of the harbor	1 sample 12/5/77 metals and pesticides in sediment only.
8	NAWILIWILI #06	21 deg. 57 min. 11 sec. N (21.953056 N)	159 deg. 21 min. 33 sec. W (159.359167)	in Nawiliwili Harbor next to marker 7 on the south side of the harbor	1 sample 12/5/77 metals and pesticides in sediment only.

Table 8—*Continued*

No.	Station	Latitude	Longitude	Location	What Data
9	NAWILIWILI #07	21 deg. 57 min. 19 sec. N (21.955278)	159 deg. 21 min. 27 sec. W (159.3575)	midway between channel markers C9 and N4	1 sample on 12/5/77 for pesticides and metals. Six samples on 5/19 & 5/20/80 for physical and nutrients.
10	NAWILIWILI #08	21 deg. 57 min. 25 sec. N (21.956944)	159 deg. 21 min. 33 sec. W (159.359167)	in Nawiliwili Harbor approximately 400 feet from the commercial piers on the north side of the harbor and 1000 feet from the piers on the east side of the harbor	1 sample 12/5/77 metals and pesticides in sediment only.
11	NAWILIWILI #09	21 deg. 57 min. 25 sec. N (21.956944)	159 deg. 21 min. 23 sec. W (159.356389)	in Nawiliwili Harbor approximately 400 feet from the commercial piers on the north side of the harbor and 375 feet from the piers on the east side of the harbor	1 sample 12/5/77 metals and pesticides in sediment only.
12	NAWILIWILI #10	21 deg. 57 min. 46 sec. N (21.962778N)	159 deg. 21 min. 16 sec. W (159.354444)	in Nawiliwili Stream where Rice St. crosses the stream	1 sample 12/5/77 metals and pesticides in sediment only.
13	NAWILIWILI #11	21 deg. 58 min. 36 sec. N (21.976667 N)	159 deg. 22 min. 25 sec. W (159.373611)	in Nawiliwili Stream where Haleko Rd. (in Līhu'e) crosses the stream	1 sample 12/5/77, metals and pesticides in sediment only.
14	NAWILIWILI #12	21 deg. 58 min. 47 sec. N (21.979722)	159 deg. 23 min. 36 sec. W (159.393333)	in Nawiliwili Stream approximately 1,550 feet upstream of water tunnel 01. It is approximately 4,200 feet mauka from where a private road intersects Nuhou Rd. and where the private road crosses the stream. The site is about 1 mile mauka of Līhu'e	1 sample 12/5/77 metals and pesticides in sediment only.

Table 8—*Continued*

No.	Station	Latitude	Longitude	Location	What Data
15	NAWILIWILI 881	21 deg. 57 min. 24 sec. N (21.956667)	159 deg. 21 min. 12 sec. W (159.353333)	in the approximate center of the Nawiliwili deep-draft harbor basin about 300 yd west of the breakwater and east of the Nawiliwili Small Boat Harbor. Deep-draft harbor port facilities are to the north of the station and bouy #7 is to the south	1/83–10/97 approximately monthly sampling. water temp, transp secchi, DO mg/l, DO satur, pH su, salinity ppth, residue tot Nflt, total NN, NH3+NH4- n total, un-ionzd NH3-N, un-ionzd NH3-nh3, tot kjel N, NO2&NO3 N-total, phos tot, chlrphyl A, phos-t ortho, turbidity lab.
16	NAWILIWILI 817	21 deg. 57 min. 30 sec. N (21.958333)	159 deg. 21 min. 26 sec. W (159.357222)	in Nawiliwili Harbor – Coast Guard pier Kauai, Lihue, Nawiliwili Bay, Waapa Rd. Harbor B B2-M C4-Y	1973–1998 intermittent, various parameters, chemical, physical, and bacteriological. 152 samples total.
17	NAWILIWILI 880	21 deg. 57 min. 0 sec. N (21.95)	159 deg. 20 min. 0 sec. W (159.333333)		2 Samples 12/5/77 (metals in sediment) and 8/9/82 (nutrients). Total of 16 samples.

Table 9. Recorded exceedances of standards on the STORET database for each of the sampling sites

Sampling site	Exceedances of standards
Kalapaki 809	1989–98 Enterococci exceeded 6/35 times 1973–75 Nitrite plus nitrate exceeded every time (N=9) – Note 1 10/74 Total nitrogen exceeded 1/9 times – Note 1 Dissolved oxygen % sat. exceeded 6/36 samples – Note 3 Turbidity NTU exceeded 5/8 samples – Note 1
Kalapaki 810	No exceedances noted – no standard parameters measured
Nawiliwili #01	7/79 Lindane at chronic standard level 7/79 Chlordane in excess of chronic standard 7/79 Dieldrin in excess of chronic standard 7/79 Endrin in excess of acute standard 7/79 DDT in excess of acute standard 7/79 Methoxychlor at >300x chronic standard 7/79 PCB at 100x acute standard
Nawiliwili #02	7/79 Lindane at chronic standard level 7/79 Chlordane in excess of chronic standard 7/79 Dieldrin in excess of chronic standard 7/79 Endrin in excess of acute standard 7/79 DDT in excess of acute standard 7/79 Methoxychlor at >300x chronic standard 7/79 PCB at 100x acute standard
Nawiliwili #03	No exceedances noted – only bottom sediment sampled
Nawiliwili #04	No exceedances noted – only bottom sediment sampled
Nawiliwili #05	No exceedances noted – only bottom sediment sampled
Nawiliwili #06	No exceedances noted – only bottom sediment sampled
Nawiliwili #07	5/80 Total nitrogen exceeded – Note 1 5/80 Nitrite plus nitrate exceeded – Note 1 5/80 Ammonia nitrogen exceeded – Note 1 5/80 Turbidity exceeded – Note 1 5/80 Dissolved oxygen % sat. exceeded – Note 3
Nawiliwili #08	No exceedances noted – only bottom sediment sampled
Nawiliwili #09	No exceedances noted – only bottom sediment sampled
Nawiliwili #10	No exceedances noted – only bottom sediment sampled
Nawiliwili #11	No exceedances noted – only bottom sediment sampled
Nawiliwili #12	No exceedances noted – only bottom sediment sampled
Nawiliwili 817	Over 25 years of sampling: Total nitrogen (8/15), nitrite plus nitrate (14/14), and ammonia nitrogen (6/6), exceeded standards – Note 1 Enterococci over 7 CFU limit 32/92 times – Note 1 Chlorophyll A over the limit 6/6 times – Note 1 Turbidity exceeded 3/15 times – Note 1

Table 9—*Continued*

Sampling site	Exceedances of standards
Nawiliwili 880	
Nawiliwili 881	Chlorophyll A over the limit 354/360 times 1983–97 – Note 1 Nitrite plus nitrate exceeded every time (N=371) 1983–97 – Note 1 Ammonia nitrogen exceeded 329/362 samples 1983–97– Note 1 Total nitrogen exceeded 116/367 samples 1983–97 – Note 1 Dissolved oxygen % sat. exceeded 241/373 samples 1983–97 – Note 3 Phosphorus exceeded 69/377 samples 1983–97 – Note 1 Turbidity exceeded 333/371 times – Note 1

NOTES:

1) Nutrient, turbidity, chlorophyll, and bacterial standards are expressed as the geometric mean of a number of observations over a period of time, whereas the data on STORET are single measurements. Furthermore, there are two standards: one for wet weather and one for dry weather. The STORET site does not indicate what the weather was like at the time of sampling.

2) pH Units—Shall not deviate more than 0.5 unit from a value of 8.1, except at coastal locations where and when freshwater from stream, stormdrain or groundwater discharge may depress the pH to a minimum level of 7.0.

3) Dissolved Oxygen—Not less than 75% saturation; determined as a function of ambient water temperature and salinity.

4) Temperature—Shall not vary more than 1° Celsius from ambient conditions.

5) Salinity—Shall not vary more than 10% from natural or seasonal changes, considering hydrologic input and oceanographic factors.

Table 10. Monitoring data for Hanamā'ulu River

Date	Fecal coliform/100 ml	Enterococcus/100 ml	*C. perfringens*/100 ml
1/5/93	650	300	
1/11/93	440	233.3	
1/20/93	700	540	120
1/25/93	490	280	
2/2/93	740	460	
2/8/93	970	1000	
2/23/93	900	830	56
3/3/93	900	7000	290
4/6/93	450	380	
4/13/93	2200	1800	72
5/3/93	500	360	42
5/10/93	490	250	57
6/1/93	570	660	73
6/21/93	510	500	120
7/13/93	660	370	32
7/20/93	1100	620	40
8/9/93	670	690	35
9/20/93	620	340	9
10/11/93	460	770	14
11/8/93	300	640	12
12/6/93	200	390	36
1/10/94	530	810	23
2/7/94	150	310	25
3/15/94	230	300	73
4/11/94	230	390	28
5/2/94	230	190	10
7/12/94	200	300	5
8/22/94	120	200	6
9/19/94	150	210	5
10/18/94	90	230	14
11/21/94	67	200	9
12/13/94	210	200	12
1/17/95	190	120	7
2/13/95	73	280	6
3/20/95	100	230	1
4/10/95	210	190	5
5/15/95	110	100	10
6/13/95	280	300	3
7/17/95	87	220	0.5
8/1/95	61	87	19
9/11/95	35	51	3
10/23/95	60	100	2

SOURCE: Hawai'i State, Department of Health.

Table 11. Monitoring data for Hanamā'ulu Beach

Date	Fecal coliform/100 ml	Salinity (ppt)	Enterococcus/100 ml	*C. perfringens*/100 ml
1/5/93	120	30	59.7	
1/11/93	163.3	12.7	70	
1/20/93	290	10	303.3	80
1/25/93	113.3	17.2	61	
2/2/93	14.7	33	9.1	
2/8/93	49	31	26	
2/17/93	53	32	43	
2/23/93	210	16	200	18
3/3/93	320	14.8	230	
4/6/93	730	13.6	35	40
4/13/93	250	13.8	110	20
5/3/93	7	20.6	1	16
5/10/93	180	16	110	33
6/1/93	210	7.7	73	14
6/21/93	110	15.4	36	23
7/13/93	34	23.6	49	4
7/20/93	50	25.8	70	1
8/9/93	87	18.9	48	3
9/20/93	11	25.1	0.7	0.1
10/11/93	73	18	180	4
11/8/93	97	22	67	5
11/30/93	48	18.7	77	7
12/6/93	83	24	150	9
1/10/94	2	25	7	15
2/7/94	70	14.9	130	10
3/15/94	70	26.1	140	30
4/11/94	160	10.5	180	15
5/2/94	80	10.9	80	6
7/12/94	110	17.4	56	4
8/22/94	49	13.3	44	5
9/19/94	19	28.6	19	1
10/18/94	300	17	180	45
10/24/94	26	14.3	16	4
11/21/94	14	17.8	42	8
12/13/94	100	14	150	14
1/17/95	61	14.4	67	1
2/13/95	0.5	36.1	5	4
3/20/95	110	11	110	1
4/10/95	77	15	70	1
5/15/95	70	13	87	11
6/13/95	87	16	100	10
7/17/95	44	16	47	1
8/19/95	41	17	36	0.5
9/11/95	23	10.4	2	2
1/1/02	200	10	21	3
1/1/01	200			

Table 12. Monitoring results for Kalapaki Beach Park

Date	Time	<> FC	Fcoli/ 100 ml	<> Ent	Entero/ 100 ml	<> CP	CP/ 100 ml	Temp (degree C)	Salinity (ppt)	DO	Turbidity (NTU)	Remarks
04-Jan-99	1048				2.7		2.5		33	0.00		
12-Jan-99	1053				54		2		31			
19-Jan-99	1058				28.7		2		31			
01-Feb-99	1045				14	<	0.3		31			
08-Feb-99	1036				6.7	<	0.3		33			
16-Feb-99	0904				6.7	<	0.3		32			
22-Feb-99	1048				2.3	<	0.3		32			
01-Mar-99	1043				21.7		3		25			
08-Mar-99	1034				6.3		0.5		34			
15-Mar-99	1042				3	<	0.3		30			
22-Mar-99	1047				13.3		3		32			
29-Mar-99	1046				1		1.3		31			
05-Apr-99	1043				40.5		0.3		31			
13-Apr-99	1050				8.3		0.3		30			
19-Apr-99	1046				3.3	<	0.3		30			
27-Apr-99	1056				0.3	<	0.3		30			
03-May-99	1053				7		0.5		30			
10-May-99	1102				8		1.3		32			
18-May-99	1056				6		1.8		31			
24-May-99	1054			<	0.3	<	0.3		31			
01-Jun-99	1050				3.3	<	0.3		32			
07-Jun-99	1039			<	0.3		0.3		32			
14-Jun-99	1035				1.3		0.5		35			
21-Jun-99	0921				52.5		0.5		35			
29-Jun-99	1327				0.3	<	0.3		34.3			
07-Jul-99	1033				15.3		1.3	26.1	35.2		54.4	
13-Jul-99	1038				4.3		0.3	26.8	34.1	2.86	53.6	
20-Jul-99	1044				3.7		0.5	26.7	34.1	2.3	53.4	
27-Jul-99	1012				4		1.3	25.8	34.5	2.9	53.1	
03-Aug-99	1028				0.7		1	28	34.1	5.7	54.2	
10-Aug-99	0929				0.7		0.3	26.8	31.9	5.8	50.1	
16-Aug-99	1113				10		0.3	27	35.1	5.5	55	
24-Aug-99	1119				0.7		0.3	27.7	35.4	5.4	56	
30-Aug-99	1119				5	<	0.3	26.7	35.1	5.7	54.7	
07-Sep-99	1123				0.3		1	27.5	34.4	6.1	54.6	
13-Sep-99	1129				4		0.5	27.2	34.4	6.3	54.7	
20-Sep-99	1123			<	0.3		0.5	26.9	34.4	6.2	54.2	
27-Sep-99	0952				66	<	0.3	25.8	33	6.3	51.1	
04-Oct-99	1117				1		0.3	27.1	34.5	6.3		
11-Oct-99	1108				0.7	<	0.3	27.4	34.6	6.4		
19-Oct-99	1113				216		8	26.1	32	6.5		Rain
25-Oct-99	1124				0.7	<	0.3	26.9	34.7	6.9		
01-Nov-99	1056				12.3	<	0.3	26.7	34.9	6.4		
08-Nov-99	1046				4.3		0.5	25.4	33.6	6.5		
15-Nov-99	0944		6.3		6.9	<	0.3	23.9	30.7	7		
22-Nov-99	1036				10.3		0.5	25.3	34.7	6.6		
08-Dec-99	0903				0.3		1	24.4	34.9	6.6		
13-Dec-99	1032		118		76		3.3	24.7	31	6.8		
20-Dec-99	1047		1440		1340		2	24.6	29	7		
27-Dec-99	1053		43		52.5	<	0.3	23.3	30.8	6.8		
03-Jan-00	1045				10		1	24.6	33.5	6.7		
10-Jan-00	1123				9		1	24.5	35	6.6		
18-Jan-00	1047		20		16.9		0.8	22.7	30.5	6.9		
24-Jan-00	1054		38		41.5		1.8	22.2	23.8	7.4		
01-Feb-00	1058				7.7	<	0.3	24.1	35.1	6.7		
07-Feb-00	1113		37.8		40		1.5	24.4	30.6	6.5		
14-Feb-00	1119				9		0.3	24.7	32.7	6.4		
23-Feb-00	0938				16.7		0.3	23.6	35.3			
28-Feb-00	1024				6.7		0.8	24.7	34.9	6		
13-Mar-00	1049			<	0.3		0.5	25.6	34.9			

Table 12—*Continued*

Date	Time	< > FC	Fcoli/ 100 ml	< > Ent	Entero/ 100 ml	< > CP	CP/ 100 ml	Temp (degree C)	Salinity (ppt)	DO	Turbidity (NTU)	Remarks
20-Mar-00	1100				3.7	<	0.3	25	35.1	6.1		
28-Mar-00	1117				1.7	<	0.3	24.9	35.2	6.2		
03-Apr-00	1117				138		1	23.2	34.6	6.5		
17-Apr-00	1047				6.7	<	0.3	23.6	33.1	6.4		
24-Apr-00	1025				8	<	0.3	24.2	32.9	6.3		
01-May-00	0833		10		16.9		0.5	24.4	31.3	6.4		
09-May-00	0741				5.7		0.3	24.3	34.4	6.1		
16-May-00	0742				7.7		1.3	24.9	33.9	6		
23-May-00	0736				3.3		0.5	25.4	33.9	6		
14-Jun-00	0735				3.3		0.8	26.2	34.6	6.2		
20-Jun-00	0728				3.7		0.8	25.9	34.2	6.8		
27-Jun-00	0734				7.7		0.3	26.3	34.8	6.1		
05-Jul-00	1120				0.3	<	0.3	27.3	34.7	5.5		
11-Jul-00	0730				82		2.3	25.4	34.5	5.5		
18-Jul-00	0759				2		0.3	26	34	5.5		
25-Jul-00	0750				14	<	0.3	26.3	33.9	5.6		
01-Aug-00	0818				2.7		1	26.7	33.9	5.3		
08-Aug-00	0804				1.7		0.3	26.3	34.9	5.5		
15-Aug-00	0820				5.7	<	0.3	26.8	34.7	5.2		
23-Aug-00	0821				0.7		0.5	26.4	34.9	5.3		
29-Aug-00	0817				3.7		0.3	26.4	34.4	5.2		
06-Sep-00	0825				0.7	<	0.3	26.2	33.3	5.8		
12-Sep-00	0815				2.3		0.3	26.2	34.1	5.8		
19-Sep-00	0824				0.7	<	0.3	26.8	34	6.2		
26-Sep-00	0812				6.3		0.3	26.3	35	5.9		
03-Oct-00	0750				120		8.5	26.6	35.1	5.8		
10-Oct-00	0745				19	<	0.3	25.8	34.5	6		
17-Oct-00	0717				4.3		0.3	25.3	35	6.1		
24-Oct-00	1044				3.3	<	0.3	26.6	33.6	6.9		
30-Oct-00	1111				2		1	26.2	34.8	6.4		
06-Nov-00	1116				3	<	0.3	26.7	35	6		
14-Nov-00	0750				4.3	<	0.3	24.9	34.7	6.8		
20-Nov-00	0745				2.3	<	0.3	24.4	33.8	6.4		
27-Nov-00	0743				4.7		0.5	24.5	34.6	6.4		
06-Dec-00	1034				13.3		1.5	25	33.8	7.2		
12-Dec-00	0754				166		2	24.2	34.4	6.4		
19-Dec-00	0800				2.3		0.3	23.5	34.6	6.5		
26-Dec-00	1106				28.5		3.5	24.9	32	7.4		
03-Jan-01	0804				8		2.5	23.2	34.2	5.9		
07-Jan-01	0806				33		29	22.6	34.9	6		Sewage spill on previous day
10-Jan-01	0818				14		0.5	24.5	34.9	6.8		
16-Jan-01	1202				30.5		2.5	25.5	33.5	6.6		
24-Jan-01	0758				1		0.3	23.4	35	6.4		
30-Jan-01	0815				1.3		0.8	23.9	34.6	6.1		
05-Feb-01	1311				0.7	<	0.3	23.9	34.3	6.4		
13-Feb-01	0801				5.3		0.5	23.5	34.6	6.7		
21-Feb-01	0756				3.3		0.3	22.8	33.8	6.2		
06-Mar-01	0753				23.3		0.5	23.3	33.9	6.1		
13-Mar-01	0750				1	<	0.3	23.2	33.6	6.5		
28-Mar-01	0743				3.3		0.3	24.3	34.4	6.5		
03-Apr-01	0750				20.8		1.8	24	34.2	6.1		
10-Apr-01	0800			Est.	626		12	23.5	34.1	6.2		
24-Apr-01	0750				94		5.5	23.8	28.4	6.6		
01-May-01	0750				10.6		0.5	23.7	31.5	6.1		
08-May-01	0800				5.3	<	0.3	24.7	34.3	5.9		
15-May-01	0758				4.7	<	0.3	24.7	34.4	7.2		
22-May-01	0750				88		3.2	25.3	31.5	5.8		
30-May-01	0740				41		5	25.6	33.6	5.6		
07-Jun-01	0816				29		5.2	26.1	27.7	6.3		
13-Jun-01	0810				24		27	26	33.5	6.1		

Table 12—*Continued*

Date	Time	< > FC	Fcoli/ 100 ml	< > Ent	Entero/ 100 ml	< > CP	CP/ 100 ml	Temp (degree C)	Salinity (ppt)	DO	Turbidity (NTU)	Remarks
19-Jun-01	0745				28		2.8	25.5	32.9	6		
26-Jun-01	0745				2.7		0.8	25.5	34.8	6.1		
05-Jul-01	0721				8		1	26.2	34.5	5.7		
10-Jul-01	0748				1		0.5	26.7	35	5.9		
17-Jul-01	0734				22		1.5	26.5	34.1	6		
06-Aug-01	0753				46		0.2	26.4	34.1	5.8		
14-Aug-01	0801				1		1	25.6	34.7	6		
20-Aug-01	1205				0.7		0.2	27.6	34.3	6		
28-Aug-01	0758				5		0.5	26.2	34	5.7		
05-Sep-01	0752				0.7		1	26.2	35.1	5.8		
11-Sep-01	0748				4.3		0.2	26.9	35.3	5.8		
18-Sep-01	0800				28	Est.	61	26.3	34.9	5.9		
25-Sep-01	0758				0.3		0.2	26	35.3	5.8		
02-Oct-01	0757				1.7		0.5	25.5	34.8	5.4		
10-Oct-01	0805				4		0.8	25.9	35.4	5.9		
24-Oct-01	0742				7.7		1	24.8	34.7	5.8		
30-Oct-01	0758				63		2.5	24.4	34.9	5.9		
29-Nov-01	0808				120		5	25.1	32	6.2		
06-Dec-01	0803				6		1.5	24.4	34.8	6.6		
10-Dec-01	1345				1		0.2	25.1	35.1	7.4		
19-Dec-01	0757				8		1.2	24	34.6	6.7		
27-Dec-01	0800				25		8	23	34.9	5.5		
03-Jan-02	0803				28		5.8	22.9	35.6	5.8		
08-Jan-02	1152				59	Est.	400	24.4	32.8	6.2		Sewage spill response
09-Jan-02	0835				28		60	23.9	34.9	5.9		Response to sewage spill
14-Jan-02	0751				6.7		8.5	23.3	35.1	5.8		
23-Jan-02	0755				76		53	22.9	33.7	6.4		
28-Jan-02	1149				300		14	23.5	27	6.8		
05-Feb-02	0801			Est.	130		20	23.2	34.2	6.3	2.4	
12-Feb-02	0804			Est.	230		50	21.5	33.7	7.1	4	
19-Feb-02	1335				3		10	26.3	33.5	5.7	2.9	Afternoon sample
05-Mar-02	0800				5.3		1.2	21.8	35.3	6.6	4.2	Clean conditions, overcast sky
12-Mar-02	0806				26		7	23.6	34.4	6.2	2.9	Stream mouth open

SOURCE: Hawai'i State, Department of Health.

NOTE: Fcoli = Fecal coliform, Entero = Enterococci, CP = *C. perfringens*.

Table 13. Monitoring results for Kalapaki Beach Park and Nawiliwili Harbor

Station No.	Location	Date	Time	Enterococcus/ 100 ml	*C. perfringens*/ 100 ml	Salinity (ppt)
000809	Kalapaki Beach Park	08-Jan-90	1155	9		
000809	Kalapaki Beach Park	12-Feb-90	1125	15		
000809	Kalapaki Beach Park	12-Mar-90	1205	3		
000809	Kalapaki Beach Park	16-Apr-90	1152	0.7		33.5
000809	Kalapaki Beach Park	07-May-90	1140	11		
000809	Kalapaki Beach Park	18-Jun-90	1015	9		35
000809	Kalapaki Beach Park	26-Jun-90	1130	6		
000809	Kalapaki Beach Park	23-Jul-90	1110	1		34
000809	Kalapaki Beach Park	30-Jul-90	1120	10		34
000809	Kalapaki Beach Park	29-Oct-90	1052	0.7		
000809	Kalapaki Beach Park	26-Nov-90	1036	19		
000809	Kalapaki Beach Park	10-Dec-90	0828	19		
000809	Kalapaki Beach Park	29-Jan-91	0936	26		
000809	Kalapaki Beach Park	11-Feb-91	0931	38		
000809	Kalapaki Beach Park	18-Mar-91	0952	540		
000809	Kalapaki Beach Park	22-Apr-91	0959	0.7		
000809	Kalapaki Beach Park	13-May-91	0945	0.7		
000809	Kalapaki Beach Park	03-Jun-91	0952	87		
000809	Kalapaki Beach Park	01-Jul-91	0850	198		
000809	Kalapaki Beach Park	05-Aug-91	0930	6		
000809	Kalapaki Beach Park	03-Sep-91	0921	0.7		
000809	Kalapaki Beach Park	30-Sep-91	0930	33		
000809	Kalapaki Beach Park	18-Nov-91	1000	7		34
000809	Kalapaki Beach Park	17-Dec-91	1116	21		27
000809	Kalapaki Beach Park	14-Jan-92	1135	0.7		36
000809	Kalapaki Beach Park	25-Feb-92	1325	1		33.7
000809	Kalapaki Beach Park	16-Mar-92	1124	40		31.5
000809	Kalapaki Beach Park	20-Apr-92	0740	14		34
000809	Kalapaki Beach Park	11-May-92	1030	0.7		34
000809	Kalapaki Beach Park	29-Jun-92	1135	0.7		32.5
000809	Kalapaki Beach Park	21-Jul-92	1127	5		33.9
000809	Kalapaki Beach Park	24-Aug-92	1040	1		33.4
000809	Kalapaki Beach Park	26-Oct-92	1105	1		34.1
000809	Kalapaki Beach Park	30-Nov-92	1130	213		32.8
000809	Kalapaki Beach Park	02-Dec-92	0838	20		33.1
000809	Kalapaki Beach Park	07-Dec-92	0840	48		27.4
000809	Kalapaki Beach Park	28-Dec-92	1124	280		29.2
000809	Kalapaki Beach Park	25-Jan-93	1110	21		31.5
000809	Kalapaki Beach Park	08-Feb-93	0835	15		33.8
000809	Kalapaki Beach Park	03-Mar-93	0837		1	
000809	Kalapaki Beach Park	03-Mar-93	0837	6		34
000809	Kalapaki Beach Park	05-Apr-93	0906		11	
000809	Kalapaki Beach Park	05-Apr-93	0906	3		33
000809	Kalapaki Beach Park	10-May-93	0732		1	
000809	Kalapaki Beach Park	10-May-93	0732	2		33.6
000809	Kalapaki Beach Park	21-Jun-93	0858		1	
000809	Kalapaki Beach Park	21-Jun-93	0858	1		33.4
000809	Kalapaki Beach Park	20-Jul-93	0824		2	

Table 13—*Continued*

Station No.	Location	Date	Time	Enterococcus/ 100 ml	*C. perfringens*/ 100 ml	Salinity (ppt)
000809	Kalapaki Beach Park	20-Jul-93	0824	6		33.8
000809	Kalapaki Beach Park	09-Aug-93	0810		4	
000809	Kalapaki Beach Park	09-Aug-93	0810	3		27.1
000809	Kalapaki Beach Park	20-Sep-93	0809		2	
000809	Kalapaki Beach Park	20-Sep-93	0809	6		34.1
000809	Kalapaki Beach Park	11-Oct-93	0746		9	
000809	Kalapaki Beach Park	11-Oct-93	0746	60		34
000809	Kalapaki Beach Park	08-Nov-93	0930		5	
000809	Kalapaki Beach Park	08-Nov-93	0930	65		34
000809	Kalapaki Beach Park	06-Dec-93	0737		1	
000809	Kalapaki Beach Park	06-Dec-93	0737	18		33.3
000809	Kalapaki Beach Park	10-Jan-94	0716	30	5	
000809	Kalapaki Beach Park	07-Feb-94	0733	350	10	23.4
000809	Kalapaki Beach Park	14-Feb-94	1306	400	21	26.5
000809	Kalapaki Beach Park	15-Mar-94	0735	17	4	35
000809	Kalapaki Beach Park	02-May-94	0853	1	1	33.7
000809	Kalapaki Beach Park	12-Jul-94	0749	2	1	34
000809	Kalapaki Beach Park	22-Aug-94	0818	1	1	33.4
000809	Kalapaki Beach Park	19-Sep-94	0740	43	1	24.1
000809	Kalapaki Beach Park	18-Oct-94	0814	11	4	33
000809	Kalapaki Beach Park	21-Nov-94	0801	1	1	31.8
000809	Kalapaki Beach Park	13-Dec-94	0813	27	4	32.6
000809	Kalapaki Beach Park	17-Jan-95	0752	25	1	33.5
000809	Kalapaki Beach Park	13-Feb-95	0827	18	9	33.1
000809	Kalapaki Beach Park	20-Mar-95	0820	22	16	34
000809	Kalapaki Beach Park	10-Apr-95	0819	570	7	20
000809	Kalapaki Beach Park	15-May-95	0750	11	1	34
000809	Kalapaki Beach Park	13-Jun-95	0753	20	1	34
000809	Kalapaki Beach Park	17-Jul-95	0710	1	1	32
000809	Kalapaki Beach Park	01-Aug-95	0730	1		34
000809	Kalapaki Beach Park	11-Sep-95	0818	1	1	31.7
000809	Kalapaki Beach Park	23-Oct-95	0801	2	1	33
000809	Kalapaki Beach Park	27-Nov-95	0824	220	10	30
000809	Kalapaki Beach Park	05-Dec-95	0730	90	1	33
000809	Kalapaki Beach Park	17-Jan-96	0802	14	7	36
000809	Kalapaki Beach Park	12-Feb-96	0755	33	9	30
000809	Kalapaki Beach Park	11-Mar-96	0810	21	1	30.3
000809	Kalapaki Beach Park	09-Apr-96	0812	13	1	32
000809	Kalapaki Beach Park	21-May-96	0758	4	1	30
000809	Kalapaki Beach Park	17-Jun-96	0837	4	1	32
000809	Kalapaki Beach Park	22-Jul-96	0816	370	13	25
000809	Kalapaki Beach Park	29-Jul-96	1148	13	1	24
000809	Kalapaki Beach Park	13-Aug-96	1016	1	1	25
000809	Kalapaki Beach Park	16-Sep-96	1026	81	1	27
000809	Kalapaki Beach Park	15-Oct-96	1045	13	1	33
000809	Kalapaki Beach Park	19-Nov-96	1006	130	6	34
000809	Kalapaki Beach Park	10-Dec-96	0806	87	5	26
000809	Kalapaki Beach Park	10-Feb-97	0730	4	1	30

Table 13—*Continued*

Station No.	Location	Date	Time	Enterococcus/ 100 ml	*C. perfringens*/ 100 ml	Salinity (ppt)
000809	Kalapaki Beach Park	10-Mar-97	0840	6	2	33
000809	Kalapaki Beach Park	08-Apr-97	0741	14	5	26
000809	Kalapaki Beach Park	12-May-97	0854	45	3	31
000809	Kalapaki Beach Park	17-Jun-97	0828	1	1	32
000809	Kalapaki Beach Park	15-Jul-97	0840	1	1	30
000809	Kalapaki Beach Park	12-Aug-97	0815	21	1	33
000809	Kalapaki Beach Park	09-Sep-97	0843	1	1	32
000809	Kalapaki Beach Park	13-Oct-97	0803	45	1	31
000809	Kalapaki Beach Park	04-Nov-97	0837	2	4	34
000809	Kalapaki Beach Park	09-Dec-97	0843	88	2	30
000809	Kalapaki Beach Park	06-Jan-98	0821	50	1	
000809	Kalapaki Beach Park	19-Feb-98	0838	5	1	33
000809	Kalapaki Beach Park	09-Mar-98	0828	84	1	32
000809	Kalapaki Beach Park	13-Apr-98	0843	8	1	35
000809	Kalapaki Beach Park	11-May-98	0815	9	1	33
000809	Kalapaki Beach Park	08-Jun-98	0831	1	1	32
000809	Kalapaki Beach Park	13-Jul-98	0845	4	2	32
000809	Kalapaki Beach Park	10-Aug-98	0901	3	0.8	33
000809	Kalapaki Beach Park	15-Sep-98	0855	2	0.3	33
000809	Kalapaki Beach Park	12-Oct-98	0840	1	0.3	33
000809	Kalapaki Beach Park	17-Nov-98	0839	7	0.8	35
000809	Kalapaki Beach Park	08-Dec-98	0851	13	0.3	32
000817	Nawiliwili Harbor	18-Jun-90	1000	4		35
000817	Nawiliwili Harbor	23-Jul-90	1045	0.7		34
000817	Nawiliwili Harbor	29-Jan-91	0930	11		
000817	Nawiliwili Harbor	11-Feb-91	0924	14		
000817	Nawiliwili Harbor	18-Mar-91	0945	210		
000817	Nawiliwili Harbor	22-Apr-91	0951	10		
000817	Nawiliwili Harbor	13-May-91	0937	0.7		
000817	Nawiliwili Harbor	03-Jun-91	0945	26		
000817	Nawiliwili Harbor	03-Sep-91	0914	0.7		
000817	Nawiliwili Harbor	30-Sep-91	0922	20		
000817	Nawiliwili Harbor	18-Nov-91	0955	0.7		30
000817	Nawiliwili Harbor	17-Dec-91	1108	18		28
000817	Nawiliwili Harbor	14-Jan-92	1130	0.7		36
000817	Nawiliwili Harbor	25-Feb-92	1112	0.7		34.9
000817	Nawiliwili Harbor	16-Mar-92	1115	3		30
000817	Nawiliwili Harbor	20-Apr-92	1045	0.7		34.7
000817	Nawiliwili Harbor	11-May-92	1022	2		34.7
000817	Nawiliwili Harbor	29-Jun-92	1123	1		31.6
000817	Nawiliwili Harbor	21-Jul-92	1115	0.7		33.9
000817	Nawiliwili Harbor	24-Aug-92	1025	1		33.4
000817	Nawiliwili Harbor	26-Oct-92	1049	0.7		33.4
000817	Nawiliwili Harbor	16-Nov-92	0959			32.9
000817	Nawiliwili Harbor	30-Nov-92	1120	19		33.7
000817	Nawiliwili Harbor	28-Dec-92	1111	110		18.1
000817	Nawiliwili Harbor	19-Jan-93	1025			29.3
000817	Nawiliwili Harbor	25-Jan-93	1055	2		34

Table 13—*Continued*

Station No.	Location	Date	Time	Enterococcus/ 100 ml	*C. perfringens*/ 100 ml	Salinity (ppt)
000817	Nawiliwili Harbor	08-Feb-93	0820	1		34.6
000817	Nawiliwili Harbor	03-Mar-93	0823		1	
000817	Nawiliwili Harbor	03-Mar-93	0823	1		34.5
000817	Nawiliwili Harbor	15-Mar-93	0944			33.1
000817	Nawiliwili Harbor	05-Apr-93	0850	2		29.9
000817	Nawiliwili Harbor	10-May-93	0719	1		32.8
000817	Nawiliwili Harbor	17-May-93	0943			32.9
000817	Nawiliwili Harbor	14-Jun-93	1036			33.1
000817	Nawiliwili Harbor	21-Jun-93	0837	1		32.6
000817	Nawiliwili Harbor	20-Jul-93	0809	1		33.7
000817	Nawiliwili Harbor	09-Aug-93	0800	1		34.7
000817	Nawiliwili Harbor	20-Sep-93	0750	2		34.5
000817	Nawiliwili Harbor	11-Oct-93	0738	15		30
000817	Nawiliwili Harbor	08-Nov-93	0910	14		29
000817	Nawiliwili Harbor	06-Dec-93	0714	22		20.8
000817	Nawiliwili Harbor	10-Jan-94	1005	1		34.9
000817	Nawiliwili Harbor	07-Feb-94	0716	1		32.7
000817	Nawiliwili Harbor	15-Mar-94	0717	9		34.7
000817	Nawiliwili Harbor	11-Apr-94	0720	9		33.9
000817	Nawiliwili Harbor	02-May-94	0835	5		33.2
000817	Nawiliwili Harbor	12-Jul-94	0725	3		32.6
000817	Nawiliwili Harbor	22-Aug-94	0754	1		33.3
000817	Nawiliwili Harbor	19-Sep-94	0723	130		7.2
000817	Nawiliwili Harbor	18-Oct-94	0754	11		9.3
000817	Nawiliwili Harbor	21-Nov-94	0743	7		25.4
000817	Nawiliwili Harbor	13-Dec-94	0754	1		25.5
000817	Nawiliwili Harbor	17-Jan-95	0736	1		25
000817	Nawiliwili Harbor	13-Feb-95	0811	2		36.1
000817	Nawiliwili Harbor	20-Mar-95	0800	1		35
000817	Nawiliwili Harbor	10-Apr-95	0803	660		12
000817	Nawiliwili Harbor	15-May-95	0730	3		31
000817	Nawiliwili Harbor	13-Jun-95	0737	1		34
000817	Nawiliwili Harbor	17-Jul-95	0700	4		31
000817	Nawiliwili Harbor	01-Aug-95	0730	1		34
000817	Nawiliwili Harbor	11-Sep-95	0802	1		33.6
000817	Nawiliwili Harbor	23-Oct-95	0750	1		32
000817	Nawiliwili Harbor	21-Nov-95	1006			30.2
000817	Nawiliwili Harbor	27-Nov-95	0805	550		18
000817	Nawiliwili Harbor	05-Dec-95	0718	190		25
000817	Nawiliwili Harbor	17-Jan-96	0750	4		33
000817	Nawiliwili Harbor	12-Feb-96	0745	1		34
000817	Nawiliwili Harbor	11-Mar-96	0755	14		6.5
000817	Nawiliwili Harbor	09-Apr-96	0800	1		33
000817	Nawiliwili Harbor	21-May-96	0748	9		27
000817	Nawiliwili Harbor	17-Jun-96	0826	1		32
000817	Nawiliwili Harbor	13-Aug-96	1006	1	1	25
000817	Nawiliwili Harbor	16-Sep-96	1004	1	1	22
000817	Nawiliwili Harbor	15-Oct-96	1035	1	1	30

Table 13—*Continued*

Station No.	Location	Date	Time	Enterococcus/ 100 ml	*C. perfringens*/ 100 ml	Salinity (ppt)
000817	Nawiliwili Harbor	19-Nov-96	0956	47	3	25
000817	Nawiliwili Harbor	10-Dec-96	0754	23	1	22
000817	Nawiliwili Harbor	10-Feb-97	0718	1	1	30
000817	Nawiliwili Harbor	10-Mar-97	0830	4	1	24.7
000817	Nawiliwili Harbor	08-Apr-97	0730	28	2	22
000817	Nawiliwili Harbor	12-May-97	0840	6	1	35
000817	Nawiliwili Harbor	17-Jun-97	0816	1	1	27
000817	Nawiliwili Harbor	12-Aug-97	0803	1	1	30
000817	Nawiliwili Harbor	09-Sep-97	0830	1	1	33
000817	Nawiliwili Harbor	13-Oct-97	0750	19	1	31
000817	Nawiliwili Harbor	04-Nov-97	0816	4	1	32
000817	Nawiliwili Harbor	09-Dec-97	0830	750	6	18
000817	Nawiliwili Harbor	06-Jan-98	0809	9	1	35
000817	Nawiliwili Harbor	19-Feb-98	0822	6	1	33
000817	Nawiliwili Harbor	09-Mar-98	0817	20	1	35
000817	Nawiliwili Harbor	13-Apr-98	0829	1	1	34
000817	Nawiliwili Harbor	11-May-98	0801	11	2	32
000817	Nawiliwili Harbor	08-Jun-98	0819	4	1	35
000817	Nawiliwili Harbor	13-Jul-98	0932	4	1	26
000817	Nawiliwili Harbor	10-Aug-98	0848	1	0.3	32
000817	Nawiliwili Harbor	15-Sep-98	0842	0.7	0.3	35
000817	Nawiliwili Harbor	12-Oct-98	0825	5	0.3	17
000817	Nawiliwili Harbor	17-Nov-98	0824	37	0.5	36
000817	Nawiliwili Harbor	08-Dec-98	0834	74	0.3	15

Table 14. Key for status code for groundwater aquifers (5 digits)

	Value	Definition
1st Digit: Developmental Stage	1	Drinking
	2	Ecologically important
	3	Neither
2nd Digit: Utility	1	Drinking
	2	Ecologically important
	3	Neither
3rd Digit: Salinity (mg/l Cl^-)	1	Fresh (<250)
	2	Low (250–1,000)
	3	Moderate (1,000–5,000)
	4	High (5,000–15,000)
	5	Seawater (>15,000)
4th Digit: Uniqueness	1	Irreplaceable
	2	Replaceable
5th Digit: Vulnerability to Contamination	1	High
	2	Moderate
	3	Low
	4	None

Table 15. Status codes for the high aquifers
(three zones; see Figure B14)

Developmental Stage	Currently used
Utility	Drinking
Salinity	Fresh (<250)
Uniqueness	Irreplaceable
Vulnerability to Contamination	High
Developmental Stage	Potential use
Utility	Drinking
Salinity	Fresh (<250)
Uniqueness	Irreplaceable
Vulnerability to Contamination	High
Developmental Stage	Potential use
Utility	Ecologically important
Salinity	Low (250–1,000)
Uniqueness	Irreplaceable
Vulnerability to Contamination	High

Table 16. Status codes for the low aquifers
(two zones; see Figure B15)

Developmental Stage	Potential use
Utility	Drinking
Salinity	Fresh (<250)
Uniqueness	Irreplaceable
Vulnerability to Contamination	Moderate
Developmental Stage	Potential use
Utility	Drinking
Salinity	Fresh (<250)
Uniqueness	Irreplaceable
Vulnerability to Contamination	Low

Table 17. Available information for rain gages in and around the Nawiliwili Watershed (see Figure B3, Appendix B). NWS is an acronym of the National Weather Service

State Key Number	NWS Number	Station Name	Observation name	Elevation (feet)	Year Established	Year Discontinued
0933		MANUHONUHONU	MCBRYDE SUGAR	00450	1938	
09331		FIELD 34	MCBRYDE SUGAR	00499		
0934	0456	EAST LAWAI	MCBRYDE SUGAR	00440	1902	
09351		PAANAU(MCBRYDE)	MCBRYDE SUGAR	00135	1951	
0936	4742	KOLOA	MCBRYDE SUGAR	00240	1887	
09361		FIELD K-43	GROVE FARM	00250	1950	
09362		KOLOA FIELD O	MCBRYDE SUGAR	00275	1951	1964
09363		KOLOA (200)	KOLOA MILL	00200	1882	1886
0941	5710	MAHAULEPU	MCBRYDE	00100	1904	1963
0990	8949	WAHIAWA MTN	MCBRYDE SUGAR	02100	1901	
0992		OMAO	MCBRYDE SUGAR	00525	1941	
0993		FLD 612	MCBRYDE	00500	1923	
0994	4750	KOLOA MAUKA	MCBRYDE SUGAR	00640	1904	
0995	4746	KOLOA FLD 52	MCBRYDE SUGAR	00600	1946	
0996	0308W	KAMOOLOA	MCBRYDE SUGAR	00720	1907	1949
09961		KOLOA DITCH	LIHUE PLANTATION	00700	1950	
0997	7777	PAPUAA	LIHUE PLANTATION CO	00550	1916	
1000		MCBRYDE F609 K-4	MCBRYDE	00540	1947	
10001		KNUDSEN	PR1	00625	1938	1944
1001	6097	M&M	MCBRYDE	00300	1924	
1002		WAITA	MCBRYDE	00250	1926	
1003		KAALA	GROVE FARM	00400	1924	
1004	8573	RESERVOIR 6	GROVE FARM	00420	1912	1974
1005	3023	KALUAHONU	GROVE FARM	00330	1923	1974
1006	1038	HALENANAHO	LIHUE PLANTATION	00490	1932	
10061	4937W	KUKAUA	H ISENBERG	01055	1900	1942
1007	0006	FLD 826	MCBRYDE	00340	1909	1974
10071		KIPU STABLE	KIPU RANCH	00340	1943	
10072		KIPU 11	KIPU RANCH	00275	1943	
10073		KIPU KAI	KIPU KAI RANCH	00025	1943	
10074		FIELD 32	GROVE FARM	00400	1947	1949
10075		KIPU KAI GAP	KIPU KAI RANCH			
1011	8570	LP RES 5	LIHUE PLANTATION	00385	1935	1974
1012		LP HI 18	LIHUE PLANTATION	00260	1945	
1013	8217	PUHI	LIHUE PLANTATION	00330	1935	
10131		FIELD 39 LIHUE	LIHUE PLANTATION	00375	1947	
10132		FIELD L-1	LIHUE PLANTATION	00340	1968	
1014		FIELD L3A	LIHUE PLANTATION	00320	1974	
1015	6537	MOLOKOA	MRS H ISENBERG	00240	1893	1950
10151	4615W	KILOHANA(LIHUE)	A W DUVAL	00330	1903	1938
10152		FIELD 11 LIHUE	LIHUE PLANTATION	00275	1947	
10153		FIELD L4	LIHUE PLANTATION	00240	1965	1966
10154		FIELD L-11(4)	LIHUE PLANTATION	00240	1964	1965
1016		LP III 4	LIHUE PLANTATION	00260	1940	

Table 17—*Continued*

State Key Number	NWS Number	Station Name	Observation name	Elevation (feet)	Year Established	Year Discontinued
1017	6055	MALUMALU	LIHUE PLANTATION	00250	1940	1963
1020	5575	LIHUE	LIHUE PLANTATION	00205	1904	
10201	5580	LIHUE AIRPORT	LIHUE PLANTATION	00103	1950	
10202		FIELD 36 LIHUE	LIHUE PLANTATION	00075	1947	
10203		FIELD 32 LIHUE	LIHUE PLANTATION	00050	1947	
10204		L 24	LIHUE PLANTATION	00125	1947	
10205		L 20	LIHUE PLANTATION	00175	1947	
10206		FIELD 21	LIHUE PLANTATION	00220	1953	1955
1021	0766	HI	LIHUE PLANTATION	00200	1885	1963
1022	1195	HANAMAULU	LIHUE PLANTATION	00175	1893	
10221		FIELD L6	LIHUE PLANTATION	00280	1966	
1052	8966	WAIAHI UPPER	LIHUE PLANTATION	00780	1931	
10521		ILIILIULA CUTOFF	LIHUE PLANTATION	01050	1927	1931
1054	8958	WAIAHI LOWER	LIHUE PLANTATION	00550	1910	
10541		LIHUE DITCH	LIHUE PLANTATION	00550	1951	
10542		FLD LIHUE 10	HAW'N CANNERIES	00800	1951	1962
10543		FLD LIHUE 8	HAW'N CANNERIES	00450	1951	1962
10544		FLD LIHUE 9	HAW'N CANNERIES	00500	1951	1955
1062		WAILUA UKA	LIHUE PLANTATION	00250	1924	
10621	5560	LIHUE VTY STA	LIHUE PLANTATION	00340	1945	
10622		FLD 38A	LIHUE PLANTATION	00425		
1064		CAMP 9	LIHUE PLANTATION	00275	1924	
10641		H 14	LIHUE PLANTATION	00330	1968	
10642		H 27	LIHUE PLANTATION	00405	1968	
10643		H 23 CAMP 9	LIHUE PLANTATION	00315	1969	
10644		FIELD H14	LIHUE PLANTATION	00320		

SOURCE: Hawaii'i Statewide GIS Program, Office of Planning.

APPENDIX A
Nawiliwili Watershed Survey

Nawiliwili Watershed Survey

please circle the appropriate responses

The State Department of Health (DOH) has included the Nawiliwili watershed on their prioritized st of polluted watersheds which need to be improved. Nawiliwili was included based on observed acceptably high levels of pollutants in the Bay - mostly turbidity (soil and other visible particles) and utrients (fertilizers, nitrogen, phosphorus, etc.). The sources of these pollutants need to be identified so iat a clean-up plan can be designed. DOH has selected scientists from the Water Resources Research enter (WRRC) at the University of Hawaii to officially make an assessment of the pollution problem in ie Nawiliwili watershed. WRRC recognizes that the most knowledgeable people regarding the Nawiliwili 'atershed are the people who live in the area, and we are getting input from them by various means, icluding this survey. We hope to obtain as much information as possible about pollution in the Nawiliwili 'atershed and to find out who is interested in further participation in the assessment project.

lease answer the following questions as thoughtfully and completely as you can. Mahalo.

1. How often do you swim, surf, boat, fish or otherwise pursue recreation in Nawiliwili Bay?

More than once a week	Two or three times a month	Once a month	Less than once a month.

2 Overall how clean do you feel that the water is in the Bay? (1 = very clean, 10 = very dirty)
1 2 3 4 5 6 7 8 9 10

3. Do you notice that the water in the Bay looks murkier sometimes? If so when?

4. Rank the following in terms of their seriousness as sources of pollution to the Bay in your opinion: (1=of little concern, 2=of some concern, 3=somewhat serious, 4=serious, 5=very serious)

Source **◂ Not serious** **Very serious ▸**

Businesses	1	2	3	4	5
Building/construction	1	2	3	4	5
Golf courses	1	2	3	4	5
Litter/dumping	1	2	3	4	5
Seepage from septic tanks and cesspools	1	2	3	4	5
Storm drains from Lihue urban area	1	2	3	4	5
Cattle operations	1	2	3	4	5
Sugar cane	1	2	3	4	5
Other crops (please specify)	1	2	3	4	5
Other (please specify)	1	2	3	4	5

5. Do you know of any specific sources of water pollution in the Nawiliwili watershed?

Where?	Kind of pollutant?	What is the source?

If you need more room please attach pages.

6. Please mark the locations or areas of the pollution sources identified in question 5 on the accompanying map with circles and note what they are on the map. The Nawiliwili watershed extends eastward to about as far as Kahoaea hill on the map.

7. Please provide any other information about pollution in the watershed that you consider important on a separate sheet of paper.

8. If we have any questions about your responses it would be convenient for us to be able to reach you. If you wouldn't mind being contacted please provide us with your name and contact information here.

   Name:

   Address:

   Phone #1: Phone #2:

   Best time to call: Email address:

NAWILIWILI WATERSHED ASSESSMENT VOLUNTEER SIGN UP FORM

We hope to recruit a number of volunteers from the community to help with some of our project activities. Activities are anticipated to include: conducting visual assessments of all of the streams in the watershed, identifying/documenting polluting activities in the watershed, enumeration and analysis of the results of this survey, helping to organize public information meetings, sampling in the streams and the bay under various conditions, etc. The work will take place between December, 2001 and November, 2003. We will try to accommodate peoples' particular interests and abilities as closely as possible. If you are interested in participating further in this project please answer the questions below. Please understand that you will in no way be held to anything you put down here. If you want to participate we would be grateful to have your help to whatever extent you can afford the time.

☐ **Please check this box if you are interested in volunteering to work on the project.**

(Please be sure to fill in contact information above)

Preferred activity (please rank: 1=favorite, 4=least favorite)

office/computer **public interaction** **sampling** **field work**

If you would like further information please call Philip Moravcik in Honolulu at 956-3097, email him at morav@hawaii.edu, or send him a regular letter at Holmes Hall 283, 2540 Dole St. Honolulu, HI 96822.

APPENDIX B
GIS Maps for the Nawiliwili Watershed

SOURCE: The Internet site of the Hawai'i Statewide GIS Program, which is managed by the State of Hawaii's Office of Planning. The URL address is given below:

- http://www.hawaii.gov/dbedt/gis/

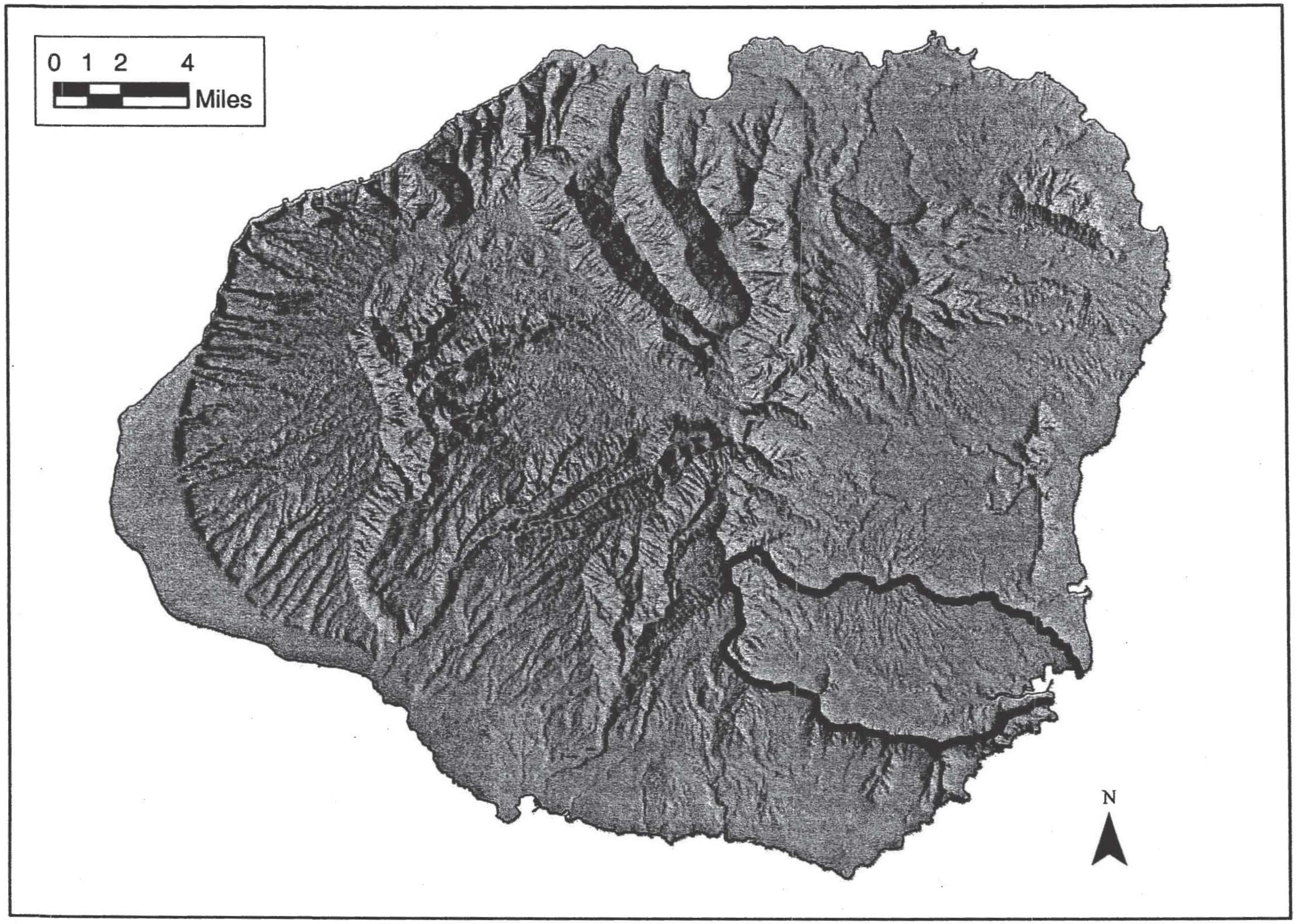

Figure B1. General location of the Nawiliwili Watershed, Kaua'i

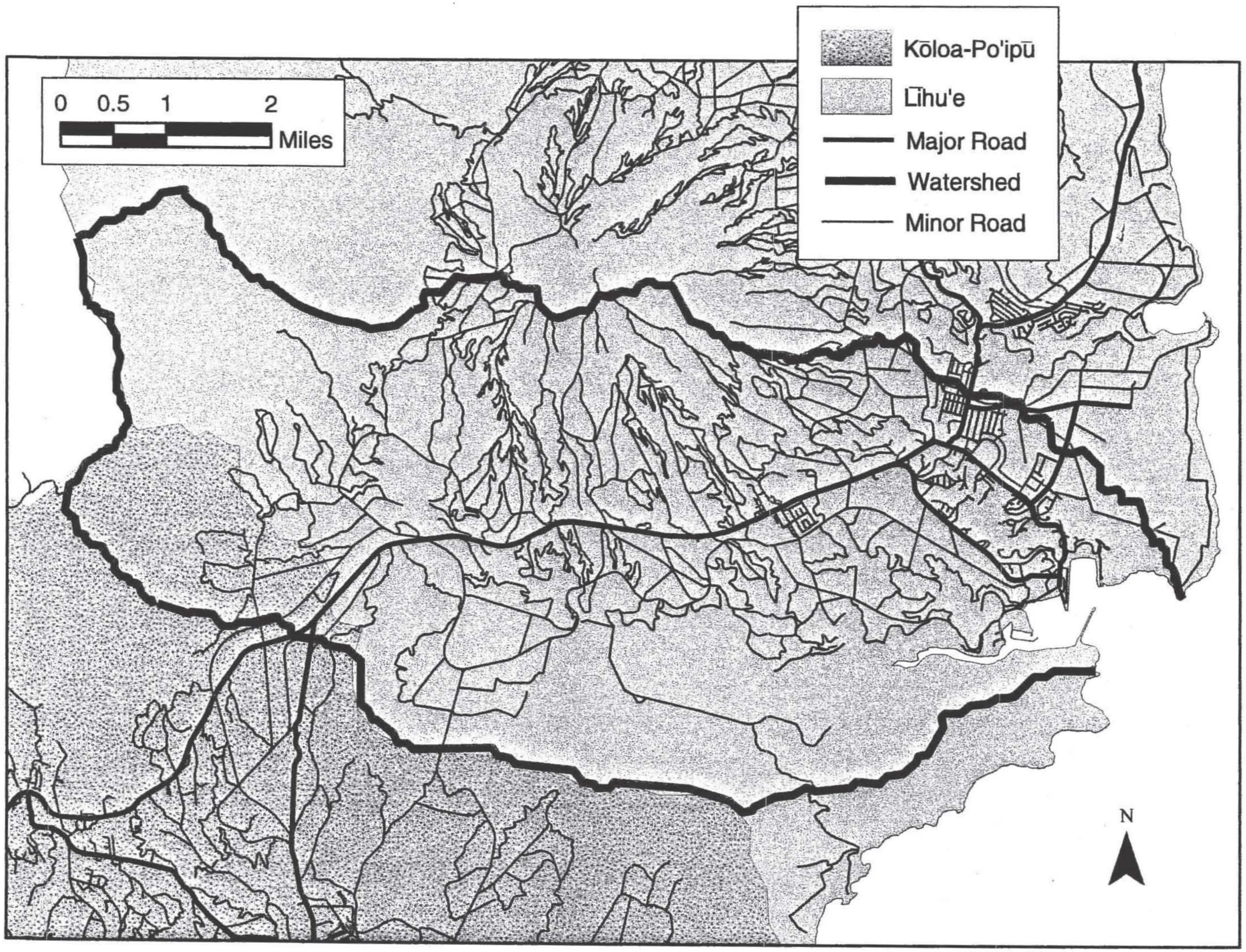

Figure B2. The Nawiliwili Watershed falls in the Līhu'e and Kōloa-Po'ipū districts

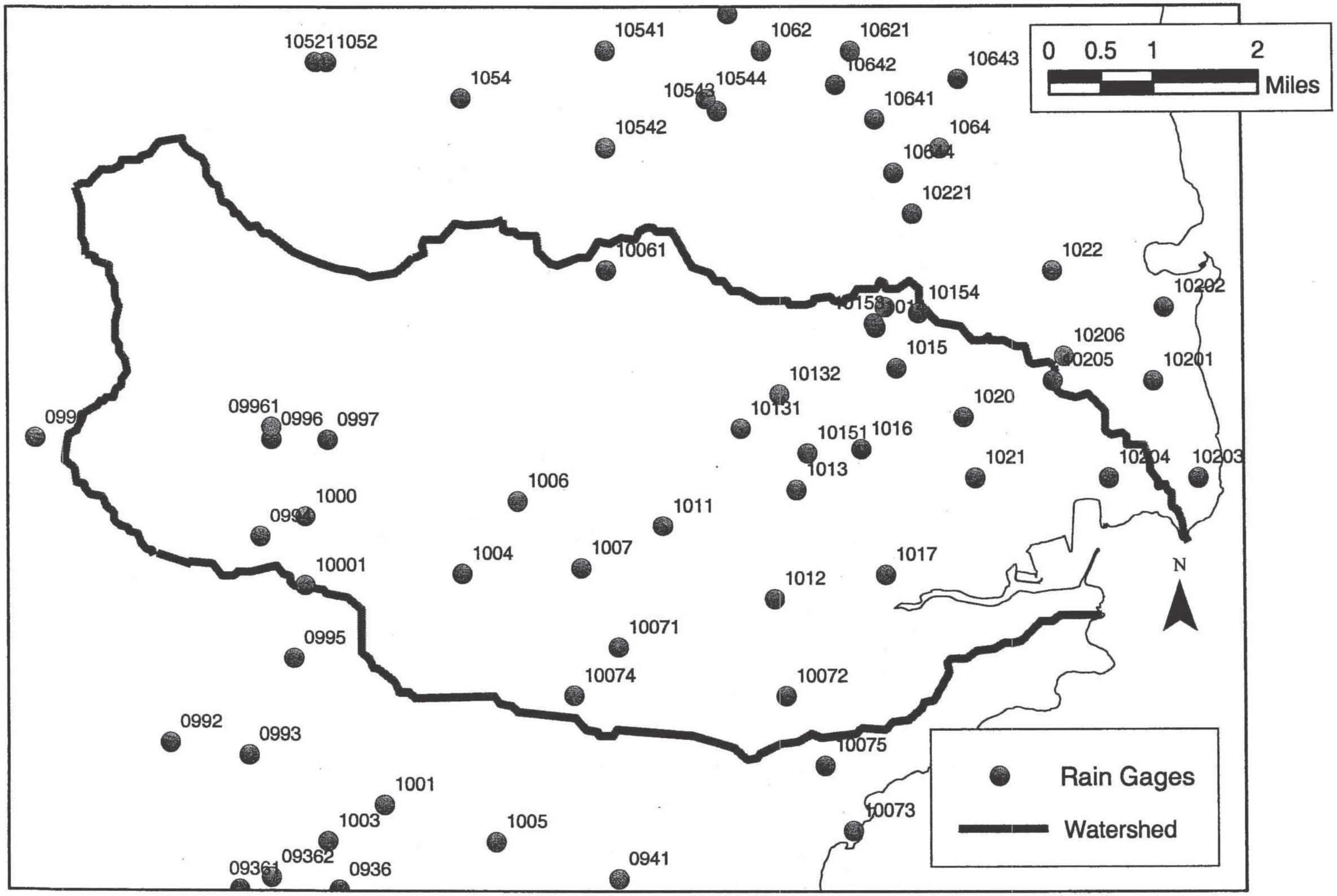

Figure B3. Rain gages in and around the Nawiliwili Watershed. The map lists the State key number of each station. Information about the satations are listed in Table 17

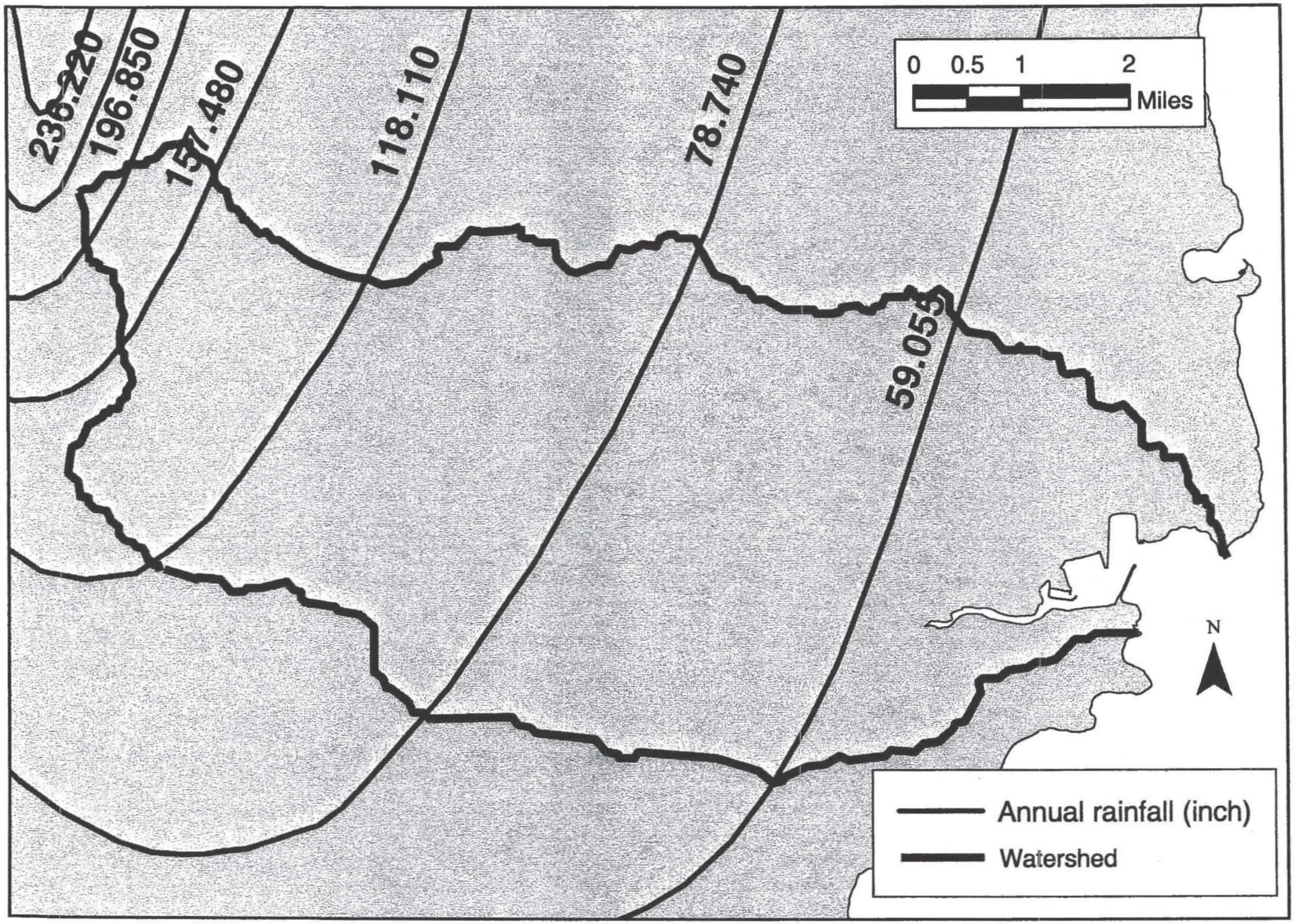

Figure B4. Average annual rainfall in the Nawiliwili Watershed

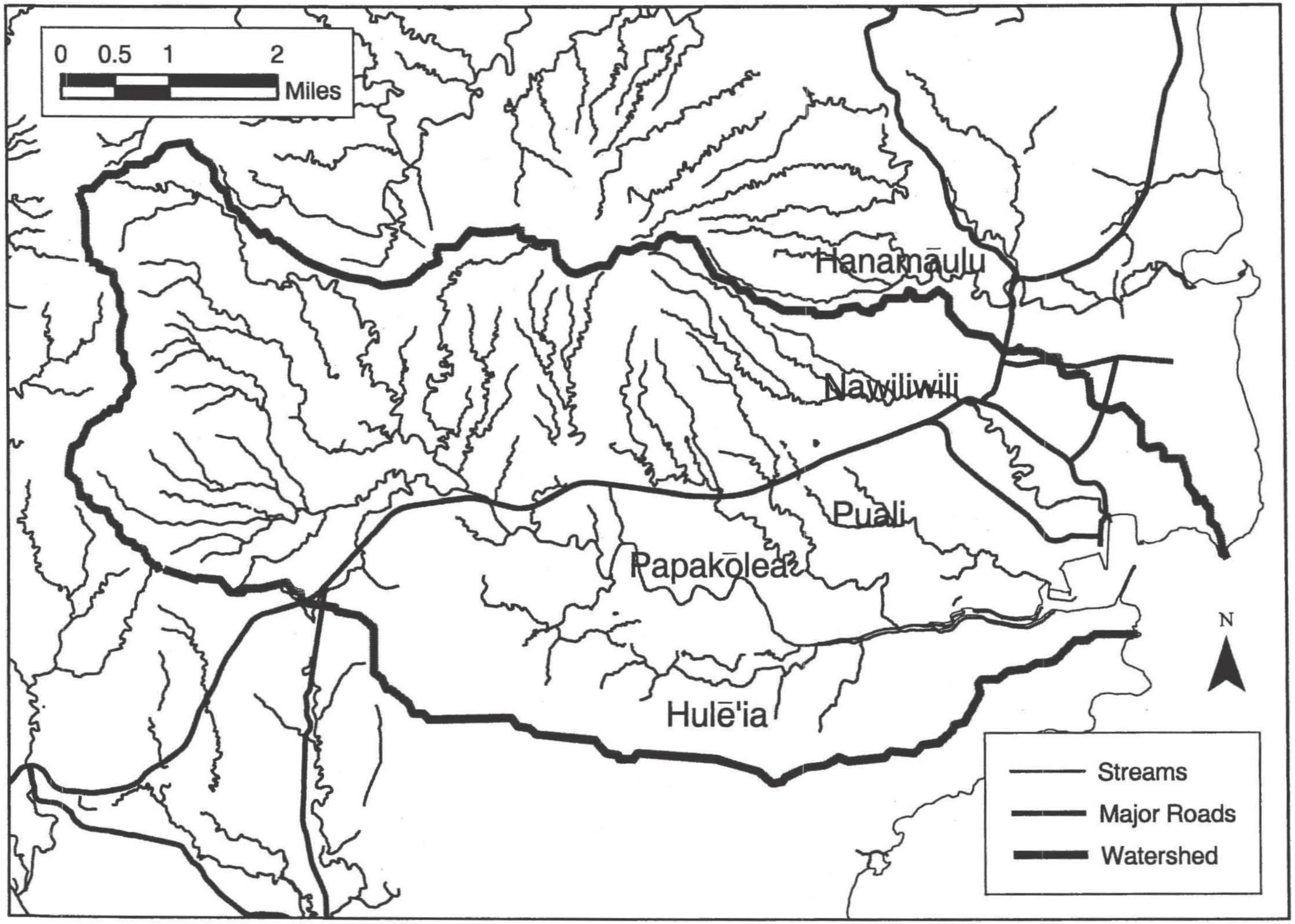

Figure B5. Perennial streams in the Nawiliwili Watershed

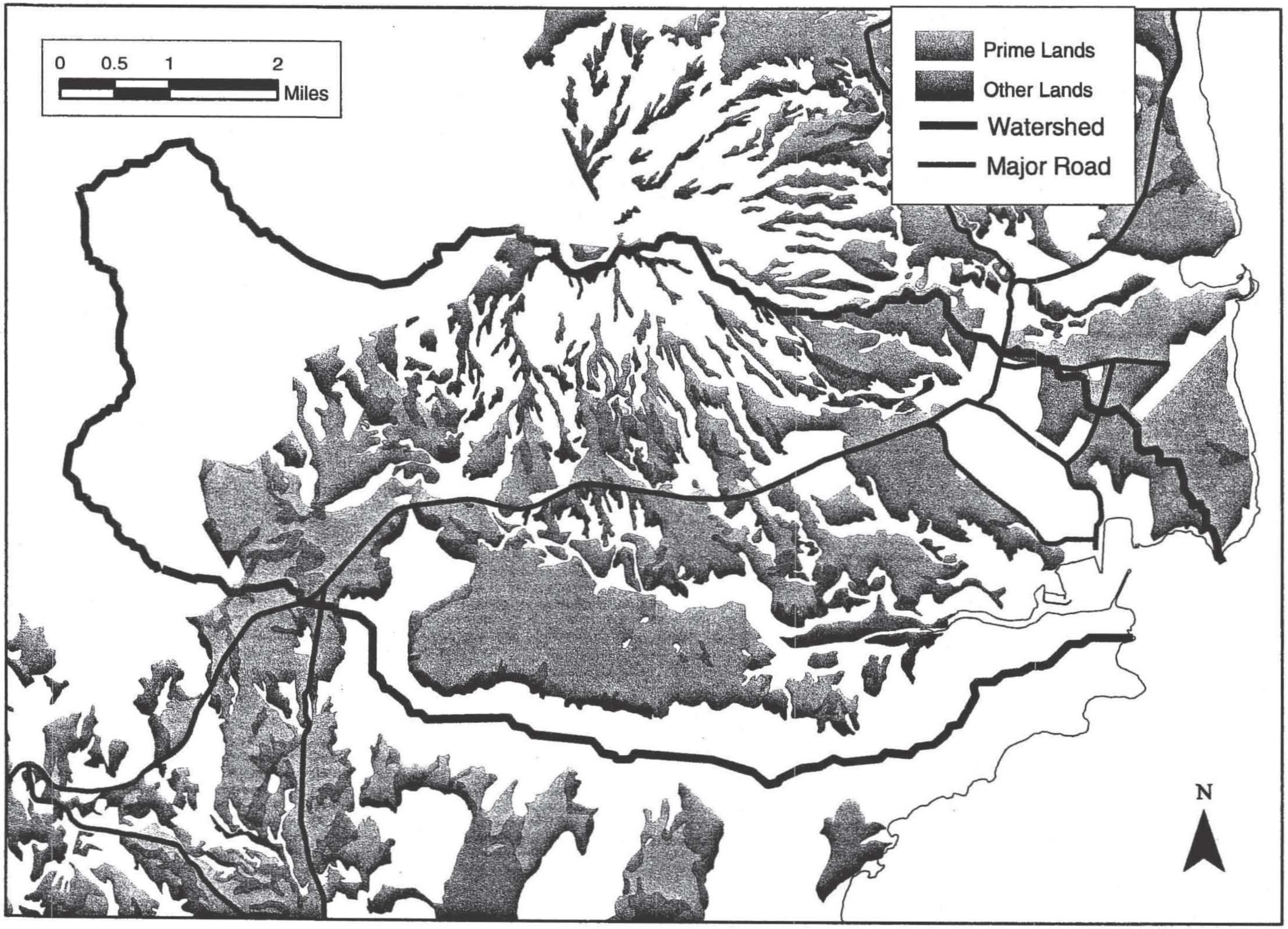

Figure B6. Land of agricultural importance, Nawiliwili Watershed

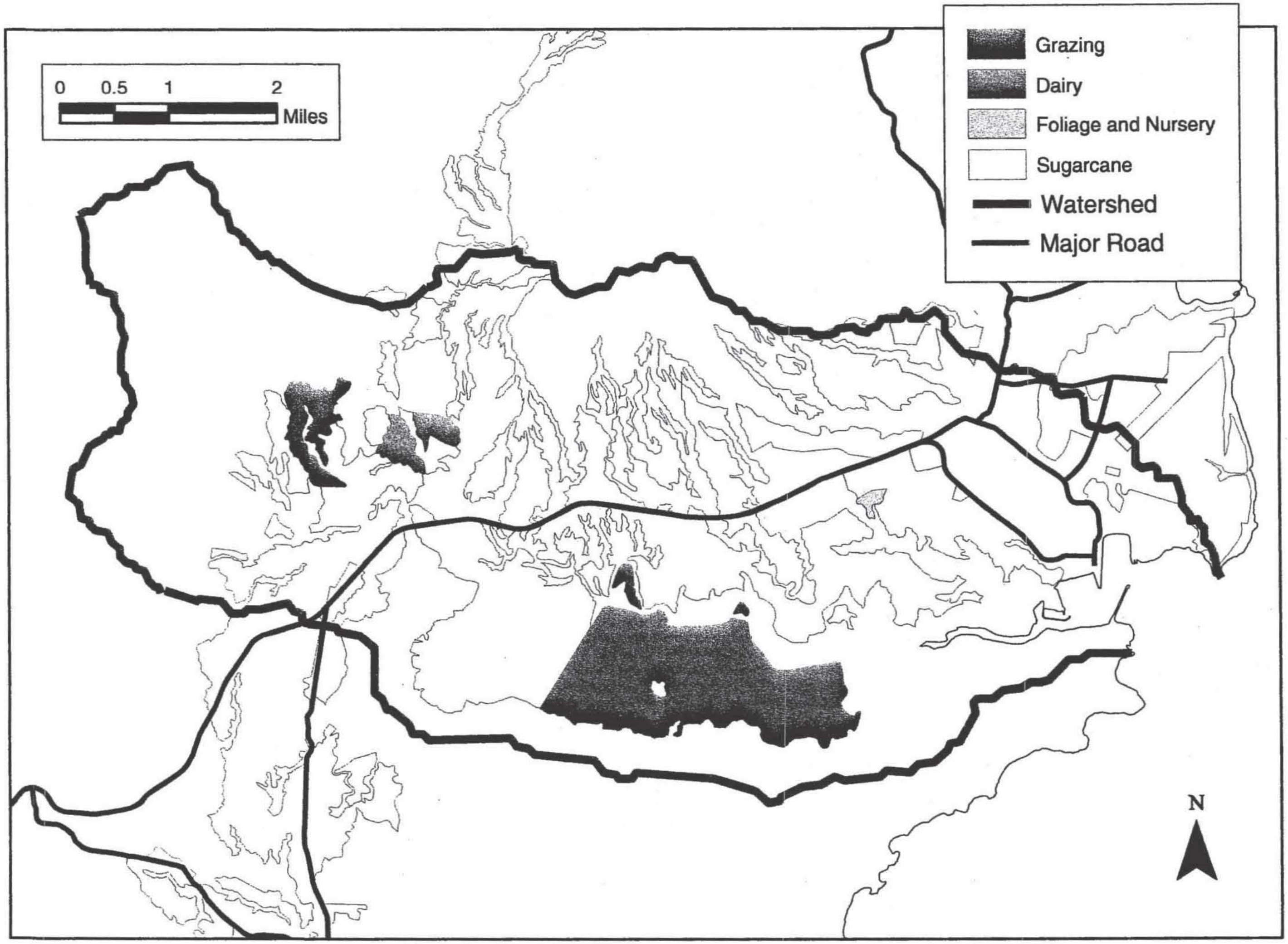

Figure B7. Agricultural land use (1978-1980), Nawiliwili Watershed

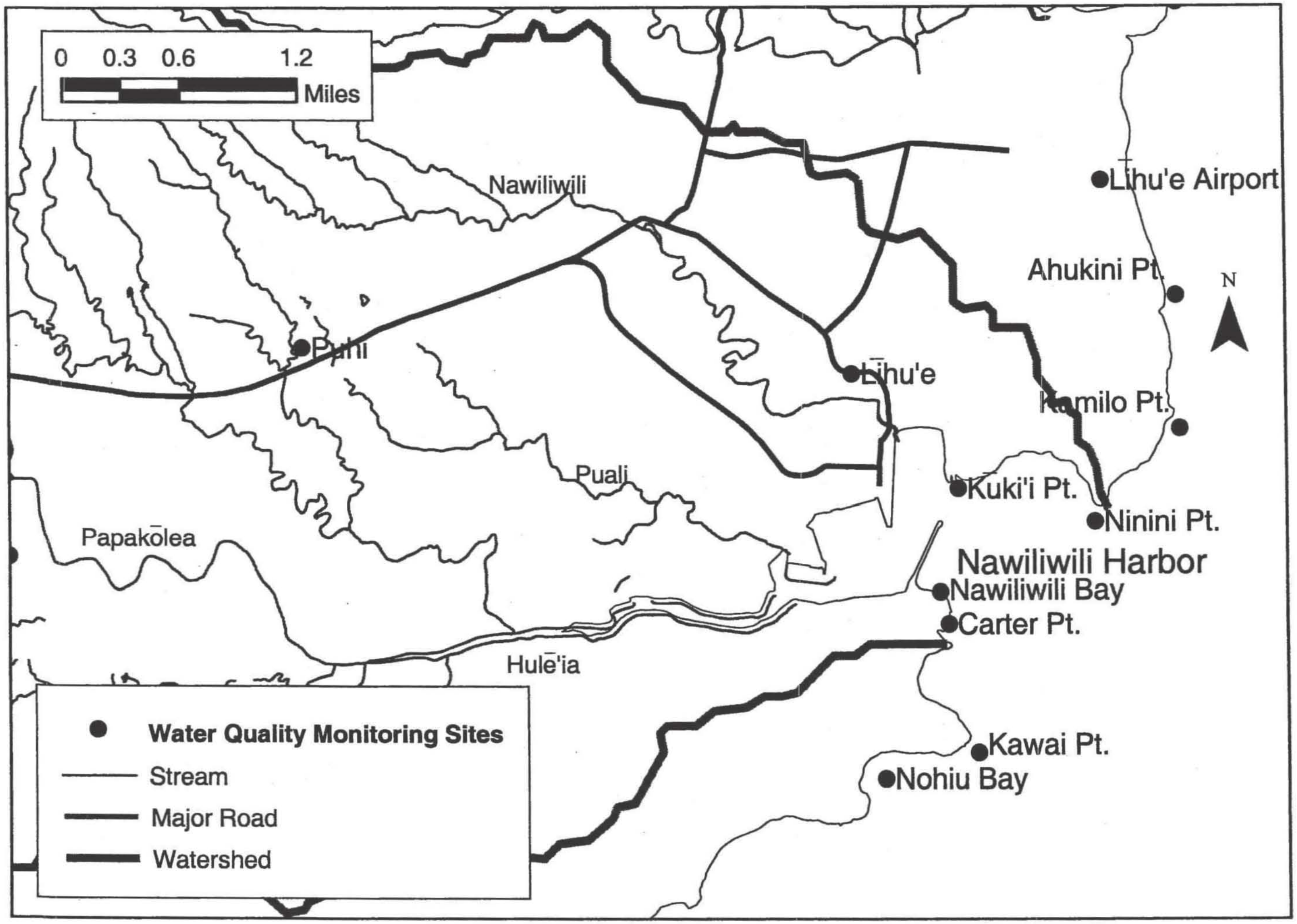

Figure B8. Department of Health's water quality monitoring sites

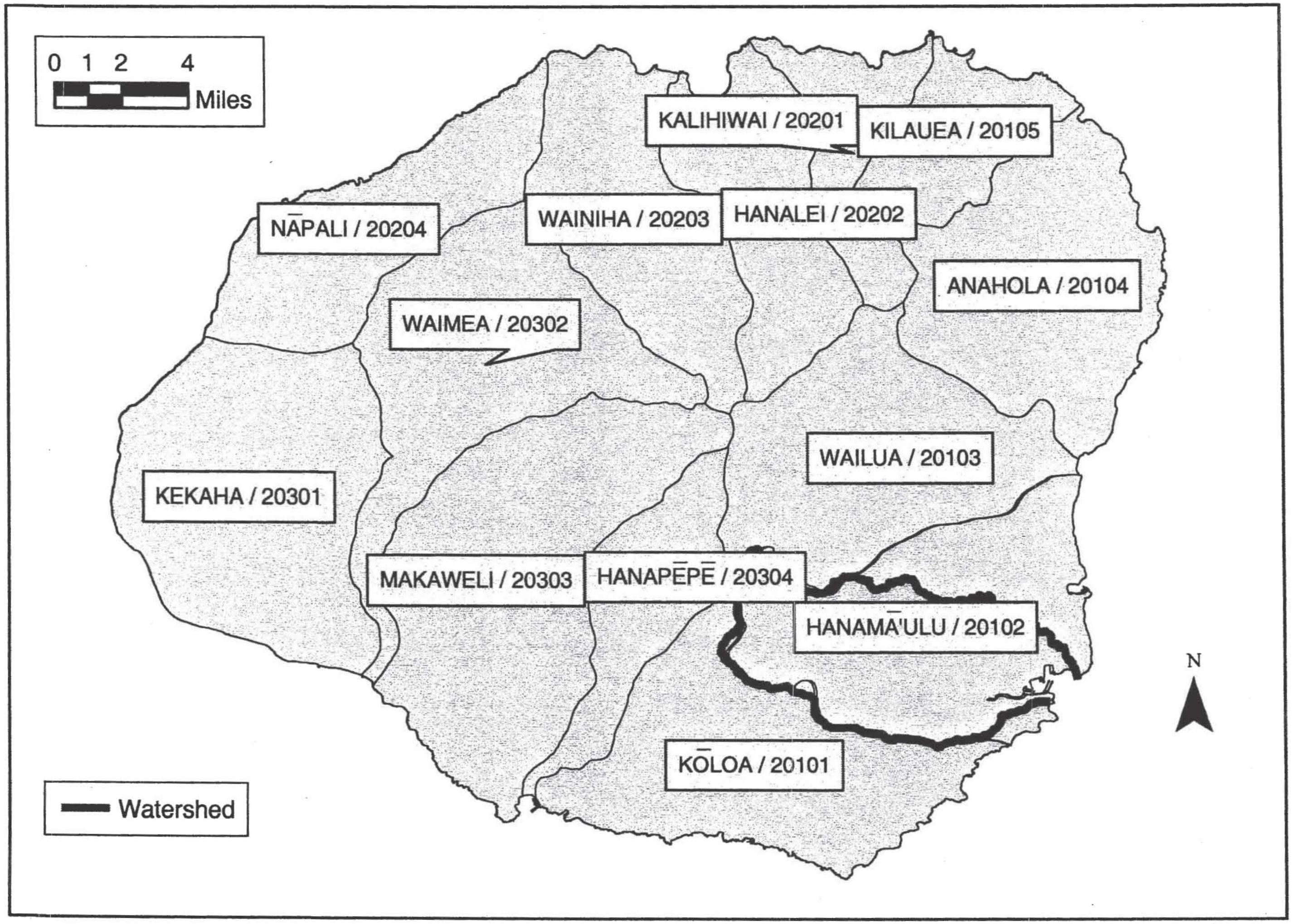

Figure B9. Kaua'i's aquifer systems and codes

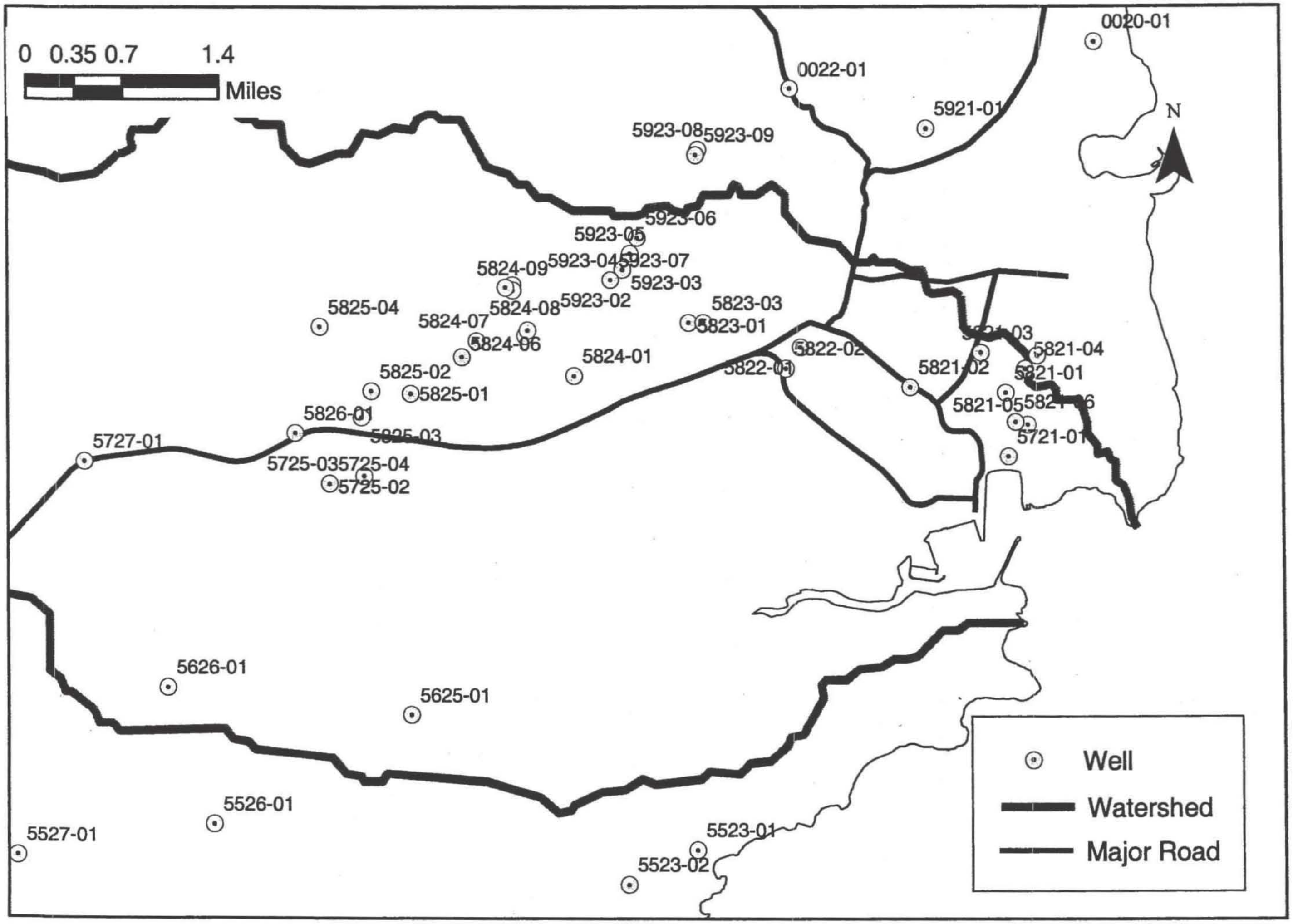

Figure B10. Groundwater wells in the Nawiliwili Watershed and surrounding area. Well numbers are also shown

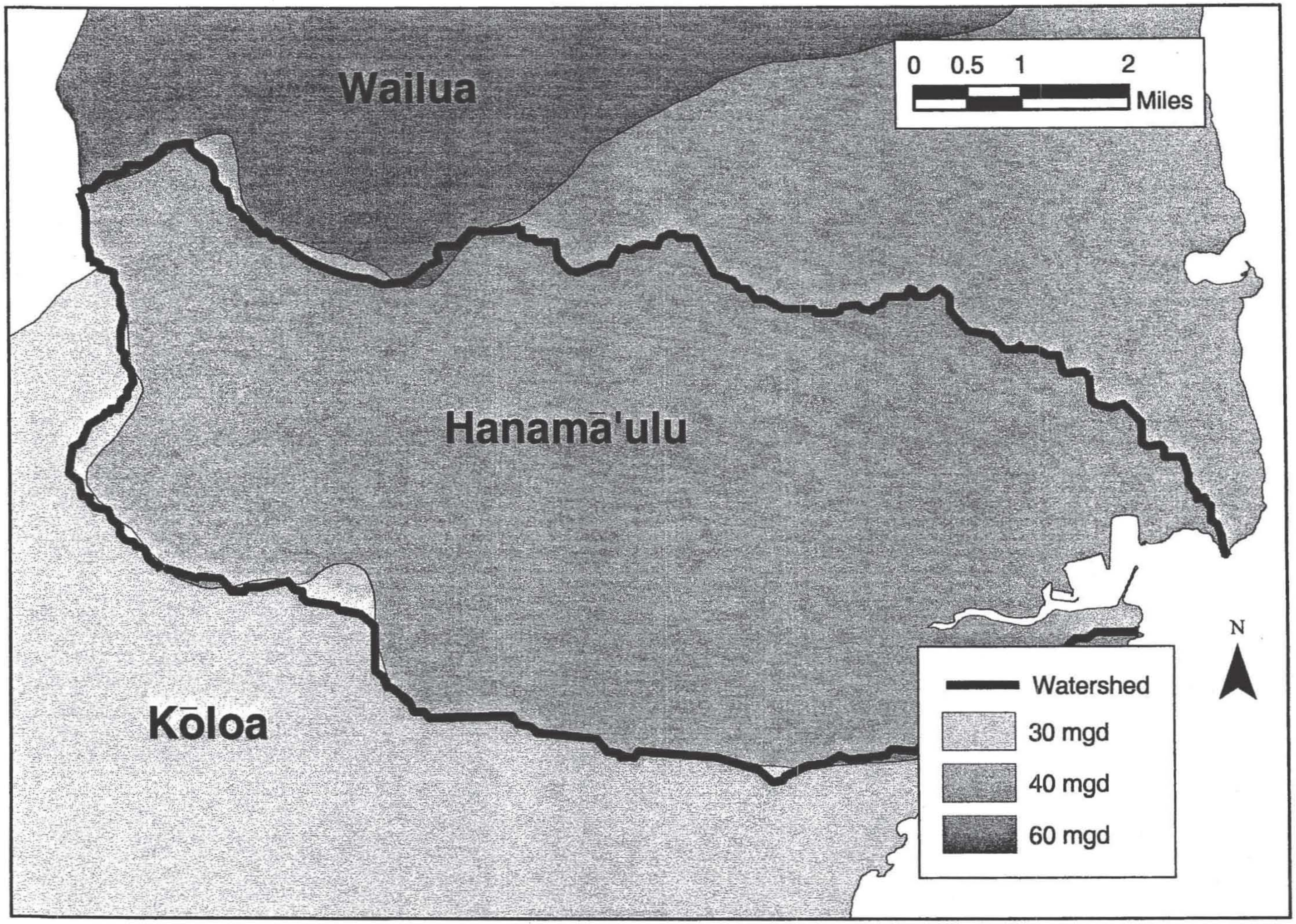

Figure B11. The Hanamā'ulu aquifer system covers most of the Nawiliwili Watershed

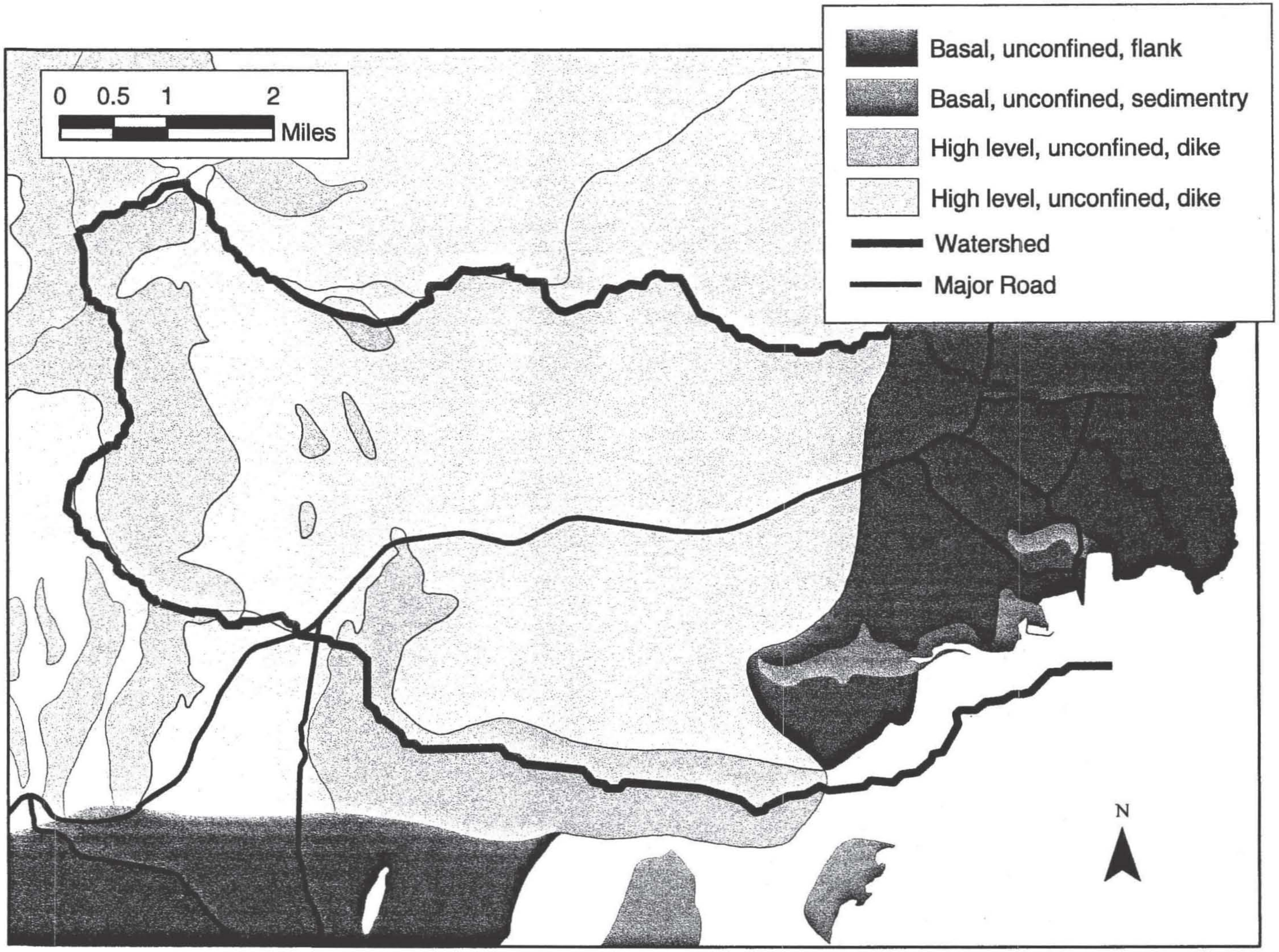

Figure B12. Hydrogeology of the upper aquifer, Hanamā'ulu system

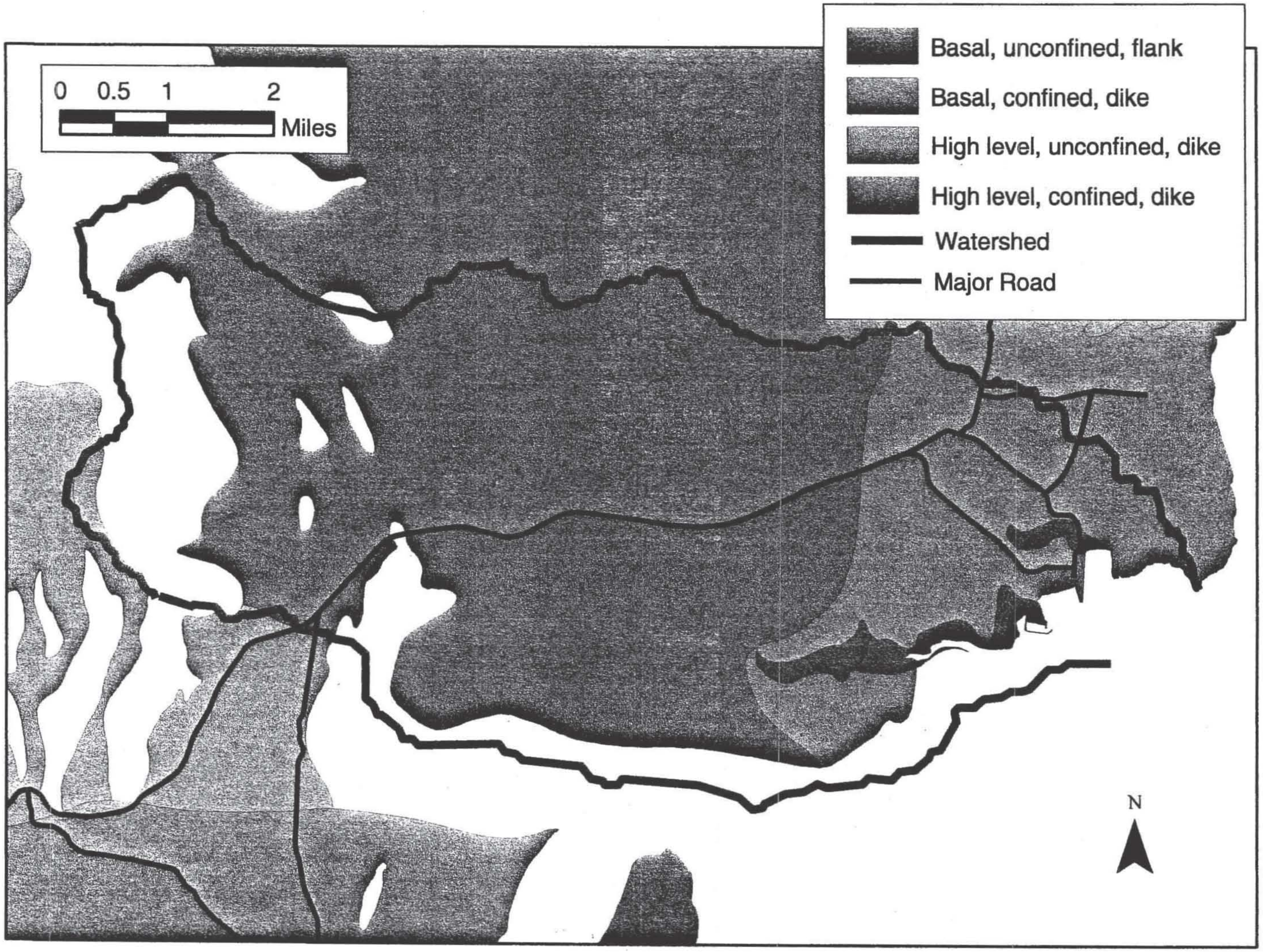

Figure B13. Hydrogeology of the lower aquifer, Hanamā'ulu system

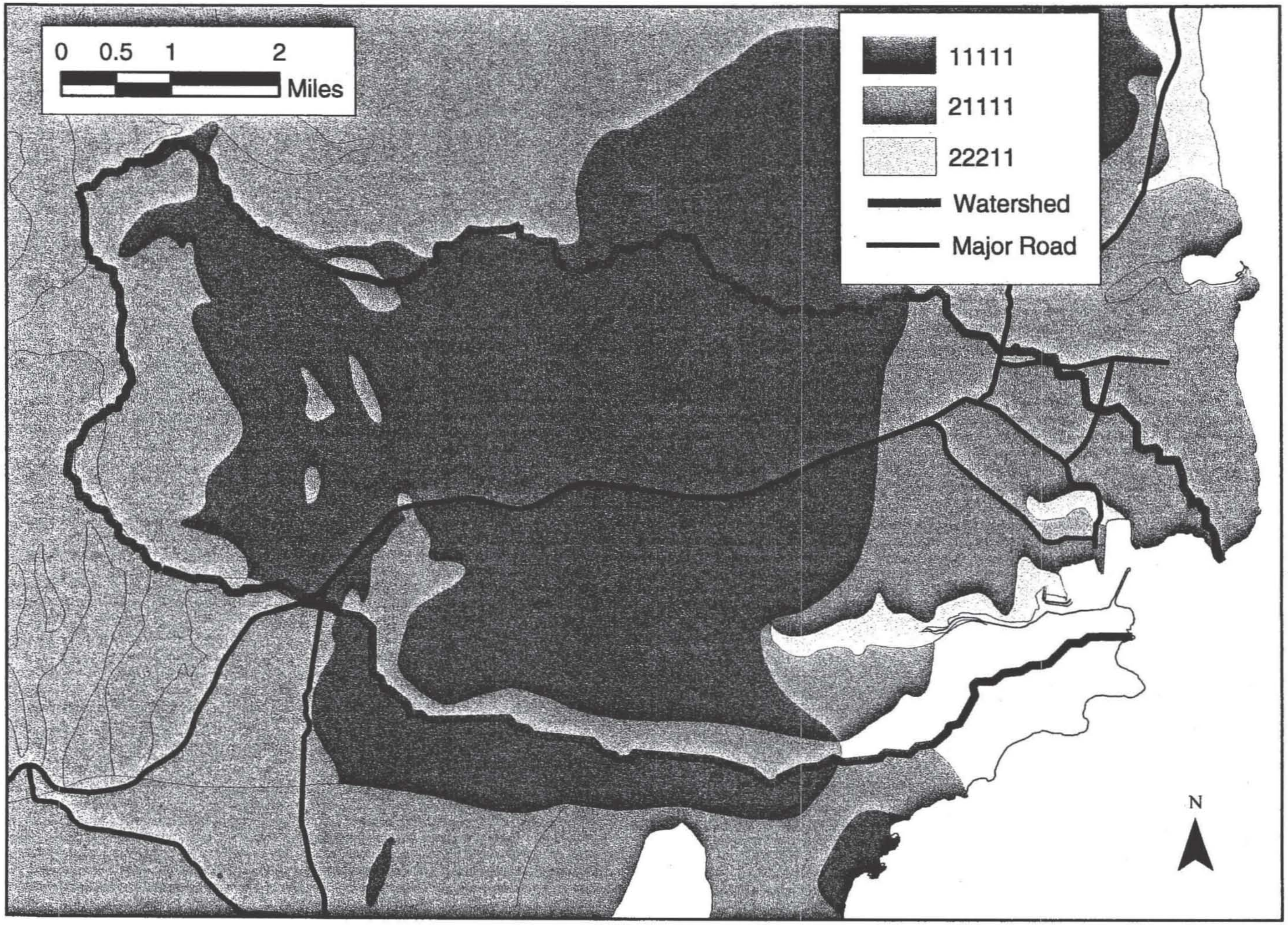

Figure B14. Status codes for the upper aquifer, Hanamā'ulu system

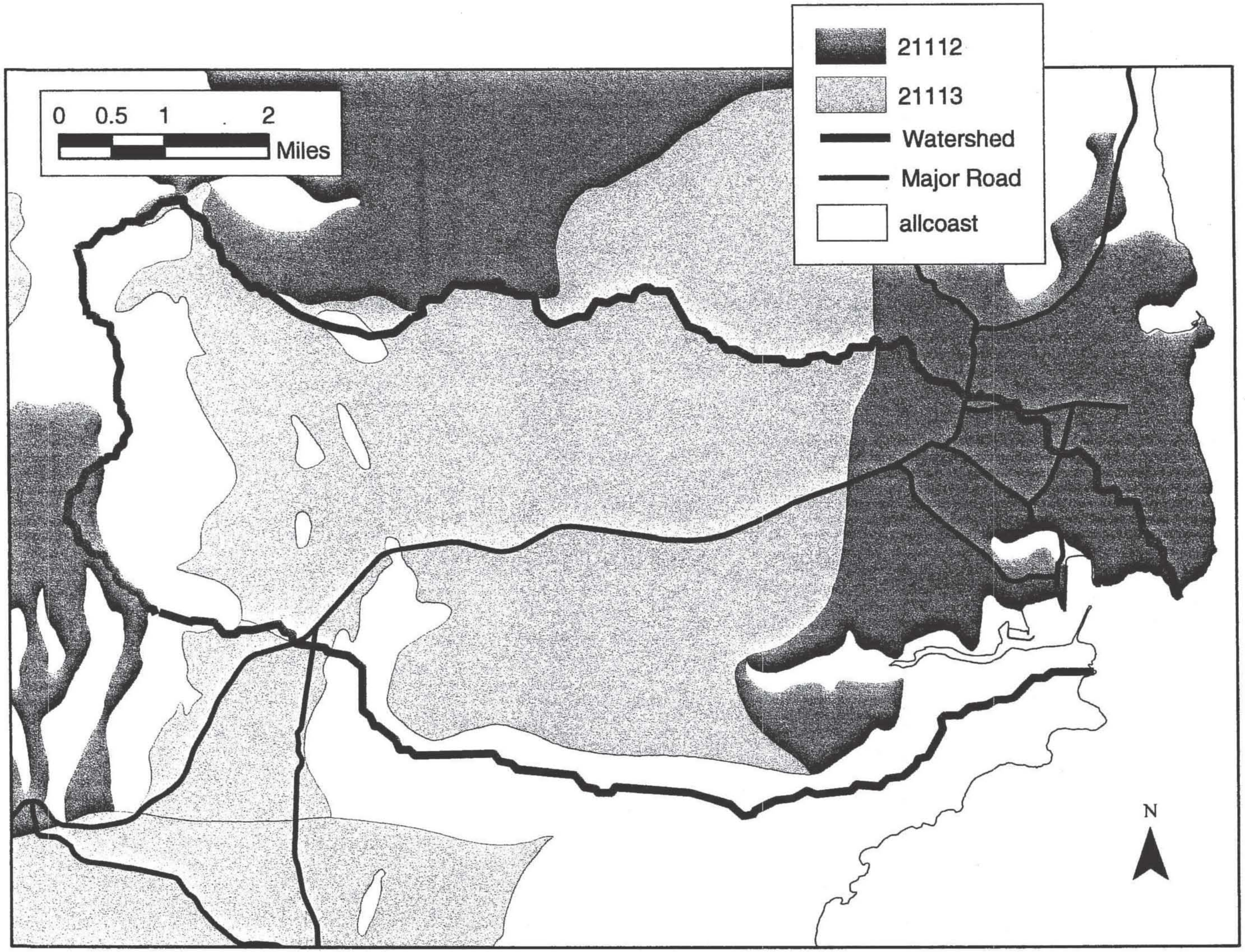

Figure B15. Status codes for lower aquifer, Hanamā'ulu system

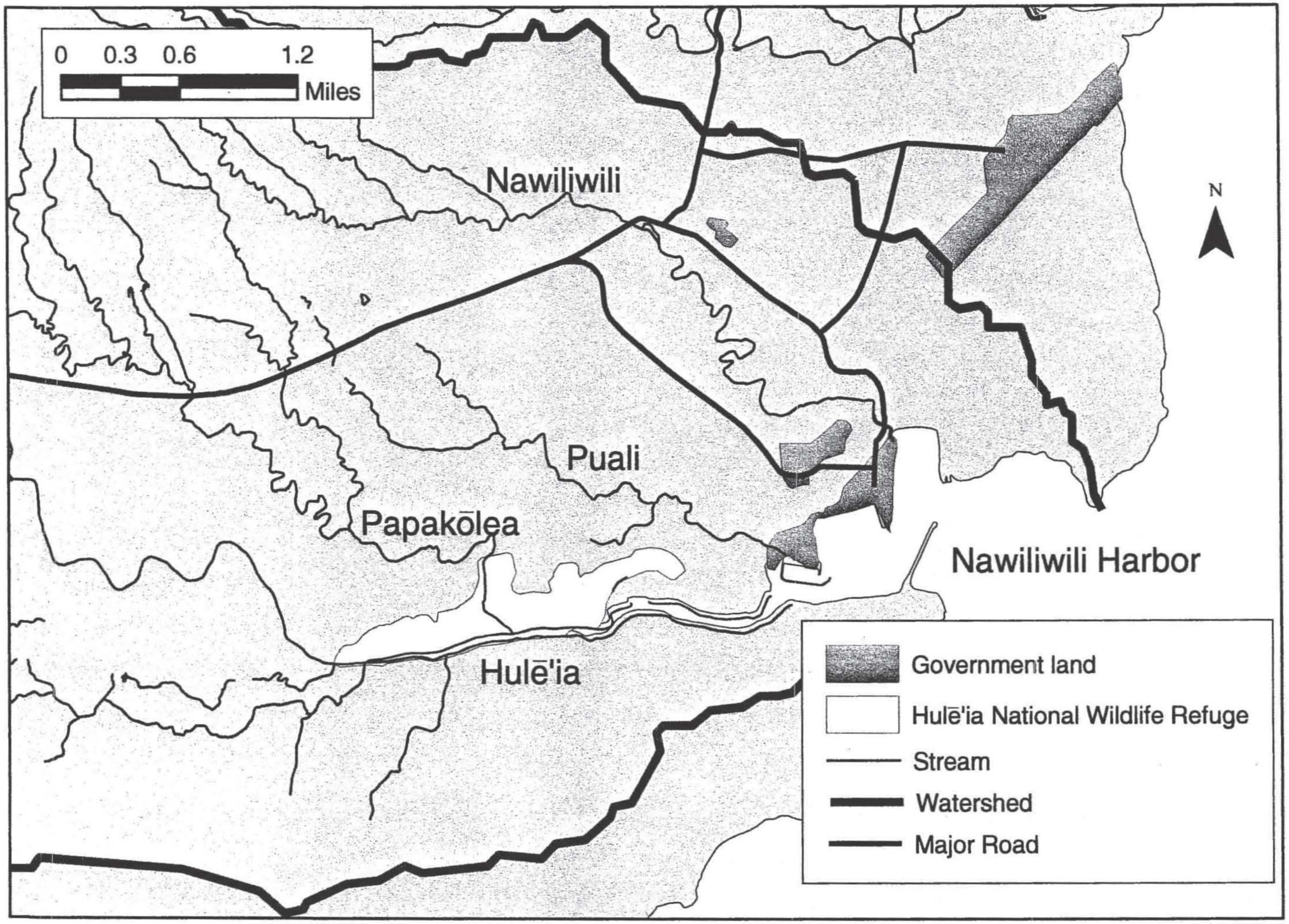

Figure B16. Federal goverment land, Hulē'ia National Wildlife Refuge, and perennial streams near the Nawiliwili Harbor

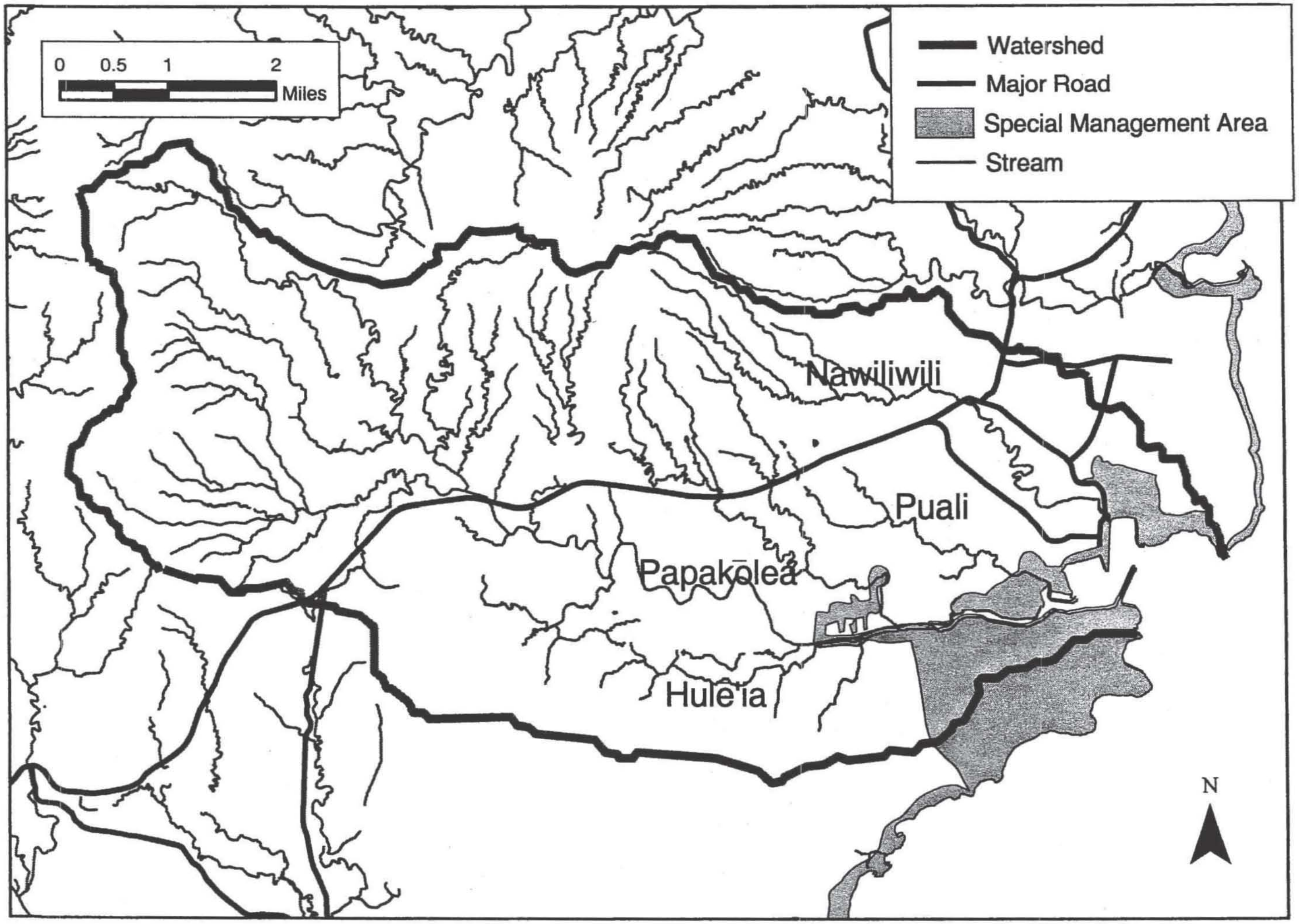

Figure B17. Special management areas, Nawiliwili Watershed

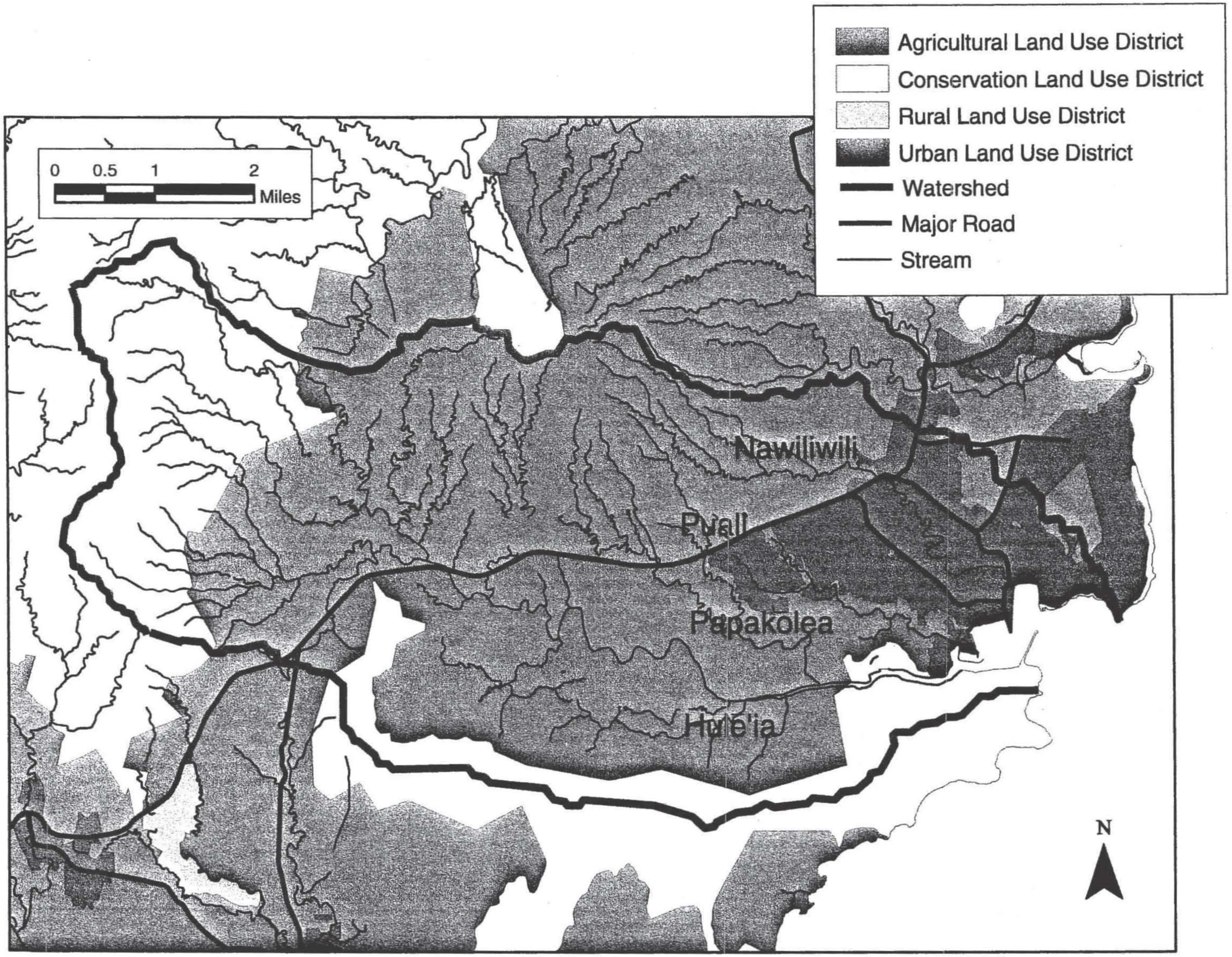

Figure B18. Land Use District Boundaries (2000), Nawiliwili Watershed

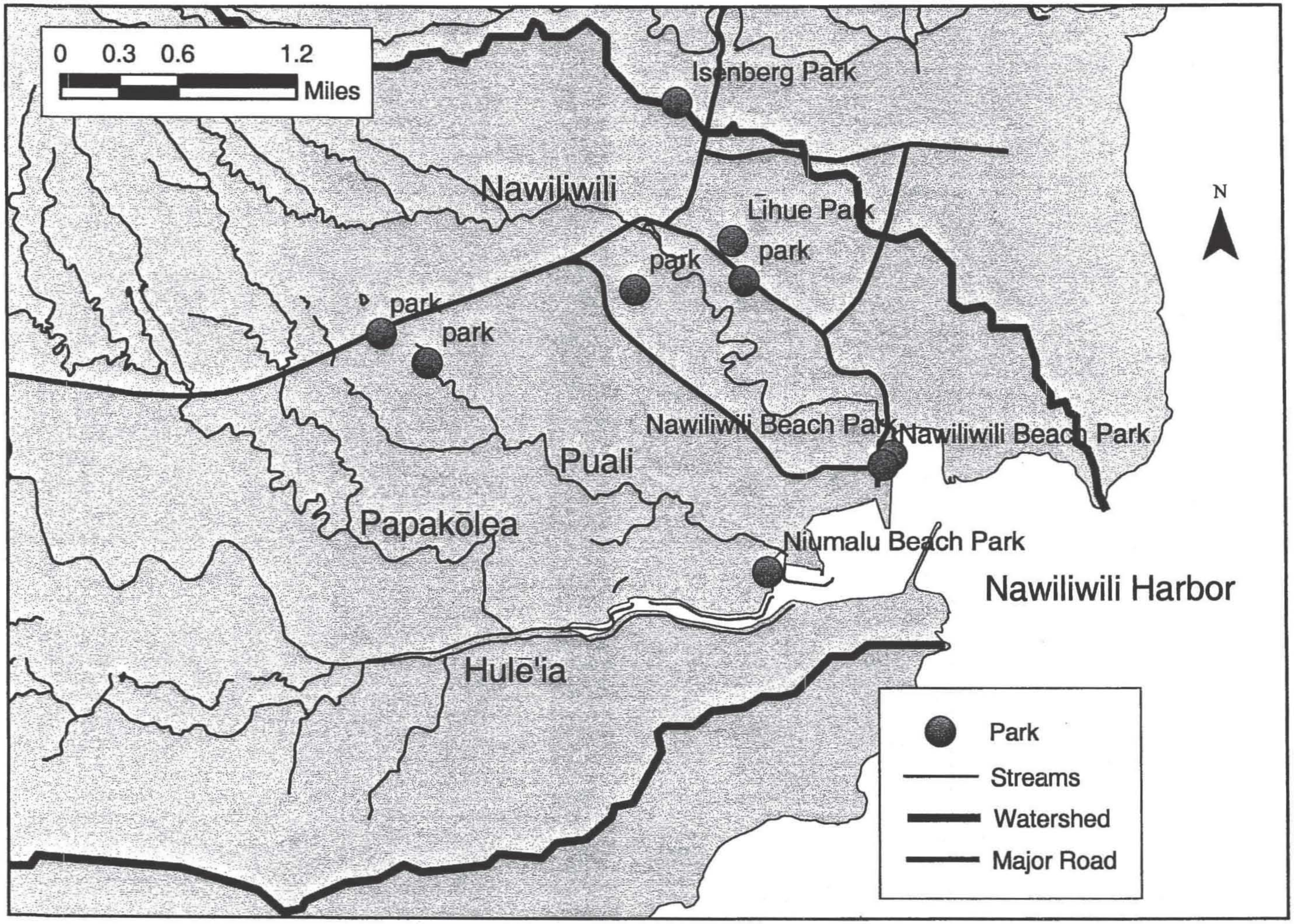

Figure B19. Parks in the Nawiliwili Watershed area

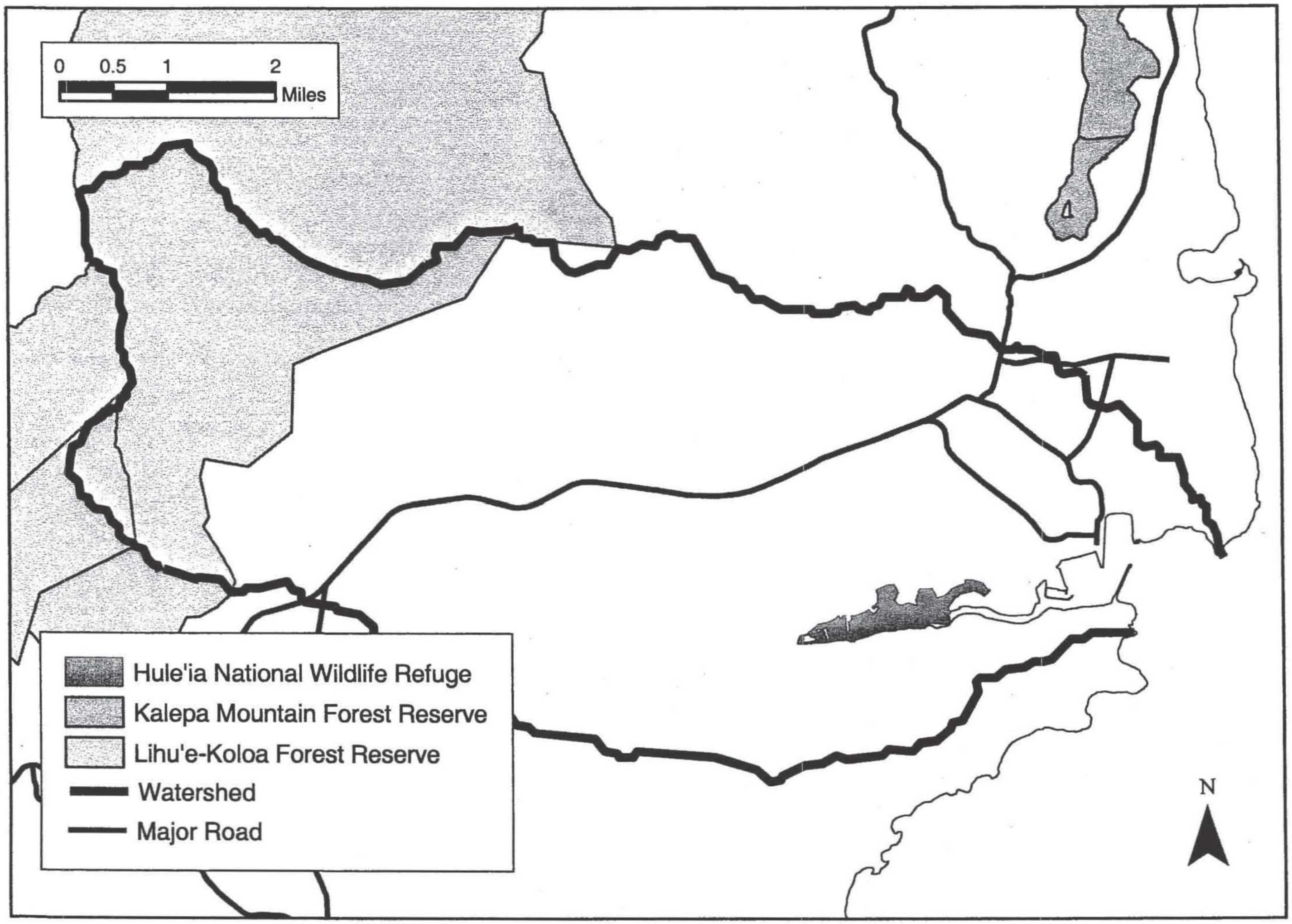

Figure B20. Reserve areas, Nawiliwili Watershed

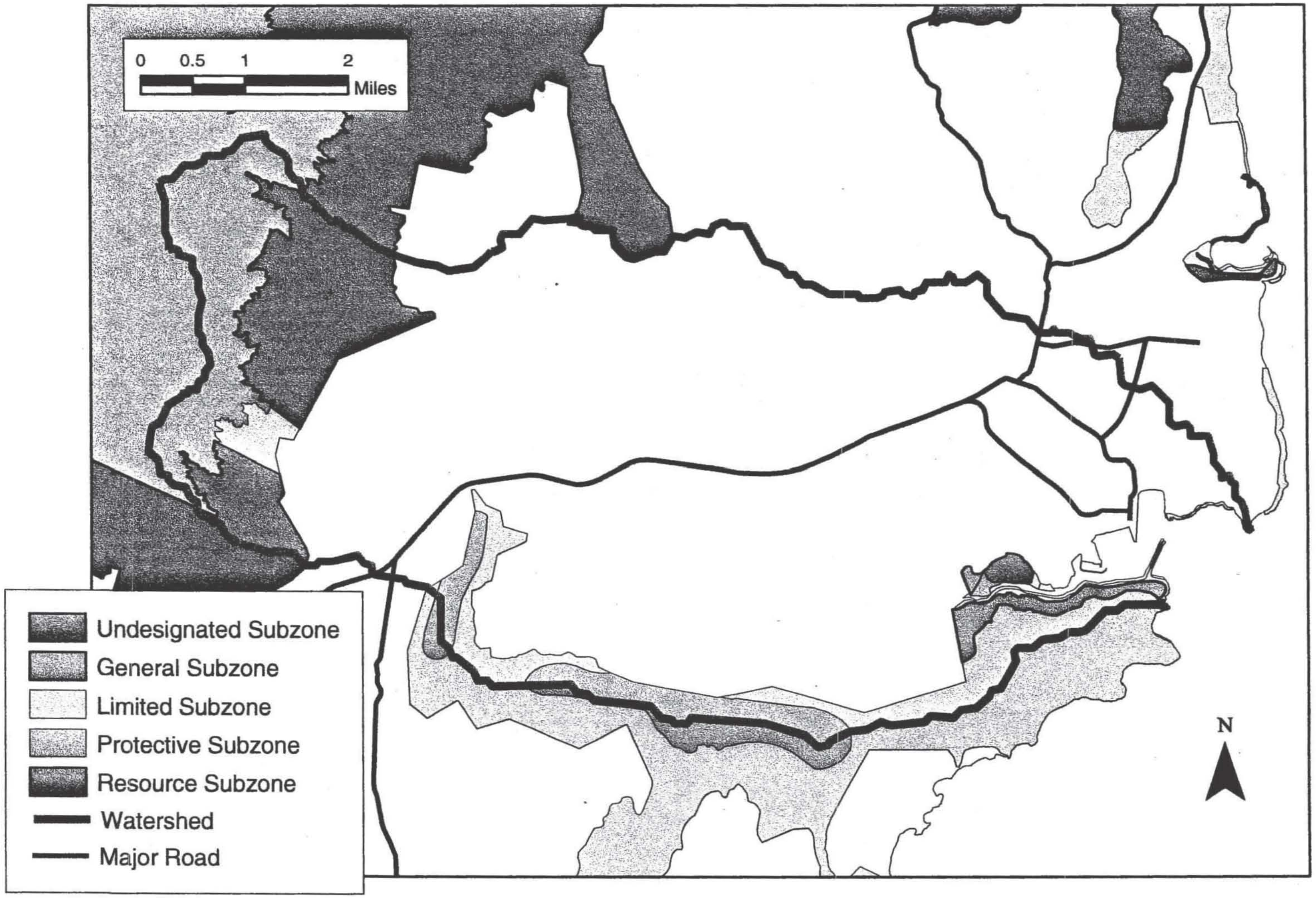

Figure B21.Conservation district subzones, Nawiliwili Watershed

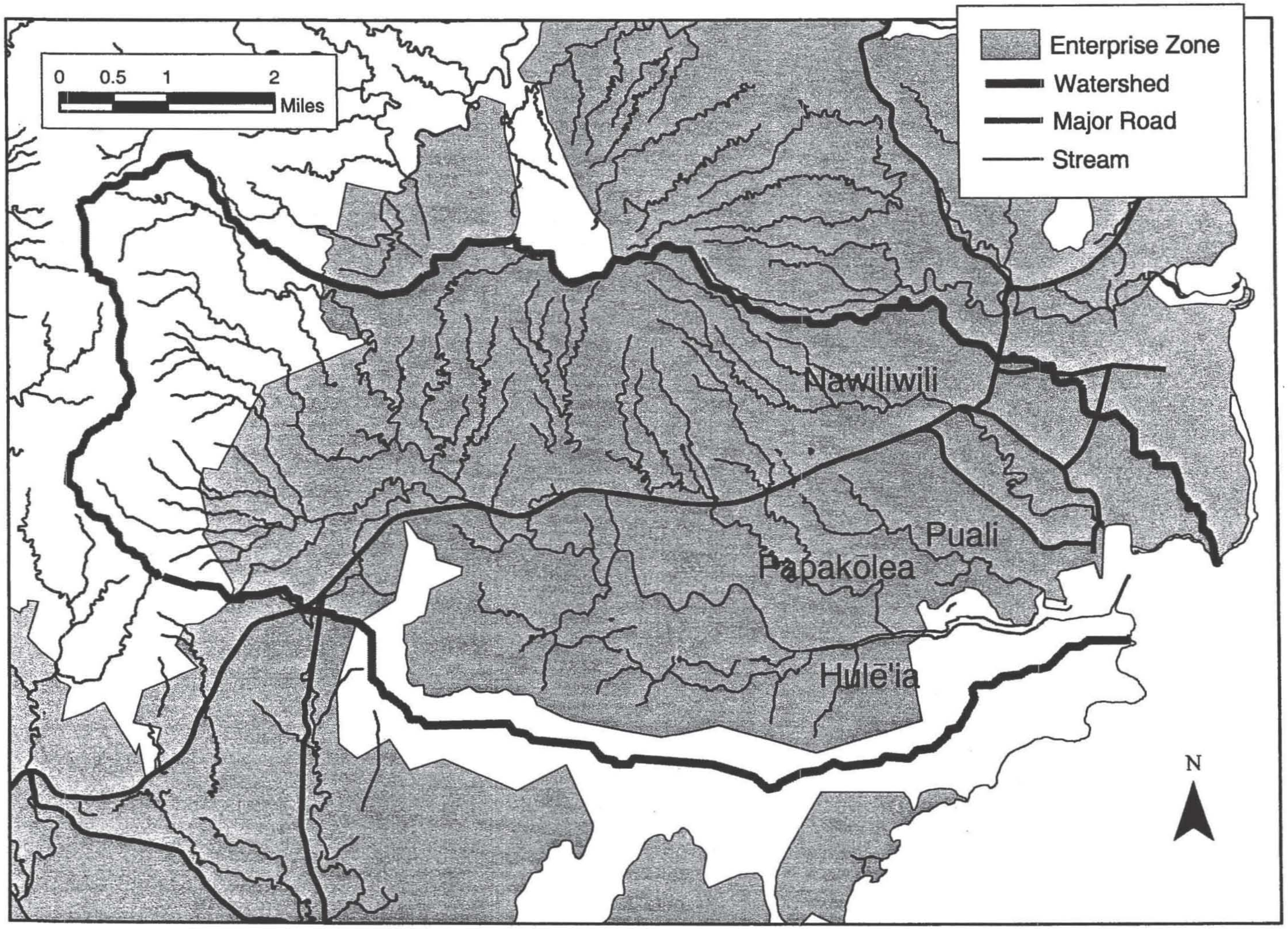

Figure B22.Enterprise zone, Nawiliwili Watershed

APPENDIX C
Definition Text Information for GIS Maps

SOURCE: The Internet site of the Hawai'i Statewide GIS Program, which is managed by the State of Hawaii's Office of Planning. The URL address is given below:

http://www.hawaii.gov/dbedt/gis/

Layer Name:	Agricultural Lands of Importance to the State of Hawaii
Coverage Name:	ALISH
Layer Type:	Polygon
Library: State	
Alt. Path:	/vg02/prime/admin/final/@alish/
Status:	Complete
Geog. Extent:	Main Hawaiian Islands
Projection:	Universal Trans Mercator, Zone 4, Old Hawaiian Datum
Description:	Agricultural Lands of Importance to the State of Hawaii for islands of Kauai, Oahu, Maui, Molokai, Lanai & Hawaii.
Source:	State Department of Agriculture 1:24,000 hand drafted blueline maps; compiled and drafted in 1977. Prepared with the assistance of the Soil Conservation Service, U.S. Department of Agriculture, and the College of Tropical Agriculture, University of Hawaii. See text below for information about the classification system, including criteria for classification.
History:	Digitized in Arc/Info version 6 using ArcEdit by the Office of State Planning (OSP) from State Department of Agriculture's 1:24,000 blueline maps.
Attributes:	Polygons:

AREA	area of polygon (sq. meters)
PERIMETER	perimeter of polygon (meters)
ALISH#	Polygon internal number (for Arc/Info use)
ALISH-ID	Polygon ID (for Arc/Info use)
AGTYPE	Agricultural Type

AGTYPE	Definition
1	Prime Lands
2	Unique Lands
3	Other Lands

Arcs:

FNODE#	From Node Number (for Arc/Info use)
TNODE#	To Node Number (for Arc/Info use)
LPOLY#	Left Polygon Number (for Arc/Info use)
RPOLY#	Right Polygon Number (for Arc/Info use)
LENGTH	Length (meters)
ALISH#	Arc Internal Number (for Arc/Info use)
ALISH-ID	Arc ID (for Arc/Info use)

FLAG	Source of Arc
FLAG	Definition
0	Digitized arc
1	Extracted arc (from 1:24,000 DLGs)
2	Closure arc
3	Coastline arc
9	Other

Note: (from "Agricultural Lands of Importance to the State of Hawaii Revised," State Department of Agriculture, November, 1977).

The Classification System:

The classification system for identification of agriculturally important lands in the State of Hawaii provides for the:

1. Establishment of classes of agricultural lands primarily, but not exclusively, on the basis of soil characteristics;

2. Establishment of criteria for classification of lands; and

3. Identification of lands which meet the criteria for the respective classes.

Three classes of agriculturally important lands were established for the State of Hawaii with the intent of facilitating the SCS effort to inventory prime farmlands nationally and adapting the classification to the types of agricultural activity in Hawaii. These classes and their corresponding SCS (national) equivalents are:

Hawaii Classificiation System	SCS Classification System
Prime Agricultural Land	Prime Farmland
Unique Agricultural Land	Unique Farmland
Other Important Agricultural Land	Additional Farmland of Statewide and Local Importance

The criteria for classification of PRIME AGRICULTURAL LAND are identical to the criteria established by SCS for national application. The criteria for UNIQUE AGRICULTURAL LAND and OTHER IMPORTANT AGRICULTURAL LAND were established cooperatively by the Soil Conservation Service in Hawaii, the College of Tropical Agriculture, and the State Department of Agriculture.

Land considered for classification may or may not currently be in agricultural use, or may be in an agricultural use other than that which its classification may indicate as its agricultural capability. An example of the latter situation is land currently being used for grazing but which meets the criteria for Prime Agricultural Land. Lands not considered for classificiation as agricultural lands of importance to the State of Hawaii are:

1. Developed urban land over 10 acres;

2. Natural or artificial enclosed bodies of water over 10 acres;

3. Forest reserves;

4. Public use (parks and historic sites) lands;

5. Lands with slopes in excess of 35%; and

6. Military installations, except undeveloped areas over 10 acres.

The classification of agriculturally important lands does not in itself constitute a designation of any area to a specific land use. The classification should, however, provide decision makers with an awareness of the long-term implications of various land use options for production of food, feed, forage, and fiber crops in Hawaii.

Over time new areas may be developed for agricultural uses, other areas may be converted to irreversible non-agricultural uses, and new knowledge may be gained regarding soil interpretations. These and other developments will necessitate the periodic review and revision of the classification system and lands identified for the various classes.

The Criteria for Classification:

PRIME AGRICULTURAL LAND

PRIME AGRICULTURAL LAND is land best suited for the production of food, feed, forage and fiber crops. The land has the soil quality, growing season, and moisture supply needed to produce sustained high yields of crops economically when treated and managed, including water management, according to modern farming methods.

PRIME AGRICULTURAL LAND meets the following criteria:

1. The soils have an adequate moisture supply. Included are:

   a. Soils having aquic or udic moisture regimes. (For definitions of moisture regimes see Soil Taxonomy, Agricultural Handbook 436, December 1975). These soils commonly are in humid or subhumid climates that have well distributed rainfall or have enough rain in the summer that the amount of stored moisture plus rainfall is approximately equal to or exceeds the amount of potential evapotranspiration. Water moves through the soils at some time in most years.

   b. Soils having xeric or ustic moisture regimes and in which the available water capacity is great enough to provide adequate moisture for the commonly grown crops in 7 or more years out of 10.

   c. Soils having aridic or torric moisture regimes and the area has a developed irrigation water supply that is dependable and of adequate quality. Also included are soils having xeric or ustic moisture regimes in which the available water capacity is limited but the area has a developed irrigation water supply that is dependable and of adequate quality.

d. Soils having sufficient available water capacity within a depth of 40 inches (1 meter), or in the root zone if the root zone is less than 40 inches deep, to produce the commonly grown crops in 7 or more out of 10 years.

A dependable water supply is one in which enough water is available for irrigation in 8 out of 10 years for the crops commonly grown.

2. The soils have a soil temperature regime that is isomesic, isothermic, or isohyperthermic. These are soils that, at a depth of 20 inches (50 cm), have a mean annual temperature higher than 47 degrees F (8 degrees C), and the difference between the mean summer and mean winter temperature differ by less than 9.0 degrees F (5 degrees C).

3. The soils have a pH between 4.5 and 8.4 in all horizons within a depth of 40 inches (1 meter) or in the root zone if the root zone is less than 40 inches deep. (Soils which have a pH of less than 4.5 in surface soil because of use of fertilizers are excluded). This range of pH is favorable for growing a wide variety of crops without adding large amounts of amendments.

4. The soils have no water table or a water table that is maintained at a sufficient depth during the cropping season to allow crops common to the area to be grown.

5. The soils can be managed so that in all horizons within a depth of 40 inches (1 meter) or in the root zone if the root zone is less than 40 inches deep, during part of each year the conductivity of saturation extract is less than 4 mmhos/cm and the exchangeable sodium percentage (ESP) is less than 15.

6. The soils are not flooded frequently during the growing season (less often than once in 2 years).

7. The soils have a product of K (erodability factor) x percent slope of less than 2.0. That is, soils having a serious erosion hazard are not included.

8. The soils have a permeability rate of at least 0.06 inches (0.15 cm) per hour in the upper 20 inches (50 cm) and the mean annual soil temperature at a depth of 20 inches is less than 57 degrees F (14 degrees C). Permeability rate is not a limiting factor if the mean annual soil temperature is 57 degrees F (14 degrees C) or higher.

9. Less than 10 percent of the surface layer in these soils consists of rock fragments coarser than 3 inches (7.6 cm). These soils present no particular difficulty in cultivating with large equipment.

10. Must not be thixotropic and have isomesic temperature regime.

UNIQUE AGRICULTURAL LAND

UNIQUE AGRICULTURAL LAND is land other than PRIME AGRICULTURAL LAND and is used for the production of specific high-value food crops. The land has the special combination of soil quality, growing season, temperature, humidity, sunlight, air drainage, elevation, aspect, moisture supply, or other conditions, such as nearness to market, that favor the production of a specific crop of high quality and/or high yield when the land is treated and managed according to modern farming methods. In Hawaii, some examples of such crops are coffee, taro, rice, watercress and non-irrigated pineapple.

Land that qualifies as PRIME AGRICULTURAL LAND and is used for a specific high-value crop is classified as PRIME AGRICULTURAL LAND rather than as UNIQUE AGRICULTURAL LAND.

OTHER IMPORTANT AGRICULTURAL LAND

OTHER IMPORTANT AGRICULTURAL LAND is land other than PRIME or UNIQUE AGRICULTURAL LAND that is of state-wide or local importance for the production of food, feed, fiber and forage crops. The lands in this classification are important to agriculture in Hawaii yet they exhibit properties, such as seasonal wetness, erodibility, limited rooting zone, slope, flooding, or droughtiness, that exclude them from the PRIME or UNIQUE AGRICULTURAL LAND classifications. Two examples are lands which do not have an adequate moisture supply to qualify as PRIME AGRICULTURAL LAND and lands which have similar characterisitics and properties as UNIQUE AGRICULTURAL LAND except that the land is not currently in use for the production of a "unique" crop. These lands can be farmed satisfactorily by applying greater inputs of fertilizer and other soil amendments, drainage improvement, erosion control practices, flood protection and produce fair to good crop yields when managed properly.

Other criteria which may qualify lands as OTHER IMPORTANT AGRICULTURAL LAND are:

1. The land has slopes less than 20%, is presently in crop or has cropping potential, and is not classified as PRIME or UNIQUE AGRICULTURAL LAND. The soils have a moisture supply which is adequate for the commonly grown crop.

2. The land has slopes less than 35%, is presently used for grazing or has grazing potential, and is not classified as PRIME or UNIQUE AGRICULTURAL LAND. The soils have:

   a. An aquic, udic, xeric, or ustic moisture regime in which the available water capacity is sufficient to produce fair to good yields of adapted forage.

b. Less than 10% rock outcrops and coarse fragments coarser than 3 inches (7.6 cm) in the surface layer.

3. The soils are thin organic soils underlain by aa lava (typic tropo-folists) having aquic, udic, xeric, or ustic moisture regimes and isohyperthemic (greater than 72 degrees F) or isothermic (59 - 72 degrees F) soil temperature regimes.

Contact: Joan Esposo, Office of Planning, State of Hawaii,
PO Box 2359, Honolulu, Hi. 96804; (808) 587-2895.
email: jesposo@dbedt.hawaii.gov

Layer Name:	Agricultural Land Use Maps
Coverage Name:	ALUM
Layer Type:	Polygon
Library:	State
Alt. Path:	/vg02/prime/admin/final/@alum
Status:	Complete
Geog. Extent:	Main Hawaiian Islands
Projection:	Universal Trans Mercator, Zone 4
Description:	Agricultural Land Use Maps for islands of Kauai, Oahu, Maui, Molokai, Lanai and Hawaii.
Source:	State Department of Agriculture 1:24,000 hand drafted stabiline maps; compiled and drafted during 1978-80 from information from State DOA Planning and Development Section, and the US Soil Conservation Service.
History:	Digitized in Arc/Info version 6 using ArcEdit by the Office of State Planning (OSP) from State Department of Agriculture's 1:24,000 stabiline maps.
Attributes:	Polygons:

AREA	area of polygon (sq. meters)
PERIMETER	perimeter of polygon (meters)
ALUM#	Polygon internal number (for Arc/Info use)
ALUM-ID	Polygon ID (for Arc/Info use)
COMMODITY	Type of Agricultural Land Use or Crop

COMMODITY	Definition
A	ANIMAL HUSBANDRY
A-1	Grazing
A-2	Dairy
A-3	Hog
A-4	Poultry
F	FIELD CROPS
F-1	Vegetables / Melons
F-2	Flowers
F-3	Foliage and Nursery
F-4	Forage and Grain
O	ORCHARDS
O-1	Banana
O-2	Papaya
O-3	Macadamia Nuts
O-4	Avocado

O-5	Coffee	
O-6	Guava	
O-7	Other	
P	Pineapple	{ }
Q	Aquaculture	{ These codes are from }
S	Sugarcane	{ Jon Chun's notes }
W	Wetlands	{ (P, Q, S, and W) }

Arcs:

FNODE#	From Node Number (for Arc/Info use)
TNODE#	To Node Number (for Arc/Info use)
LPOLY#	Left Polygon Number (for Arc/Info use)
RPOLY#	Right Polygon Number (for Arc/Info use)
LENGTH	Length (meters)
ALUM#	Arc Internal Number (for Arc/Info use)
ALUM-ID	Arc ID (for Arc/Info use)
FLAG	Source of Arc

FLAG	Definition
0	Digitized arc
1	Extracted arc (from 1:24,000 DLGs)
2	Closure arc
3	Coastline arc
9	Other

Note: For more complete layer documentation, please see file alum.meta.

Contact: Joan Esposo, Office of Planning, State of Hawaii,
PO Box 2359, Honolulu, Hi. 96804; (808) 587-2895.
email: joan_m_esposo@exec.state.hi.us

Layer Name: Coastline

Coverage Name: COAST

Layer Type: Polygon

Library: State

Alt. Path: /vg02/prime/basemap/final/@coast

Status: Complete

Geog. Extent: Main Hawaiian Islands

Projection: Universal Trans Mercator, Zone 4 (Meters)

Description: Coastlines for the main hawaiian islands.

Source: USGS Digital Line Graphs, 1983 version.

History: Extracted by OSP staff from the 1983 1:24,000 USGS Digital Line Graphs.

Attributes: Polygons:

AREA	area of polygon (sq. meters)
PERIMETER	perimeter of polygon (meters)
COAST#	Polygon internal number (for Arc/Info use)
COAST-ID	Polygon ID (for Arc/Info use)

Arcs:

FNODE#	From Node Number (for Arc/Info use)
TNODE#	To Node Number (for Arc/Info use)
LPOLY#	Left Polygon Number (for Arc/Info use)
RPOLY#	Right Polygon Number (for Arc/Info use)
LENGTH	Length (meters)
COAST#	Arc Internal Number (for Arc/Info use)
COAST-ID	Arc ID (for Arc/Info use)
FLAG	Source of Arc

FLAG	Definition
0	Digitized arc
1	Extracted arc (from 1:24,000 DLGs)
2	Closure arc
3	Coastline arc
9	Other

Note: For more complete layer documentation, please see file coast.meta.

Contact: Joan Esposo, Office of Planning, State of Hawaii,
PO Box 2359, Honolulu, Hi. 96804; (808) 587-2895.
email: jesposo@dbedt.hawaii.gov

Layer Name: DOH Aquifers

Coverage Name: DOHAQ

Layer Type: Polygon

Library: State

Alt. Path: /vg02/prime/natres/final/@aquifers

Status: Complete

Geog. Extent: Islands of Hawaii, Kauai, Lanai, Maui, Molokai and Oahu

Projection: Universal Trans Mercator, Zone 4, Old Hawaiian Datum

Descript: Aquifers, as determined/defined by DOH. (Note: DLNR maintains another version of aquifers, which is more administrative in nature, and which has different boundaries than the DOH version, which is more resource-oriented in nature).

The attribute data represent aquifer type codes and status codes that describe an aquifer's geology and status (ie. development stage, utility, salinity, uniqueness, and vulnerability).

Source: Original maps prepared by John F. Mink and L. Stephen Lau (Water Resources Research Center)for the Department of Health's Groundwater Protection Program. Digitized by DOH - Environmental Planning Office from the original mylars, based on USGS 1:24,000 scale maps.

History: Digitized in 1992 by DOH - Environmental Planning Office from the original mylars, based on USGS 1:24,000 scale maps.

Attributes: Polygons:

AREA	area of polygon (sq. meters)
PERIMETER	perimeter of polygon (meters)
<isl>DOHAQ#	Polygon internal number (for Arc/Info use)
<isl>DOHAQ-ID	Polygon ID (for Arc/Info use)
ISLAND	Island Code
SECTOR	Aquifer Sector
SYSTEM	Aquifer System
TYPEA	Aquifer Type (see Note 1, below)
TYPEB	Lower Aquifer Type, when present (see Note 1, below)
STATA	Aquifer Status
STATB	Lower Aquifer Status, when present (see Note 1, below)

Redefined Items:

Note: STATUS is made up of DEV, UTILITY, SALINITY, UNIQUE and VULN

DEVA	Aquifer Status
UTILITYA	Aquifer Utility
SALINITYA	Aquifer Salinity (mg/l Cl-)

UNIQUEA	Aquifer Uniqueness
VULNA	Aquifer Vulnerability
DEVB	Lower Aquifer Status, when present (see Note 1, below)
UTILITYB	Lower Aquifer Utility, when present (see Note 1, below)
SALINITYB	Lower Aquifer Salinity, when present (see Note 1, below)
UNIQUEB	Lower Aquifer Uniqueness, when present (see Note 1, below)
VULNB	Lower Aquifer Vulnerability, when present (see Note 1, below)

....

Attribute Descriptions (Polygons):

ISL.	SECTOR	SYSTEM
02 Kauai	01 Lihue	01 Koloa
		02 Hanamaulu
		03 Wailua
		04 Anahola
		05 Kilauea
	02 Hanalei	01 Kalihiwai
		02 Hanalei
		03 Wainiha
		04 Napili
	03 Waimea	01 Kekaha
		02 Waimea
		03 Makaweli
		04 Hanapepe
03 Oahu	01 Honolulu	01 Palolo
		02 Nuuanu
		03 Kalihi
		04 Moanalua
		05 Waialae
	02 Pearl Harbor	01 Waimalu
		02 Waiawa
		03 Waipahu
		04 Ewa
		05 Kunia
	03 Waianae	01 Nanakuli
		02 Lualualei
		03 Waianae
		04 Makaha
		05 Keaau
	04 North	01 Mokuleia
		02 Waialua
		03 Kawailoa

	05 Central	01 Wahiawa
		02 Koolau
	06 Windward	01 Koolauloa
		02 Kahana
		03 Koolaupoko
		04 Waimanalo
04 Molokai	01 West	01 Kaluakoi
		02 Punakou
	02 Central	01 Hoolehua
		02 Manawainui
		03 Kualapuu
	03 Southeast	01 Kamiloloa
		02 Kawela
		03 Ualapue
		04 Waialua
	04 Northeast	01 Kalaupapa
		02 Kahanui
		03 Waikolu
		04 Haupu
		05 Pelekunu
		06 Wailau
		07 Halawa
05 Lanai	01 Central	01 Windward
		02 Leeward
	02 Mahana	01 Hauola
		02 Maunalei
		03 Lapaiki
	03 Kaa	01 Honopu
		02 Kaumalapau
	04 Manele	01 Kealia
		02 Manele
06 Maui	01 Wailuku	01 Waikapu
		02 Iao
		03 Waihee
		04 Kahakuloa
	02 Lahaina	01 Honokohau
		02 Honolua
		03 Honokowai
		04 Launiupoko
		05 Olowalu
		06 Ukumehame
	03 Central	01 Kahului
		02 Paia
		03 Makawao

		04 Kamaole
	04 Koolau	01 Haiku
		02 Honopou
		03 Waikamoi
		04 Keanae
	05 Hana	01 Kuhiwa
		02 Kawaipapa
		03 Waihoi
		04 Kipahulu
	06 Kahikinui	01 Kaupo
		02 Nakuula
		03 Lualailua
08 Hawaii	01 Kohala	01 Hawi
		02 Waimanu
		03 Mahukona
	02 E. Mauna Kea	01 Honokaa
		02 Paauilo
		03 Hakalau
		04 Onomea
	03 W. Mauna Kea	01 Waimea
	04 NE. Mauna Loa	01 Hilo
		02 Keaau
	05 SE. Mauna Loa	01 Olaa
		02 Kapapala
		03 Naalehu
		04 Ka Lae
	06 SW. Mauna Loa	01 Manuka
		02 Kaapuna
		03 Kealakekua
	07 NW. Mauna Loa	01 Anaehoomalu
	08 Kilauea	01 Pahoa
		02 Kalapana
		03 Hilina
		04 Keaiwa
	09 Hualalai	01 Keauhou
		02 Kiholo

....

TYPEA/TYPEB - 3 digit/character code describing aquifer hydrology and geology:

1st Digit: Hydrology

Value	Definition	Description

1	Basal	Fresh water in contact with seawater
2	High Level	Fresh water not in contact with sea water

2nd Digit: Hydrology

Value	Definition	Description
1	Unconfined	Where water table is upper surface of saturated aquifer
2	Confined	Aquifer bounded by impermeable or poorly permeable formations, and top of saturated aquifer is below groundwater surface
3	Confined or Unconfined	Where actual condition is uncertain

3rd Digit: Geology

Value	Definition	Description
1	Flank	Horizontally extensive lavas
2	Dike	Aquifers in dike compartments
3	Flank/Dike	Indistinguishable
4	Perched	Aquifer on impermeable layer
5	Dike/Perched	Indistinquishable
6	Sedimentary	Nonvolcanic lithology

....

Status Code (Groundwater) - 5 digit/character code describing aquifer status:

1st Digit: Developmental Stage

Value	Definition
1	Currently used
2	Potential use
3	No potential use

2nd Digit: Utility

Value	Definition
1	Drinking
2	Ecologically important
3	Neither

3rd Digit: Salinity (mg/l Cl-)

Value Definition

1	Fresh (<250)
2	Low (250-1,000)
3	Moderate (1,000-5,000)
4	High (5,000-15,000)
5	Seawater (>15,000)

4th Digit: Uniqueness

Value	Definition
1	Irreplaceable
2	Replaceable

5th Digit: Vulnerability to Contamination

Value	Definition
1	High
2	Moderate
3	Low
4	None

....

Note 1:

In order to distinguish areas where there are aquifers above other aquifers (such as coastal caprock areas), the fields have been labeled typea and typeb, and stata and statb. Typea and stata represent the upper aquifers, while typeb and statb represent the lower aquifers, when they occur.

Note 2:

Although these coverages are complete, final QA/QC procedures have not yet been performed. Attribute data on the aquifer codes and status codes were entered manually and are correct to the best of our knowledge.

An explanation of these delineations and protocols can be found in the following documents WRRC documents:

Technical Report No. 179 - Aquifer Identification and Classification for Oahu: Groundwater Protection Strategy for Hawaii. Feb. 1990 (Rev.)

Technical Report No. 185 - Aquifer Identification and Classification for Maui: Groundwater Protection Strategy for Hawaii. Feb. 1990.

Technical Report No. 186 - Aquifer Identification and Classification for Kauai: Groundwater Protection Strategy for Hawaii. Sept. 1992.

Technical Report No. 187 - Aquifer Identification and Classification for Molokai: Groundwater Protection Strategy for Hawaii. Oct. 1992.

Technical Report No. 190 - Aquifer Identification and Classification for Lanai: Groundwater Protection Strategy for Hawaii. April 1993.

Technical Report No. 191 - Aquifer Identification and Classification for the Island of Hawaii: Groundwater Protection Strategy for Hawaii. May 1993.

These technical reports are available from the Groundwater Protection Program, Department of Health. For more information contact:

Glen Fukunaga
586-4378 or 586-4343.
Fax: 586-4370

Contact: Joan Esposo, Office of Planning, State of Hawaii, PO Box 2359, Honolulu, Hi. 96804; (808) 587-2895.
email: jesposo@dbedt.hawaii.gov

Layer Name:	Government Land Ownership
Coverage Name:	<ISL>OWN
Layer Type:	Polygon
Library: State	
Alt. Path:	/vg02/prime/admin/final/@ownership
Status:	Complete
Geog. Extent:	Main Hawaiian Islands
Projection:	Universal Trans Mercator, Zone 4, Old Hawaiian Datum
Description:	Government owned lands for the islands of Kauai, Oahu, Molokai, Kahoolawe, Maui and Hawaii.
Source:	1976 USGS digital 1:100,000 GIRAS files.
History:	Loaded into Arc/Info version 5 by the Office of State Planning (OSP).
Attributes:	Polygons:

AREA	area of polygon (sq. meters)
PERIMETER	perimeter of polygon (meters)
GOVOWN#	Polygon internal number (for Arc/Info use)
GOVOWN-ID	Polygon ID (for Arc/Info use)
STATE	State ownership type
FEDERAL	Federal ownership type

STATE	Definition
1	State of Hawaii ownership
2	Hawaiian Home Lands ownership

FEDERAL	Definition
	DEPARTMENT OF AGRICULTURE:
11	Agricultural Research Service
12	Forest Service (National Forest)
13	Forest Service (National Grassland)
	DEPARTMENT OF COMMERCE:
21	NOAA
	DEPARTMENT OF DEFENSE:

31	Air Force
32	Army
33	Army Corps of Engineers
34	Navy
	DEPARTMENT OF THE INTERIOR:
41	Bonneville Power Administration
42	Bureau of Indian Affairs
43	Bureau of Land Management
44	Bureau of Mines
45	Bureau of Reclamation
46	USFWS - National Wildlife Refuge
47	National Park Service - National Monument, Seashore, or Recreation Area
48	National Park Service - National Park
	DEPARTMENT OF JUSTICE:
51	Bureau of Prisons
	DEPARTMENT OF TRANSPORTATION:
71	Federal Aviation Administration
72	Federal Railroad Administration
73	US Coast Guard
	OTHER AGENCIES:
81	Energy Research and Development Administration
82	General Services Administration
83	NASA
85	Veteran's Administration

Arcs:

FNODE#	From Node Number (for Arc/Info use)
TNODE#	To Node Number (for Arc/Info use)
LPOLY#	Left Polygon Number (for Arc/Info use)
RPOLY#	Right Polygon Number (for Arc/Info use)
LENGTH	Length (meters)
GOVOWN#	Arc Internal Number (for Arc/Info use)
GOVOWN-ID	Arc ID (for Arc/Info use)

Note: For more complete layer documentation, please see file govown.meta.

Contact: Joan Esposo, Office of Planning, State of Hawaii,
PO Box 2359, Honolulu, Hi. 96804; (808) 587-2895.
email: joan_m_esposo@exec.state.hi.us

Layer Name: DLG Major Roads

Coverage Name: <ISL>MAJRD

Layer Type: Line

Library: State

Alt. Path: /vg02/prime/basemap/final/@roads/<isl>majrd

Status: Complete

Geog. Extent: Islands of Kauai, Oahu, Molokai, Lanai, Maui and Hawaii

Projection: Universal Trans Mercator, Zone 4

Description: "Major roads" extracted from the USGS 1983 DLGs for the main hawaiian islands.

Source: USGS Digital Line Graphs, 1983 version.

History: Subset of the roads layer of the 1983 DLGs, obtained by reselecting arcs using USGS major and minor codes. H-3 was added to the layer by the Office of Planning.

Attributes: Arcs:

FNODE#	From Node # (for Arc/Info use)
TNODE#	To Node # (for Arc/Info use)
LPOLY#	Left Polygon # (for Arc/Info use)
RPOLY#	Right Polygon # (for Arc/Info use)
LENGTH	Length (Length of arc in meters)
<ISL>MAJRD#	Arc Internal Number (for Arc/Info use)
<ISL>MAJRD-ID	Arc ID (for Arc/Info use)
MAJOR1	Major Code 1
MINOR1	Minor Code 1
MAJOR2	Major Code 2
MINOR2	Minor Code 2
MAJOR3	Major Code 3
MINOR3	Minor Code 3
MAJOR4	Major Code 4
MINOR4	Minor Code 4
MAJOR5	Major Code 5
MINOR5	Minor Code 5
MAJOR6	Major Code 6
MINOR6	Minor Code 6

Major Codes (1-6):

170	DLG Roads and Trails layer
171	(with minor code xxxx) # of lanes
172	(with minor code xxxx) Interstate Route Number
173	(with minor code xxxx) U.S. Route Number
174	(with minor code xxxx) State Route Number
175	(with minor code xxxx) Reservation, park or

military route number
176 (with minor code xxxx) County Route Number
177 (with minor code XXYY) Alphabetic Portion of Route # - Sub. numeric equiv. of alpha. for XX and for YY as follows:
00=blank, 01=A, 02=B, 03=C, 04=D, 05=E, 06=F, 07=G, 08=H, 09=I, 10=J, 11=K, 12=L, 13=M, 14=N, 15=O, 16=P, 17=Q, 18=R, 19=S, 20=T, 21=U, 22=V, 23=W, 24=X, 25=Y, 26=Z.
178 (with minor code = 0000) best estimate of position or classification
179 (with minor code 00xx) Coincident feature

Minor Codes (1-6):

0001	Bridge abutment
0002	Tunnel portal
0004	Gate
0005	Cul-de-sac
0006	Dead end
0007	Drawbridge
0100	Void Area
0201	Primary route, class 1, symbol undivided
0202	Primary route, class 1, symbol divided by centerline
0203	Primary route, class 1, divided, lanes separated
0204	Primary route, class 1, one way, other than divided highway
0205	Secondary route, class 2, symbol undivided
0206	Secondary route, class 2, symbol divided by centerline
0207	Secondary route, class 2, symbol divided, lanes separated
0208	Secondary route, class 2, one way, other than divided highway
0209	Road or street, class 3
0210	Road or street, class 4
0211	Trail, class 5, other than four-wheel-drive vehicle
0212	Trail, class 5, four-wheel-drive vehicle
0213	Footbridge
0214	Road ferry crossing
0215	Perimeter of parking area
0216	Arbitrary extension of line (join or closure)
0217	Road or street, class 3, symbol divided by centerline
0218	Road or street, class 3, divided lanes separated
0219	Road or street, class 4, one way
0220	Closure line
0221	Road or street, class 3, one way
0222	Road in transition
0299	Processing line
0401	Traffic circle
0402	Cloverleaf or interchange
0403	Toll gate, toll plaza or perimeter of toll plaza
0404	Weigh station

0405	Nonstandard section of road
0601	In tunnel
0602	Overpassing, on bridge
0603	Under construction, classification known
0604	Under construction, classification unknown
0605	Labeled "old railroad grade"
0606	Submerged or in ford
0607	Underpassing
0608	Limited access
0609	Toll road
0610	Privately operated or controlled public access
0611	Proposed
0612	Double-decked
0613	In service facility or rest area
0614	Elevated
0615	Bypass route
0616	Alternate route
0617	Business route
0618	On drawbridge
0619	Spur
0620	Loop
0621	Connector
0622	Truck route
0650	Road width 46-55 feet, 0.025 inches at 1:24,000
0651	Road width 56-65 feet, 0.030 inches at 1:24,000
0652	Road width 66-75 feet, 0.035 inches at 1:24,000
0653	Road width 76-85 feet, 0.040 inches at 1:24,000
0654	Road width 86-95 feet, 0.045 inches at 1:24,000
0655	Road width 96-105 feet, 0.050 inches at 1:24,000
0656	Road width 106-115 feet, 0.055 inches at 1:24,000
0657	Road width 116-125 feet, 0.060 inches at 1:24,000
0658	Road width 126-135 feet, 0.065 inches at 1:24,000
0659	Road width 126-145 feet, 0.070 inches at 1:24,000
0000	Photo revised feature

Note: For more complete layer documentation, please see file dlgmajrd.meta.

Contact: Joan Esposo, Office of Planning, State of Hawaii,
PO Box 2359, Honolulu, Hi. 96804; (808) 587-2895.
email: jesposo@dbedt.hawaii.gov

Layer Name: Rainfall

Coverage Name: RAINFALL

Layer Type: Line

Library: State

Alt. Path: /vg02/prime/natres/final/@rainfall

Status: Complete

Geog. Extent: Islands of Hawaii, Kauai, Lanai, Maui, Molokai and Oahu

Projection: Universal Trans Mercator, Zone 4, Meters

Description: Median annual rainfall in millimeters and inches.

Source: State Department of Land and Natural Resources, DOWALD mylar maps of varying scales and sizes (see below).

History: Digitized in early 1990's in Arc/Info by the Office of Planning using ArcEdit from island-wide maps of varying scales and sizes.

Scales varied by island, and were as follows:

Kauai	1-1/4" = 2 mi. (~ 1:101,376)
Oahu	1" = 2 mi. (~ 1:126,720)
Molokai	1" = 2 mi. (~ 1:126,720)
Lanai	1" = 2 mi. (~ 1:126,720)
Maui	13/16" = 2 mi. (~ 1:155,963)
Hawaii	3" = 16 mi. (~ 1:337,920)

Attributes: Arcs:

FNODE#	From Node Number (for Arc/Info use)
TNODE#	To Node Number (for Arc/Info use)
LPOLY#	Left Polygon Number (for Arc/Info use)
RPOLY#	Right Polygon Number (for Arc/Info use)
LENGTH	Length (meters)
<isl>RAIN#	Arc Internal Number (for Arc/Info use)
<isl>RAIN-ID	Arc ID (for Arc/Info use)
RAIN.MM	Median annual rainfall in millimeters
RAIN.IN	Median annual rainfall in inches

Contact: Joan Esposo, Office of Planning, State of Hawaii,
PO Box 2359, Honolulu, Hi. 96804; (808) 587-2895.
email: jesposo@dbedt.hawaii.gov

Layer Name:	Rain Gauges
Coverage Name:	RAINGAGE
Layer Type:	Point
Library:	State
Alt. Path:	/vg02/prime/natres/final/@raingage
Status:	Complete
Geog. Extent:	Islands of Hawaii, Kauai, Lanai, Maui, Molokai and Oahu
Projection:	Universal Trans Mercator, Zone 4, Meters
Description:	Rain gauges located on the main Hawaiian Islands
Source:	DLNR, CWRM, Hing Tai Lee, 1997
History:	Rain gauge sites were generated in Arc/Info using latitude/longitude coordinates contained in the database. Attributes were then "JOINED" to the point layer in 1997 by Hing Tai Lee, DLNR.

Attributes: Points

AREA	not used - point data
PERIMETER	not used - point data
RAINGAGE#	point internal number (for Arc/Info use)
RAINGAGE-ID	point ID (for Arc/Info use)
SKN	State Key Number
NWS_INDEX	Nat'l Weather Service Number
STN_NAME	Station Name
OBS_NAME	Observer/Observer Agency Name
DEG_LAT	Degrees Latitude
MIN_LAT	Minutes Latitude
SEC_LAT	Seconds Latitude
DEG_LON	Degrees Longitude
MIN_LON	Minutes Longitude
SEC_LON	Seconds Longitude
ELEVATION	Elevation in feet
YEAR_EST	Year Established
YEAR_DISC	Year Discontinued
MIS_PERIOD	Boolean field - discontinuous data = X (missing periods) Values = X, Y OR BLANK
READ_CONT	Boolean field - Read Continuously or not Values = *, C OR BLANK
READ_DAILY	Boolean field - Read Daily or not Values = *, D OR BLANK
READ_WEEK	Boolean field - Read Weekly or not Values = *, W OR BLANK
READ_MONTH	Boolean field - Read Weekly or not Values = *, M OR BLANK
READ_OTHER	Boolean field - Read at some other interval or not Values = *, O OR BLANK

DATA_NWS	Boolean Field - Data about this gauge is kept at NWS Values = *, W OR BLANK
DATA_DWRM	Boolean Field - Data about this gauge is kept at DWRM Values = *, D OR BLANK
DATA_HSPA	Boolean Field - Data about this gauge is kept at HSPA Values = *, H OR BLANK
DATA_OBS	Boolean Field - Data about this gauge is kept by the Observer Values = *, S OR BLANK
DATA_OTHER	Boolean Field - Data about this gauge is kept by some other entity Values = *, O OR BLANK
ELEM_TEMP	Boolean Field - Temperature data is also kept Values = *, T OR BLANK
ELEM_EVAP	Boolean Field - Evaporation data is also kept Values = *, E OR BLANK
ELEM_WIND	Boolean Field - Wind data is also kept Values = *, W OR BLANK
ELEM_HUMID	Boolean Field - Humidity data is also kept Values = *, H OR BLANK
ELEM_OTHER	Boolean Field - Other data is also kept Values = *, O OR BLANK
REMARK	Various

Contact: Joan Esposo, Office of Planning, State of Hawaii,
P.O. Box 2359, Honolulu, Hi. 96804; (808) 587-2895.
e-mail: jesposo@dbedt.hawaii.gov

Reserve Layer Compilation Information:

Compiled 1998 by SOH, DLNR, DOFAW from various sources including the data provided by DSP and the C&C parcel boundaries with input from State foresters and others familiar with the reserve boundaries. The boundaries in these coverages are not final; they are updated frequently. Refer to "<isle>reserve" for the most recent update for each island and check the date of the update in the file properties.

Projection: Universal Trans Mercator, Zone 4, Old Hawaiian Datum

4/30/99 - Note:

The reserve layer for the island of Maui is still under review, therefore this coverage should be used with caution.

Reserve Layer Item Values:

TYPE:

bs	Bird Sanctuary
fr	Forest Reserve
gma	Game Management Area
hp	Historic Preserve
mlcd	Marine Life Conservation District
nar	Natural Area Reserve
nhp	National Historical Park
nhs	National Historic Site
np	National Park
p	Preserve
pf	Platform
ps	Plant Sanctuary
rr	Research Reserve
shp	State Historical Park
sm	State Monument
sp	State Park
spr	State Park Reserve
sra	State Recreation Area
srp	State Recreation Pier
ss	Seabird Sanctuary
sup	State Underwater Park
sw	State Wayside
uel	Unencumbered Land (wating for an upgrade to a reserve status)
wr	Wildlife Refuge
ws	Wildlife Sanctuary
xs	Various Other Sanctuaries
xx?	Not sure

For Kauai and Hawaii

OWNER:

fed	Federal

hhl	Hawaiian Homes Land
st	State
pr	Private
pr.sr	Private but Surrendered
xx?	Not sure

Layer Name: Ground Water Wells

Coverage Name: WELLS

Layer Type: Point

Library: State

Alt. Path: /vg02/prime/admin/final/@wells

Status: Complete

Geog. Extent: Main Hawaiian Islands

Projection: Universal Trans Mercator, Zone 4

Description: Ground Water Index Wells database for main hawaiian islands.

Source: Department of Land & Natural Resources, Commission on Water Resource Management wells database (maintained in DBase) April, 2001.

History: DLNR, CWRM generated points in Arc/Info using coordinates stored in DBase files maintained and continuously updated by CWRM. Database is periodically converted into Arc/Info. Last converted to Arc/Info in December, 2000. Maintained on a daily basis by CWRM, transferred to Statewide GIS on a quarterly basis.

Attributes: Points:

AREA	not used - point data
PERIMETER	not used - point data
WELLS#	Point internal number (for Arc/Info use)
WELLS-ID	Point ID (for Arc/Info use)
ISLAND	Island
WELL_NO	Well Number - 6 digits, assigned by DWRM, based on latitude/longitude position of well.
WELL_NAME	Well Name
OLD-NAME	Old Well Name
YR_DRILLED	Year Drilled
DRILLER	Driller
QUAD_MAP	USGS 7-1/2 minute topo map containing well
LATITUDE	Latitude coordinates of well
LONGITUDE	Longitude coordinates of well
GPS	Method of locating well on USGS Quad maps, Y or N
UTM	Method of locating well on USGS Quad maps, Y or N
OWNER_USER	If well is USED, then USER name, else OWNER name
OLD_NUMBER	Old Well Number
WELL_TYPE	Well Construction Type
CASING_DIA	Casing Diameter in Inches
GROUND_EL	Ground surface elevation in feet
WELL_DEPTH	Total Depth of well in feet
SOLID_CASE	Depth to bottom of solid casing in feet
PERF_CASE	Depth to bottom of perforated casing in feet

USE	Major use of Well
USE_YEAR	Year use was recorded
INIT_WATER	** field no longer used **
INIT_HEAD	Elevation of top of water above Mean Sea Level (msl)
INIT_CHLOR	** field no longer used **
INIT_CL	Chloride value - when first hit water
TEST_DATE	First day of testing (mm/dd/yy)
TEST_GPM	Pumping test rate in gallons/min.
TEST_DDOWN	Measured drop in water level during testing
TEST_CHLOR	Measurement of chlorides during test
TEST_TEMP	Measurement of temperature during test
TEMP_UNIT	Fahrenheit (F) or Centigrade (C)
PUMP_GPM	Pump capacity of permanent pump installed in gallons / minute
DRAFT_MGY	Average annual draft from well in million gallons / year
HEAD_FEET	Static water level elevation in feet
MAX_CHLOR	** field no longer used **
MIN_CHLOR	** field no longer used **
GEOLOGY	Geologic formation symbols from geologic maps
PUMP_YR	Date of pump installation (mm/dd/yy)
DRAFT_YR	** field no longer used **
HEAD_YR	Date of latest head measurement
MAXCHL	Highest measured chlorides since well was drilled
MAXCHL_YR	Date of highest chloride measurement (mm/dd/yy)
MINCHL	Lowest measured chlorides since well was drilled
MINCHL_YR	Date of lowest chloride measurement (mm/dd/yy)
BOT_HOLE	Bottom of hole, i.e. total depth of well
BOT_SOLID	Bottom of solid, unperforated section of casing
BOT_PERF	Bottom of perforated or screened sect. of casing
SPEC_CAPAC	Specific well capacity in gallons per minute per foot of drawdown
PUMP_MGD	Installed pump capacity, million gallons / day
DRAFT_MGD	Average annual draft from well, in million gallons / day
AQUIFER	** field no longer used **
TMK	Tax Map Key of parcel containing well
OLD_AQUI	** field no longer used **
AQUI_CODE	Code of Aquifer tapped by well; symbols listed are geologic formation symbols used on published Island aquifer maps.
LATEST_HD	Latest head measurement (value in feet)
CUR_HEAD	Current head measurement (value in feet)
CUR_CL	Current chlorides measurement (value in mg/l)
CUR_TEMP	Current temperature measurement (value in deg. C)
WCR	Well construction report received (mm/dd/yy)
PIR	Pump installation report received (mm/dd/yy)
SURVEYOR	Name of surveyor or company name
T	Survey was done - Y or N
PUMP_ELEV	Pump intake elevation in feet
PUMP_DEPTH	Pump intake depth in feet
JOIN	Used to convert file from DBase to Arc/Info

ISLAND	Definition
1	Niihau
2	Kauai
3	Oahu
4	Molokai
5	Lanai
6	Maui
7	Kahoolawe
8	Hawaii

GPS	Definition
N	GPS coordinates not available
Y	GPS coordinates available

UTM	
N	UTM coordinates not available
Y	UTM coordinates available

WELL_TYPE	Definition
DUG	Dug Well
PER	Percussion Drill
ROT	Rotary Drill
TUN	Tunnelled

USE	Definition
MUN	Municipal
IRR	Irrigation
IND	Industrial
DOM	Domestic
UNU	Unused
SLD	Sealed
OBS	Observation
DIS	Disposal
LOS	Lost
RCH	Recharge
OTH	Other

TEMP_UNIT	Definition
C	Degrees Centigrade
F	Degrees Fahrenheit

Notes: For more complete layer documentation, please see file wells.meta, or contact Department of Land & Natural Resources, Commission on Water Resource Management.

Contact: Joan Esposo, Office of Planning, State of Hawaii,
PO Box 2359, Honolulu, Hi. 96804; (808) 587-2895.
email: jesposo@dbedt.hawaii.gov

Layer Name: Water Quality Monitoring Sites

Coverage Name: WQSITES

Layer Type: Point

Library: State

Alt. Path: /vg02/prime/admin/final/@wqsites

Status: Complete

Geog. Extent: Main Hawaiian Islands

Projection: Universal Trans Mercator, Zone 4, Old Hawaiian Datum

Description: Locations of water quality monitoring sites

Source: U.S. EPA provided latitude/longitude coordinates for STORET sites; SOH/DOH provided latitude/longitude coordinates for ODES sites.

History: Files provided by sources above were converted to point coverages using the Arc/Info GENERATE command by Ogden Environmental in 1994 in Arc/Info version 6.1.2. Generated coverages were then projected into UTM Zone 4, Old Hawaiian Datum.

Note 1: Fresh water monitoring sites were not checked by DOH. Several were not located directly on streams (based on lat/long) - Ogden recommended locational checks on these sites.

Note 2: For more information, refer to "Final Report: Comprehensive Management of Coastal Resources, Phase1," Ogden Environmental Services for the Coastal Zone Management Program, Office of Planning, June 1994.

Attributes: Points:

AREA	Point layer - not used
PERIMETER	Point layer - not used
WQSITES#	Point internal number (for Arc/Info use)
WQSITES-ID	Point ID (for Arc/Info use)
SITEID	ID used in original database (STORET or ODES)
SITENAME	Site name from orig. database (STORET or ODES)
COASTCODE	Type of site - marine or fresh water site
DRAWCODE	Code to determine where to draw label text
DATABASE	Database source of site (STORET or ODES)
SYMBOL	Code to determine draw symbol for site
SITENAME_SHORT	Short version of site name

COASTCODE	Definition
1	Marine site
2	Fresh water site

DRAWCODE	Definition
1	Label drawn to UR of label point
2	Label drawn to LL of label point
3	Label drawn to LR of label point
4	Label drawn to UL of label point

SYMBOL	Definition
23	STORET, Fresh water
24	STORET, Marine
52	ODES (all marine sites)

Note: For more information regarding attribute codes and citations, please see the final report for the Comprehensive Management of Coastal Resources - Phase I (Ogden, 1994).

Contact: Joan Esposo, Office of Planning, State of Hawaii, PO Box 2359, Honolulu, Hi. 96804; (808) 587-2895. email: joan_m_esposo@exec.state.hi.us

Layer Name:	Special Management Areas
Coverage Name:	SMA
Layer Type:	Polygon
Library: State	
Alt. Path:	/vg02/prime/admin/final/@sma
Status:	Complete
Geog. Extent:	Main Hawaiian Islands
Projection:	Universal Trans Mercator, Zone 4
Description:	Special Management Area maps for islands of Niihau, Kauai, Oahu, Maui, Molokai, Lanai and Hawaii.
Source:	All islands except Oahu: County Planning Department blueline maps; compiled and drafted on USGS quadrangle base. Oahu: C&C of Honolulu GIS database.
History:	All islands except Oahu: digitized in Arc/Info version 7.1.1 using ArcEdit by the Office of Planning (OP) from County blueline maps, 1998.
Attributes:	Polygons:

AREA	area of polygon (sq. meters)
PERIMETER	perimeter of polygon (meters)
SMA#	Polygon internal number (for Arc/Info use)
SMA-ID	Polygon ID (for Arc/Info use)
SMAREA	Special Management Area

SMAREA	Definition
0	Not within Special Management Area
1	Within a Special Management Area

Note: for Oahu SMAs only:

1	Within a Special Management Area
2	Not within Special Management Area

Arcs:

FNODE#	From Node Number (for Arc/Info use)
TNODE#	To Node Number (for Arc/Info use)
LPOLY#	Left Polygon Number (for Arc/Info use)
RPOLY#	Right Polygon Number (for Arc/Info use)
LENGTH	Length (meters)

SMA#	Arc Internal Number (for Arc/Info use)
SMA-ID	Arc ID (for Arc/Info use)
FLAG	Source of Arc

FLAG	Definition
0	Digitized arc
1	Extracted arc (from 1:24,000 DLGs)
2	Closure arc
3	Coastline arc
9	Other

Contact: Joan Esposo, Office of Planning, State of Hawaii, PO Box 2359, Honolulu, Hi. 96804; (808) 587-2895. email: jesposo@dbedt.hawaii.gov

Layer Name: Land Use District Boundaries, 2000

Coverage Name: LUDB00

Layer Type: Polygon

Library: State

Alt. Path: /vg02/prime/admin/final/@ludb

Status: Complete

Geog. Extent: Main Hawaiian Islands

Projection: Universal Trans Mercator, Zone 4, Old Hawaiian Datum

Description: State Land Use District Boundaries for the 8 main Hawaiian Islands, as of May, 2000.

Source: State Land Use Commission 1:24,000 mylar maps. State Land Use District Boundaries were compiled by the State Land Use Commission using the State of Hawaii's Geographic Information System (GIS). The State Land Use Districts depicted in these files are not official and are merely representations for presentation purposes only. A determination of the official State Land Use District Boundaries should be obtained through the State Land Use Commission. Duplication of these files or the information therein is prohibited unless authorized by the State Land Use Commission.

History: Initially digitized in Arc/Info versions 4, 5, and 6 using ArcEdit by the Office of Planning (OP) from State Land Use Commission's (LUC) 1:24,000 mylar maps. Updated by LUC staff, May 2000.

Attributes: Polygons:

AREA	area of polygon (sq. meters)
PERIMETER	perimeter of polygon (meters)
LUDB00#	Polygon internal number (for Arc/Info use)
LUDB00-ID	Polygon ID (for Arc/Info use)
LUDCODE	Land Use District Boundary Code

LUDCODE	Definition
A	Agricultural Land Use District
C	Conservation Land Use District
R	Rural Land Use District
U	Urban Land Use District

Arcs:

FNODE#	From Node Number (for Arc/Info use)
TNODE#	To Node Number (for Arc/Info use)
LPOLY#	Left Polygon Number (for Arc/Info use)

RPOLY#	Right Polygon Number (for Arc/Info use)
LENGTH	Length (meters)
LUDB00#	Arc Internal Number (for Arc/Info use)
LUDB00-ID	Arc ID (for Arc/Info use)
FLAG	Source of Arc

FLAG	Definition
0	Digitized arc
1	Extracted arc (from 1:24,000 DLGs)
2	Closure arc
3	Coastline arc
9	Other

Note: For more complete layer documentation, please see file ludb00.meta.

Contact: Joan Esposo, Office of Planning, State of Hawaii,
PO Box 2359, Honolulu, Hi. 96804; (808) 587-2895.
email: joan_m_esposo@exec.state.hi.us

Layer Name: Parks

Coverage Name: <isl>parks, <isl>pkspt

Layer Type: Polygon, Point

Library: None yet

Alt. Path: /vg02/prime/admin/final/@parks

Status: Complete

Geog. Extent: Islands of Kauai, Maui and Oahu

Projection: Universal Trans Mercator, Zone 4, Old Hawaiian Datum

Description: Park maps for islands of Kauai, Maui, Oahu.

Source: C&C parcel data (Oahu), GDSI parcel data (Kauai and Maui).

History: Derived from parcel data described above, 1998. Created point coverages from polygon coverages for redistribution, 10/99.

Attributes: Polygons:

AREA	area of polygon (sq. meters)
PERIMETER	perimeter of polygon (meters)
<isl>PARKS#	Polygon internal number (for Arc/Info use)
<isl>PARKS-ID	Polygon ID (for Arc/Info use)
NAME	Name of Park
OWN	Owner of Park
TMK	Tax Map Key
TYPE	Type of Park or Type of feature (e.g. road w/in park, donut poly, etc.)

Arcs:

FNODE#	From Node Number (for Arc/Info use)
TNODE#	To Node Number (for Arc/Info use)
LPOLY#	Left Polygon Number (for Arc/Info use)
RPOLY#	Right Polygon Number (for Arc/Info use)
LENGTH	Length (meters)
<isl>PARKS#	Arc Internal Number (for Arc/Info use)
<isl>PARKS-ID	Arc ID (for Arc/Info use)
FLAG	Source of Arc

FLAG	Definition
0	Digitized arc
1	Extracted arc (from 1:24,000 DLGs)
2	Closure arc
3	Coastline arc
9	Other

Contact: Joan Esposo, Office of Planning, State of Hawaii, PO Box 2359, Honolulu, Hi. 96804; (808) 587-2895. email: joan_m_esposo@exec.state.hi.us

Layer Name: Judicial District Boundaries

Coverage Name: JUDICIAL

Layer Type: Polygon

Library: State

Alt. Path: /vg02/prime/admin/final/@judicial

Status: Complete

Geog. Extent: Main Hawaiian Islands

Projection: Universal Trans Mercator, Zone 4, Old Hawaiian Datum

Description: Judicial District Boundaries for the 8 main Hawaiian Islands.

Source: USGS Digital Line Graphs, 1983 version.

History: Extracted by OP staff from the 1983 1:24,000 USGS Digital Line Graphs.

Attributes: Polygons:

AREA	area of polygon (sq. meters)
PERIMETER	perimeter of polygon (meters)
JUDICIAL#	Polygon internal number (for Arc/Info use)
JUDICIAL-ID	Polygon ID (for Arc/Info use)
DISTRICT	Judicial District Name

Arcs:

FNODE#	From Node Number (for Arc/Info use)
TNODE#	To Node Number (for Arc/Info use)
LPOLY#	Left Polygon Number (for Arc/Info use)
RPOLY#	Right Polygon Number (for Arc/Info use)
LENGTH	Length (meters)
JUDICIAL#	Arc Internal Number (for Arc/Info use)
JUDICIAL-ID	Arc ID (for Arc/Info use)
FLAG	Source of Arc

FLAG	Definition
0	Digitized arc
1	Extracted arc (from 1:24,000 DLGs)
2	Closure arc
3	Coastline arc
9	Other

Contact: Joan Esposo, Office of Planning, State of Hawaii, PO Box 2359, Honolulu, Hi. 96804; (808) 587-2895. email: joan_m_esposo@exec.state.hi.us

Layer Name:	Fisheries Management Areas
Coverage Name:	FMA
Layer Type:	Polygon
Library: State	
Alt. Path:	/vg02/prime/admin/final/@fma/fma
Status:	Complete
Geog. Extent:	Main Hawaiian Islands
Projection:	Universal Trans Mercator, Zone 4, Old Hawaiian Datum
Description:	Locations of fisheries management areas, managed by DLNR, Division of Aquatic Resources.
Source:	DLNR, Division of Aquatic Resources; most boundaries were compiled by Ogden Environmental onto USGS quadrangle maps from unregisterable maps; a few boundaries were verified using GPS. For more information on sources and methods used, see CZM report cited below.
History:	Compiled and digitized by Ogden Environmental in 1994 in Arc/Info version 6.1.2 using source maps described above.
Note:	For more information, refer to "Final Report: Comprehensive Management of Coastal Resources, Phase1," Ogden Environmental Services for the Coastal Zone Management Program, Office of Planning, June 1994.
Attributes:	Polygons:

AREA	Area of polygon (for Arc/Info use)
PERIMETER	Perimeter of polygon (for Arc/Info use)
FMA#	Polygon internal number (for Arc/Info use)
FMA-ID	Polygon ID (for Arc/Info use, also link to .lut)
NAME	FMA Name
SUBZONE	FMA Subzone Name, if any
TYPE	FMA Type: Fresh or Marine
YEAR	Year established?
LEGISLATE	Enabling legislation? from HAR 13-47 thru 13-64
BOUNDARY1	Boundary Description
BOUNDARY2	Continuation of boundary description, if needed
BOUNDARY3	Continuation of boundary description, if needed
BOUNDARY4	Continuation of boundary description, if needed
GEAR_TYPE	Gear type(s) allowed in FMA

GEAR_TYPE	Definition
1	Hook and line
2	Nets
3	Thrownets

4	Crab nets
5	Hand nets
6	Spearfishing
7	Hand harvesting
8	Traps
9	All legal gear - for personal consumption only
10	None allowed

Note: For more information regarding attribute codes and citations, please see the final report for the Comprehensive Management of Coastal Resources - Phase I (Ogden, 1994).

Contact: Joan Esposo, Office of Planning, State of Hawaii, PO Box 2359, Honolulu, Hi. 96804; (808) 587-2895. email: joan_m_esposo@exec.state.hi.us

Layer Name: Enterprise Zones

Coverage Name: EZ

Layer Type: Polygon

Library: State

Alt. Path: /vg02/prime/admin/final/@ezones

Status: Complete

Geog. Extent: Islands of Kauai, Oahu, Hawaii, Molokai, Lanai and Maui.

Projection: Universal Trans Mercator, Zone 4 (Meters)

Datum: Old Hawaiian Datum

Description: Enterprise Zones are authorized under Chapter 209E, HRS, as amended. The governor is authorized to designate up to six enterprise zones per county for a period of twenty years.

Source: Specific boundary definitions were provided by the Community Economic Development Program, DBEDT. City & County of Honolulu provided the Oahu boundaries. New Big Island boundaries provided by County of Hawaii Planning Dept.

History: Some portions of the boundaries were extracted by OP staff from USGS DLG files and US Census TIGER files, while other portions were digitized from USGS 7.5" topographic paper quadrangles, in 1995 and 1997. Oahu, Hawaii and Molokai were updated in 1999. North Kohala, Lanai, and East Maui were added in May 2000. Koolauloa, Waianae, and Honolulu zones were added in May 2001. New Big Island boundaries (effective 12/18/01) were added Jan 2002. Maui boundaries corrected 6/19/02.

Attributes: Polygons:

AREA	area of polygon (sq. meters)
PERIMETER	perimeter of polygon (meters)
EZ#	Polygon internal number (for Arc/Info use)
EZ-ID	Polygon ID (for Arc/Info use)
ZONE	Enterprise Zone Name
INZONE	1 = In Enterprise Zone 0 = Not in Enterprise Zone

Note: For more complete layer documentation, please see file entzones.meta.

Contact: Joan Esposo, Office of Planning, State of Hawaii, PO Box 2359, Honolulu, Hi. 96804; (808) 587-2895. email: jesposo@dbedt.hawaii.gov

Layer Name: Conservation District Subzones

Coverage Name: ALLSUBZONES

Layer Type: Polygon

Library: State

Alt. Path: /vg02/prime/admin/final/@ludb

Status: Complete

Geog. Extent: Main Hawaiian Islands

Projection: Universal Trans Mercator, Zone 4, Old Hawaiian Datum

Description: Conservation District Subzones, Statewide Coverage as of 1995.

Source: The Conservation District Subzones were extracted from the LUD95 layers. Subzones are administered by the Department of Land and Natural Resources. The Conservation Districts are administered by the State Land Use Commission. The Conservation District Subzone boundaries depicted in these files are not official and are merely representations for presentation purposes only. A determination of the official subzone boundaries should be obtained through the Dept. of Land and Natural Resources.

History: Statewide Subzone coverage created by The Office of Planning (OP), Sept. 2000.

Attributes: Polygons:

AREA	area of polygon (sq. meters)
PERIMETER	perimeter of polygon (meters)
ALLSUBZONES#	Polygon internal number (for Arc/Info use)
ALLSUBZONES-ID	Polygon ID (for Arc/Info use)
CONDIST	Conservation District Code
MARINE	Marine Feature

CONDIST	Definition
C	Undesignated Subzone
G	General Subzone
L	Limited Subzone
P	Protective Subzone
R	Resource Subzone
SS	Special Subzone

MARINE	Definition
0	Not a marine district, i.e. w/in coastline
1	Marine district, i.e. outside coastline

Contact: Joan Esposo, Office of Planning, State of Hawaii, PO Box 2359, Honolulu, Hi. 96804; (808) 587-2895.

email: joan_m_esposo@exec.state.hi.us