REPORT DOCUMENTATION FORM

WATER RESOURCES RESEARCH CENTER
University of Hawaii at Manoa

ERIES UMBER	Project Report PR-94-09	[2] COWRR	05-C
TLE	ailua Bay bacteriological water quality and rculation assessment report (KB-6)	[4] REPORT DATE	October 1993
		[5] NO. OF PAGES	vii + 18
		[6] NO. OF TABLES: 1	[7] NO. OF FIGURES: 7
THORS	ans-Jürgen Krock oger S. Fujioka	[9] GRANT AGENCY	Department of Wastewater Management City and County of Honolulu
		[10] CONTRACT NUMBER	C62710

ESCRIPTORS: assessments, water quality, bacteria, water circulation

ENTIFIERS: research assessments, public participation assessment, Kailua Bay, Oahu, Hawaii

BSTRACT (PURPOSE, METHOD, RESULTS, CONCLUSIONS)

he purpose of this assessment is to integrate the results of the bacteriological, water circulation, and ommunity interaction study elements to evaluate the health and aesthetic conditions of Kailua Bay, ahu. The results show that the water quality conditions in the recreational area near Kailua Beach are imarily influenced by land-derived input and that the Mokapu Ocean Outfall discharge has an significant effect in this area. The outfall discharge is transported in a northerly direction and has some fect on the bacteriological conditions in the waters off the Mokapu Peninsula beach area. Recommen-ations include further studies to define indicator organisms for tropical waters, continued monitoring, nonpoint source control program for the Kailua Bay drainage basin, and a study to define the source enteric indicator organisms off the Mokapu Peninsula beach.

2540 Dole Street • Honolulu, Hawaii 96822 • U.S.A. • (808) 956-7847

KAILUA BAY BACTERIOLOGICAL WATER QUALITY AND CIRCULATION ASSESSMENT REPORT (KB-6)

Hans-Jürgen Krock
Roger S. Fujioka

Project Report PR-94-09

October 1993

PREPARED FOR
Department of Wastewater Management
City and County of Honolulu
Project Report
for
"Kailua Bay Studies: Water Quality and Water Circulation"
Project No.: C62710
Project Period: 1 July 1990–31 October 1993
Principal Investigator: Roger S. Fujioka

WATER RESOURCES RESEARCH CENTER
University of Hawaii at Manoa
Honolulu, Hawaii 96822

ABSTRACT

The purpose of this assessment is to integrate the results of the bacteriological, water circulation, and community interaction study elements to evaluate the health and aesthetic conditions of Kailua Bay, O'ahu. The results show that the water quality conditions in the recreational area near Kailua Beach are primarily influenced by land-derived input and that the Mokapu Ocean Outfall discharge has an insignificant effect in this area. The outfall discharge is transported in a northerly direction and has some effect on the bacteriological conditions in the waters off the Mōkapu Peninsula beach area. Recommendations include further studies to define indicator organisms for tropical waters, continued monitoring, a nonpoint source control program for the Kailua Bay drainage basin, and a study to define the source of enteric indicator organisms off the Mōkapu Peninsula beach.

CONTENTS

Figures

Table

INTRODUCTION

This Kailua Bay assessment report seeks to integrate the results of three bacteriological water quality studies, a water circulation study, and a community interaction program. The bacteriological water quality studies cover the effects of inputs to Kailua Bay from three major land sources: Mōkapu wastewater outfall, Kawainui Canal, and Ka'elepulu Stream. The circulation study covers the transport characteristics of several zones in Kailua Bay. The community interaction program attempted to provide an effective process for members of the Kailua community to make their concerns known to the researchers and for the researchers to inform the community of their progress.

This combination of studies was proposed by the Water Resources Research Center (WRRC) and the Department of Ocean Engineering of the University of Hawaii at Manoa in response to concerns expressed by Kailua residents about the health and aesthetic conditions in Kailua Bay. The concerns were expressed in various forums associated with public discussions on the question of the requirement of secondary treatment of municipal wastewater before ocean discharge. The concerns centered around the possible adverse health effects of the Mokapu Ocean Outfall wastewater discharge in the nearshore recreational zone at Kailua Beach and on the reports of many people that there has been a deterioration in the water quality of Kailua Bay. At the beginning of this study, the principal examples of such deterioration cited by members of the public were the presence of various objects and solids that were found on the beach or floating in the water, as well as greenish scum that was occasionally observed in coastal waters—all of which were assumed to have been discharged or caused by the Mōkapu outfall.

STUDY DESIGN AND PUBLIC INTERACTION

Study Organization

University of Hawaii researchers designed and proposed several studies to address the scientific questions that appeared to them to be most pertinent in addressing initial public

concerns. These studies included measuring the standard indicator organisms specified by federal and state regulations to detect the possible presence of enteric pathogens (see Table 1 for the indicator organisms and the specified 30-day geometric mean values), as well as a proposed indicator organism, *Clostridium perfringens*, which is possibly more appropriate for tropical areas.

One study proposed to measure the distributions of these indicator organisms in Kailua Bay at shoreline stations, nearshore stations, outfall stations, and offshore stations (Figures 1 and 2). The second and third studies proposed to make measurements of these organisms in Ka'elepulu Stream and the Kawainui drainage area (see Figures 3 and 4 for station locations) and to identify the sources of these organisms. The fourth study proposed to measure the transport characteristics of Kailua Bay—using current meters, drogues, and dye—to assess the amount of influence the inputs from the Mōkapu outfall and land-derived sources have on the recreational areas of Kailua Bay. Figure 5 gives the current meter locations for the first deployment. The fifth portion of the overall study sought to organize the interaction between the concerned public and the researchers. Proposals for all of these studies were submitted by WRRC researchers through the University of Hawaii Office of Research Administration and accepted by the Department of Public Works of the City and County of Honolulu. The contract for these activities now comes under the Department of Wastewater Management, which was formerly a division of the Department of Public Works.

Public Interaction

Before and after the start of the studies by the UH researchers, several meetings were held between the researchers and interested members of the public, as well as with attorneys and political representatives. These meetings were useful and informative but occasionally were also antagonistic and confrontational. The history and results of these meetings are detailed in Moravcik and Heitz (1993). The most productive portions of these meetings were those containing discussions of genuine public concerns of health and water quality problems and

TABLE 1. State and Federal Recreational Freshwater and Marine Water Quality Standards (CFU/100 ml)

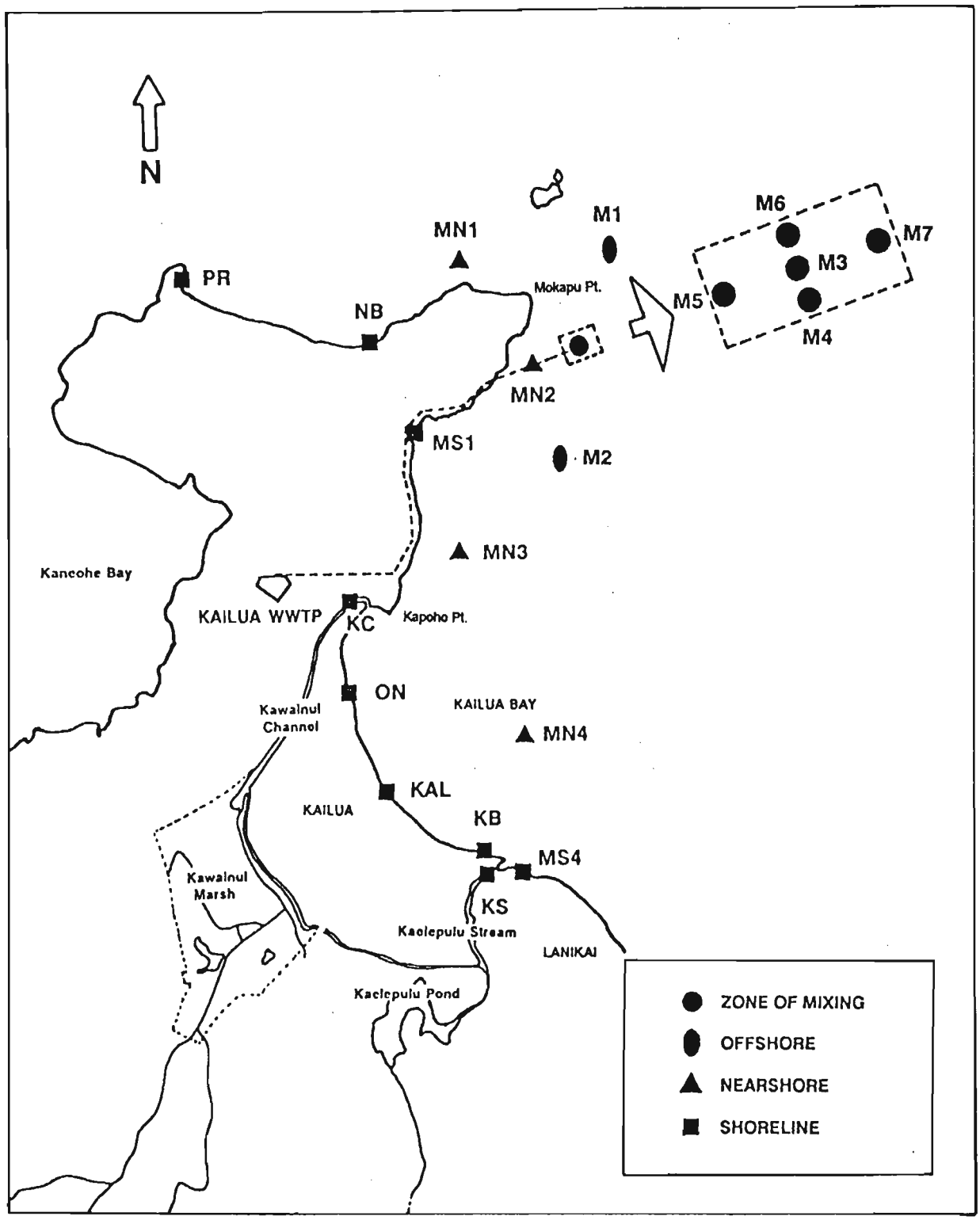
Indicator Organism	State of Hawaii	U.S. EPA
Freshwater		
Enterococci	Not recognized	33
Escherichia coli	Not recognized	126
Fecal Coliform	200	Old Standard
Marine Water		
Enterococci	7	35

SOURCE: Roll and Fujioka (1993), p. 56.

their probable causes. Unfortunately, some other portions of these meetings were dominated by attacks on the personal integrity and motivation of the researchers.

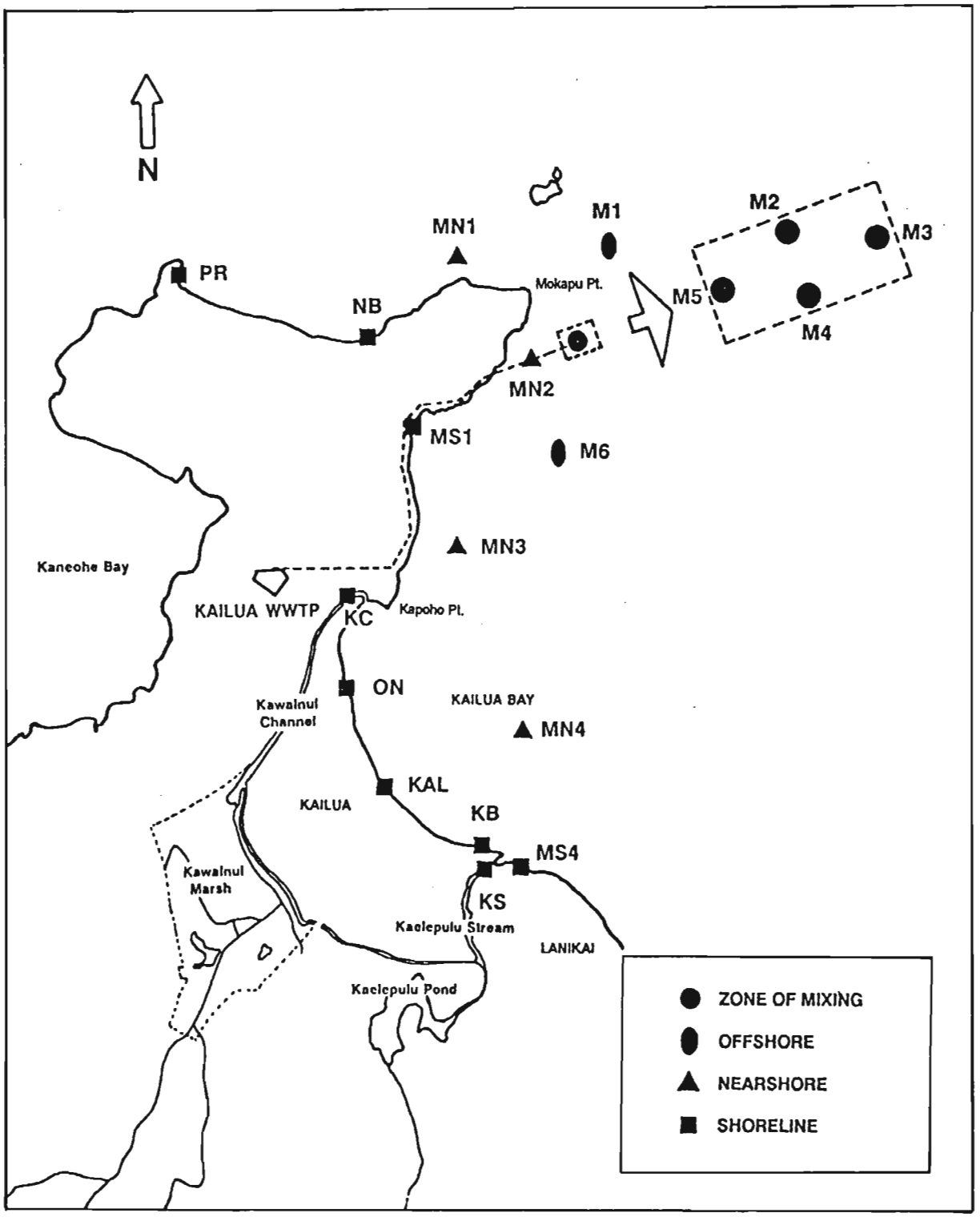
Genuine concerns not already being covered by the ongoing research were expressed in the public interaction portion of this study. The three concerns deemed extremely important by the community were (1) sampling water at frequency interval mandated by U.S. Environmental Protection Agency to determine whether the quality of water meets the recreational standard as stated in the EPA and State of Hawaii regulations, (2) the occasional presence of areas of yellow-green, foamy water near Kailua Beach, and (3) dermatological health problems.

The first of these concerns were met, and the results are detailed in the Kawainui study (Ahuna and Fujioka 1993) and the Ka'elepulu Stream study (Roll and Fujioka 1993). It should be noted that monitoring water sites to determine whether the quality of water meets the legal definition of meeting the recreational water quality standard is the ongoing responsibility of the Hawaii Department of Health. In contrast, our study was research in nature to determine the sources and movement of the various water quality indicators at various water sites. As a result, we used our resources to include analyzing for more types of indicator bacteria and sampling water at sites that normally would not be sampled. However, in response to



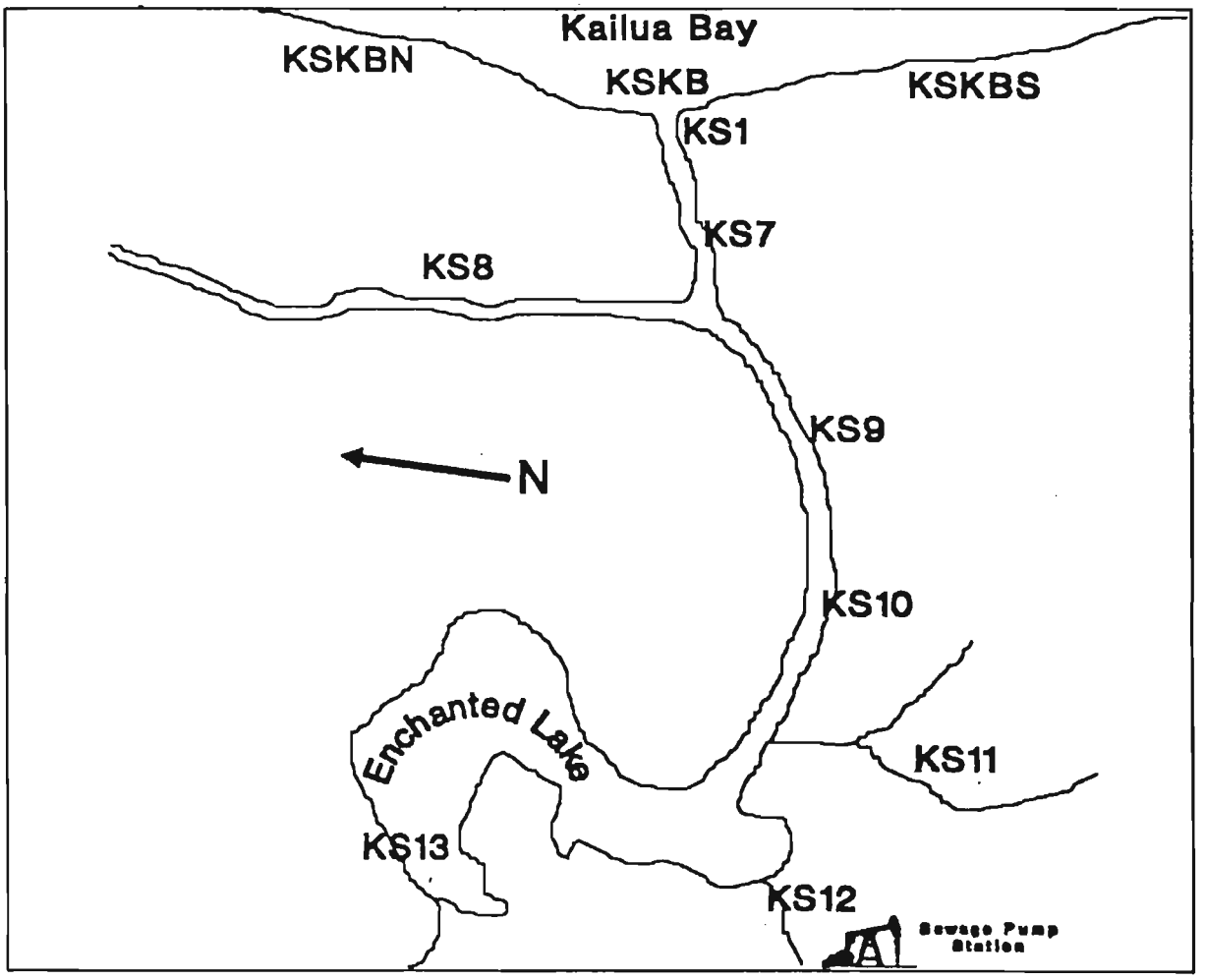
SOURCE: Fujioka et al. (1993), p. 90.

FIGURE 1. 1990 Mokapu Ocean Outfall monitoring stations



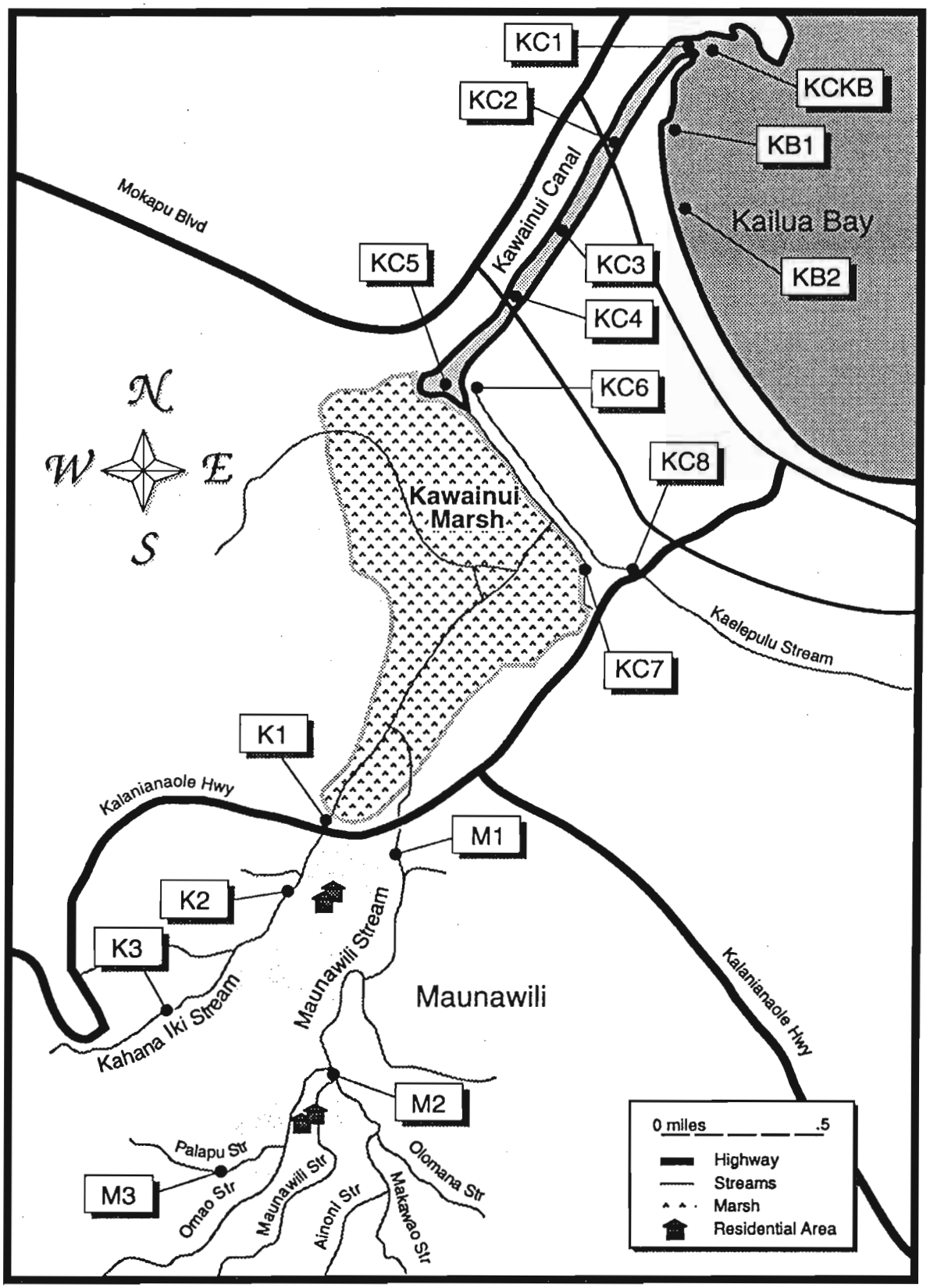
SOURCE: Fujioka et al. (1993), p. 89.

FIGURE 2. 1991 Mokapu Ocean Outfall monitoring stations



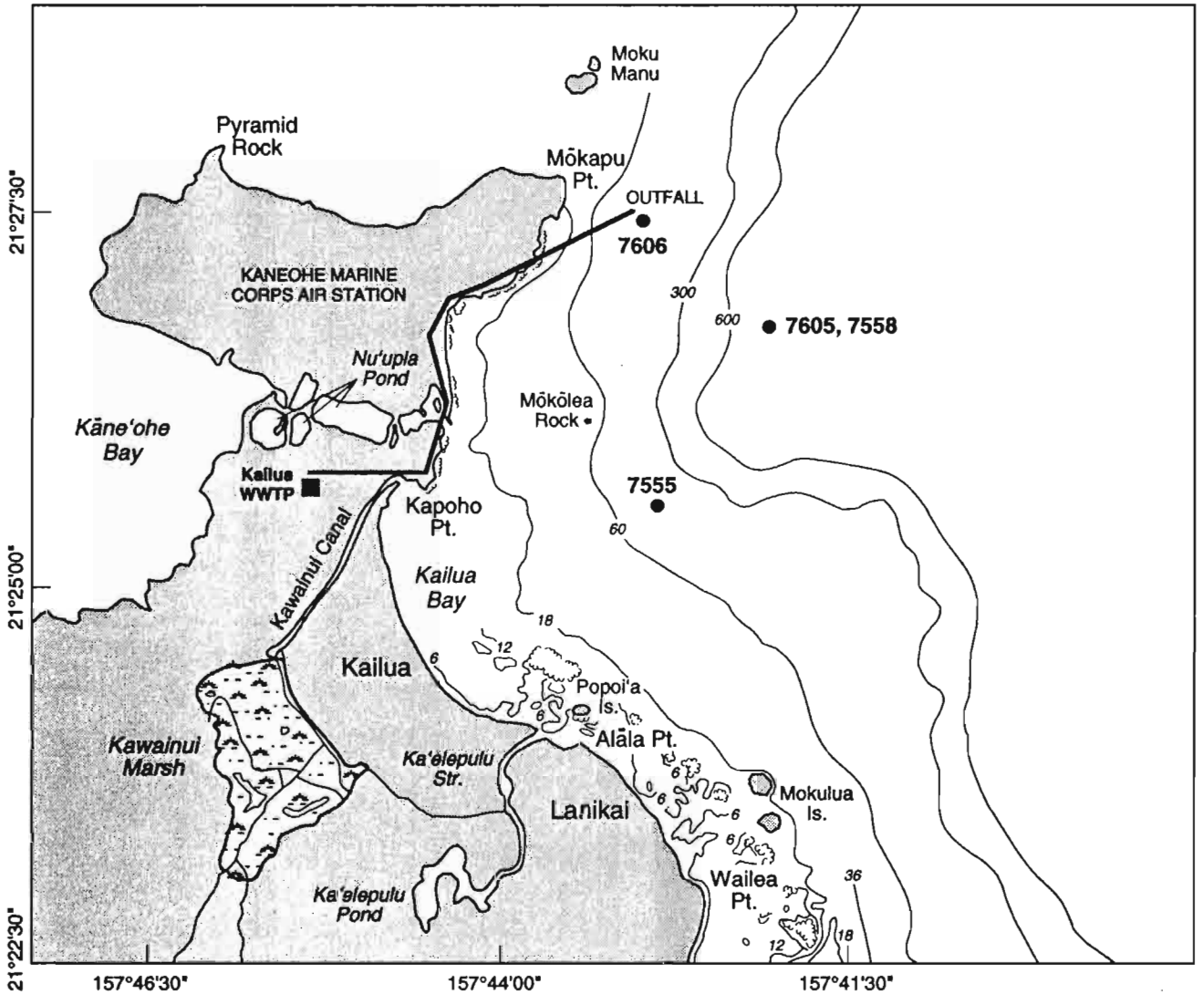
SOURCE: Roll and Fujioka (1993), p. 30.

FIGURE 3. Sample site locations for Ka'elepulu Stream



SOURCE: Ahuna and Fujioka (1993), p. 30.

FIGURE 4. Sample site locations at Maunawili, Kawainui Marsh/Canal, and Kailua Bay



SOURCE: USGS base map, 1:24 000 scale.
SOURCE: Krock and Sundararaghavan (1993), p. 6.
NOTE: Bathymetry in feet.

FIGURE 5. Current meter locations for first deployment, Kailua Bay

community concerns, we did increase our sampling frequencies at various sites to determine compliance or non-compliance to federal and state recreational water quality standards.

In response to the second concern, the WRRC study element dealing with the Kaelepulu Stream included analysis of samples of the yellow-green water and identified the problem as a green algal bloom of the genera *Pyramimonas*. These samples contained no higher concentrations of enteric indicator bacteria. Exploration of the detailed dynamics of this algal bloom was beyond the scope of this study, although it is clear from the location of the yellow-green water and the transport characteristics of Kailua Bay that the most likely cause is an increase in the mass emission rates of nutrients (total nitrogen and/or total phosphorus) resulting from the increased urban area and larger human and animal population in the drainage basin, and the corresponding decrease in the nutrient-absorbing wetland area. The nutrient loading from wastewater discharges to the area where the yellow-green water was found has decreased since the discontinuation of discharge from the old Kailua outfall in 13 ft (4.0 m) of water not far from Kapoho Point near the northern end of Kailua Beach. Consequently, the solution to the apparent excess nutrient problem in the nearshore area of Kailua Bay lies in drainage basin management, rather than in any alteration of wastewater treatment.

The third concern dealt with skin infections that may be associated with contact with marine waters and are not adequately addressed by the present bacteriological water quality standards. Present standards deal with enteric organisms and seek to trace and prevent sewage-related disease outbreaks transmitted by ingestion of water. As noted in the reports by Ahuna and Fujioka (1993) and Roll and Fujioka (1993), a large number of possible waterborne diseases are not related to enteric organisms or sewage, and a continuing need exists to develop more comprehensive indicators for possible health problems related to aquatic activities. Those organisms found in recreational waters that have been known to be associated with skin infections and infections of wounds include the species of *Aeromonas, Staphylococcus,* and *Vibrio*. This problem has been addressed in a separate study conducted by the Water Resources Research Center (Fujioka and Charoenca 1991; Charoenca and Fujioka 1993); the study

provided evidence that the concentration of staphylococcus in recreational water is related to the concentration of people in the water. In addition, the concentration of *Vibrio* may be related to the concentration of organic material in the water. The identification of an acceptable indicator organism for water-related dermatological health problems and the establishment of a tropical water standard for such an indicator organism have yet to be researched. Such a new health standard would involve epidemiological investigations at several locations and the development of reliable and inexpensive testing methodology.

Three other studies were conducted in response to concerns raised by the Kailua community. These studies were directed by Dr. Roger Fujioka as student research projects conducted by the Water Resources Research Center. These studies were funded by Water Resources Research Center and involved contributory time of some students. None of the funds from the Kailua Bay studies was used to support these independent, although related studies. The results of these studies are written up in the following reports:

- Kuge, R. 1992. Kawainui Marsh bacteriological and nutrient assessment. Final project completion report for field training study under the supervision of R. Fujioka and B. Roll, Water Resources Research Center, University of Hawaii at Manoa, Honolulu, Hawaii.

- Caplan, F. 1992. A microbiological assessment of Kaelepulu Stream quality through the analysis of water and indigenous Pacific oysters. M.S. Thesis, School of Public Health, University of Hawaii at Manoa, Honolulu, Hawaii. 100 pp.

- Bromwell, K.B. 1993. Assessing the primary biological productivity of Kailua Bay, its influencing streams and secondary treated effluent through algal biostimulation analysis. M.S. Thesis, School of Public Health, University of Hawaii at Manoa, Honolulu, Hawaii. 78 pp.

The Kailua Bay study is the first in which a community interaction component was included as a separate but integral part of the overall environmental research study. The community interaction component was included because the principal investigators of this study recognized the potential benefits to both the project principal investigators and the community. For the principal investigators, the community interaction component is an opportunity to learn about all the concerns of the community and to receive relevant input from people who best know the conditions of the study site. Thus, beneficial modifications of the

study design can be implemented during the study. For the community, this component of the study is an opportunity to better understand the project design, the methods used, and the results of the data as the study is being conducted. It is an opportunity to contribute to the study and to be in a better position to evaluate the results of the study long before the final report is written.

Having completed this study, we recognize some of the disadvantages of including a community interaction component. First, once this component is agreed upon, the community has high expectations that principal investigators will keep the community fully informed and are willing to answer all questions of doubt or misunderstanding by any member of the community. Thus, principal investigators must be ready to commit considerable time and effort to explain scientific principles, methodology, and interpretation of data to people who are not trained in this area. Principal investigators must be patient and learn to use language and concepts more familiar to everyday use. Fulfilling these responsibilities can interfere with the time required to address the research objectives of the study. Second, principal investigators and project personnel can expect to meet some hostile members of the community who will question their moral integrity as well as their qualifications as scientists capable of conducting the study. Third, some individuals who attend public presentations can be expected to use the occasion as a forum for their own agenda, be it personal, political, or legalistic in nature. Fourth, principal investigators have very little control during public presentations and are expected to answer each and every question put forth to them—even if some of the questions raised are not relevant to the study at hand. Moreover, new people attending these public presentations at various stages of the project expect principal investigators to explain the whole history and the collection of data from the very beginning.

Based on our experience, we believe the advantages of the public interaction component of this study outweighs the disadvantages. We therefore recommend that a public interaction component be added to all large environmental studies that can afford to add this component without sacrificing the needs of the research. Moreover, principal investigators of the project

should not be responsible for this component of the study; instead, a person trained in technology transfer and skilled in interacting with the community should be given the responsibility. Finally, effort should be made to establish some guidelines before the study is begun to scope out the bounds of responsibility for all parties to ensure that the study proceeds efficiently, effectively, and fairly.

ASSESSMENT

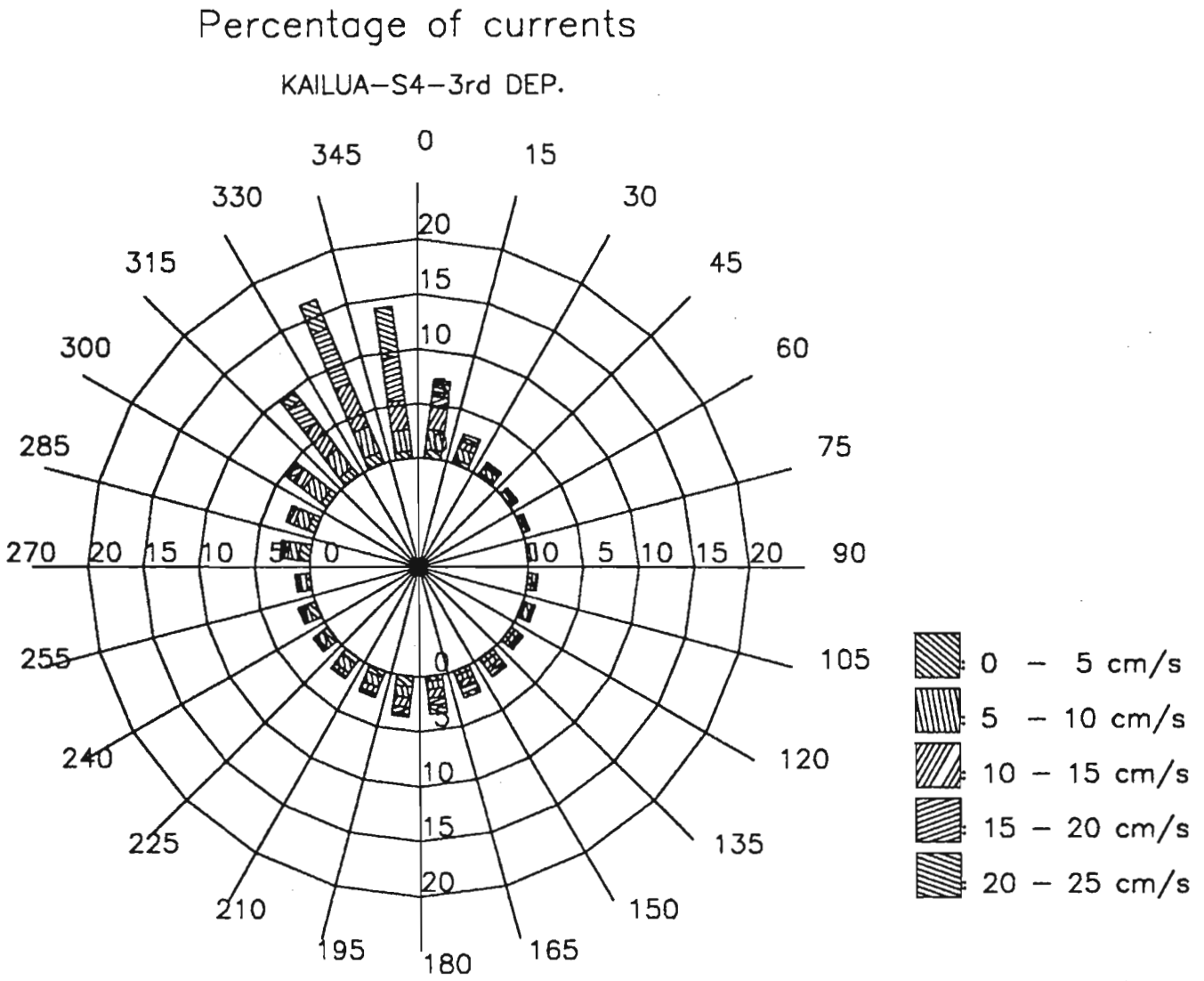
The basic objective of this assessment is to determine the relative importance of the Mōkapu outfall discharge and the land-derived discharges on the observed pollution on the beaches of Kailua Bay and on the concentration of enteric bacteriological indicator organisms in the coastal recreational waters. Two independent approaches were taken to determine the relative importance of the discharges from the two sources on the bacteriological conditions in the bay. The most direct approach was to measure the concentrations of indicator organisms at several depths and locations throughout the Kailua Bay area over a period of two years. The spatial pattern of the results is described in great detail in Fujioka et al. (1993). The pattern shows that bacteriological levels are higher in the Mōkapu zone of mixing in bottom and mid-water samples than in surface samples. The pattern also shows more influence from the discharge in a northerly direction than to the south. Virtually no indicator organisms were found in samples taken at locations approximately halfway between the outfall diffuser and the Kailua Beach area. Organisms in shoreline samples were found to be highest at the discharge points of Kawainui Channel and Ka'elepulu Stream (especially during flood flow) and lowest away from these points. Concentrations of organisms found in samples taken at shoreline stations on the beach on the north shore of the Mōkapu Peninsula occasionally exceed bacteriological standards.

The indirect approach was to measure the transport pattern in Kailua Bay and use the results to calculate and estimate the distribution of bacteriological indicator organism concentrations. The results of that approach are reported in Krock and Sundararaghavan

(1993). They used the results of measurements taken over a three-year period, as well as the results of previous studies, to describe the transport pattern in Kailua Bay. As shown in Figure 6, the transport in the vicinity of the Mōkapu diffuser is predominantly in a northerly direction away from Kailua Bay. In the nearshore area within the 5-m bathymetric contour, the transport is due primarily to breaking waves and secondarily to freshwater inflow. This pattern is shown in Figure 7. Transport from the Mōkapu outfall diffuser area to the reef area near the southern end of Kailua Beach is possible when a combination of events occurs. These events include a surfacing plume, a southerly current of several hours duration at the diffuser, and a significant wind velocity from the north or north by northeast. This combination is estimated to occur about 1.7% of the time. However, the resultant effect on the bacteriological conditions at the reef area is expected to be below the limit of detection, because of the high dilution and long exposure time. On the other hand, the wind-related transport pattern does include occasional transport of some of the discharge from the Mōkapu outfall to the beach area on the north-facing shore of the Mōkapu Peninsula.

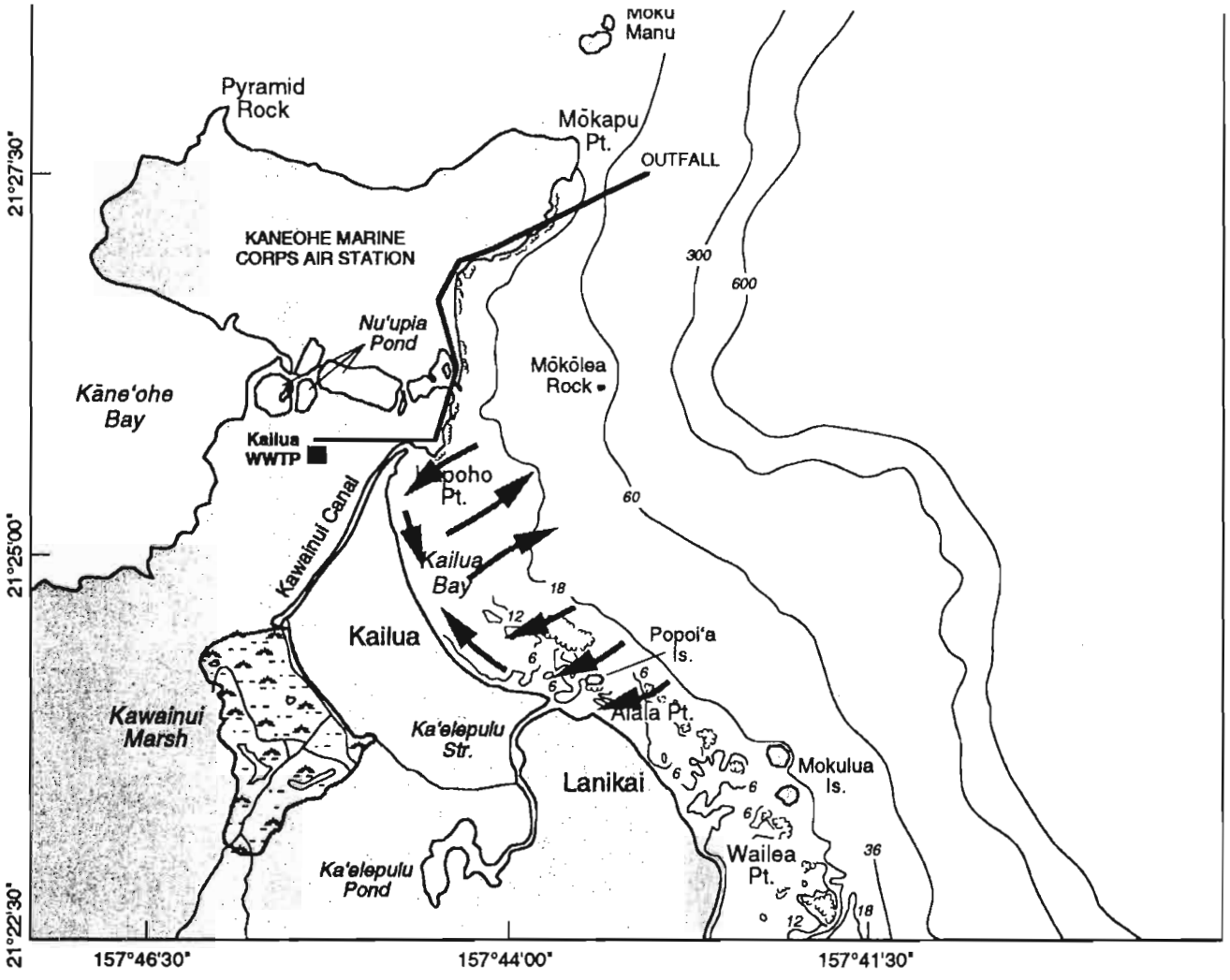
The transport pattern and the bacteriological sampling result pattern are essentially identical and, thereby, indicate that a reliable description of the dynamics of Kailua Bay is achieved. This description shows that the bacteriological water quality conditions in the recreational area adjacent to Kailua Beach are primarily influenced by land-derived discharges and direct recreational usage and that the influence of the Mōkapu outfall discharge on this area is insignificant. This description also shows that bacteriological conditions inside the zone of mixing are frequently higher than desirable for recreational contact; therefore, this zone should not be used for recreational activities.

The practical result of these findings is that efforts to improve the bacteriological conditions in the nearshore recreational area of Kailua Bay should be directed to discharges from the Kailua Bay drainage basin if they are to be effective. The reports by Ahuna and Fujioka (1993) and Roll and Fujioka (1993) identify the sources of the bacteriological indicator organisms in this area. These reports support the conclusion of previous studies conducted in



SOURCE: Krock and Sundararaghavan (1993), p. C-11.

FIGURE 6. Current rose at Mokapu Ocean Outfall diffuser



SOURCE: USGS base map, 1:24 000 scale.
SOURCE: Krock and Sundararaghavan (1993), p. 16.
NOTE: Bathymetry in feet.

FIGURE 7. Nearshore circulation pattern at Kailua Bay

Hawaii that there are three sources (human sewage, animal feces, and soil) of the indicator bacteria used to determine the quality of water. Of these sources, raw sewage represents the greatest health hazard to the community. Thus, emphasis should be placed on preventing the discharge of raw sewage into environmental waters, especially inland waters that are in close association with people.

Animals such as birds as well as pets that discharge feces into streams constitute a second source of indicator bacteria. However, this source of indicator bacteria poses less of a risk to people than human sewage. The practice of discharging feces deteriorates the quality of water; therefore, more control of animals should be instituted in areas where water is to be used for recreational purposes.

The third source of indicator bacteria is soil. This source most likely accounts for the highly elevated concentrations of indicator bacteria in receiving waters following heavy rain events. The public health significance of this source of indicator bacteria still needs to be documented. However, because these bacteria are most likely multiplying in the soil, their numbers would not be a good indicator for pathogenic microorganisms.

The presence of high concentrations of indicator bacteria in the soil and streams appears to be a phenomenon of tropical islands. The aforementioned results indicate that better indicators of water quality are required for tropical islands. The results of the current study support the results of earlier studies, which indicate that *C. perfringens* is a superior indicator of sewage pollution in tropical islands as compared to EPA-approved indicators (fecal coliform, *E. coli,* enterococci).

The origin of undesirable materials that have been found on Kailua Beach (such as prophylactics and fecal material) is likely beach users and their dogs as well as marine turtles. Since all of the Kailua Wastewater Treatment Plant effluent passes through a fine screen before entering the outfall pipe, the discharge contains no large-size solids and, therefore, cannot be the source of these materials. However, floatable material such as oil and grease, if in high-enough concentration, is susceptible to direct wind-induced transport from the discharge area to

Kailua Beach. Consequently, the removal of such floatables should remain a high priority of the treatment process.

PROJECT RECOMMENDATIONS

Based on the results of this study, the following recommendations are made for future considerations:

1. Encourage EPA and the Hawaii Department of Health to resolve the question of inappropriate enteric indicators used to establish recreational water quality standards in Hawaii and other tropical islands.
2. Encourage EPA and the Hawaii Department of Health to begin a research program to identify an appropriate indicator organism for dermatological health problems in tropical waters and to set a standard for that organism.
3. Continue the monitoring program for the shoreline stations in Kailua Bay and on the beach at Mōkapu Peninsula.
4. Develop a nonpoint source control program for the Kailua Bay drainage basin to control the detrimental water quality conditions in Kailua Bay.
5. Encourage the inclusion of a community interaction component for all large environmental projects. Persons skilled in technology transfer should be in charge of this component. Guidelines should be developed to increase the effectiveness and fairness of community interaction.
6. Conduct a study of the bacteriological conditions in the waters off the beach on the north side of the Mōkapu Peninsula to determine if the seabird population or the Mokapu Ocean Outfall is the most important contributing factor to the enteric indicator organism level. If the most important factor is the Mokapu Ocean Outfall and if future increases in flow resulting from population increases are expected to cause excessive violations of the bacteriological standard, then consideration should be given to

extending the Mokapu outfall to deeper water to reduce the frequency of plume surfacing.

REFERENCES CITED

Ahuna, L., and R. Fujioka. 1993. Impact of Kawainui Canal on the recreational water quality of Kailua Bay (KB-4). Project Rep. PR-94-07, Water Resources Research Center, University of Hawaii at Manoa, Honolulu.

Charoenca, N., and R. Fujioka. 1993. Assessment of *Staphylococcus* bacteria in Hawaii Marine recreational waters. *Water Sci. Tech.* 27:283–289.

Fujioka, R.S., and N. Charoenca. 1991. Establishing the concentrations of staphylococcus, vibrio, pseudomonas bacteria and phosphate in Hawaii's recreational waters. WRRC project completion report to Department of Health, State of Hawaii. 115 pp.

Fujioka, R.S., C. Wu, and C.K. Fujioka. 1993. Assessing the impact of Mokapu sewage outfall on the shoreline water quality of Kailua Bay (KB-2). Project Rep. PR-94-05, Water Resources Research Center, University of Hawaii at Manoa, Honolulu.

Krock, H.-J., and H. Sundararaghavan. 1993. Kailua Bay circulation (KB-5). Project Rep. PR-94-08, Water Resources Research Center, University of Hawaii at Manoa, Honolulu.

Moravcik, P., and L. Heitz. 1993. Kailua Bay studies: Community interaction (KB-1). Project Rep. PR-94-04, Water Resources Research Center, University of Hawaii at Manoa, Honolulu.

Roll, B.M., and R.S. Fujioka. 1993. Microbiological assessment of Kaelepulu Stream and the impact of discharge in Kailua Bay (KB-3). Project Rep. PR-94-06, Water Resources Research Center, University of Hawaii at Manoa, Honolulu.