A GUIDE TO VOLUNTEER WATER QUALITY MONITORING FOR HAWAI'I

A WORKING DOCUMENT

by

Sea Grant College Program
School of Ocean and Earth Science and Technology
University of Hawai'i

with collaboration from

Clean Water Branch
Department of Health
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SECTION 1

PREFACE AND ACKNOWLEDGMENTS

PREFACE AND ACKNOWLEDGMENTS

This manual was developed out of a perceived need working with volunteers during our pilot project on windward O'ahu. It represents the efforts of many people both employed by the project as well as by volunteers. This pilot project, the Kailua and Waimanalo Bays Volunteer Water Quality Monitoring Program, began with an appropriation from the 1993 Hawai'i State Legislature to the Department of Health to "...develop a pilot program to determine the contribution that volunteers from a community could make to monitoring water quality working with governmental agencies and the scientific community." The initial funding allowed the program to continue through December 1994; subsequently, additional funds carried the program to completion in June 1996.

The volunteer manual was completed in draft form in December 1994. Positions funded under the original program terminated at that time due to the depletion of funds. The draft document developed under the original funding source is presented in Section 2. Since the authors are no longer with Sea Grant, editorial changes have been addressed as needed and our contribution to this section has primarily been to obtain clean copies of, and permission for, the reproduction of materials used in this section. Also presented in Chapter 2 (Appendix XI) is a report prepared by the authors of Chapter 2 for the Eighteenth Hawaii State Legislature on the progress made up to 1994 on the project. This report provides some of the rationale as to the selection of projects carried out by the pilot volunteer water quality monitoring program.

The manual is a working document. As such, it has not been bound. We believe that future programs should be able to add to and update the existing document. It is presently divided into four sections and additional sections may be easily added in the future. Hawaiian watersheds and the characteristics of water quality in subtropical insular settings as well as the biological components may be very different from those found in temperate North American settings. This manual was developed, in part, because of these differences. Section 1 is an introduction to the overall document and Section 2 presents the draft manual as noted above. Section 3 is a compilation of the work done under our administration of the project (from January 1995 through June 1996) and it focuses primarily on the scientific aspects of the program. Section 3 also evaluates the pilot volunteer water quality monitoring program from a scientific perspective. Section 4 is a bibliography of documents that would be useful for any volunteer water quality monitoring program whether in Hawai'i or elsewhere. Many of the documents cited in this section are from state and/or federally funded programs. We have reproduced the title page and abstract (where available) of each of these, as well as the addresses of where they may be available.

There have been numerous individuals as well as agencies contributing to the success of this pilot project. First, the 1993 legislative appropriation to the Department of Health must be acknowledged. This appropriation carried the program from its inception in November 1993 to January 1995. Subsequent funding from the Department of Health in September 1995 allowed the program to complete scientific objectives and the overall evaluation of the program by 30 June 1996. The able administration of the Department of Health has guided our work here at Sea Grant from the inception of the program. The cooperation with this agency has been outstanding and without them the project would not have enjoyed the success that it has.

With the initial funding, David Tarnas (now Representative), Adam Rose, Arvin Wu and Daniel Sailer, working under the auspices of Sea Grant, established the program and ably met all

objectives. As noted above, funds for this first phase were depleted by January 1995. The program was turned over to Richard Brock, Alan Kam and Christine Woolaway at Sea Grant who donated their time and energies to completing the project. In the period from January through mid-September 1995 the project continued without any funding. Additional funds from the Department of Health were awarded in September 1995 allowing the program to come to completion in June 1996. The numerous volunteers from Waimanalo and Kailua who contributed their time, ideas and wisdom to the project are owed a great Mahalo. Without them, the project would never have come to be. Lastly, we wish to thank the Sea Grant fiscal office and Communications Program whose help made this all a success.

Included with this manual (in the back pocket of the binder) is a set of maps developed using a GIS system and data from the City and County of Honolulu. We would not have been able to develop these maps without the assistance and sharing of data from the City and County Honolulu. These maps were ably produced by Eric Yamashita of the Geography Department, University of Hawai'i. They were originally developed in color which delineated many features well, but due to the costs of reprography, they have been xerox copied thus losing some detail. The maps were developed during the latter part of the project in response to some volunteers wanting local area maps with more detail to assist them in the field. Detailed maps may be a useful addition to some volunteer projects and are included here as examples of what may be done with today's technology.

The results of this study have led to a number of conclusions and recommendations. None of the findings endorse certain products over others. The readers of this document should explore all relevant materials prior to embarking on their own program. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

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SECTION 2

VOLUNTEER WATER QUALITY MONITORING MANUAL FOR STREAMS

Prepared for the

**Hawai'i State Department of Health
and the Communities of Hawai'i**

by

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This manual would not have been possible without the invaluable assistance and participation of the Kailua and Waimanalo communities. Their work and dedication to the Kailua Bay and Waimanalo Bay Volunteer Water Quality Monitoring Program will undoubtedly inspire other communities to follow in their steps. In particular we would like to thank Nancy Glover and Armand Pelletier for their contributions and editorial assistance, former House Vice Speaker Jackie Young for the initial funding of the pilot program, the Hawai'i State Department of Health, the Division of Aquatic Resources in the State Department of Land and Natural Resources, and the administrative staff of the University of Hawai'i Sea Grant Extension Service for their unending patience.

We would also like to thank Kim Des Rochers and the Sea Grant Communications staff for their timely editing and grace under pressure.

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I. INTRODUCTION

A growing number of people in Hawai'i are becoming increasingly concerned about our islands' aquatic environment. They are noticing a decline in the water quality of both our marine and freshwater resources, and citizens' groups and high schools are responding by organizing monitoring projects.

This manual is the result of a pilot project that was established on windward O'ahu in October 1993 by the Hawai'i State Department of Health, the University of Hawai'i Sea Grant Extension Service, and the communities of Waimanalo and Kailua. The goals of the pilot project were to:

- Help develop an educated and involved community committed to preserving and protecting Hawai'i's waters.
- Organize community members into monitoring groups to collect usable water quality data relating to the local bays and watersheds.
- Help develop community-based solutions to water quality problems that can be replicated elsewhere in Hawai'i.

Because much of the pollution from anthropogenic sources in Hawai'i involves inorganic nutrients (e.g., from cesspools), many professional monitoring programs focus on determining the concentrations of these constituents. In most marine waters, nutrient concentrations are relatively low and require costly and sophisticated analytical procedures. However, these nutrient concentrations are often much greater in streams. Relatively low-cost analytical techniques and equipment are available that can be used easily by volunteers and will result in reasonable and repeatable measurements of inorganic nutrient concentrations. Because this demonstration program used volunteers and funding was limited, emphasis was placed on monitoring the streams on windward O'ahu.

Written to help establish other community-based volunteer water quality monitoring programs, this manual provides some guidance and a basic framework for other communities to organize and conduct their own watershed surveys and stream water analyses.

The manual should only be considered as a basic primer on some aspects of developing a community-based volunteer monitoring program. It was developed for a windward O'ahu setting for the purpose of establishing a volunteer stream water quality and biological monitoring program, and covers the basic elements of such a program and is not intended to replace accepted standard scientific protocols.

Each volunteer water quality monitoring program should be designed with an awareness and sensitivity toward the needs of the local community. Programs should be planned and implemented with full consideration of the study area's social, cultural and geographic realities, as well as the area's specific environmental characteristics and constraints. For example, some goals, organizational principles and implementation mechanisms may be similar and related to each other; however, other project aspects may differ and should be considered on a case-by-case basis when developing programs. Programs must be site specific. Communities may find it necessary to supplement this manual with additional materials, literature, technical advice and expertise, as needed.

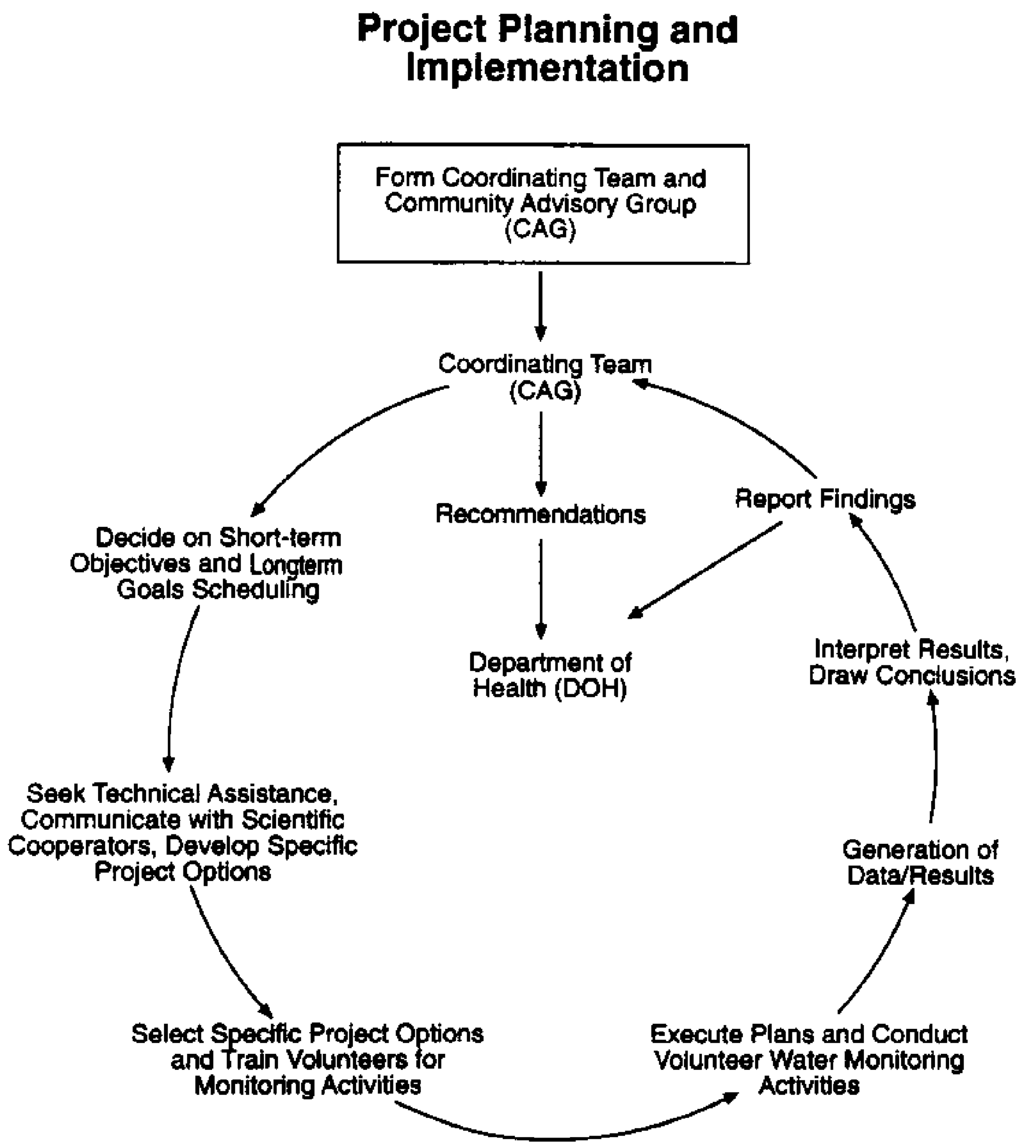


Figure 1. A composite overview of the Pilot Project's planning phases. It traces the stages of the project's implementation.

II. PROJECT ORGANIZATION

A. GETTING STARTED

1. Basic Steps and Useful Tips

- An important initial step is to find a professional project coordinator. This individual should have a scientific background as well as skills in mediation; the commitment of the coordinator is central to the project's success.
- The next step is to get people involved. Conduct an initial public information meeting with interested persons from local civic groups, neighborhood boards and environmental groups. Advertise this meeting well, and brainstorm on how you can recruit more volunteers. Try to obtain mailing lists from local environmental and community organizations. Be sure to contact local papers and publications, use community bulletin boards, free radio and television public service announcements to inform your target audience. Get as much publicity as you can early on. A project brochure is a great way to generate local interest in the project (see Appendix VIII for an example). Also, collect the names and addresses of attendees at every meeting; they will be the core of your organization.
- Form a community advisory group made up of representatives from local organizations, community members, scientific experts and government agencies.
- Identify local people with relevant skills. Develop a resource base of previous reports, local surveys and area information. A familiarity with your area's watershed will help guide your own investigations.
- Develop a short- and longterm schedule, and define specific goals and objectives. Clear objectives keep volunteers focused and aware of what they are doing, and why they are doing it.
- Have a clear purpose behind your monitoring activities. Seek to answer specific questions in a direct, investigative manner.
- Design a program that is sustainable in terms of both funding and realistic volunteer activities with longterm goals.
- Develop a realistic budget. Be aware that the bulk of the costs incurred will be for equipment, data analysis and project administration for a breakdown of the Pilot Project budget.
- Develop fundraising strategies and secure funding from federal, state and private sources, as well as charitable foundations. Money is an essential component for any successful environmental monitoring program.
- Develop a plan to ensure the credibility of the data collected. Contact interested scientists and relevant government agencies for their assistance in establishing the necessary quality controls.
- Be creative in finding ways to maintain the dedication and motivation of volunteers. Developing and organizing a program is a lengthy process; do not expect the program to fall into place immediately. Prepare a regular newsletter and be available for questions and requests. Volunteers like short-term results and positive feedback. Easy service projects, like litter pick-ups or field trips, are helpful for maintaining enthusiasm and attracting

new volunteers. News releases of major program events and informational library displays also keep community interest alive. Monitoring activities may be lengthy and involved. Keep enthusiasm and dedication levels high by encouraging creativity and innovation!

2. Establishing Meeting Places

A community-based volunteer monitoring project needs to have regular meetings in easily accessible venues that are comfortable and acceptable to participants. It is also important to hold meetings in situations that are neutral and open to any member of the community. It may be more appropriate to hold meetings in public places, such as libraries or school meeting rooms, rather than volunteers' private residences. It is helpful when meeting places are available on a regular basis and are easy to reserve. Meeting places also should accommodate a large group of people who are participating in a facilitated and interactive gathering.

3. Training Volunteers and the Importance of Quality Data

It is crucial that all volunteers are properly trained to perform water quality monitoring activities. Good results can only be obtained if volunteers correctly follow established monitoring procedures and use accepted analytical techniques.

Bad data are not only useless, but they can lead to misrepresented environmental conclusions. Therefore, to ensure confidence in your results, it is essential to consistently use rigorous quality assurance and quality control protocols. Quality assurance ensures that the set of monitoring activities meets defined standards of quality within stated confidence levels. Quality control guarantees that monitoring activities are correctly performed on a step-by-step level in order to: produce quality data. For example, volunteers could split their samples and have one sample tested by a private laboratory. When compared against one another, ideally, the volunteers' and the lab's results should be nearly identical.

Quality data also result from a sound understanding of the basic principles of water quality and the environment. Because volunteers will not always be trained environmental scientists, education and training by experts will be necessary. Specifically, one should address the subject areas of hydrology, water chemistry, physics, aquatic ecology and the causes of water pollution.

The teaching process should use a wide range of stimulating instructional media, such as live presentations, videos and workshops. The creative presentation of information makes learning fun and engaging. Field trips led by experts can also provide valuable environmental interpretations and information, as well as provide opportunities for hands-on learning.

4. Interpretation of Results

Good quality data are meaningless until they have been interpreted. Data analysis and interpretation must be conducted by scientific experts and technical consultants. The community, of course, still needs to be informed of all findings and conclusions drawn from the data. A presentation to the community by the expert is an excellent way to inform them of the results. Additionally, conducting a workshop on how data are interpreted will not only make monitoring activities more meaningful, but will serve to educate volunteers on a critical element in the monitoring process. Also, be sure to make the results available to all interested parties in a clear and intelligible manner. Lastly, keep all volunteers informed on how their data are being used.

B. THE COMMUNITY ADVISORY GROUP

A volunteer water quality monitoring program is designed to empower a community by educating members about water quality and water management. It also gives members of the community the decision-making authority in the design and implementation of their project through a Community Advisory Group. A Community Advisory Group consists of representatives from various community organizations, as well as government agencies involved with water quality. Representatives decide on project direction and funding priorities and are responsible for informing their organizations of the program's activities.

The following groups actively serve on the Pilot Project's Community Advisory Group:

Waimanalo Neighborhood Board
Save Our Bays and Beaches
Sierra Club
Save Mount Olomana
City and County of Honolulu
  Department of Wastewater Management
  Department of Public Works

Kailua Neighborhood Board
Kawai Nui Heritage Foundation
Kalaheo High School
Hawai'i State Department of Health

C. THE PROJECT COORDINATING TEAM

The effective management and administration of a volunteer monitoring program is the primary responsibility of the project coordinating team. The Pilot Project's coordinating team consists of the following; one trained facilitator and coastal planner, two staff assistants, an environmental biologist, and an environmental health specialist. Their combined work hours totaled nearly two full-time positions. The pilot project's coordinating team is housed at the University of Hawai'i Sea Grant Extension Service, allowing easy access to university scientists and other resources for project design and implementation.

A volunteer water quality monitoring program requiring only implementation, could be launched with only one full-time coordinator. Water quality monitoring projects in other areas will need to tailor their project coordinating team to budgetary constraints and available resources.

D. THE SCIENTIFIC COOPERATORS

It is essential to receive advice and technical assistance from many experts when dealing with complex environmental issues, such as watershed management, nonpoint source pollution, and coastal water quality. A key role of the coordinating team is to establish and develop a network of scientific and technical experts.

Scientific cooperators serve the following functions:

- **Advisors**

Scientific cooperators are volunteer technical consultants who advise community volunteers and project coordinators, and also help direct the project's investigations and research. The scientific cooperators answer questions and recommend acceptable research methods of environmental analysis.

Community volunteers assist the project's scientific advisors, collecting data that may aid scientific advisors in their research. Community volunteers represent a potential resource to many environmental managers and scientists.

- **Education and training**

Scientific cooperators are also involved in the educational aspects of the project, such as teaching and training volunteers. Training and educational workshops should be led by experts who are experienced in giving informal talks, presentations, and answering questions on water quality and the environment. For example, experts from the Hawai'i State Department of Health, the Department of Land and Natural Resources, the City and County of Honolulu Water Quality Section, the University of Hawai'i, and the Bishop Museum have all made presentations for the Pilot Project. Using video, slides and a range of other educational media, the cooperators presented a wide range of information in a stimulating and interesting manner.

In the Pilot Project, such sessions were often followed by field trips during which many of the same experts provided volunteers with personal environmental evaluations and interpretations of the sites visited. This educational aspect of the project is a key part of the volunteers' training, ultimately helping to develop a more informed and knowledgeable community.

- **Resource base**

The scientific cooperators also provide a project with an extensive resource base. Many are willing to do analysis and other environmental tests at cost, using their organization's equipment and facilities.

In our experience, most of the scientific cooperators have aided the Pilot Project in an unpaid context. Others have been involved in our project as part of their professional activities.

- **Mutual support and collaboration**

Experts have been involved in varying levels of the Pilot Project, such as answering technical questions and offering informal advice. In many cases, they were willing to be involved in the project to gain information and practical assistance from a network of dedicated and informed volunteers acting as extensive and free human resources.

Furthermore, most environmental scientists and managers welcome the opportunity to receive data from actual situations in the real world. Investigations, such as longterm surveys and studies relating to infrequent and unpredictable environmental events (e.g., water monitoring during storm events), are almost impossible without personnel who are permanently stationed in the field. Because most research and environmental management institutions have limited staff and funds, it is often difficult for them to practically attempt such projects. Trained community volunteers have an important role in such studies and can assist in data collection for such situations.

When initially soliciting the help of potential scientific cooperators, emphasize that the project is a collaborative effort between communities, landowners, government, private industry, academics and scientists. This usually serves to mitigate many of the suspicions and skeptical attitudes some experts have toward volunteers and local communities. Also, one should stress that volunteers may be able to assist the scientist in his/her field of research, and that the program seeks to work with government researchers and communities in a mutually beneficial and cooperative manner.

E. THE STREAM TEAMS

1. Stream Team Function

Because of the large number of streams in the Waimanalo and Kailua pilot project area, we created separate stream teams to investigate the water courses within the study area's catchments. The stream teams consist of the community volunteers who are the heart of the Pilot Program.

Each stream team is responsible for a single stream or a composite stream system, and is a discrete and autonomous operational unit. This enables individual stream teams to determine their schedules and meet at their convenience. When dealing with large numbers of volunteers, this is certainly advantageous as it is obviously easier for small groups of people to agree on meeting times and places. Such an organizational device also creates more intimate social settings. Overall volunteer efforts will be far more efficient and productive when volunteers are familiar with each other, and have established good working relations. It must be stressed that although the stream teams work independently, they all carry out the same basic investigations and should regularly communicate with each other and with the coordinating team.

2. Stream Team Organization

Team Leader

The team leader coordinates and oversees the stream team's surveying and sampling activities, and communicates with the project coordinating team, the Community Advisory Group, and other team leaders.

The team leader's responsibilities include:

1. The organization and planning of field excursions for stream team sampling and surveying;
2. Storing and distributing the team's equipment, and collecting and organizing all surveying and sampling forms, as well as any other results, samples and information (e.g., photos);
3. Preparing and delivering the stream report on time.

It is important to emphasize that the team leader is free to solicit help from, and delegate tasks to, team members as appropriate.

Team Members

Stream teams can be split into sampling and surveying units. Each unit consists of three to six members who conduct activities relevant to their unit's mission.

Members should finish activities and complete any survey or sampling forms on the same day they are started. All completed forms, results and samples should be properly marked and returned to the team leader promptly.

Team members should follow all the recommended safety precautions and avoid doing anything that will negatively affect the reputation of the project, relationships with landowners, or other community members.

Team members should not attempt to make any investigations or carry out any activities other than those specified by the team leader.

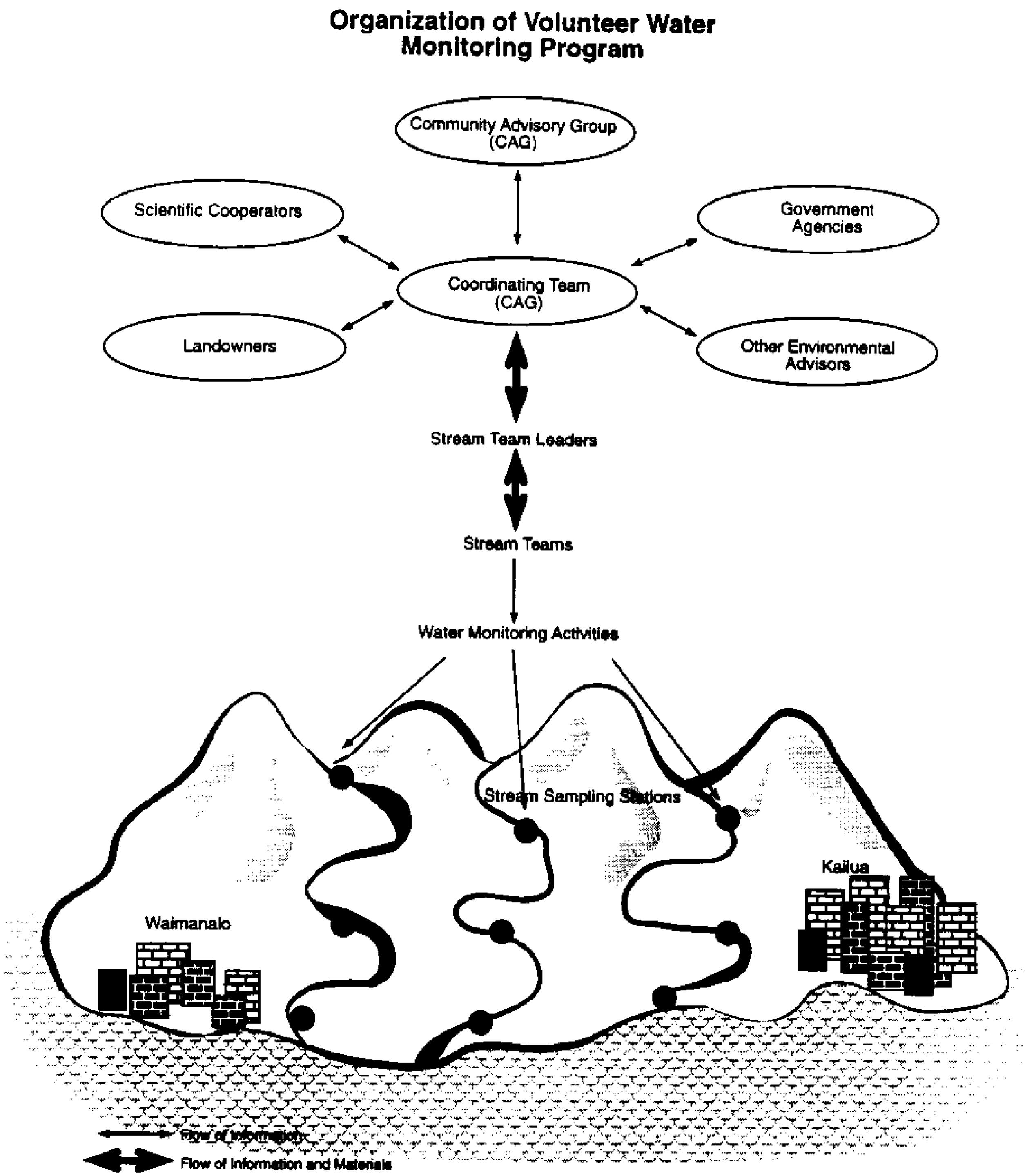


Figure 2. Illustrates how a volunteer monitoring program can be organized.

III. STREAM TEAM PROCEDURES

A. PRELIMINARY PROTOCOLS

1. Identifying the Landowners

Before any investigations are attempted, it is essential to determine the landowners (using tax key maps) and to receive their permission to access their property. The official letters requesting permission need to be prepared by the project coordinator once he/she has received the landowners' names and addresses (see Appendix X).

2. Walking the Stream Length

In order to select the sampling/surveying stations, the stream team should walk the entire length or majority of the stream. This helps determine if there are any general visible water quality problems to be investigated and gives each team an impression of the stream they will be investigating.

3. Sampling Station Selection

The pilot program set a minimum of three sampling/surveying stations per stream; one in the farthest *mauka* (inland) reach, the second in the middle reach, and the third close to the ocean. When selecting sampling/survey stations, the following criteria should be kept in mind:

- Water should be free and flowing
- Water should be well mixed
- Access to the stream should be safe and easy

It may also be useful to establish sampling stations above and below areas of specific interest such as stream junctions, effluent outfalls, or storm drains. The farthest *mauka* site must be upstream of any major confluences and human habitation, if possible. Depending on the program's goals, additional stations may be needed. Water sampling and surveying should be conducted from the same stream stations when possible. The sampling/surveying stations chosen on each stream must be checked by the coordinating team before investigations proceed. Again, use appropriate safety measures when sampling as leptospirosis, giardiasis, and flash floods are very real dangers.

4. Color Coding

To avoid confusion, each stream should be given a color code which helps to easily identify all samples and results taken from the streams. For instance, if an area's stream is color-coded yellow, it follows that all samples are labeled using yellow labeling tape, and all survey forms and sampling forms should also be marked on the top left-hand corner either with a yellow pen or with yellow tape.

5. Sampling Schedule

It is important to establish a sampling/surveying schedule. Every effort should be made to complete the sampling event for a given stream in a single day. Stream teams should also attempt to complete all stream sampling and surveying by a predetermined date, at which time the stream team leader will give the project coordinator all information gathered by the team in the form of a stream report. Stream team leaders may also wish to make progress reports, particularly if the surveying and sampling are conducted over an extended period of time. Progress reports help maintain close contact with project coordinators and ease final stream report compilations. Federal and state agencies often require quarterly reports from funded projects; timely and relevant data from the stream teams will be essential for the preparation of these periodic reports.

B. STREAM REPORT

The stream report includes the following items:

- **Cover page.** The team leader records on the cover page the landowner's name, address, and copies of letters granting the team access to the land. The cover page also lists the stream name, team leader's name, and names of all the team members (see Appendix V).
- **Maps.** A clear map showing the stream catchment and sampling/surveying stations.
- **Survey forms.** A set of completed and color-coded survey forms (see Appendix II).
- **Sampling forms.** A set of completed and color-coded water quality sampling forms (see Appendix III).
- **Algal survey forms.** A set of completed and color-coded algal survey forms. Algal samples should also be returned to the project coordinator (see Appendix IV).
- **Photographs.** Photographs should illustrate sampling/surveying stations and any other areas or features of interest. The locations should be clearly identified on the back of the photograph.
- **Additional information.** Include any other relevant information about the stream.

IV. STREAM SURVEY PROCEDURES

A. PHYSICAL CHARACTERIZATION

1. Visual Survey

A stream survey's primary purpose is to characterize a stream's physical and ecological traits. This is accomplished by making regular, detailed stream inspections at specific locations (i.e., surveying stations) and by conducting a more general examination of a stream while walking its length.

It is often a complex and time-consuming task to walk or follow the entire length of a stream in Hawai'i. In fact, in many situations it is difficult to accurately determine the exact course a stream takes in a watershed. Nevertheless, it is essential to attempt to investigate most of a stream's length in order to potentially locate visible water quality problems.

2. Maps

To help determine the stream's route and geographic setting, be sure to obtain a variety of local area maps. The following types of maps will provide a range of relevant information pertaining to the study area in question: U.S. Geological Survey maps, City and County Land Use Zoning and Public Facilities maps, irrigation system maps, and other maps used in past studies focusing on stream resources. It may also be useful to obtain aerial photographs of the watershed, so that the area's streams and tributaries can be stereo plotted. If resources allow, obtain Geographic Information System (GIS) data, and use Global Positioning System (GPS) technologies to obtain accurate coordinates of sampling/surveying stations and to record positions of any threatened or endangered native plants and animals.

3. Photographs

All monitoring sites should be photographed comprehensively. Photograph any unusual animals or plants you see to help identify them later. Make photographic records of any sites that have visibly poor water quality, or at which you find discharges, effluents, or any kind of activities that seem to be affecting water quality. Photographic documentation may be helpful in developing future studies.

Develop your film as quickly as possible and have double prints made. Submit one copy to the team leader or project coordinator, and keep one copy for yourself. All costs for film and development will be covered by the project budget, so keep receipts.

B. BIOLOGICAL CHARACTERIZATION

The biological inventory of a stream can help determine the habitats present and the status of the ecosystem. As stated previously, the stream survey should be conducted at a minimum of three locations, although more stream sites can be surveyed if the team wishes to do so. The stream survey form should be completed at every site. The algal survey should be conducted when benthic algae is observed. This necessitates setting up a transect, completing the algal survey form, and collecting samples in labeled glass vials (see Appendix IV for complete instructions).

If an organism cannot be identified, the volunteer should either take clear photographs of the organism or request that a biologist visit the site to make the necessary identification. Alternatively, live fish or invertebrate samples can be collected and put into project tanks (which can be established at local libraries) for later identification. Project tanks at local libraries allow communities to observe live samples and may ease identification for biologists. All organisms should be returned to the streams where they were originally found.

C. STREAM SURVEY FORM

The stream survey form (see Appendix II) is a mechanism to help direct and standardize visual observations of the stream environment, and to help chronicle recorded data. You must use concise and clear language when completing the form. The following is a guide to explain survey questions and technical terms.

- **Where Are You?**

Record names of the volunteers, the **date** and **time** of the survey, and also describe the current weather conditions. Report on weather conditions by indicating whether it is windy or calm, sunny or cloudy (include percent cloud cover), rainy or dry.

Location/area refers to the general district and overall watershed you are in.

Stream reach refers to the division of the stream into different stretches of its total length; the upper reach being the mountain part, and the lower reach being the ocean stretch.

Record your specific location. You can identify your whereabouts by noting your map location, the sampling station's name, or by indicating your location relative to a particular landmark.

• Streamside Characteristics

Record the land uses that are adjacent to the stream survey site. Limit your observations to an area within 100 yards of the stream survey site. It is difficult to determine land uses that occur over a larger area without being too general.

• Stream Characteristics

Note any effluents or runoff entering the stream and, if possible, determine the source(s) or origin(s) of these inputs.

Note whether the stream is channelized. Fully channelized streams no longer have their natural stream banks or streambeds. The modified stream course has usually been totally or partially lined in concrete or some other material. The stream course also may have been altered, straightened, or realigned. Some streams banks are lined with concrete, but retain their natural streambed.

Note if the stream banks are **vegetated** and give a general description of what type of vegetation is present. Also estimate the percentage of vegetation cover on the stream bank you are surveying. For instance, you might record that 50% of the bank is covered with grass, 30% with herbaceous plants, and 20% with woody shrubs or trees.

Look for signs of stream bank **erosion or trampling**. Such signs might include exposed soil, subsiding banks, evidence of livestock or wheeled vehicles, or heavily used paths. Any **soil dumping** should also be noted.

Can you see **litter** in or beside the stream? Try to describe what sort of material it is and give an indication of how much is present.

Describe the water **clarity**. Translucent water tends to be a sign of good water quality. Poor clarity may indicate water quality problems. It is also important to note that some streams, or parts of streams, will have naturally turbid waters.

A **scum or sheen** refers to a film or layer of material on the water's surface.

When describing the **streambed**, indicate the type of substrate over which the water is passing. If the bottom is not uniform in composition, try to indicate what percentage of substrate materials is present.

Some stream surveying projects will be carrying out **algal** surveys to help characterize the benthic algae. Algae are simple single-celled or multicellular plants. In the future we may be able to use algae as biological monitors of water quality. If they are found growing on the stream substrate, they are benthic in nature. If you are doing an algal survey, you will collect samples and conduct algal survey activities at that point (see Appendix IV).

• Stream Habitat, Stream Life

Survey the stream biology and habitat.

To identify the habitat type you must determine if you are sampling a pool, run, riffle, or a fall.

Pools are zones in which the water is deeper than surrounding areas and is running slowly (less than 20 cm/sec). Deep pools may have depths exceeding two meters and have little turbulence. Plunge pools are found at the bottom of waterfalls (cascades).

A **run** is an area of water that is swiftly flowing, but has little surface turbulence. Runs vary in depth, but tend to be less than two meters.

A **riffle** is a turbulent area of water flowing rapidly over submerged, or partially submerged, parts of the streambed. Riffles are also called small rapids.

A **cascade/fall** is an area with high turbulence, strong current, and a steep gradient. Cascades are also called waterfalls.

The **water depth** and **stream width** can be determined by using a measuring tape or ruler.

The stream's **flow velocity** can be determined by placing a buoyant and easily seen object in the stream, and allowing it to float along a predetermined distance. The time it takes to travel this distance is recorded. Divide the time by the distance to get the flow velocity. For instance, if you measure out a 5-meter stretch of stream and the object takes 10 seconds to float this distance, you would divide 5 by 10 to obtain a stream flow velocity of 0.5m/second. An orange can make a good float for this exercise.

You should look for any of the major groups of **organisms** listed in the stream and in the general area of the stream.

Amphibians to look for include frogs and toads (tadpoles and adults).

Mollusks include snails and other shellfish such as *hīhīwai* and *hapawai.*

Crustaceans include shrimp (*'ōpae*) and crayfish.

Insects are an enormous group. Keep a lookout for adult and nymph dragonflies and damselflies.

There are many **birds** which may live in or near streams. Look for our native rails, waders and ducks.

Although there are no **mammals** that are obviously associated with streams, mongooses, pigs, feral cats, and dogs may live near streams.

This kind of visual biotic survey will give a qualitative indication of the area's riparian life. Do not just use your eyes. Many animals are easier to hear than to see. For instance, some of Hawai'i's rarest waterfowl are more often heard than seen, as they are secretive and tend to hide themselves well. Do not forget to look for tracks, nests, droppings and feeding remains. You may not see any animals, but you might find signs of them. When you are surveying, keep quiet and try to remain still. By remaining still you will see more of what's living in the area.

When doing a fish survey, first stand quietly near a stretch of stream, making sure your shadow is not cast on the water, and try to see what is living in the water. To clearly identify the fish, attempt to catch a specimen with a scoop net and place the specimen into a bucket or jar with stream water in it.

If you cannot identify an organism you can:

1. Keep the live specimen in a tank or bottle so that an expert can identify it at a later date.

2. Photograph field specimens comprehensively. These can be used later to help identify the organisms.
3. Request an expert to visit the field site and identify the organism in question.

Many of the fish in our streams are exotic aliens that have been introduced deliberately or accidentally from other parts of the world. The most common alien species in streams include: tilapia, guppies, swordtails, mosquito fish, bass and various catfish.

Five species of native *'O'opu may be encountered.*

Use the accompanying *Stream Fauna Field Guide* in Appendix I and other publications to help identify what you find. Also refer to Part III, A of this manual before starting any survey work.

• **Other Comments**

Record any **other observations or comments** about the stream environment or perceived water quality problems on the back of the form.

V. WATER QUALITY ANALYSIS

A. INTRODUCTION

Monitoring water quality involves sampling water and measuring predetermined variables to provide an indication of water quality. These measurements are often instrumental in revealing the presence of contaminants, pollutants and other elements of poor water quality.

It is important to realize that data alone will not directly reveal the sources and origins of poor water quality. As part of an overall strategy, data collection and its interpretation can help to locate and identify specific causes of water contamination. This approach primarily relies on investigative sampling methods. Monitoring can also provide baseline data about a site. Baseline information records an area's water quality characteristics over time. Remember, there must be a clear purpose motivating any water monitoring activities. Data collection requires a clear understanding of why you are taking measurements and how the data will be used.

Commonly tested water quality variables include:

- Dissolved oxygen
- pH
- Nitrate-nitrite
- Orthophosphates
- Salinity
- Temperature
- Total suspended solids

B. ENVIRONMENTAL SIGNIFICANCE OF WATER QUALITY VARIABLES

1. Dissolved Oxygen

The dissolved oxygen (DO) test measures the amount of oxygen dissolved in water. Dissolved oxygen is essential for a healthy stream ecosystem. The oxygen dissolved in water comes primarily from the atmosphere, but some oxygen is derived from aquatic plants through photosynthesis. As oxygen is relatively insoluble in water, DO concentrations are highly dependent on temperature and atmospheric pressure. In general, the higher the temperature, the lower the DO levels; the higher the atmospheric pressure (which decreases with elevation), the higher the DO levels. The solubility of oxygen also decreases as the salinity increases. The saturation (maximum) DO concentration in freshwater at sea level at 25°C (77°F) is 8.4 mg/L. Generally, highly turbulent waters are more saturated with DO than stagnant or slowly flowing waters.

The amount of dissolved oxygen in water largely determines the types of organisms that are present. Most of the aquatic plants and animals we are familiar with require high dissolved oxygen levels (aerobic conditions) for respiration. In waters with low dissolved oxygen levels (anaerobic conditions) only a few tolerant species, such as certain types of worms, midge larvae, and microorganisms, thrive. In polluted waters, fish kills may result when dissolved oxygen concentrations dip below 4 mg/liter. The foul odors associated with stagnant waters are typically produced by anaerobic microorganisms that reduce inorganic salts like sulfates and produce hydrogen sulfide and methane.

As a result of photosynthesis, DO levels in streams typically fluctuate through the course of a day, rising gradually through the day and decreasing at night. Thus, the sampling time must be noted when interpreting DO data.

Low DO concentrations in water can be an indication of many water pollution problems. Low DO conditions are usually a result of microbiological decomposition of organic wastes. Microorganisms consume oxygen when breaking down organic wastes associated with storm water runoff, sewage, animal wastes, and dairy and food production effluents.

According to state standards, DO concentrations in stream water shall not be less than 80% saturation as a function of ambient water temperature.

2. pH

The pH value can be considered as a measure of the acidity or alkalinity of a substance. The value is one of the most crucial indicators of water quality because many organisms, particularly fish, have very narrow tolerances of pH changes. Waters with either unusually high or low pH levels will usually have fewer aquatic specimens.

The pH value is measured on a 14-point scale, with 1 being the most acidic, 14 being the most basic (alkaline), and 7 as neutral. In acidic conditions, hydrogen ions predominate, and in basic conditions, hydroxyl ions predominate. At the neutral pH of 7, there are equal amounts of hydrogen and hydroxyl ions. The pH of natural waters is predominantly determined by the region's geology.

Acidic conditions can be the result of acid rain brought about by sulfate emissions, industrial wastes, and natural geologic formations. Acidic conditions may dissolve toxic heavy metals that could affect aquatic life. Alkaline conditions may result from the removal of dissolved carbon dioxide from water. Because carbon dioxide is a slightly acidic gas, its removal by algae in algal blooms can raise the pH to as high as 10. Algal blooms are a serious problem, particularly in the channelized reaches of streams that receive considerable amounts of sunlight and nutrients. The pH levels of 10 are also very stressful to all but the hardiest of fish, like tilapia.

According to state standards, the pH of stream water should not deviate more than 0.5 units from ambient conditions and should not be lower than 5.5, nor higher than 8.0.

3. Nitrogen

Nitrogen is an essential element for all life on earth. Nitrogen is a very common element in the atmosphere. It is insoluble in water and found only as compounds of nitrogen such as ammonia, nitrites, nitrates, and in organic matter such as plant and animal proteins. These forms of nitrogen are all integral parts of the nitrogen cycle.

Plants need nitrogen in the form of ammonia and nitrates for their healthy growth, which is why it is a major constituent of fertilizers. The addition of excess levels of nitrates and ammonia in natural waters may lead to an overabundance of aquatic plant life. The decomposition of this plant material may result in lower oxygen levels in the water. This process changes the characteristic of the aquatic ecosystem. Sources of nitrogen compounds that may pollute waters include animal wastes, sewage and fertilizers.

The state standard for stream water nitrogen levels are as follows:

a. Total nitrogen

The geometric mean of total nitrogen should not exceed 0.250 mg/L during the wet season and 0.180 mg/L during the dry season. The total nitrogen should not exceed 0.520 mg/L during the wet season, and 0.380 mg/L in the dry season, more than 10% of the time. Total nitrogen should not exceed 0.800 mg/L during the wet season, and 0.600 mg/L during the dry season, more than 2% of the time.

b. Nitrate + nitrite nitrogen

The geometric mean of nitrate + nitrite nitrogen should not exceed 0.070 mg/L during the wet season and 0.030 mg/L during the dry season. Nitrate + nitrite nitrogen should not exceed 0.180 mg/L during the wet season, and 0.090 mg/L during the dry season, more than 10% of the time. Nitrate + nitrite nitrogen should not exceed 0.300 mg/L during the wet season, and 0.170 mg/L during the dry season, more than 2% of the time. The wet season is from November 1 through April 30 and the dry season is from May 1 through October 31.

4. Phosphorus

Phosphorus is another essential element for plant and animal life. It is found in dissolved organic and inorganic forms in water and in particulate matter. Phosphorus often appears as phosphates in the aquatic environment. High phosphate levels may lead to algal blooms. Phosphorus is introduced as phosphates into natural waters through sewage effluents derived from both detergents and human wastes and in agricultural fertilizers found in agricultural runoff. Phosphorus occurs in the aquatic environment in various chemical states. Tests for orthophosphates were made in the Pilot Project and the instructions follow.

According to state standards, the geometric mean of phosphorus levels in stream water should not exceed 0.050 mg/L during the wet season and 0.030 mg/L during the dry season. Total phosphorus should not exceed 0.100 mg/L during the wet season, and 0.060 mg/L during the dry season, more than 10% of the time. Total phosphorus should not exceed 0.150 mg/L during the wet season, and 0.080 mg/L during the dry season, more than 2% of the time.

5. Salinity

Salinity is a measure of the amount of dissolved salts in water. Salinity is important in determining if a stream is affected by tides (e.g., estuaries). Ocean waters tend to have salinity values between 34 and 36 parts per thousand (ppt). Stream waters generally have salinity values less than 1 ppt. Thus, the brackish waters of an estuarine environment have salinities between 0 and 36. Nutrient levels (phosphorus and nitrogen) in an estuarine environment are highly dependent on the salinity levels. Because the ocean is nutrient poor, nutrient levels decrease as the salinity increases. Salinity is one of the major factors determining the distribution of marine and intertidal organisms.

6. Temperature

Temperature is a critical factor for aquatic life. Most physical, chemical and biological processes are temperature dependent. Temperature affects the solubility of compounds in water and determines the density of water. Temperature also has a major role in the distribution and abundance of organisms, affecting their metabolism and overall health. Consequently, major temperature fluctuations can be quite detrimental to aquatic ecosystems.

Increases in temperature can be caused by industrial effluents, power plants, storm water runoff passing over warmed urban surfaces, and channelization. Channelization increases water temperature by removing shade trees and replacing the streambeds with concrete.

According to state standards, stream water temperatures should not vary more than 1°C from ambient conditions.

7. Total Suspended Solids

Suspended solids, which are particulate matter suspended in water, are found in most kinds of effluents and occur naturally in streams. Suspended solids are a major source of pollution in Hawai'i's streams. A layer of silt on the streambed can smother benthic organisms and change substrate habitats. Suspended solids can injure sensitive tissues of organisms (e.g., the eyes and gills of fish). Suspended solids also affect the feeding behavior of predatory organisms by decreasing the visibility of water. Additionally, increased suspended solids concentrations reduce light penetration, thereby slowing the rate of photosynthesis and potentially reducing dissolved oxygen levels. Suspended solids can also increase the water temperature and further reduce dissolved oxygen concentrations. When deposited into nearshore waters, suspended solids may impact coral reefs. Suspended solids also pose a public health concern. Among the suspended particulates found in waters are microorganisms such as *Giardia, Cryptosporidia, Escherichia coli* and coliform bacteria.

Nonpoint sources of pollution associated with improper agricultural practices and urbanization are among the major anthropogenic sources of suspended solids in stream waters.

According to state standards, the geometric mean of total suspended solids in stream water should not exceed 20 mg/L during the wet season and 10 mg/L during the dry season. Total suspended solids should not exceed 50 mg/L during the wet season, and 30 mg/L during the dry season, more than 10% of the time. Total suspended solids should not exceed 80 mg/L during the wet season, and 55 mg/L during the dry season, more than 2% of the time.

C. THE CONCEPTS OF PRECISION, ACCURACY AND ERROR

Another inevitability that comes with sampling and analysis is error. Knowing the different types of errors will aid in understanding the nature and limitations of scientific analysis, as well as minimizing uncertainties.

1. Sources of Error

• Instrument errors

Instruments are potential sources of error. For example, the slight differences in marked gradations on the test tubes found in test kits are a type of instrument error.

• Method errors

Method errors are introduced by the non-ideal nature of chemical reactions. Theoretically, chemical reactions are supposed to react in only one particular way. In reality, however, every chemical reaction is slightly different due to interferences, slow and incomplete reactions, and chemical instabilities.

• Human errors

Human errors occur when the analyst introduces the error, which occurs when the measurement depends on personal judgments. For example, interpreting color differences on a color wheel varies from person to person.

• Random errors

Random errors are caused by the various uncontrollable factors involved in physical and chemical measurement.

• Gross errors

Gross errors are usually caused by the analyst and are a result of ignorance or carelessness. Examples of gross errors include performing a test incorrectly, reading the wrong scale, arithmetic mistakes and recording wrong numbers.

2. Accuracy and Precision

The terms accuracy and precision are often used interchangeably, although scientifically, and their meanings are quite different.

• Accuracy

The accuracy of a measurement indicates how close it is to the true value. Accuracy is often referred to as the gold standard; however, because it is not theoretically possible to measure the true value of any quantity, accuracy can only be estimated.

• Precision

Precision refers to the closeness of several measurements determined in the same manner. In contrast to accuracy, precision can be measured after a series of repeated measurements. Precision does not necessarily imply accuracy. An instrument or test can be very precise by returning consistent results. Yet, if these results are consistently wrong, they are not accurate.

3. Error Prevention

• Replicate analysis

Performing a measurement more than once increases the precision of the analysis, prevents gross personal errors, and ensures consistent testing techniques.

• Controls

The accuracy of a test can be measured by testing a control. For example, if the pH of distilled water is known, you can measure the accuracy of the litmus paper by comparing the test result with the known level. By verifying the accuracy of your measurements, you can have confidence that your chemical reagents are working properly, and that your testing technique is proper.

• Blanks

By measuring a blank, or a solution with no water sample (typically distilled water), errors involving interfering contaminants from the chemical reagents or equipment are revealed.

• Split samples

Splitting a sample and having it analyzed independently by a professional laboratory using precision equipment can minimize the possibility of gross and human error, as well as method and instrument errors. We strongly recommend that such an independent analysis be a part of any volunteer program.

VI. WATER SAMPLING PROCEDURES

A. SAFETY

1. Risks and Responsibilities

There are inherent risks when collecting water samples and performing chemical analyses. An awareness of these hazards can go a long way toward minimizing these risks and preventing accidents. Team leaders should inspect and restock safety equipment such as the first aid kit, gloves and eye wash, keep a record of all accidents, and ensure that all team members are following safety rules. Team members should immediately report all accidents and injuries to their team leader. Additionally, each team member should sign an accident waiver.

2. Types of Hazards

The stream team should familiarize themselves with the following types of hazards:

• Chemical hazards

Although you do not have to be a trained chemist to use the test kits, this does not mean the chemicals are any less dangerous. Team members must exercise extreme caution when working with chemicals.

There are two types of chemical injuries: internal and external. Internal injuries occur when substances are absorbed into the body and have toxic or corrosive effects. External injuries occur from skin exposure to caustic or corrosive substances.

Volunteers should always wear gloves and safety glasses when conducting water tests to prevent chemical injuries. If any skin contact occurs, immediately flush the area with water and check the Material Safety Data Sheets (MSDS) for specific instructions. The MSDS are issued by the manufacturer of the test kits and should be thoroughly read before any test chemicals are used. If chemicals splash into the eyes, flush them with the emergency eyewash for 15 minutes, following the instructions on the eyewash container and on the MSDS. If clothes become contaminated, wash them thoroughly before wearing them again. An uncluttered work area and cleanliness is helpful in preventing accidents like chemical spills and splashes.

Some of the substances in the test kits are especially hazardous. Cadmium is found in the nitrate-nitrite test and the MSDS warns that it is very toxic; [and a] recognized carcinogen. The dissolved oxygen test uses sodium azide, which the MSDS calls extremely toxic. Most of the other chemicals used in the test kits are not as hazardous; however, even a casual glance of the MSDS will convince one that they are far from safe or non-toxic.

Mercury is of great concern to the stream teams using mercury thermometers because it is a liquid at room temperature, easily vaporized, and highly toxic. All broken thermometer pieces should be carefully collected and kept tightly sealed in a sampling bottle for disposal at the University of Hawai'i or another appropriate facility.

• Biological hazards

Pathogenic microorganisms such as *Giardia* and *Leptospira* exist in Hawai'i's stream waters. Do not drink stream water, and try to avoid direct contact with stream water. Wear gloves when water sampling, particularly if you have open cuts or wounds. Immediately treat and clean any cuts or abrasions incurred while you are in or near streams. Hand to mouth contamination can be minimized by not eating food or snacks during sampling and testing, and by frequent hand washing.

• Physical hazards

Physical hazards include slipping and falling, automobile accidents, vicious dogs, sunburn and drowning. Appropriate footwear, an awareness of your surroundings and physical limitations, and simple common sense can prevent most physical injuries from occurring.

3. Safety Rules

a. Always use disposable latex gloves to avoid direct exposure of skin to water and chemicals. As previously discussed, leptospirosis and other water-borne pathogens are a serious threat in Hawaiian stream waters. Some chemicals are very toxic and carcinogenic and others may irritate the skin.

b. Always use safety goggles to protect your eyes from chemical splashes when conducting water quality tests. An eye rinse should be nearby and available.

c. Always bring the first aid kit and eye rinse with you when you are sampling.

d. Never sniff chemicals or solutions.

e. Wash your hands after conducting every water quality test. Avoid touching your eyes or mouth during testing. Do not eat or chew gum during testing.

f. Read the Material Safety **Data Sheets** for specific first aid and chemical information on test kit chemicals.

B. PRELIMINARY PROTOCOLS

1. Collecting the Water Sample

Collect the water sample at a safe and accessible location where the water is freely flowing. Be careful not to slip or fall, and wear gloves when coming in contact with stream water, especially if you have open cuts. Leptospirosis is a serious concern. Please refer to the Safety section.

2. Replicate Tests

If possible, each test should be conducted at least twice by two different volunteers. If their results do not agree, a third volunteer should repeat the analysis. The final reading will be the average of the two closest values. Record the results on the data sheet with the initials of each analyst next to their test results.

3. Where to Perform the Analysis

Ideally, all the tests should be performed on site; however, temperature and dissolved oxygen must be tested on the stream bank. Salinity, pH, orthophosphate, nitrate-nitrite, and total suspended solids may be analyzed later at a central location (such as someone's house, provided it is well lighted and ventilated). Water samples must be stored in the dark, kept on ice, and analyzed within two hours. Be sure the sample bottles are clearly labeled.

4. How Much Sample to Collect

If the analysis is to be performed at a central location, be sure to collect enough water sample to perform all the tests: at least 500 ml for salinity, pH, phosphate, and nitrate-nitrite, and an additional 1,000 ml for the total suspended solids.

5. Sample Bottles

All sample bottles were acid washed prior to being issued to the stream teams. To avoid cross-contamination, the same sampling bottle must always be used for the same sampling location. Therefore, each sampling bottle must be clearly labeled. After sampling, rinse the sampling bottles with the stream water, then cap loosely. You may rinse them out at home with tap water, but never wash them with soap. Soap introduces phosphates on the inner surfaces of the container. Finally, rinse each sampling bottle thoroughly with distilled water prior to storage.

6. Waste Disposal

All chemical wastes must be properly disposed. Wastes generated by the nitrates test must be stored in the **Cadmium Waste Container** for special disposal at the University of Hawai'i or a designated toxic waste disposal site. All other (non-cadmium) wastes must be collected in a separate container. The non-cadmium wastes may be disposed of at home followed by a thorough flushing, provided that the residence is connected to a wastewater treatment plant. **Never** pour chemical wastes into the stream or ground.

7. Cleaning

Cleaning the kits prevents residue from building up and causing potential contamination and interference. Prior to storing the test kits, clean all test tubes by scrubbing them with a test tube brush using only tap water. **Never** use soap or detergent. Rinse the tubes thoroughly with distilled water before putting the test kits away.

C. WATER QUALITY SAMPLING FORM (see Appendix III for an example)

Using a ballpoint pen, record the following information on the **Water Quality Sampling Form** when you reach your sampling station. A copy of this form is provided in Appendix III.

- **Date:** month/day/year.
- **Sample Site:** Use the colored tape to indicate which stream you are sampling as well the station number. If this station has no number, clearly identify the sampling location by roads and other landmarks.
- **Collection Time:** Record the time the sample is collected, be sure to specify a.m. or p.m.
- **Salinity:** Following the instructions on page 36, use the refractometer to measure the salinity.
- **pH:** Following the instructions on page 30, use the Hach pH test kit to measure the pH and record the result.
- **Water Temperature:** Following the instructions on page 38, use the thermometer to measure the temperature of the water sample.
- **Weather:** Record the current weather (sunny, cloudy, drizzle, heavy rain).
- **Water Color:** The color of the water may interfere with some of the tests, so indicate whether the water appears clear, or contains other colors like blue, green, or yellow. Also record the water clarity (clear or cloudy?).
- **Air Temperature:** Following the instructions on page 38, use the thermometer to measure the air temperature.
- **Sample Collector:** Write down the full name(s) of the sample collector(s).
- **Notes:** Look around and jot down anything you think may influence the water quality at that sampling site (e.g., a heavy rain event the previous day, a discharge pipe, a fish kill, or new construction upstream).

For the dissolved oxygen, nitrate-nitrite, total suspended solids, and phosphate tests, record the following information:

- **Analysts:** Record the full name(s) of the analyst(s).
- **Completion Time:** Record the time the test is completed.
- **Replicate:** For each replicate, record the pertinent information immediately upon completion, following the instructions below.

VII. WATER QUALITY ANALYSIS TEST PROCEDURES

Note: Hach chemical reagents are italicized and in bold
e.g., ***Dissolved Oxygen 1 Reagent Powder Pillow***

Hints are italicized and bracketed.
. *<<Notes and hints look like this>>*

To distinguish the two Hach Kit test tubes used for the orthophosphates, nitrates, and pH tests, label them A and B. Tube A is for the untreated sample, and Tube B is for the prepared sample. Similarly, the left slot of the color comparator should be labeled A for the untreated sample, and the right slot B for the prepared sample.

A. DISSOLVED OXYGEN

1. How the Test Works

The glass stoppered bottle is used because it is an air-tight container and prevents the introduction of excess oxygen from contaminating the sample.

The ***Dissolved Oxygen 1 Reagent Powder Pillow*** contains manganous sulfate powder. When manganous sulfate is dissolved in the water sample, the oxygen oxidizes the manganous sulfate and precipitates as a brown hydrate oxide — this reaction fixes the oxygen in the sample. The ***Dissolved Oxygen 2 Reagent Powder Pillow*** contains sodium azide powder, which prevents the nitrite interference during titration. The ***Dissolved Oxygen 3 Reagent Powder Pillow*** contains sulfamic acid powder. The acid lowers the pH of the water sample. In low pH conditions, manganese oxidizes iodine ions, producing free iodine and a yellow color. This solution is then titrated using a standard sodium thiosulfate solution which reacts with the free iodine and changes the solution back to a clear color.

2. Apparatus

Hach OX-2P dissolved oxygen test kit

Distilled water

3. Experimental Method

a. If possible, the dissolved oxygen should be measured twice (2 replicates) by two different volunteers.

b. If the volunteers' results do not agree, a third volunteer should repeat the analysis and the final reading will be the average of the two closest values.

c. Record the results on the **Water Quality Sampling Form** with the initials of each analyst next to their test results.

d. The dissolved oxygen must be measured on site; however, steps (a) through (g) of the dissolved oxygen test may be performed on site and the titration — steps (h) through (l) of the dissolved oxygen test — may be done at another location, provided it is completed within 2 hours.

4. Test Procedure

a. Fill the dissolved oxygen bottle (glass bottle with stopper) with the mouth of the bottle 2-3" below the surface of the water to be tested, allowing the stream water to overflow for 2 or 3 minutes.

<<Avoid trapping air bubbles in the bottle by inclining the bottle slightly when inserting the stopper. Leave a little water above the stopper.>>

b. Open one ***Dissolved Oxygen 1 Reagent Powder Pillow*** and use the clippers to open one ***Dissolved Oxygen 2 Powder Pillow.*** Add the contents of both pillows into the glass bottle.

c. Stopper the bottle carefully to exclude air bubbles.

<<A tiny squirt of deionized water on the glass stopper may make excluding air bubbles easier.>>

d. Grip bottle and stopper firmly and shake vigorously until the powder dissolves (about 1 minute).

<<*If oxygen is present, a brownish-orange precipitate will form.*>>

e. Let the precipitate settle in the glass bottle halfway, then shake the glass bottle again.

f. After the precipitate again settles halfway in the glass bottle, add the contents of one ***Dissolved Oxygen 3 Powder Pillow*** to the glass bottle.

g. Carefully re-stopper the bottle and shake to mix.

<<*The precipitate will disappear and a yellow color will develop if oxygen is present.*>>

h. Pour enough sample from the glass bottle to fill the thin plastic measuring tube.

i. Pour the contents of the tube into the square mixing bottle.

j. Pour another thin tube full of sample into the square mixing bottle.

k. Add the ***Sodium Thiosulfate Standard Solution*** drop by drop to the square mixing bottle, swirling to mix after each drop, until the sample changes from yellow to colorless.

<<*Hold the dropper vertically above the bottle and* ***count each drop.***>>

l. Each drop used to bring about the color change is equal to 0.5 mg/l of dissolved oxygen (DO).

m. Pour all wastes into the waste bottle.

n. Rinse all tubes thoroughly with distilled water.

B. The pH Value

1. How the Test Works

The ***Wide Range 4 pH Indicator Solution*** contains several compounds that undergo specific color changes at certain pH ranges. These compounds are called pH indicator solutions. An example of a pH indicator solution is litmus. Litmus is red under acidic conditions and blue in basic conditions.

2. Apparatus

Hach 17-N wide range (4-10) pH test kit

Distilled water

3. Experimental Method

a. To ensure that the pH indicator solution gives accurate results, periodically test the standards.

b. The pH should be read twice (2 replicates) by two different volunteers.

c. If the volunteers' results do not agree, a third volunteer should repeat the test.

d. Record the results on the Water Quality Sampling Form with the initials of each analyst next to their test results.

4. **Test Procedure**

a. Rinse both test tubes with the stream water sample 3 times.

b. Fill both tubes to the first line (bottom of frosted area) with the stream sample water.

c. Add 6 drops of the Wide ***Range 4 pH Indicator Solution*** into tube B and swirl to mix. Now your sample is prepared.

d. Place tube B (the prepared sample) into opening B of the comparator wheel.

e. Place tube A into opening A of the comparator wheel.

f. Hold the comparator up to a light source. Rotate the wheel until the color on the wheel matches the color of tube B.

g. When the colors match, the pH value of the sample can be read through the window.

h. Record the pH value.

i. Pour the wastes into the waste container.

j. Rinse both tubes thoroughly with deionized water.

C. NITRATE-NITRITE

1. How the Test Works

The nitrate-nitrite test is a two-step process. First, the nitrates in the water sample are converted by the cadmium in the ***Nitraver 6 Reagent Powder Pillow*** into nitrites. Second, two organic reagents found in the ***Nitriver 3 Nitrite Reagent Powder Pillow*** react with the nitrites to produce a reddish-pink color. The intensity of this red color development is proportional to the amount of nitrites in the solution at that time. Because this test measures the sum of nitrate and nitrite levels, the results from this test are reported as the nitrate plus nitrite nitrogen. State standards similarly measure for nitrate plus nitrite nitrogen levels in stream waters.

2. Apparatus

Hach NI-14 low range nitrate test kit

Distilled water

3. Experimental Method

a. To ensure that the nitrate test kit reagents are still working properly, periodically test the control.

b. The nitrate-nitrite levels should be measured twice (2 replicates) by two different volunteers.

c. If the volunteers' results do not agree, a third volunteer should repeat the analysis and the final reading will be the average of the two closest values.

d. Record the results on the **Water Quality Sampling Form** with the initials of each analyst next to their test results.

4. Test Procedure for 0-1 mg/l Nitrate + Nitrite Nitrogen

a. Rinse tube A with the stream sample 3 times, then fill it to the bottom line (the 5 ml mark).

b. Add the contents of one ***Nitraver 6 Reagent Powder Pillow*** into tube A.

c. Stopper tube A and shake for 3 minutes.

d. Allow the sample to stand undisturbed for another 30 seconds.

<<*This procedure allows any unoxidized particles of cadmium to settle to the bottom of tube A.*>>

e. Carefully pour the treated sample from tube A into tube B so that the cadmium particles remain in tube A.

<<*Leave the last drop of liquid behind in tube A even if you don't see any particles.*>>

f. Rinse out the cadmium particles in tube A into the **Cadmium Waste Container**.

g. Add the contents of ***Nitriver 3 Nitrite Reagent Powder Pillow*** into tube B.

h. Stopper tube B and shake vigorously for 30 seconds.

i. Insert tube B into opening B on the color comparator.

j. Allow at least 10 minutes, but no more than 20 minutes, for full color development.

<<*A red color will develop if nitrate is present.*>>

k. While waiting for color development, fill tube A with the original water sample to the top line and insert into opening A.

l. Hold the color comparator up to a light source such as the sky and view the openings on the front.

m. Rotate the color disk to obtain a combined color and density match.

n. Read the mg/l nitrate nitrogen on the color wheel through the scale window of the color comparator.

<<Note: *If the nitrate + nitrite nitrogen levels exceed the scale on the color wheel, repeat the test using the 0-10 mg/l nitrate + nitrite nitrogen test procedures below.*>>

o. Pour the wastes of tube B into the **Cadmium Waste Container**.

p. Pour the wastes of tube A into the waste container.

q. Rinse both tubes thoroughly with deionized water.

5. Test Procedure for 0-10mg/l Nitrate + Nitrite Nitrogen

a. Rinse the dropper with stream sample.

b. Rinse tube A 3 times with the stream sample.

c. Fill the dropper to the 0.5 ml mark.

d. Add the contents of the dropper to tube A.

e. Fill tube A with distilled water to the bottom line (5 ml mark).

f. Follow steps b-n in the procedures for the 0-1mg/l nitrate + nitrite nitrogen test.

g. Multiply the number on the color wheel by 44 to obtain the results as mg/L nitrate-nitrite.

h. Pour the wastes of tube B into the **Cadmium Waste Container**.

i. Pour the wastes of tube A into the waste container.

j. Rinse both tubes thoroughly with deionized water.

D. ORTHOPHOSPHATES

1. How the Test Works

The ***PhosVer 3 Phosphate Reagent Powder Pillow*** contains several chemicals, the most important of which are potassium pyrosulfate, ascorbic acid, and sodium molybdate. When the ***PhosVer 3 Phosphate Reagent Powder Pillow*** is dissolved in the water sample, the orthophosphate will react with the potassium pyrosulfate and sodium molybdate to form a chemical compound that is reduced to a blue solution by ascorbic acid. Thus, the intensity of this blue color is proportional to the amount of orthophosphates in the water sample.

2. Apparatus

Hach PO-24 total phosphate test kit or PO-19 orthophosphate kit

Distilled water

3. Experimental Method

a. To ensure that the phosphate test kit reagents are working properly, periodically test the control.

b. The phosphate levels should be measured twice (2 replicates) by two different volunteers.

c. If the volunteers' results do not agree, a third volunteer should repeat the analysis and the final reading will be the average of the two closest values.

d. Record the results on the **Water Quality Sampling Form** and initial your test results. Also note on the Water Quality Sampling Form the test being done, i.e., either total phosphate with the Hach PO-24 kit or orthophosphate that uses the Hach PO-19 kit.

4. Test Procedure

a. Rinse the scaled square mixing bottle with stream water 3 times.

b. Fill the scaled square mixing bottle with stream water to the 20 ml mark.

c. Add the contents of one ***PhosVer 3 Phosphate Reagent Powder Pillow*** into the square mixing bottle.

d. Swirl to mix for at least 1 minute.

<<Not all the powder may dissolve.>>

<<A blue color will develop if phosphates are present.>>

e. Allow at least 2 minutes, but no more than 10 minutes, for color development.

f. Insert the mirrors inside the color comparator for lengthwise viewing of the tubes.

g. Pour the contents of the square mixing bottle into tube B until it reaches the top line.

h. Insert tube B into opening B of the color comparator.

i. Fill tube A to the top line with the original stream sample.

j. Insert tube A into opening A of the color comparator.

k. Look through the openings in the front of the comparator.

<<Orient the comparator so that the top of the tubes are pointing to a light source above.>>

<<Be careful not to spill the samples from the unstoppered tubes.>>

l. Rotate the color wheel to obtain a color match.

<<If the color in tube B is not blue, try to match the light intensity.>>

m. Divide the number on the color wheel by 50 for mg/l orthophosphate.

n. Pour all wastes into the waste bottle.

o. Rinse all tubes with deionized water.

E. SALINITY

1. How This Test Works

The refractometer works on the basis of differences in the refractive index of water due to salinity; the higher the salinity, the greater the refractive index of the water. Thus, just as the differences in the refractive index between air and water appear to bend a spoon in a glass of fresh water, the spoon would bend even more in saltwater. The refractometer quantitatively measures the angle that light is bent, thereby giving an estimate of salinity. Because the refractive index of water is temperature dependent, it is very important to keep the refractometer and the water sample as close as possible before measuring the salinity.

2. Apparatus

Aquatic Ecosystems salinity refractometer

Distilled water

Kimwipes

3. Experimental Method

a. To ensure that the refractometer is properly calibrated, begin by measuring the salinity of distilled water at room temperature. If the salinity level is not 0 ppt, calibrate the refractometer as instructed below.

b. The salinity should be measured twice (2 replicates) by two different volunteers.

c. If the volunteers' results do not agree, a third volunteer should repeat the measurement and the final reading will be the average of the two closest values.

d. Record the results on the **Water Quality Sampling Form** and initial your test results.

4. Calibration

a. Keep the refractometer at room temperature (25°C) for at least one hour.

b. Place 1 drop of room temperature distilled water under the daylight plate. The boundary refraction line should read 0 ppt.

c. If it does not read 0 ppt, remove the plastic cap located near the top of the prism.

d. Gently peel back the plastic film. Using the small screwdriver provided with the refractometer, turn the screw until the refractometer reads 0 ppt.

e. Carefully cover up the screw with the plastic film and cap.

5. Test Procedure

<<Because this test is temperature sensitive, try to keep the refractometer as close as possible to room temperature (25°C). You should not keep the refractometer in the sun, nor should you hold the instrument in your hands when you are not using it.>>

a. Close the daylight plate gently.

b. Open the daylight plate and apply 1 or 2 drops of the stream sample onto the prism surface.

<<The stream sample solution will spread into a thin film between the daylight plate and prism. The sample should be spread completely over the prism surface with no bubbles. If not, repeat steps a and b with more of the stream sample.>>

c. Hold the refractometer with the daylight plate upwards and observe the field of view through the eyepiece.

<<If the field of view is not clear, adjust it by turning the cross stripe portion of the eyepiece either clockwise or counterclockwise.>>

d. Read the scale where the boundary line of the blue and white fields cross the scale.

e. The value of the scale to the right of the field of view is the salinity in parts per thousand.

f. Open the daylight plate and rinse the prism with deionized water.

g. Lightly dab (not wipe) the prism with a Kimwipe to dry.

F. TEMPERATURE

1. Apparatus

Fisherbrand 14-985 mercury thermometer or Fisherbrand 15-021B pocket field thermometer

2. Experimental Method

a. The temperature should be measured twice (2 replicates) by two different volunteers.

b. The temperature must be measured on site.

c. If the results do not agree, a third volunteer should repeat the measurement and the final reading will be the average of the two closest values.

d. Record the results on the **Water Quality Sampling Form** and initial your test results.

e. Be careful not to break the thermometer. If a mercury thermometer breaks, collect all the spilled mercury and the pieces of the thermometer into a sampling container for special disposal at the University of Hawai'i or a designated toxic waste disposal site.

3. Test Procedure

a. Lower the thermometer three inches below the water surface.

<<Pick a site out of direct sunlight.>>

b. Keep the thermometer below the water surface for about 2 minutes to ensure a constant reading.

c. Read the thermometer while it is still in the water.

d. To measure air temperature, pick a site out of direct sunlight, hold the thermometer by the top (not the bulb end), and read the air temperature after 3 minutes.

G. TOTAL SUSPENDED SOLIDS

1. How the Test Works

Total suspended solids are determined by passing a known volume of water through a glass fiber filter and weighing the filtered residue. The glass fiber filters in this experiment have been pre-washed and weighed in accordance with U.S. Environmental Protection Agency approved methods. The final quantity of total suspended solids are determined by drying and weighing the filters on an analytical balance that is capable of measuring to 0.001 grams.

2. Apparatus

Gelman magnetic filter funnel

Nalgene hand-operated vacuum pump with gauge

1-l filter flask assembly

Pre-weighed and prepared glass fiber filters

250-ml graduated cylinder

Tweezers

Distilled water

Analytical balance

3. Experimental Method

a. The total suspended solids test should be run twice for each sample (2 replicates) for each site.

b. Record the results on the **Water Quality Sampling Form** and initial your test results.

4. Test Procedure

a. Collect at least 1 liter of stream water sample below the surface of the water, leaving out any large particles or debris.

b. Place the magnetic filter funnel in the filter flask. Make sure the stopper on the base of the filter fits snugly into the filter flask to prevent leakage.

c. Rinse the magnetic filter funnel thoroughly with distilled water.

d. Lift the filter housing from the funnel base.

e. Using the tweezers, carefully lift the filter from the aluminum weighing pan and place it onto the funnel base of the magnetic filter funnel.

<<Be sure to have the same side of the glass fiber filter facing up as on the aluminum weighing tray (it should be the fuzzier side).>>

f. Replace the filter housing on top of the base. It should lock into place by magnetic force.

g. Record on the **Water Quality Sampling Form** the "Sample #" that is printed on the aluminum weighing pan of the filter.

<<Try not to contaminate the aluminum weighing pan by keeping it out of the way.>>

h. Attach the PVC tubing onto the vacuum inlet of the hand-held pump and the filter flask assembly.

i. Shake the sample thoroughly for 30 seconds.

j. Measure out the stream water sample using the graduated cylinder and pour the sample into the magnetic filter funnel.

<<If the water sample is relatively clean and clear, pass at least 500 ml of sample through the filter to ensure a weighable residue.>>

k. Record the sample volume on the **Water Quality Sampling Form.**

l. Pump out the water sample through the filter using the hand-held pump.

m. Wash the filter and the filter funnel with 3 successive 10-ml rinses of distilled water. If the water sample is brackish or is ocean water, wash with at least 5 successive rinses.

n. Continue pumping air through the filter for another 2 minutes.

o. Carefully remove the glass fiber filter using the tweezers and place it back on the original aluminum weighing tray.

p. Place the tray into a plastic sandwich bag for drying and weighing.

<<If time permits, an additional sample should ***always*** *be taken to increase the precision of this test. In particular, if there does not appear to be enough weighable residue left on the filter, a second sample should definitely be taken using a greater volume of water.>>*

q. If these plates are not going to be weighed within 24 hours, dry them in an oven on a low setting (i.e., 200°F for 10-15 minutes, or until dry) to prevent mold from growing on the filters.

<<Pour out the water from the filter flask before performing the next replicate.This is to prevent drawing water into the pump.>>

Real solutions to Hawai'i's water quality problems begin at home in your own communities. The future of our water resources will be determined by our ability to collaborate and protect our life-giving waters.

APPENDIX I

Volunteer Water Quality Monitoring Project for Waimanalo Bay and Kailua Bay

A Field Guide to Aid in the Identification of Some Common Stream Animals

This manual is a compilation of previous works.
Images and text have been taken from the following references:
DOE, Environmental Education. 1984. *Kaua'i: Streams and Estuaries.*
DLNR, Division of Aquatic Resources. 1993. *Freshwater Fishing in Hawaii.*
Polhemus, D. 1994. *Quick Key to Lowland Dragonflies of Oahu.*
Cover page illustrations from DOE, and BISHOP MUSEUM and MOANALUA GARDENS FOUNDATION. 1989. *Ohi'a Project.*

Identification and Biology of Native Stream Animals

Crustaceans

There are two endemic shrimp (*'ōpae*) found in Hawaiian streams. Both apparently have marine larval stages.

'Ōpae kala'ole (*Atya bisulcata*)

Common names are "black *'ōpae*" and "mountain *'ōpae*." This small (up to 3"; 8 cm), dark shrimp is found in the middle and upper reaches of the stream. It can be found on the sides of rocks where the water flow is the fastest (the "riffle" zone). Feeding is accomplished in an unusual manner: bristle-tipped pincers are held out into the water flow to trap organic particles for food. This species can be recognized by the blunt appearance of the head and the small, bristled pincers. *Kala'ole* is found on all islands and is netted for use as food and fish bait. This is the most common native stream animal other than insects.

'Ōpae 'oeha'a (Macrobrachium grandimanus)

This brown native prawn is recognized by the long rostrum (swordlike structure between the eyes) with 12 or more spines on the upper border. In large males the pincers are longitudinally striped and unequal in size; in fact, the species name, *grandimanus*, means "large hand." This species prefers downstream areas and estuaries. It is omnivorous and reaches 5" (13 cm) in length. Do not confuse it with the introduced Tahitian prawn, *Macrobrachium lar*, which reaches a much larger size, has long, thin blue pincer legs, and less spines on the rostrum (8 or 9).

Mollusk

Two mollusks common in streams are the ***hīhīwai*** and the ***hapawai***. Both have limpet-like shell and a strong muscular foot which aid in clinging to rocks in swift currents. Both are in the family Neritidae, which includes the black *pipipi* (*Nerita picea*) common along Hawai'i's rocky shorelines. The *hīhīwai* and *hapawai* are endemic to Hawaiian streams.

Hīhīwai (*Neritina granosa*)

This species lives attached to stones in streams and under waterfalls. The low, rounded tubercles of the black shell are distinctive of animals living near the sea. (*Hīhīwai* shells found above waterfalls or on vertical cliffs may have fairly smooth shells which are oval in shape.)

This species is not abundant on O'ahu and Kaua'i due to over-fishing and habitat degradation. It is herbivorous and grows to 2" (5 cm). Its eggs are deposited on submerged rocks and on the shells of other *hīhīwai* in tough white capsules about 2 mm in length. Each capsule may contain as many as 450 developing *hīhīwai*. When the capsule breaks open, the surviving larvae are swept out to sea where they also undergo early development as marine plankton. Spawning takes place in late spring and summer, and postlarvae (spat) return to streams from June through September.

Hapawai (Theodoxus vespertinus)

The Hawaiian name "*hapawai*" means "half water" and refers to the brackish water habitat of this species. It resembles the *hīhīwai*, but lacks the low, rounded tubercules and is brown in color. It is found attached to rocks in stream areas where the freshwater meets the saltwater. It grows to 1" (2.5 cm) and is herbivorous. It reproduces in the same fashion as the *hīhīwai*.

Native Fishes

'O'opu nākea (Awaous guamensis)

This species has a mottled coloration with vertical dark and light stripes on dorsal and caudal fins; distinct dark patch on caudal peduncle; the courting male is dark gray and may have a chalky white patch below the eyes. The male is larger than the female and has a broader head and mouth. The largest of the stream gobies, the male grows to a length of 14" and the female up to 11".

The *'o'opu nākea* can be found in all major streams on all islands, and is a bottom dweller; centered in lower stream reaches but found at elevations up to 450 meters. It feeds primarily on filamentous green algae, but also on animal matter (earthworms, snails, etc.). The adult migrates downstream to breed during the first heavy rains of autumn where the eggs are laid close to mouths of streams and guarded by the male and female. Upon hatching, the larvae go out to sea for several months before reentering the river mouths from December through July.

'O'opu nōpili (Sicyopterus stimsonii)

This species has a mottled brown or gray coloration; the courting male may be almost black, and has a prominent lateral white stripe on head and body. The first dorsal fin of the male is very large and broadly overlaps the second dorsal fin when folded down. It usually grows to a length of 7".

The *'o'opu nōpili* is more abundant on neighbor islands than on O'ahu, and can be found in the middle stream reaches in swift water over hard bottoms rather than gravel or sand. It is herbivorous; the upper jaw extends to scrape hard bottom substrate with tricuspid teeth. The female lays eggs on the bottom, which hatch about a day later. Larvae spend about five months in the ocean, then return to freshwater streams.

'O'opu naniha (Stenogobius hawaiiensis)

This species has a yellow-brown coloration, with black patches extending down and behind the eyes on adults. The courting male has 9 to 11 dark bars on the side of the body, and a red border on dorsal fins. It grows to a length of 4".

The *'o'opu naniha* is found in lower stream reaches, often in brackish water or just upstream from estuaries, and prefer soft bottom rather than rocks or boulders. They are omnivorous feeders, burrowing into the substrate. Its life cycle includes spawning in the lower stream. The larvae develop in the ocean, then return to streams.

'O'opu 'alamo'o (Lentipes concolor)

The male of the species often has a black anterior region, and a posterior that is red or chalky white tinged with red, particularly when displaying aggression. The aggressive male will also have brilliant white dorsal and anal fins. When not displaying, the male quickly reverts to an olive to brown coloration while retaining traces of the bicolor body. The females tends to be olive to brown and grows to a length of 2".

The *'o'opu 'alamo'o* is more abundant on neighbor islands than on O'ahu. It is found in most perennial streams on the windward side of the islands, generally at mid- to high stream elevations, up to 1,800 ft. It is omnivorous, but primarily feeds on animal matter. The newly hatched larvae drift out to sea and juveniles return upstream several months later. The larvae are randomly distributed statewide during their period at sea and show no homing behavior.

'O'opu 'akupa (Eleotris sandwicensis)

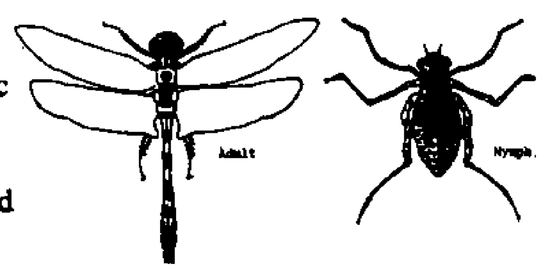
The coloration for this species is dark brown or black; during courtship, the male and female display jet black bodies with gold borders on median fins. The pelvic fins are separate, unlike true gobies. It has a large mouth, and the male is larger than the female. The average length is 10".

'O'opu 'akupa is abundant on all islands, and found in lower reaches of streams up to the first substantial waterfall. It is a voracious carnivore which preys on invertebrates and fishes. The life cycle includes spawning in the lower stream with larval development in the open ocean.

Insects

Dragonflies, Pinao *(Anax strenuus)* and ***Damselflies*** *(Megalagrion)*

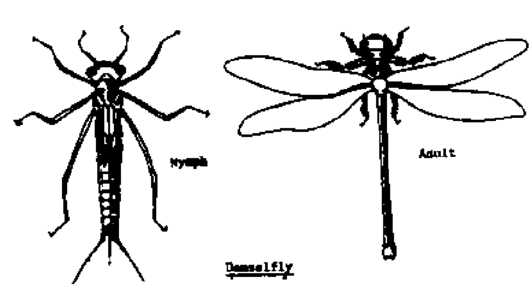
The most conspicuous of the freshwater insects are the dragonfly and damselfly. Both belong to the order of insects called *Odonata*, and both have members endemic to Hawai'i. The larval form is called a nymph. The nymph lives in freshwater and is part of that ecosystem. Some nymphs occur in running streams, others are found in damp vegetation along stream banks; one occurs in water captured in the leaves of the *'ie'ie* plant, high on mountain sides. Nymphs are predaceous on other small animals.



dragonflies

Hawai'i's endemic dragonfly, the "green darner" or *pinao (Anax strenuus)*, is the largest Hawaiian insect, with a body length of 11 cm and a wingspan of 14 cm.

The damselfly has evolved into at least 23 different endemic species belonging to the genus *Megalagrion*. (For more information on Hawaiian insects, see Zimmerman, C.U. 1948 Hawaiian Insects. Honolulu, University of Hawaii Press.)



While the dragonfly and damselfly look superficially similar, it is not hard to tell them apart:

1. The dragonfly rests with its wings held horizontally, while damselfly rests with its wings folded vertically.
2. Dragonfly eyes are joined, while damselfly eyes are separate.

Quick key to lowland dragonflies of O'ahu:

1. a. Coloration bright pink or lavender, *Orthemis ferruginea* (Fabricius)
   b. Coloration generally black, brown, blue or green
2. a. Wings with dark spots basally, *Tramea lacerata* Hagen
   b. Wings clear, or with at most a light touch of yellow basally
3. Large species; thorax marked with green, abdomen blue, *Anax junius* (Drury)
   Moderate sized species, body uniformly yellowish to dark brown, *Pantala flavescens* (Fabricius)

Amphibians

There are three species of frogs and toads in Hawaiian streams. The adult and tadpole can be identified by the following:

Bullfrog *(Rana catesbeiana)*

The bullfrog tadpole is light in color, length to 4". The adult has smooth skin, is mottled brown with a green snout, and grows to a length of 4-7".

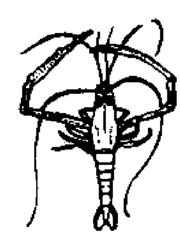
Wrinkled frog *(Rana rugosa)*

The wrinkled frog tadpole is light in color with a dotted outline on the head, and will grow to a length of $1\frac{1}{2}$". The adult has wrinkled skin, is brown colored, and grows to a length of $1\frac{1}{4}$ to $1\frac{3}{4}$".

Neotropical toad *(Bufo marinas)*

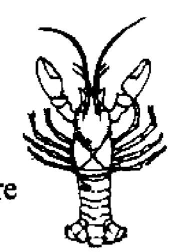
The neotropical toad tadpole is black in color, and 1/2" long. The adult is brownish in color with warty skin, and grows to a length of 7".

Crustaceans



Tahitian prawn *(Macrobrachium lar)*

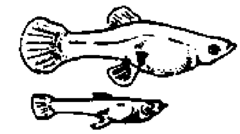
Introduced in 1956 into Pelekunu Stream on the northern coast of Moloka'i and subsequently on O'ahu in 1957 and 1961. Brownish in color, with long, thick, dark pincer legs. The rostrum has 8-9 spines on the dorsal surface. Now found on all major islands, the Tahitian prawn may grow to a length of 6".



Crayfish *(Procambarus clarkii)*

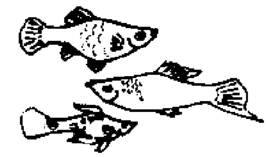
There is no record of this species being introduced to Hawai'i, but there are records of introductions of two other species. Perhaps this one was mistakenly identified as one of the others. The coloration is reddish to brown, and it grows to a length of 4". Abundant on all major islands, the crayfish is considered a pest in taro patches where it burrows through dikes.

Fish



Mosquito fish *(Gambusia affinis)* family Poeciliidae

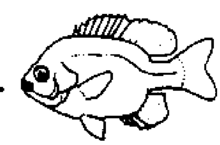
Brought from Texas in 1905 for mosquito control, it is abundant in lower reaches of streams. It is found on all the islands, and grows to a length of 1".



Mollies, Guppies, Top Minnows and **Swordtails** (family Poeciliidae)

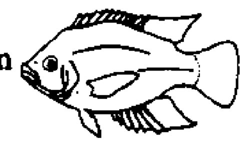
This species is common in streams, ponds and reservoirs. A large family of small, live-bearing fish, they are used as aquarium fish and as bait fish.

Bluegill *(Lepomis macrochirus)*



Introduced in 1946, this species is greenish in color, with a dark blue or black opercular flaps (gill covers). It grows to a length of 4-6", and eats insects, crustaceans and small fishes.

Tilapia (four introduced species)



Introduced in the 1950s, the tilapia was cultured for food in Africa and Asia. The young species has dorsally horizontal black bars, and is differentiated from the bluegill by having no blue or balck opercular flap. Tilapia is characterized by long dorsal fins, and grows to a length of 4-6". It is useful in controling aquatic plants in the irrigation systems, and as a food fish.

Dojo *(Misgurnus anuillicaudatus)*

Introduced prior to 1900 on Kaua'i, O'ahu and Mau'i, this fish is used as bait. It can growth to a length of 4".

Smallmouth Bass *(Micropterus dolomieu)*

Introduced in 1953, this species is distinguished from the largemouth bass by a less deeply notched dorsal fin. It can grow from $^1/_2$ to 3 pounds. A carnivorous eater, its mouth ends in front of the eye.

Largemouth Bass *(Micropterus salmoides)*

Introduced in 1908, this species has a more deeply notched dorsal fin than the smallmouth bass. It ranges in size from 1-7 pounds, and its mouth extends beyond the eye.

Chinese Catfish *(Clarius fuscus)*

Introduced around 1900, the coloration ranges from black to flesh-colored. This fish inhabits muddy bottoms of taro patches, streams and ditches.

Armored Catfish *(Hypostomus* sp.*)*

This species has a color range from dark brown to black, is covered with enlarged scales that form a heavy armor plating, and has huge pectoral fin spines. The length averages 12", with the maximum length measuring 26". The armored catfish feeds on algae and organic material in bottom mud. It spawns during summer when the male digs a tunnel into the bank and the female deposits a mass of several hundred eggs, which are guarded in the tunnel by the male through hatching and development to the free-swimming stage. Orange-red eggs are similar in size and appearance to salmon roe and are considered high quality caviar.

Caddisflies *(Trochoptera)*

Although there is no native Hawaiian caddisfly, there are three alien species that may be seen. The most common is an uncased caddisfly larvae that has a hard-shelled head and three front pairs of legs. Caddisfly larvae are completely aquatic. After metamorphosis the adult (looks like small moths) leave the water and spend, its short life on the wing searching for mates.

APPENDIX II. Stream Survey Form

WHERE ARE YOU?

Your **names**:____

Today's **Date & Time**:________________Today's **Weather**:________________________

Location/Area:____

Stream **Name**: _______________________ Stream **Reach**: Upper Middle Lower

Map **Location**/Sampling Station, Landmarks, GPS, etc:____________________________

STREAMSIDE CHARACTERISTICS

Visible **Land Uses** Adjacent to Stream: Residential, Commercial, Industrial, Construction. Grazing, Agricultural-Crops (which?):______________________________________

Forest (managed/unmanaged) Dune/scrub Military Other Land Use:_____________________

How close is nearest road to site? ________________ Road name: ______________________

STREAM CHARACTERISTICS

Can you see any **discharge pipes**, Storm drains or other sources of **effluents**?_______________

If so, can you determine where they come from?________________________________

Is the stream **channelized**?______ If so, how is it channelized?_________________________

Are there any **other stream modifications** ? _____ If so, what are they? ___________________

Are the stream banks **vegetated**? _____ If so, give a description of what type of plants are present? (i.e., trees, shrubs, etc.) and what % cover? ____

Are there signs of **bank erosion or trampling**? _____________________________________

Is there **litter** in or near the stream? _______________ If so, what kind/how much?

____

Is the water **clarity**; Good Fair Poor Is there **scum or a sheen** on the surface?___________

Streambed type (%): Concrete___ Bedrock___ Boulders (your head size and larger)_________

Cobbles (your fist size)___Gravel (thumb nail size)___Sand/mud____

Is there an **algal covering**? ____ If there is, conduct algal survey and take samples.

STREAM HABITAT, STREAM LIFE

Habitat Type: Pool (deep, shallow) Run Riffle cascade/falls

Water **Depth**: _______ Stream **Width**:___________ Stream **Flow Velocity:**_______________

Organisms: Fish Amphibians Mollusc Crustaceans Insects Birds Mammals

Fish species:____

____

Other animals:____

Dragonflies and Damselflies (nymphs or adults): ___________________________________

OTHER COMMENTS

Any **other observations or comments** about stream environment (write on the back of the form if you need to):

____

APPENDIX III. Water Quality Sampling Form

Date: ____ / ____ / ____ Sample Site: ______________ Collection Time: ______________

Salinity: ______________ ppt pH: ______________ Water Temp: ______________ °C

Weather: ______________ Water Color: ______________ Air Temp: ______________ °C

Sample Collector(s): ____

Notes: ____

Dissolved Oxygen

Analyst(s): ______________ Completion Time: ________

Replicate	# drops	(#drops)/2
1		
2		

Average: ________ mg/L DO

Nitrate-Nitrite

Analyst(s): ______________ Completion Time: ________

Replicate	Color Wheel	Color Wheel x 4.4
1		
2		

Average: ________ mg/L Nitrate-Nitrite

Total Suspended Solids

Analyst(s): ______________ Completion Time: ________

Replicate	Filter Number	Sample Volume
1		ml
2		ml

Phosphate

Analyst(s): ______________ Completion Time: ________

Replicate	Color Wheel	Color Wheel /50
1		
2		

Average: ________ mg/L Phosphate

APPENDIX IV. Benthic Algae Survey Instructions and Algal Survey Form

OBJECTIVE: To collect algal specimens for identification and monitoring.

MATERIALS NEEDED:

Specimen containers
3% to 4% formalin* (formaldehyde & water mixture)
Tweezers
Scalpel or knife
Labels (stick-on or non-stick)
Pencil
Transect line (10-15 m long marked off at every decimeter: roughly 4 inches)

* Formalin is a mix of formaldehyde diluted with water. You will need to purchase formaldehyde from a scientific supply dealer (two local companies are listed at the end of this handout). Treat the formaldehyde as 100% formalin and dilute accordingly with water to make formalin.

4% formalin = 1 part formaldehyde + 24 parts of water

PROCEDURE:

Prior to beginning the actual survey, the stream will need to be generally surveyed to assess the area and determine the location and number of stations. Select areas where it would be most convenient for you to collect specimens in terms of time and ease. A minimum of one lower, middle and upper reach station would be ideal.

Please note that there are not many flowery or leafy forms of freshwater algae. Most will be filamentous and gooey. Some will be a layer or film over the rocks or bottom. Under a microscope you will probably find many different types of algae including single-celled algae, such as diatoms.

1. Fill several containers about 1/3 to 1/2 full with the 3-4% formalin before going out in the field. This will be safer and save you time in the field.

2. At each station, lay the transect line across the stream and secure both ends. You will be collecting specimens from every other decimeter (sampling areas). Whatever specimens you see under the transect line will be collected and preserved. You do not have to collect everything. Collect a specimen of each different alga or category of alga that you see within the sample area.

3. Refer to attached survey form. Record the following information:
   - *Date* - date of observation
   - *Observer* - observer's initials
   - *Station No.* - assign numbers or letters to established stations
   - *Transect No.* - transect line no. 1, no. 2, etc.
   - *Weather* - sunny, windy, cloudy, etc.
   - *Time Started* - time transect began
   - *Elevation* - approximate elevation of stream at transect point
   - *Light* - measurement of the amount of light will be based on the percentage cover of canopy
   - *Water Temp.*- in either Fahrenheit or Celsius
   - *Transect point* - number of points in transect line (alternate decimeters)
   - *Specimen label* - number or label for each specimen taken from a particular transect point

Specimen description - categories for the volunteers will be 1) filamentous, 2) gooey, 3) blue-black, 4) gold, or any combination of the above, and any additional colors (i.e., green). This is to make it easier for data collection and identification. Division staff will take all specimens and will identify them to the genus level with the help of Dr. Isabella Abbott of the UH Botany Department.

Habitat/Substrate type - description of the bottom habitat of the attached algae (e.g., mud, mud/edge of stream, pool, bedrock/riffle, side of boulder, etc).

Flow - Flow will be classified into either three categories (low, medium, high), or determine the flow rate by dividing the distance a buoyant object travels by the time it takes to move that predetermined distance.

Depth - the depth at which each sample was taken will be measured in inches or centimeters.

4. Depending on the width of the stream, the transect line can be replaced within the station area more than once until a minimum number of 50-decimeter areas have been sampled.

When collecting filamentous algae, use the tweezers to pick small bits of the tufts or use something like a scalpel to scrape off some of the algal film. You do not need a whole lot.

5. Label your specimens with the following information:

Date:
Station No.:
Transect No.:
Sample No.:
Collector: (initials are fine)

Also put in whatever other information that is not recorded on the basic survey form. You can use labels that stick on the outside or you can use non-stick labels placed inside with the specimen. If you decide to use non-stick labels, use a pencil so that the writing will not run when it comes into contact with the formalin.

Local scientific supply dealers:

Curtin Matheson Scientific, Inc.
99-1169 Iwaena St.
Aiea, Hawai'i 96701
Ph: 487-7220

Hawai'i Chemical & Scientific
2363 N. King St.
Honolulu, Hawai'i 96819
Ph: 841-4265

APPENDIX IV. (continued)

ALGAL SURVEY FORM

page no.____

Date:____________Observer:________________Station No.________Transect No.:_______

Weather:____________________Time:_______________Elevation:____________________

Light:______________________________Water Temp.:______________________________

Transect Point	Specimen Label	Specimen Description	Habitat/ Substrate Type	Flow	Depth

APPENDIX V. Stream Report Cover Page

Stream name and color code: ______________________________

Landowners' names & addresses: ______________________________

____

____

____

(Please also enclose landowners' letters of permission)

Stream team leader's name: ______________________________

Stream team members' names: (Please indicate which members are in the surveying or sampling units).

____

____

____

____

____

How many water quality sampling stations did you use? ______________________________

How many stream survey stations did you use? ______________________________

Which of these stations are used for both sampling and surveying? ______________________________

____

Please highlight all the sampling/surveying stations on the map on the next page.

APPENDIX VI. Water Quality Testing Equipment and Supplies

The following are companies from which we purchased most of our water quality testing equipment and supplies.

<u>General Scientific Supplies</u>

Cole-Parmer Instrument Company
7245 North Oak Park Ave.
Niles, IL 60714
Ph: (800) 323-4340
Fax: (708) 647-9660

Fisher Scientific
711 Forbes Avenue
Pittsburgh, PA 15219-4785
Ph: (800) 766-7000
Fax: (800) 926-8355

<u>Test Kits</u>

Hach Company
P.O. Box 389
Loveland, CO 80537
Ph: (800) 227-4224
Fax: (303) 669-2932

LaMotte Chemical Products
P.O. Box 329
Chesterson, MD 21620
Ph: (800) 344-3100
Fax: (301) 778-6394

<u>Salinity Refractometer</u>

Aquatic Ecosystems, Inc
2056 Apopka Blvd.
Apopka, FL 32703
Ph: (800) 422-3939
Fax: (407) 886-6787

APPENDIX VII. Stream Team Materials List

Item	Catalog/Catalog #	Qty	Unit Price	Total Price
Hach OX-2P, Dissolved Oxygen Kit, 100 tests	Hach 1469-00	1	44.00	44.00
Hach NI-14, Low Range Nitrate Kit, 50 tests	Hach 14161-00	1	42.50	42.50
Hach 17N, Wide Range pH Kit, 300 tests	Hach 1470-11	1	47.50	47.50
Hach PO-19, Orthophosphate Kit, 100 tests	Hach 2248-00	1	54.50	54.50
Salinity Refractometer, Non-temperature Compensated	Aquatic Ecosystems	1	215.00	215.00
Vacuum Filter Holder, Magnetic, Gelman 4201	Fisher 09-735	1	123.03	123.03
Hand Pump with meter, Nalgene 6130-0020	Fisher 01-070A	1	40.53	40.53
Filter Flask	Fisher 10-182-50B	1	10.50	10.50
Graduated Cylinder, 250 ml	Fisher 08-570-21E	1	8.08	8.08
Sandwich Bag		1	0.84	0.84
Tweezers, Broad Tipped Forceps	Fisher 10-300	1	4.00	4.00
Thermometer, red liquid, with protective case	Fisher 15-021B	3	7.45	22.35
Thermometer, mercury	Fisher 14-985-C	1	4.47	4.47
Bottle, Nalgene, 500 ml, wide mouth	Fisher 02-893-C	10	1.93	19.30
Bottle, Nalgene, 1000 ml, wide mouth	Fisher 02-893-D	5	3.38	16.40
Test tube rack	Fisher 14-809-48	1	7.98	7.98
Test Tubes, 20x150 mm	Fisher 14-957-J	15	0.28	4.20
Wash Bottle, PE, 250 ml	Fisher 03-409-10D	1	1.95	1.95
Spatula, with square end, 7"	Fisher 14-373	1	5.60	5.60
White Bucket, 3 gallon	Fisher 03-687-10	1	6.66	6.66
Bucket, 5 gallon, with lid	City Mill	1	4.88	4.88
Marker pen, black, X-fine	Fisher 13-382-21	1	1.02	1.02
Marker Pen, black	Fisher 13-381	1	0.90	0.90
First Aid Kit	Longs Drug	1	15	15
Emergency Eye Wash		1	9.45	9.45
Safety Glasses	Fisher 11-402-3	3	5.31	15.93
Gloves, Ndex, 50 count	Fisher 11-395-19B	2	11.90	23.80

APPENDIX VIII. Project Brochure

KAILUA & WAIMANALO VOLUNTEER WATER QUALITY MONITORING PROGRAM

Established By:
The Hawaii State Legislature
Act 292, House Bill #1536

Coordinated By:
The University of Hawaii
Sea Grant Extension Program
for the Hawaii Department of Health

Are you concerned about the condition of our streams? Do you think the waters in our bays are as clean as they should be? If you are interested by these questions and want to be more informed, read on. If you want to make a difference, get actively involved and join the Kailua & Waimanalo Volunteer Water Quality Monitoring Program.

GOALS:

The goals of the Volunteer Water Quality Monitoring Program are:

1. To help develop educated and involved community members that are committed to preserving and protecting Hawaii's water resources.

2. To organize community volunteers to collect usable water quality information relating to the local watershed and bays.

3. To develop community-based solutions to pollution problems.

4. To develop a program that can be replicated elsewhere in Hawaii.

WHAT IT IS:

This program is not a vigilante program, rather it is a partnership between government, private landowners, the University of Hawaii, and concerned volunteers. The program is being carried out in close cooperation with the Hawaii Department of Health (DOH), Department of Land and Natural Resources, the Water Commission, City and County of Honolulu Dept of Public Works and Dept of Waste Water Managememt., and other relevant government agencies. The monitoring is being done in collaboration with related monitoring and research programs involving the University of Hawaii.

IMPLEMENTATION:

In a series of publicly announced meetings, interested members of the Kailua and Waimanalo communities identified the goals for the program as listed above. An initial set of volunteers has received the required training and has begun characterizing selected streams and obtaining and testing water samples. Any permission required for accessing private land has been or is being obtained by contacting private landowners (either directly or through the University of Hawaii).

THE NEED:

Hawaii's 376 perennial (year-round flowing) streams are a vital resource, providing habitat for unique flora and fauna, irrigation water, hydroelectric power, and recreation. The citizens of Hawaii recognize the need to balance increasing human use of the state's streams with environmental protection.

Water quality at certain sites in Kailua and Waimanalo Bays varies daily from clean to chemically and/or biologically polluted. It has been determined that non-point source pollution (i.e., pollution which does not generally come from a specific location, for example; soil run-off containing insecticides and fertilizers, and storm drain discharge containing oil, grease and household toxins) is a major contributor.

Frequent sampling of the streams, ponds, and bays in the Kailua and Waimanalo watershed areas is required to provide baseline data on the sources of pollution. These data can then be used to develop short- term and long-term strategies to prevent and/or reduce water pollution in the watershed areas.

Unfortunately, the State does not have the funds necessary to provide the long-term, statewide education and sampling programs required.

THE RESPONSE:

In order to complement existing DOH coastal water quality monitoring programs and to establish a pilot program that can be used throughout the state, the Kailua and Waimanalo Volunteer Water Quality Monitoring Program was established by Act 292, House Bill #1536 in 1993.

An Advisory Council was formed to help direct the program. It consists of representatives from various Departments of the City and County of Honolulu as well as community groups such as, The Neighborhood Boards, Save our Bays and Beaches, Surfrider, Windward Community College, Kawainui Heritage Foundation, Save Mt Olomana Association, Kalaheo High School Environmental Club, Sierra Club, and the Ohana Council.

The program, which is being jointly developed by the UH Sea Grant, DOH, and the community, provides regular training, proper equipment, supervision, and timely laboratory analysis. Community volunteers will:

---Actively participate in water quality monitoring through a central core of trained water samplers.

---Actively work to educate other residents, schools, and businesses on methods to prevent water pollution.

IN THE FUTURE:

In the future, given regular monitoring of a watershed area, the DOH will be able to:

--- Develop a comprehensive, statewide community volunteer based monitoring plan.

---Develop an educational program for the communities to help reduce pollution in the state's watershed areas.

---Achieve the goals of the Clean Water Act.

HOW YOU CAN HELP:

To volunteer your time, technical expertise, or contribute financial support to this program, call the University of Hawaii Sea Grant, School of Ocean and Earth Science and Technology at 956-8475.

Prepared by AMP and Associates

APPENDIX IX.

Volunteer Registration Form

1. NAME ________________________________ DATE______________

2. MAILING ADDRESS____

PHONE (Home) ____________________(Work)____________________

CITY______________ STATE ______ ZIP ________ FAX__________

3. CURRENT OR PAST OCCUPATION ____________________________

4.WHEN ARE YOU AVAILABLE TO VOLUNTEER? ___________________

5. DO YOU HAVE A CAR? YES ________NO ________

6. DO YOU HAVE A CURRENT DRIVER'S LICENSE? YES ________ NO________

7. EDUCATION AND SPECIAL SKILLS (i.e., computers, orienteering, etc.)

____

____

8. IN CASE OF EMERGENCY, PLEASE NOTIFY:

NAME ________________________________ PHONE ______________

RELATIONSHIP__________________________(Work)______________

9. DO YOU HAVE ANY MEDICAL CONDITION THAT WE SHOULD BE AWARE OF?

____

APPENDIX IX. (continued)

VOLUNTEER WATER QUALITY MONITORING AND WATERSHED SURVEYING PROGRAM FOR WAIMANALO BAY AND KAILUA BAY

VOLUNTEER RESPONSIBILITIES CONSENT FORM

(Please initial each item and sign at the bottom of the form)

1. Fulfill the given assignments or notify the program coordinator of any change in plans.

____

2. Each stream team leader and member will fulfill roles and responsibilities as established by the program.

____

3. Always obtain permission from landowner before entering private property. __________

4. Follow the safety guidelines for sampling and surveying, including the following:

Wear rubber boots, hiking boots, tabis, or similar protective footwear when conducting stream survey and sampling work. __________

Do not survey or take samples in or close to the stream during flooding. __________

Always conduct surveying and sampling field work with a partner. __________

Do not enter the ocean at high surf for sampling or surveying purposes. __________

Always wear safety glasses and protective gloves during sampling and water quality analysis.

____

Always carry a first aid kit while on a field survey or sampling trip. __________

NAME (Please print)______________________________

SIGNATURE______________________________DATE__________

APPENDIX X. Land Access Permission Letter and Landowner Consent Form

From: Sea Grant Extension Service, University of Hawaii

To:

Re: Permission to access stream as part of the Kailua-Waimanalo Volunteer Water Quality Monitoring Program

Aloha,

The accompanying brochure explains the Kailua & Waimanalo Volunteer Water Quality Monitoring Program. I am writing to inform you about the program, and to ask for your cooperation (and assistance if you care to join the Stream Team) in carrying out the program.

As you own property near one of the streams, I am sure you are interested in keeping the water in the stream as clean as possible. We feel that through a collaborative program with the community, private landowners and government, we can achieve our goal toward a healthy watershed. The program is designed to assess the quality of the water in the stream and, if any source of pollution is detected, we will seek to solve the problem cooperatively.

As the volunteers begin to characterize portions of the stream and take water samples, they may require access to a part of your property in order to get to or up streams. It is our policy never to allow our volunteers to cross private land unless we have written permission from the landowner.

We only need limited access to and along the stream. All reasonable care will be taken to limit any impact on your property. In most cases, the access would be a one-time event as the volunteers walk up the stream to verify their maps showing the course of the stream. After verifying the course of the stream, the team will select 4-6 water monitoring stations. We foresee a group of 3-4 volunteers requiring access possibly 2-3 times a month to obtain water samples at these stations. All volunteers are registered and trained and have been given extensive safety briefings.

The enclosed form is provided to make it easy for you to allow the team members access to your property under any limitations you feel necessary to impose. If you would life further information, you may contact me at 956-8475.

Please return the form in the enclosed envelope by ______________________________ as we have an ambitious schedule to accomplish the tasks we have outlined for ourselves. We are looking forward to working with you on this important community project.

APPENDIX X.

KAILUA & WAIMANALO VOLUNTEER WATER QUALITY MONITORING PROGRAM

______________	______________	______________
Last Name	First Name	Plot Number

______________	________	________	________
Address	City	Day Time Phone	Evening Phone

_____ I will give team members permission to cross my property to access the stream with the following conditions: (Check any condition(s) you wish to impose.)

_____ That the team leader contact me before the first instance of access.

_____ That I know at least one day in advance of each access.

_____ I also would like to add the following restriction(s) and/or comment(s).

____

____

____

____

____

If permission is granted, we request that any dangerous dogs be restrained by the owner. All reasonable care will be taken by the volunteers to ensure that no damage is done to the property.

_____ I will not allow access to my property under any circumstances.

______________________	____________
Signature	Date

Please return the completed form in the enclosed envelope.

APPENDIX XI

1994 Annual Report to
the Eighteenth Legislature
State of Hawai'i
on the
Kailua and Waimanalo Bays
Volunteer Water Quality Monitoring Pilot Program

1994 ANNUAL REPORT TO THE

EIGHTEENTH LEGISLATURE

STATE OF HAWAI'I

ON

THE KAILUA AND WAIMANALO BAYS

VOLUNTEER WATER QUALITY MONITORING PILOT PROGRAM

PREPARED FOR THE

HAWAI'I STATE DEPARTMENT OF HEALTH

BY

David Tarnas, Principal Investigator
Adam Rose, Program Coordinator
Arvin Wu, Program Assistant
Daniel Sailer Program Assistant

UNIVERSITY OF HAWAI'I AT MANOA, SEA GRANT EXTENSION SERVICE,
SCHOOL OF OCEAN AND EARTH SCIENCE AND TECHNOLOGY

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OVERVIEW

A growing number of people in Hawai'i are becoming increasingly concerned about our islands' aquatic environment. We are noticing a decline in the water quality of our marine and freshwater resources, and both citizens' groups and high schools have responded by organizing water quality monitoring projects. Established by the 1993 Hawai'i State Legislature, the Kailua and Waimanalo Bays Volunteer Water Quality Monitoring Program arose out these community concerns. This state sponsored program follows the lead of successful volunteer programs in other states, and hopes to further demonstrate the value of volunteer water quality monitoring programs.

GOALS

Beginning in October of 1993, the Pilot Program sought to determine what volunteers could realistically and usefully do in monitoring water quality, what training and education programs work in Hawai'i, and how a community could collaborate with governmental agencies and the scientific community to cooperatively manage watershed areas.

Specifically, the goals of the Pilot Program were threefold.

1) To organize community members into monitoring groups to collect water quality data relating to their local bays and watersheds.

2) To help develop an educated and involved community committed to preserving and protecting Hawaii's waters.

3) To help develop community based solutions to water quality problems that can be replicated elsewhere in Hawai'i.

OBJECTIVES

The objectives were to organize community volunteers to perform simple water quality sampling and tests, and to conduct surveys of coastal zone and watershed areas. These monitoring activities hoped to identify sources of water contamination, and were designed to complement existing coastal water quality monitoring and watershed management efforts by the Hawai'i State Department of Health and the Department of Land and Natural Resources. Additionally, the Pilot Program hoped to continue at Kailua and Waimanalo Bays after one year's time, and be replicated elsewhere in the state.

CONCLUSIONS

After a year of project design, organization, and implementation, we have the following remarks and conclusions about the program.

The scientific usability of the volunteer collected data cannot be evaluated at this point given that water sampling is still taking place, and interpretation of the data will begin in November. The primary reason for this is that community members wanted to include in their measurements, at least a portion of the wet seasonal effects on their area's water quality. This should provide a better environmental picture of the kinds of problems the communities are facing, before any management measures are prescribed.

Despite the lack of an independent assessment of the usability of the data, several preliminary conclusions can still be drawn. In terms of water sampling, community members have been producing consistent data. Community members have become skilled in water sampling and are conscientious in their data collection. Thus, while the reliability of the data has yet to be independently verified, the program has demonstrated that with organization and training, community volunteers can become a cost-effective and skilled labor force for the collection of water quality information.

In terms of water surveying activities, the water surveying data similarly awaits independent interpretation. Nonetheless, community members did make several significant sightings of native organisms in the course of their surveying efforts. For example, a nesting *Alae'ula* or Hawaiian Moorhen was discovered by Waimanalo community volunteers. The *Alae'ula* is on the State of Hawai'i and Federal Endangered Species List. Its discovery highlights the value of community volunteer efforts when surveying for native and exotic inhabitants of Hawai'i's watersheds. The documentation of this kind of baseline data is a necessary precondition to any comprehensive watershed management plan.

The project was successful in educating community members to assist in the protection of water resources. The education and training of community volunteers empowered those members to take an active and collaborative role in the management of their water resources and environment. Once the data results are interpreted, educational efforts will be focused beyond project volunteers, and the communities as a whole can then cooperatively move forward to develop community-based solutions to water quality problems. Collaboration between government agencies, scientific cooperators, and community members was the key element to the success of this aspect of the program.

The Pilot Program was also successful in producing a training manual, based on mainland models, but designed for Hawai'i's watersheds and stream ecosystems. This manual will serve as a useful guide to those seeking to establish their own volunteer water quality monitoring programs.

With the design, organization, and implementation challenges worked out, similar programs are now possible in other areas of Hawai'i.

I. PROJECT BACKGROUND

A. Introduction and Impetus for the Project

Over the past few years, there has been increasing public concern over the quality of Hawai'i's water resources. In particular, both Kailua Bay and Waimanalo Bay have experienced periods of poor water quality caused by point and nonpoint sources of pollution. Nearshore water quality problems were initially attributed to failing cesspools, antiquated sewer lines, and a waste water treatment plant that periodically flooded during heavy rains. Agricultural runoff containing agrichemicals and animal wastes also contributed their share to water quality problems.

However, Hawai'i State Department of Health samplings of the area's coastal waters pointed to a more complex picture, with bacteriological counts indicating that nonpoint source pollution was playing a far greater role than previously thought. Agreed upon by all parties was the need for comprehensive information on the impact of point and nonpoint pollution on the area's coastal and riparian environments. This required frequent sampling of the streams, ponds, and bays of the Kailua and Waimanalo watershed areas to provide the baseline data on the sources and impact of area pollution. Unfortunately, the state lacked the necessary funds such a long-term sampling program. Additionally, given the current and planned housing and agricultural developments in Waimanalo, further community educational efforts were sorely needed to achieve any long-term reduction of nonpoint source pollution. In response to these problems, the 1993 Hawai'i State Legislature directed the Department of Health to establish the Kailua and Waimanalo Bays Volunteer Water Quality Monitoring Program, and to study the economic benefits and long-term feasibility of volunteer monitoring programs in Hawai'i.

B. Goals and Objectives

Beginning in October of 1993, the Pilot Program sought to determine what volunteers could realistically and usefully do in monitoring water quality, what training and education programs work in Hawai'i, and how a community could collaborate with governmental agencies and the scientific community to cooperatively manage watershed areas.

Specifically, the goals of the Pilot Program were threefold.

1) To organize community members into monitoring groups to collect water quality data relating to their local bays and watersheds.

2) To help develop an educated and involved community committed to preserving and protecting Hawai'i's waters.

3) To help develop community based solutions to water quality problems that can be replicated elsewhere in Hawai'i.

The objectives were to organize community volunteers to perform simple water quality sampling and tests, and to conduct surveys of coastal zone and watershed areas. These monitoring activities hoped to identify sources and impacts of water contamination, and were designed to complement existing coastal water quality monitoring and watershed management efforts by the Department of Health. Additionally, the Pilot Program hoped to continue at Kailua and Waimanalo after one year's time, and be replicated elsewhere in the state.

C. Scope and Methodology

The scope of the project addressed three areas of community concern, education of community members about water quality issues, sampling and surveying of the main streams in the Kailua and Waimanalo watersheds, and bacteriological sampling of coastal waters in the Kailua Bay and Waimanalo Bay areas.

The Pilot Program began in October of 1993, and has just received a no-cost funding extension from the Hawai'i State Department of Health to the end of January 1995. Although the 1993 Hawaii State Legislature allocated $45,000 for a one-year project, the Community Advisory Group designed the project to be a long-term program, with a mixture of both public and private sources of funding. Additional funding sources are currently being explored.

Given the need to hold meetings in situations which were neutral and open to any member of the community, regular meetings took place in public venues easily accessible and acceptable to the participants. These venues included public libraries and school meeting rooms, rather than volunteers' private residences.

Conventional water sampling test parameters were selected based on their proven value for volunteer water quality monitoring programs on the mainland. The selected parameters were dissolved oxygen, pH, nitrate-nitrite, orthophosphate, salinity, temperature, and total suspended solids. The Community Advisory Group decided to test for these parameters using Hach kits. While it was understood that Hach kits produce low quality data, ease of use and relatively low equipment costs were the main determining factors for this decision.

Close collaboration was sought between governmental agencies, the scientific community, and community members. When initially soliciting the help of potential scientific cooperators, we emphasized that the project was a collaborative effort between community, landowners, government, private industry, academics and scientists. This usually served to mitigate many of the suspicions and skeptical attitudes some experts have towards volunteers and the community. We also stressed that the volunteers were able to assist the scientists in their field of research, and that the program aimed to work with government researchers and community in a mutually beneficial and cooperative manner.

The project coordinating team was in communication with the following government agencies, university officials, schools, and private companies:

State

Department of Health:
- Clean Water Branch
- Environmental Planning Office

Department of Land and Natural Resources:
- Division of Aquatic Resources
- Water Commission
- Division of Forestry and Wildlife
- Division of Land Management

University of Hawai'i at Manoa:
- School of Ocean and Earth Science and Technology
- Zoology Department
- Water Resources Research Center
- Geography Department
- Botany Department
- Oceanography Department

Department of Education:
- Aikahi Elementary School
- Kalaheo High School

City and County

Department of Public Works
Wastewater Management Department
Parks and Recreation Department

Federal

United States Fish and Wildlife Service
United States Environmental Protection Agency

Private

AECOS Inc.
Environmental Laboratory of the Pacific
Nexus Environmental Group Inc.
Condor Earth Sciences

It is important to emphasize that this was a partnership among government, private landowners, university, and concerned volunteers. This was not a vigilante environmental program. Private property rights were respected, and every effort was made to include landowners in the program. Also, all community meetings were conducted by a trained facilitator to ensure effective and highly participatory interaction.

II. PROJECT ORGANIZATION

The project consisted of a community advisory group, a coordinating team, scientific cooperators, stream teams, and trained volunteers (see **Figure 1**).

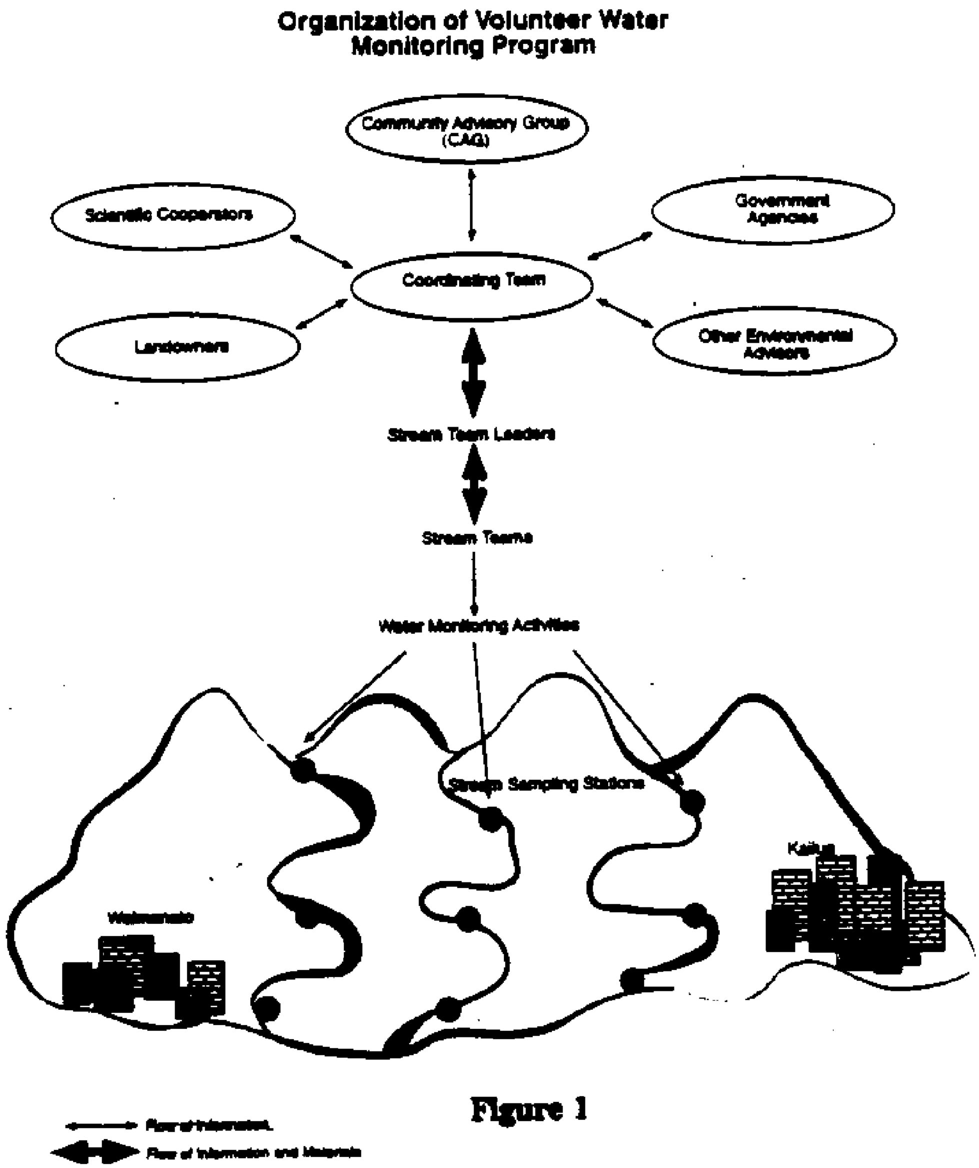


Figure 1

A. Community Advisory Group

By design, the project sought to empower the community by educating them about water quality and management programs, and by giving them the decision making authority to design and implement the volunteer monitoring program through the Community Advisory Group (CAG). The Community Advisory Group consisted of representatives from different community organizations, and representatives from the government agencies involved with water quality. Representatives decided on project direction and funding priorities, and were responsible for informing the members of the groups they represent of the program activities.

It was important to identify and involve a comprehensive range of participants for the Community Advisory Group. Local community members and organizations, as well as government resource managers, university scientists, and private environmental scientists, were all encouraged to become members of the Community Advisory Group. Additionally, landowners, ranchers, and stream side residents were also contacted, but the majority did not seek membership in the Community Advisory Group. All relevant government agencies were also involved from the onset of the project, including county, state, and federal resource management agencies.

Groups and members that actively served on the Community Advisory Group included:

Waimanalo Neighborhood Board:	Nancy Glover and Greg Field
Kailua Neighborhood Board:	Michael Compton and Ron Jackson
Save Our Bays and Beaches:	Jeff Harris
Kawai Nui Heritage Foundation:	Susan Miller
Sierra Club:	Thomas Shields
Kalaheo High School:	Barbara Volhein
Save Mount Olomana:	Eve Anderson
Hawai'i State Department of Health:	Eugene Akazawa and Denis Lau
City and County of Honolulu Department of Wastewater Mgt:	Robbie Dingeman
City and County of Honolulu Department of Public Works:	Bob Rock

Under the direction of the Community Advisory Group, the project developed as follows:

a.) The initial meetings focused on identifying the goals for the project and objectives.

b.) The Community Advisory Group then reviewed over a dozen project options relating to watershed surveying, water quality analysis, and physical oceanography of the bays (see **Appendix I** for project descriptions). These projects all had an associated scientific cooperator from a local university, private environmental scientific laboratory, government agency, or other group. The CAG decided that the best way to organize the project was to do an initial survey of the streams and surrounding watershed, then conduct water quality sampling and analysis. The relatively low cost of water sampling was one of the major reasons for this decision. They also decided to do the initial work themselves, rather than give samples to a private lab to conduct the analysis (final data analysis would be performed at a later stage). The scientific cooperators who helped design the various project options, continued to provide technical assistance upon request during these initial stages of the project.

c.) Next, the CAG decided that the project's first stage, the surveying and initial sampling work, would be best done by dividing the volunteer group into four stream teams, two in each watershed.

d.) In addition to the volunteer surveying and sampling work, the CAG also decided to sample and analyze coastal waters for bacterial contamination. The CAG designed the project themselves and agreed to have project assistant Arvin Wu, of the Water Resources Research Center (WRRC), do the sampling, and then analyze the samples in the laboratory at WRRC. The CAG selected four sampling sites in Kailua and Waimanalo, two that corresponded with Department of Health (DOH) sampling stations. Each site was sampled five times within thirty days allowing comparison to State and Federal water quality standards. Samples were taken with DOH personnel at the DOH stations twice. The results of this project are described in **Appendix II**. This separate project was a useful complement to the volunteer surveying and sampling because it provided the microbiological data that the volunteers could not effectively obtain in their own field analyses.

e.) As a quality control measure, a scientist at the School of Ocean and Earth Science and Technology was contacted for the purpose of analyzing random split samples from each stream team. This first independent analysis should be completed by the end of November, with periodic random testing to follow given sufficient budget funds.

f.) Volunteer sampling and surveying activities are currently still continuing with data interpretation scheduled to begin in late November.

B. Project Coordinating Team

The Project Coordinating Team consisted of three staff. A trained facilitator and coastal planner were employed at 25% full-time employment, an environmental biologist was employed at 100% full-time employment, and an environmental health specialist was employed at 50% full-time employment. The Project Coordinating Team was housed in the University of Hawai'i Sea Grant Extension Program, allowing them easy access to university scientists and other resources for the project design and implementation.

The staffing of three people on the coordinating team with a total of 175% full time employment was necessary for the Pilot Project given the effort required for the project design. A volunteer water quality monitoring program requiring only implementation, could be launched with only one full-time coordinator.

C. Scientific Cooperators

Given the complex environmental issues of watershed management, nonpoint source pollution, and coastal water quality, it was essential to receive advice and technical assistance from a wide range of experts. A key role of the coordinating team was to establish and develop a network of scientific and technical experts.

Scientific cooperators served the following functions:

- **Advisors**

  Scientific cooperators were volunteer technical consultants who advised community volunteers and project coordinators, and also helped direct the project's investigations and research. The scientific cooperators answered questions and recommended acceptable methods of environmental analysis.

- **Educators**

  Scientific cooperators were also involved in the educational aspects of the project, such as teaching and training volunteers. Training and educational workshops were held for volunteers, and during these sessions experts gave informal talks and presentations on water quality and the environment. Experts from the Hawai'i Department of Health, the Department Of Land and Natural Resources, the City and County of Honolulu Water Quality Section, the University of Hawai'i, and the Bishop Museum have all made presentations for the project. Using video, slides, and a range of other educational media, the cooperators presented a wide range of information in a stimulating and interesting manner.

  Such sessions were often followed by field trips, during which many of the same experts provided volunteers with personal environmental evaluations and interpretations of the sites visited.

  The project's educational aspect was a key part of the volunteers' training, helping to develop a more informed and knowledgeable community.

- **Resource base**

  The scientific cooperators also provided the project with an extensive resource base, providing expertise and information that validated volunteer findings. Additionally, many of the cooperators were willing to do analysis and other environmental tests at cost, using their organization's equipment and facilities.

  Most of the scientific cooperators aided our project in an unpaid context. Others were involved in our project as part of their professional activities. For instance, when an aquatic biologist from the DLNR, or an ornithologist from the Federal Fish and Wildlife Service came out to the field to verify the identification of native riparian species discovered by volunteers, this was clearly part of their professional duties as government scientists.

- **Mutual Support**

A number of experts were involved to varying levels in this project. Most were more than willing to assist as they sympathized with the project's aims and were excited, challenged, and curious to be a part of it. Experts were normally willing to answer technical questions and give informal advice relating to the subject of enquiry. In many cases, experts were willing to be involved in the project as they felt they would gain information and practical assistance from a network of dedicated and informed volunteers acting as an extensive and free human resource.

Further, most environmental scientists and managers welcomed the opportunity to receive information and data relating to actual situations in the real world. Indeed, some kinds of investigations such as long term surveys and studies relating to infrequent and unpredictable environmental events (e.g., water monitoring during storm events) are almost impossible without personnel who are permanently stationed in the field. As most research and environmental management institutions have limited staff and funds, it is hard for them to practically attempt such projects. Trained community volunteers can have an important role in such studies, and can significantly assist in the data collection for such situations.

D. Stream Teams

Because of the number of streams in Waimanalo and Kailua, separate stream teams were created to investigate the water courses within the study area's catchments. The stream teams consisted of project volunteers who were the heart of the program. For the Waimanalo area, the stream teams selected the perennial Waimanalo stream, and the intermittent Inoa'ole stream. For the Kailua area, teams selected the Maunawili system, and the Kaelepulu system. **Figures 2, 3,** and **4** on the following pages illustrate the sampling stations for each stream team.

Each stream team was responsible for a single stream, or a composite stream system, and were discrete and autonomous operational units. This enabled individual stream teams to determine their own schedules and meet at their own convenience. Such an organizational device also created more intimate social settings. Overall volunteer efforts were more efficient and productive when volunteers became familiar with each other and established good working relations. It must be stressed that although the stream teams worked independently, they all performed the same basic investigations and communicated regularly with the coordinating team.

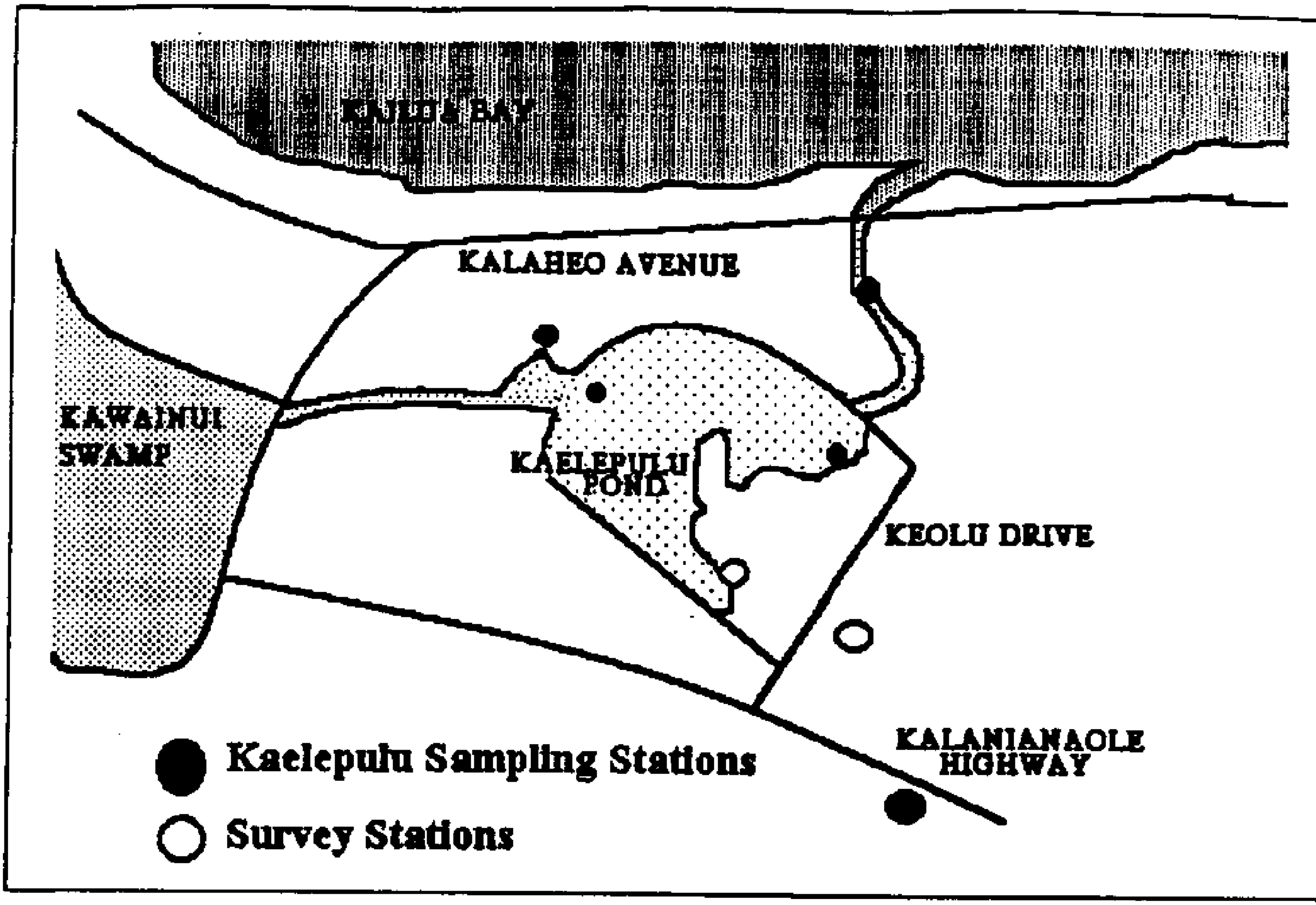


Figure 2

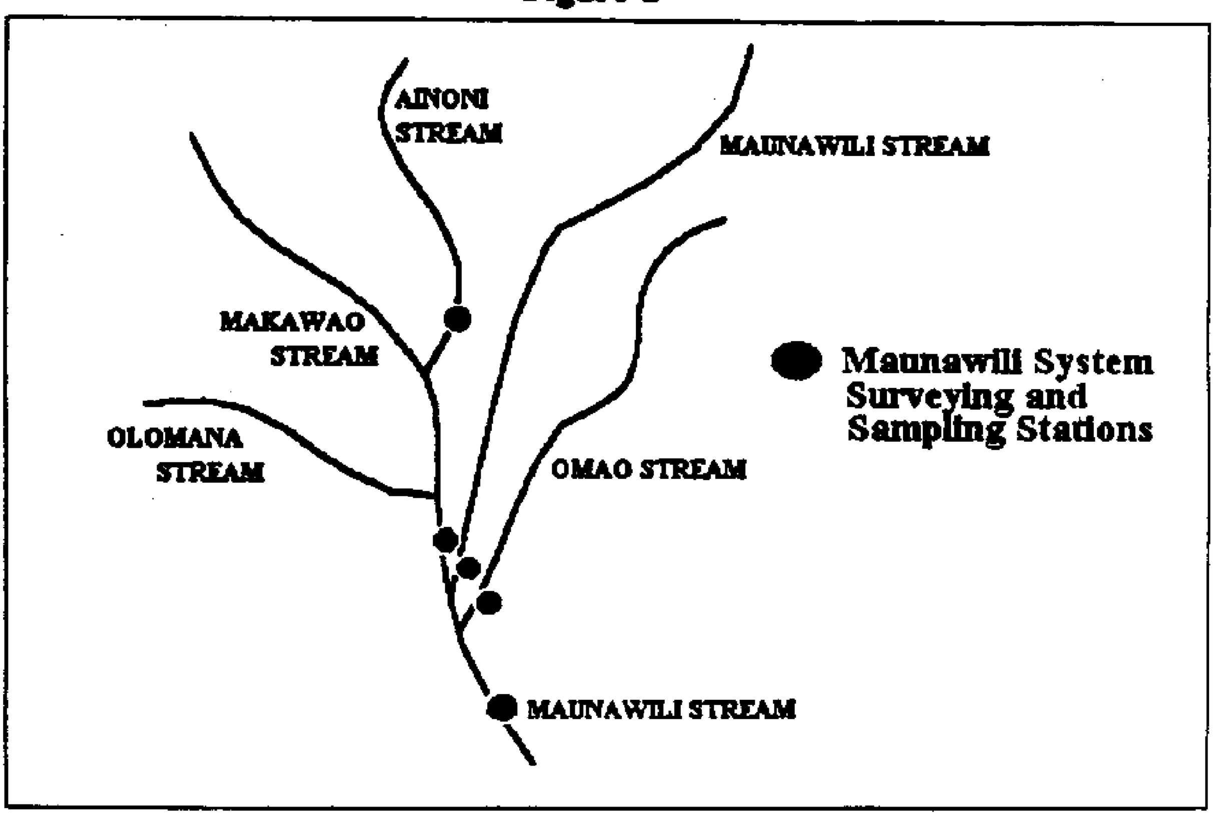
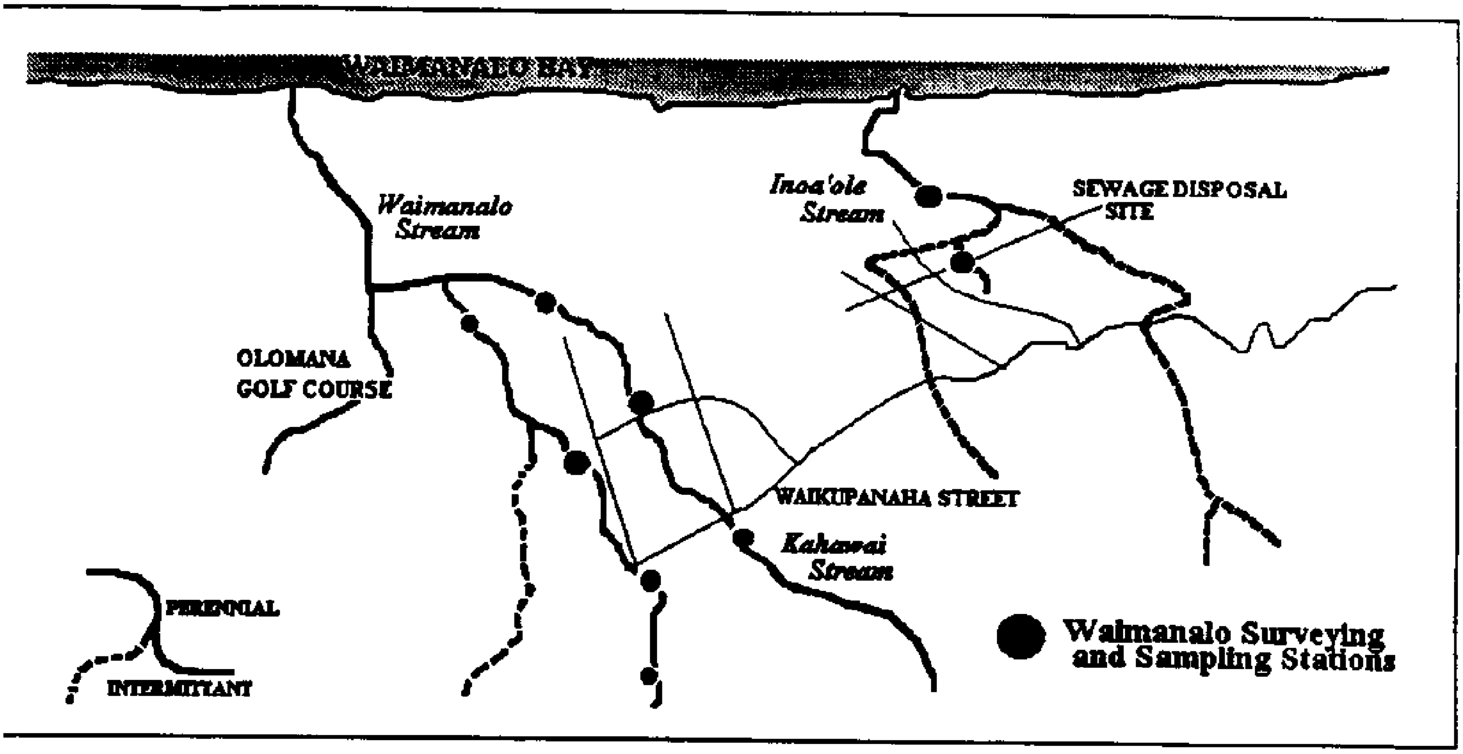


Figure 3.



WAIMANALO BAY
Waimanalo Stream
Inoa'ole Stream
SEWAGE DISPOSAL SITE
OLOMANA GOLF COURSE
WAIKUPANAHA STREET
Kahawai Stream
PERENNIAL
INTERMITTANT
Waimanalo Surveying and Sampling Stations

Figure 4

III. PROJECT BUDGET AND MATERIALS   Period: 10/01/93 - 01/31/95

Salaries and Fringe Benefits:	
David Tarnas	$10,849
Fringe Benefits	1,865
Adam Rose	15,361
Fringe Benefits	1,782
Training Materials (printing)	351
Travel	249
Supplies, film, processing	685
Materials and supplies for public meetings	120
Report Preparation (printing and logistics support)	1,465
Postage	29
Water Quality Analysis (includes provision of sterile prepared sampling equipment and analysis of samples)	10,722
Subtotal of direct costs	$43,478
Indirect costs (3.5%)	1,522
TOTAL	$45,000

MATERIALS:

1) Field Based Water Quality Test Kits and associated apparatus for determining; Dissolved Oxygen, pH, Nitrate-nitrite, Orthophosphate.
2) 4 Hand held Refractometers (for measuring salinity)
3) 8 Armored Alcohol Thermometers
4) 4 First Aid Kits, Protective Gloves, and Safety Glasses
5) Hand Pump and Meter with Filter Flasks (for determining suspended solids)
6) 4 Scoop Nets
7) Transect Line and Tape Measure
8) Glass Vials with 4% Solution Formaldehyde (for collecting algal samples)
9) Various Maps

For an inclusive list of the Water Quality Sampling Materials see **Manual Appendix VII**.

IV. OVERVIEW OF PROJECT PLAN

As stated previously, final analysis and interpretation of volunteer data will begin in November. The project is now at step four and five in the following overview.

Project Planning and Implementation:

1) Form CAG and develop a comprehensive monitoring strategy plan;
2) Train volunteers in water quality monitoring skills and quality control measures;
3) Conduct volunteer based water monitoring activities and related watershed investigations;
4) Conduct quality assessments of the performance of volunteers collecting the data
5) Compile data and interpret results;
6) Use the data to draw conclusions, report findings, and make recommendations.

See also the following flow diagram, **Figure 5**.

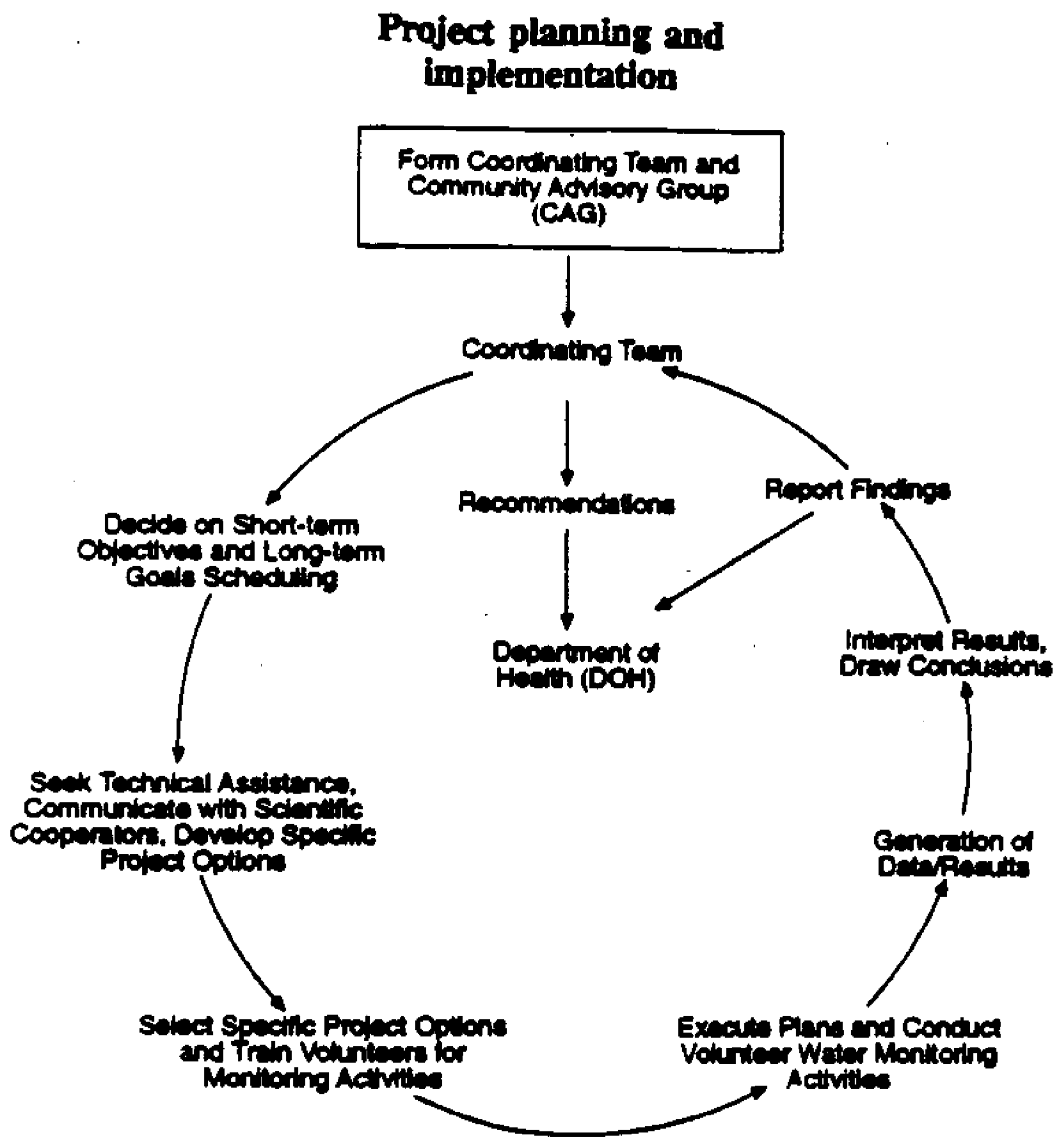


Figure 5

V. PROJECT EVALUATION AND CONCLUSIONS

A. Summary of Findings

After nearly one year, the Pilot Program has the following results:

- At the time of this writing, the initial data set had not yet been interpretated. Thus at this point, the usability of volunteer data is still undetermined.

- The project was successful in creating a community-based core of trained volunteers committed to preserving and protecting their local water resources, and organized to carry out basic water quality monitoring. The establishment of this program provided a mechanism to help educate and empower the community about water quality issues. Community volunteers now see themselves as active and necessary participants in the process of watershed management.

- Community members performed over a dozen beach litter clean-ups and are actively conducting a beach sediment and plastics analysis, as well as photographically recording the morphology at Kailua beach. (See **Appendix I, options C and D**.) These are ongoing long-term projects.

- The collaborative approach adopted by the project has proven effective in improving the rapport between community members, landowners, government agencies, university and private scientists, and a range of other relevant organizations. When addressing complex environmental issues such as nonpoint source pollution and coastal water quality concerns, this cooperative approach was conceptually and practically advantageous for all concerned. Through this collaborative approach, we believe the program has also helped to defuse the charged and confrontational atmosphere witnessed in the recent past.

- Given that the bulk of volunteer data still requires interpretation, the program has been unable to officially prescribe specific management measures or community-based solutions to the water quality problems facing the Kailua and Waimanalo communities at this time. Nonetheless, the program has been informally considering native re-forestations of riparian corridors as both a flood prevention measure, and as a means to protect and preserve stream ecosystems.

- This program provided a framework upon which other community-based water quality monitoring projects can be based within the state. The training manual produced as a result of the program will be an invaluable aid in this respect.

- Insufficient time and funds, have precluded the development of a preliminary watershed management plan. This preliminary watershed management plan is meant to include existing and potential sources of contamination, current and historical vegetation species, areas of erosion, land uses, and areas where remediation or corrective action is needed. The funds and resources required for such a large project, currently exceed the resources available to the Pilot Program.

- The bacteriological survey of Kailua and Waimanalo Bays indicated that all four sites sampled met both the Federal and State recreational water quality standards for the period tested. For a complete discussion of sampling results, see Appendix II.

A detailed evaluation of the project follows. The different sections reflect the various areas of concern relating to volunteer water monitoring and to the project at large.

B. Scientific Merits

1. Usability of Data and Volunteer Findings

Although the volunteer data has yet to be interpreted, several remarks on the sampling methods can still be made.

Hach kits were found to be easy to use albeit tedious and time consuming when processing a number of water samples. Since their initial training sessions in early May, volunteers became very proficient in using test kits and have devised methods of streamlining procedures, while preventing errors. Though the overall accuracy of their results has yet to be determined, consistent results were obtained in this period through conscientious data collection procedures. Furthermore, though the Hach kits have a large tolerance range of error (plus or minus 20%), with a large enough data set over an extended period of time, long-term trends should become evident, despite the low-quality of the data.

At the very least, the project has succeeded in demonstrating that community members can become a skilled labor force for the collection of chemical water quality information. It should be noted that the past summer's water samplings were designed as a training period in order to learn and practice proper sampling techniques. The community members themselves understood that no one immediately starts off by taking high quality data, and that a long-term sampling effort was needed for the data to be of maximum use.

To date, volunteer water surveying efforts have yielded some significant baseline information about the states of the Maunawili and Waimanalo watersheds, even before the final interpretation of the data. Volunteer biological surveying activities helped reveal the presence of several native riparian species. The findings are as follows.

The endemic shrimp species 'Opae kala'ole (*Atyoida bisulcata*) was found in the upper reaches of the Maunawili stream catchment.

Two species of native 'o'opu were found in both the Maunawili area and in streams in the

Waimanalo area. These were the endemic 'O'opu naniha (*Stenogobius hawaiiensis*) and the endigenous 'O'opu nakea (*Awaous guamensis*).

A nesting population of the native Hawaiian moorhen, or Alae'ula, (*Gallinula chloropus sandvicensis*) was also discovered in the lower reaches of a Waimanalo stream. This bird has state protection and is on the U.S. Endangered Species List.

All the above identifications were verified by either State biologists from the Division of Aquatic Resources, or wildlife biologists from the U.S. Fish and Wildlife Service.

Additionally, volunteer mapping activities revealed the inaccuracy of area maps showing stream courses. Plans to correct existing maps are now underway.

The documentation of this kind of baseline information is a necessary precondition to the drafting of a preliminary watershed management plan. The impact of point and nonpoint sources of pollution on these native species will be a determining factor for future management measures.

2. Quality Assurance Plan

While not formalized into a clearly specified Quality Assurance Project Plan, the following quality controls were used.

1) <u>Training and Proper Test Techniques</u>

Volunteers were thoroughly trained in water sampling and surveying procedures and protocols. There were four training sessions, one in-class session, and the others in the field. These sampling procedures and protocols emphasized quality control measures and methods for preventing errors. After the training sessions, volunteer sampling activities were initially supervised in the field to ensure that proper analytical techniques were being practiced.

2) <u>Replicate Samples and the Prevention of Gross Error</u>

Volunteers were instructed to measure dissolved oxygen, pH, nitrate-nitrite, orthophosphate, salinity, temperature, and total suspended solid levels twice by two different volunteers. If the two results differed, a third measurement was taken and the two closest measurements were averaged to obtain the recorded result.

3) <u>Use of Standards and Equipment Calibration</u>

Initial water sampling training sessions used chemical standards for comparison against volunteer results. Significantly, chemical testing of controls have not been consistently practiced, due to concerns over budgetary constraints, and the need to allow volunteers to practice test procedures without additional complications. The Community Advisory Groups will decide on the extent of the use of chemical test controls at the mid-October meeting.

The salinity refractometer was calibrated before each use.

4) Split Samples and the Validation of Results through Independent Confirmation

Random split samples are currently in the process of being collected for independent analysis using high quality testing equipment. The comparison between the volunteer and the laboratory results should bear out the accuracy of the volunteer measurements.

While these quality controls are by no means comprehensive, we have found them to be sufficient for the kinds of tests used and the parameters being tested for. A Quality Assurance Project Plan is currently under development and should be in place at the end of November.

C. Benefits to the Kailua and Waimanalo Communities

1. Educational Benefits

To date, the most successful aspect of the program has been the education of community members on water quality issues and the problems faced when deciding upon management measures. A few of the program's educational efforts follow:

- The program sponsored a series of workshops enabling community members to acquire a better understanding of the basic concepts of water chemistry, aquatic ecology, watershed dynamics, and potential sources of pollution.
- Community members were trained in methods of determining water quality through chemical sampling of stream waters and through surveying biota.
- Community members were informed of the roles and responsibilities of regulators and environmental management agencies, that is, who does what, where, and why.
- Community members learned about their own aquatic resources and the future threats their communities face. Volunteers were asked to share their knowledge and findings with neighbors and other interested parties. Also, participants were encouraged to ask others (particularly kupuna), about their community's history in order to identify changes in the area's aquatic resources. Overall communication within the community was improved through the establishment of a communication network among government resource managers, scientists, residents, and community organizations.

Through these activities, a sense of stewardship developed. Close collaboration with government managers, scientists, and environmental organizations, encouraged community members to become active caretakers of their local water resources. Publicizing the program's discovery of the highly endangered Alae'ula or Hawaiian Moorhen, was just one example of how the entire Waimanalo community was reminded of the sensitivity of their stream ecosystems, and the need to collectively protect their water resources from further degradation. See **Appendix IV** for article.

2. Economic Benefits

Pollution costs are notoriously difficult to identify and measure. Conversely, benefits from any reduction in pollution levels are often equally difficult to monetarily quantify. Nonetheless, the following remarks can still be made on the projected economic benefits of the Pilot Project.

If the future management measures are successful in improving water quality, local coastal recreation and their associated revenue dollars should increase. While it is currently difficult to estimate present revenue losses to local businesses due to beach closures, one would only expect increases in tourism and coastal recreation, to proportionally increase local business revenues, with all other factors being equal. Educational efforts on nonpoint source pollution will do much to improve the water quality of the two communities, particularly in the long-term.

In Waimanalo, given the large native Hawaiian community, the number of agricultural farms and nurseries, and the interest in native ecosystems, there is a potential for a localized native re-planting industry. Commercial growing of native hawaiian plants is currently limited given the lack of demand. Streamside management and the development of riparian corridors would be the primary focus of such activities. With an organized native planting of riparian corridors, there is an opportunity to create local jobs in restoration technologies, and to expand local agricultural markets. The costs for such a program could be borne through aggressive fundraising from environmental and community organizations, as well as through federal grants. While the costs, benefits, and ecological considerations of any native re-forestation effort need to be well thought out beforehand, the benefits to the Waimanalo community are potentially significant. It is important to note that a largely privately funded native restoration is already underway in Kawainui Marsh (see **Appendix IV**). In the near future, the Pilot Program hopes to model additional restoration activities upon these kinds of private/public partnerships.

D. Benefits to Government and Resource Managers

1) Community Empowerment and Resource Management

Successful management of coastal watersheds and stream ecosystems requires active community participation. The volunteer-based water quality program focused community members' attention on water quality issues, and educated community members on such issues as nonpoint source pollution. They were made aware of how their lifestyles and actions contribute to water quality problems, and how their efforts could help mitigate nonpoint source pollution. The program also served as a clearing house for the dissemination of informational literature, brochures, and other governmental publications on attitudes and behaviors affecting water quality. These direct educational efforts complemented state efforts to control nonpoint source pollution, and were performed at minimal cost. Indeed, public education is perhaps the most important component of any comprehensive state effort to mitigate nonpoint source pollution.

Additionally, the program provided a forum for community members, government representatives, and scientists to regularly discuss nonpoint source pollution and other water quality issues. This communication effort between government and community, is a necessary and important process when dealing with nonpoint source water quality problems. The communication network not only furthered the community's understanding of water quality issues, but also allowed governmental representatives to hear first hand, relevant community concerns on a regular basis. Direct public involvement allows the design of watershed and coastal management policies to be even more sensitive to community needs and local concerns.

Further, the monitoring program developed and mobilized an organized and enthusiastic volunteer labor force. They engaged in stream clean-ups, beach litter pick-ups, and surveyed and monitored the area's watersheds and watercourses. This voluntary labor force dedicated considerable time and effort towards their tasks, and have become a valuable source of manpower and trained expertise. A trained core of volunteers who have an intimate knowledge of area watercourses and capable of collecting reliable water quality data, certainly represent a valuable resource to watershed managers, particularly in these times of zero-growth state budgets and Department of Health cutbacks. Future collaborative projects between the community, government agencies and environmental managers should enable this source of skilled, cost-effective labor to be further utilized.

2) Complete Ecosystem Protection

In addition to public education efforts, the Pilot Program is also seeking to execute the state policy of complete ecosystem protection for native freshwater plants and animals. With native Hawaiian aquatic organisms in sharp decline on Oahu, targeting the Waimanalo and Kailua watersheds for comprehensive management measures could provide an ideal test-model for the re-establishment of native plant and animal populations within geographically discrete ecosystems. Indeed, with Kawainui Marsh, Kaelepulu Canal, and Waimanalo Stream all being identified in the State Hawai'i Stream Assessment as having at least substantial riparian resources, and with community members already committed to protecting their aquatic resources, the two watersheds offer favorable circumstances for becoming an example of system-wide protection.

If expanded, this type of bottoms-up, system-wide prevention and protection effort potentially offers a much cheaper and more effective method of environmental protection than traditional band-aid approaches which often come as a result of expensive lawsuit cases. With water quality problems like nonpoint source pollution inherently multi-faceted, a holistic, system-wide management strategy is all but demanded. Complete ecosystem protection also requires experts from a wide range of disciplines to address common environmental concerns. The Pilot Project has been well on its way in cultivating this interdisciplinary approach.

VI. PROJECT STATISTICS

Number of trained volunteers: 54
Number of scientific cooperators: 32
Number of stream teams: 4
Number of meetings: ~19
Number of training sessions: 14
Number of water quality samples and analysis: ~375
Number of people on the mailing list: 180
Number of monthly newsletters: 14

VII. FUTURE OF THE PILOT PROJECT

The following remarks are a tentative timeline for the near future of the program:

November: Finalize quality assurance plan and run split samples for independent analysis.
Collect initial volunteer data for interpretation.
Begin aggressive private and public fundraising efforts.
Expand community outreach efforts, particularly involving more public schools.
Continue sampling and surveying efforts.

December: Complete data interpretation of initial data set.
Prepare results for community presentations.
Continue fundraising and volunteer recruitment efforts.
Continue series of community educational workshops on nonpoint source pollution, scientific data interpretation, and streamside management techniques.
Water monitoring training and re-fresher course for volunteers.

January: Present findings and results of the project in a series of community presentations.

Formulate and begin applying specific management measures.
Distribute training manual developed by Pilot Project to other interested communities and parties across the state.
Coordinate stream clean-up effort with the City and County of Honolulu and the windward community.

VIII. RECOMMENDATIONS FOR STATE WIDE IMPLEMENTATION

The following recommendations are suggested for future volunteer-based water monitoring programs in Hawai'i.

Volunteer programs and the data they gather would be most usefully utilized to:

- Educate communities on nonpoint source pollution issues and include their participation in mitigative efforts to improve water quality.
- Complement long-term studies characterizing aspects of the aquatic environment.
- Gather water samples as part of large scale, coordinated sampling efforts to determine spatial or temporal trends relating to a range of water quality parameters.
- Investigate, sample, and monitor for, or during, acute or stochastic events, such as pollution episodes or rain events.
- Assist resource managers in monitoring the effects of significantly higher stream flows or stream bed restorations.
- Assist aquatic biologists to monitor populations of native and exotic riparian species, and assist in baseline biological surveys.

In general:

- Community based water quality monitoring programs should aim to involve local landowners from the onset of the project.
- Developing programs should also involve Hawaiian civic groups and local farmers during their establishment, and through subsequent phases of the project.
- The community should be actively involved in deciding on long-term watershed management objectives, and must participate in the planning process of developing integrated watershed and coastal management strategies. The formation of community based water monitoring programs helps to empower communities in this respect, as well as organizing volunteer labor for potential use when implementing these plans. For example, volunteer labor can be used to help meet long-term watershed objectives through maintenance of riparian corridors and restoration projects.
- We strongly advise that a biological monitoring system be established that employs common and easily identified riparian species (densities and diversity) from the aquatic community, as an index of various water quality parameters. Several native species of riparian fauna are already being investigated by the state as potential indicator species. A more comprehensive and widely disseminated effort is needed. Such a monitoring device could be an invaluable tool to volunteer monitoring programs.

APPENDIX I. PROJECT OPTIONS

The following options were reviewed in January of 1994 by the Community Advisory Group. When reviewing these options, the community was asked to keep in mind the following: (1) it is important that the project generates reliable, quality data that would be useful to the community, the DOH, and others; and (2) any investigations the project conducted must be relevant for the aquatic environments of Kailua and Waimanalo Bays.

Project Option A. Coastal Water Quality Sampling During Visible Event. (Analysis). *Major Cooperator: Dr. Ed Laws. UH Manoa Oceanography.* This project would attempt to determine what factors cause the algal blooms which are sometimes seen in the bays. Are these blooms periodic 'natural' events, or are they caused by anthropogenic determinants? Could it be the sewage effluent which is responsible for these events, or are they caused by nutrient-rich fresh water originating from agricultural land?...This project would address such questions.

Two or three water samples would be taken from the bays when there is a visible algal bloom or high turbidity. The samples would then be analyzed at the UH Oceanography laboratory for such factors as; nutrients, pigments, salinity, dissolved organic carbon & nitrogen, and possibly some isotopes (N & C). Local weather and sea conditions would also be noted and recorded photographically by volunteers.

Training: The scientists would train volunteers in basic sampling methods. The analysis of the samples would be conducted by Ed Laws (or a representative) at the UH Manoa Oceanography Dept. He will also interpret the results and draw conclusions.

Approximate Cost: $40/sample for analysis of inorganic nutrients (ammonia, phosphate, silicate), dissolved organic carbon & nitrogen, pigments, salinity. If there was a very large algal bloom, isotope analysis would also be done, at about $10/sample (need large quantities of water to do analysis). The project would also need to purchase necessary sampling equipment. This appears to be an inexpensive project.

Project Option B. Coastal & Stream Characterization. (Survey) *Major cooperators: Soil & Water Conservation District, DOH, Dept of Land & Natural Resources, and private land owners.* This project would be a survey of the catchments and shoreline. Volunteers would conduct visual monitoring, noting and photographing problematic areas/activities which appear to be detrimental to water quality (eg. highly erodible land, steam-bank damage, animals in the water, effluent outlets, dumping etc.). Apparent stream and coastal biota would also be recorded. Volunteers would work with the management agencies and land owners to identify the appropriate management measure. If the landowner agrees, volunteers may participate in the implementation of the management measure. The appropriate parameter (eg. turbidity) may be measured before and after the remedial action to assess the effectiveness of the management measure.

Training: Scientists from the University of Hawaii and other organizations will train volunteers in survey techniques including basic identification of biota and criteria for determining erodibility of land. Cooperating agencies will assist the community in developing an appropriate survey for the project.

Approximate Cost: Project costs include survey forms, clipboards, film, and developing costs. This is a rather inexpensive project.

Project Option C. Litter Pick-up Along Beaches & Steams. (Survey) *Major Cooperators: State Litter Control Office, DOH, City & County of Honolulu, private land owners.* This project would involve picking up litter along beaches & streams and cataloging the type and amount. This could be conducted on a monthly or quarterly basis. Such a project would superficially clean up the place and may help determine the origins of litter. This kind of investigation may also provide information about illegal garbage tipping. This type of data may help us establish a more effective management strategy. Training and costs are minimal.

Project Option D. Beach Survey/plastic analysis. (Survey & Analysis) *Major Cooperator: Dr. Floyd McCoy. Windward Community College (M.O.P.).* This project has two major aims. First, it represents an attempt to characterize and record the processes of accretion and erosion which largely determine sediment dynamics and beach form in the area. This would be done by making visual and photographic records of the beach at frequent and regular intervals and from a constant vantage point (i.e., someone's beach-front lanai).

The second part of the project would represent a pilot study investigating the form and quantity of plastics in beach sand. Samples of sand would be collected and analyzed for plastic content. This kind of sediment analysis has not been carried out before and could generate useful information relating to the impact of plastics on coastal environments and ecosystems. Recent analysis of some fish tissues has revealed high levels of plastics. How have such levels of plastics entered the food-chain? Does it enter through the feeding activities of filter feeders and detritivores which have ingested tiny particles of plastic from among the beach sediment? As high levels of plastic are present in some fish tissue, does this represent food chain magnification? This project could produce some background information which may begin to help in answering such questions.

Training: Dr. McCoy will train volunteers in sampling methods. He will also train 2-4 volunteers to prepare & analyze sediment samples. Dr. McCoy will interpret the results and draw conclusions.

Approximate Cost: This is a relatively inexpensive project. Sample collection is simple, and analysis is practically free (using facilities at Windward Community College-Marine Option Program). The project would need to cover costs of sampling materials and to reimburse Dr. McCoy for the use of perishable supplies and other resources.

Project Option E. Investigation into Coastal Water Turbidity Events. (Analysis) *Major Cooperator: Dr. Richard Brock. UH Manoa, Sea Grant.* Residents of Kailua and Waimanalo know only too well that the bays' waters sometime become murky, dirty and discolored. This project would gather information about such turbidity events, and try to establish how environmental factors (such as wind, rain, surf conditions, tides, and freshwater runoff) may affect or relate to these events. Water samples would be taken every other day for six months at seven stations (total of 637 samples). Volunteers would also record general environmental conditions. Such a study could provide baseline information enabling a better understanding of the periodic turbidity which occurs in the bays. Such a project could also help us to form a model to aid our predictive capabilities which could assist in making more informed future management decisions in the area.

Training: Dr. Brock will train volunteers in sample collection and preparation procedures. Two volunteers will be trained in Dr. Brock's laboratory to use analytical apparatus (i.e., nephelometer & salinometer). Dr. Brock will interpret the results.

Approximate Cost: Samples would need to be taken to the UH Manoa Marine Biology Laboratory for analysis. This project would purchase a nephelometer (turbidimeter) at $1500. Analysis of the samples would be free. For the project described, at 637 samples, the cost per sample is $2.40. The project would also need to cover costs of sampling materials and reimburse for use of perishable supplies and other resources.

Project Option F. Steam Water Sampling During Rainfall Event. (Analysis) *Major Cooperators: DOH, City & County of Honolulu, US. Geological Survey, private landowners.* This project would aim to determine stream-flow and water quality during rainfall events in the Kailua and/or Waimanalo watershed. Such an investigation may provide data about such processes as storm runoff, sediment loading of streams, soil erosion, agricultural runoff, etc. Samples would be taken (every 15 minutes during heavy rainfall) at a flow meter in the Kailua and/or Waimanalo watershed. This project is risky because of the flash flood danger when collecting samples in the rain-swollen stream. Training and costs are minimal.

Project Option G. Geography & History Project for High Schools. (Survey) *Major Cooperators: Local high schools (Barbara Volhein) & History Day in Hawaii (Kathy Ellwin).* This project would be an attempt to evaluate land use changes that have occurred over time in the local watersheds and beaches. This would involve a thorough literature search and compilation of historical records as well as interviews with local *kupuna* who would provide oral histories regarding changes they have seen in the bays and watershed areas.

This project also has two educational aspects. There is a possibility that local school students could participate in Hawaii History Day 1994. This would involve students in conducting investigation and research in order to present papers, projects or performances which are based on this year's History Day theme; 'Geography in History: People, Places, Time'. This would give students an opportunity to investigate what impact the localities' environments have had upon its peoples. The areas' watersheds, beaches and historical land use patterns would obviously be relevant factors for such a project. Student/school projects could be entered into the regional and state competition.

There could also be an educational outreach program involving local schools and the community. This could include such activities as lectures, workshops and community programs with an environmental water quality theme. Such a project could possibly coordinate with Dr. W. Stapp's project 'Green', which has a water quality emphasis and involves Aikahi Elementary School.

Project Option H. Watershed Mapping. (Survey) *Major Cooperators: Office of State Planning, City & County Honolulu, DAGS-Land Survey Office, private land owners.* This project would involve surveying the land uses in the watersheds and along the coast. This would involve the collection of existing information relating to land use in the watersheds of Kailua & Waimanalo. Community volunteers would establish field surveys and initiate a literature search, as well as taking aerial and other photographs. Training and costs are minimal.

Project Option I. Marine Life Survey. (Survey) *Major Cooperators: UH Marine Option Program, DLNR.* This project would be an attempt to survey the local reefs' marine biota by conducting reef transects on a quarterly basis. An underwater video camera would be used to record data. Training would need to be extensive and costly, such as the UH-Hilo summer program in QUEST (Quantitative Underwater Exploration Survey Techniques). Costs are also significant for equipment, depending on the number of surveyors.

Project Option J. Characterization of Ocean Current patterns for both Bays (Survey) *Major Cooperators: University of Hawaii, Kailua High School, Sea Engineering.* This project would involve doing a literature search and initiate field research using drogues. Scientists would train volunteers. Costs should be minimal.

Project Option K. Heavy Metal Analysis of Stream & Nearshore Sediments. (Analysis) *Major Cooperator: Eric H. De Carlo. UH Manoa, Geochemistry.* There appears to be little information available relating to the heavy metal status of the area's stream and coastal sediments. Such activities as landfilling, sewage disposal, automobile use and urban development often produce heavy metal pollutants in the aquatic environment. The heavy metal loading could also be increased locally by such factors as: the light industry in Kailua, the use of agricultural chemicals in Waimanalo, and the use of certain common household chemicals. This project would attempt to evaluate stream, and some inshore sediments for a range of possible heavy metal contaminants. The project would involve the collection of about five samples from a limited and discrete area; such as the upper, middle and lower reaches of a stream and its marine outlet. The areas of investigation would have to be carefully chosen as information gathered from this survey would be site specific. Some core samples could also be taken to show how metal concentrations vary within the sediment over time. This would give a historical dimension to the study.

Training: Dr. De Carlo will supervise sample collection and train two volunteers to prepare samples for analysis at UH Manoa. Sediment analysis and the interpretation of results will be conducted by Eric De Carlo.

Approximate Cost: A comprehensive analysis would test for the following metals; lead, copper, nickel, cobalt, zinc, cadmium, chromium ($10 each). Arsenic, mercury and tin would require a separate analysis at a cost of $25 per metal. Therefore the price of analysis per sample would be approximately $150. It would cost $750 to analyze the five samples selected in the project design. This analysis would be conducted at the UH Manoa Marine Science, Geochemistry laboratory. Interpretation of results and a comprehensive mineralogical sediment analysis will also be conducted for free by Dr. De Carlo. Sediment mineralogy could give some indication of sediment sources and metals' origins.

Project Option L. Microbiological Analysis/survey of waters/soils (Survey) *Major cooperator: Roger Fujioka. UH Water Resource Research Center.* This project represents an opportunity to investigate some aspects of the watersheds' microbiological characteristics. Dr. Fujioka has expressed an interest in investigating three areas of interest: (1) Conduct a survey of the bacteriological levels in the areas' soils. This investigation would aim to determine which pathogenic bacteria inhabit the local soils and may contaminate waters; (2) a bacteriological quantitative analysis of fresh and nearshore waters during a heavy rainfall event or algal bloom; and (3) a specific investigative analysis of a site (eg. a sewage outlet) to determine whether water quality is satisfactory in bacterial terms.

Training: WRRC staff would identify sampling sites and train volunteers to take samples.

Approximate Cost: As long as the number of samples is small, the cost would be minimal. If the number of samples is large, we would need to go to a private laboratory which charges about $60/sample for fecal coliform testing.

APPENDIX II

BACTERIOLOGICAL TESTING IN KAILUA AND WAIMANALO BAY FOR THE VOLUNTEER WATER QUALITY MONITORING PROGRAM.

Prepared by:

Arvin Wu

Prepared for:

Volunteer Water Monitoring Project in Kailua Bay and Waimanalo Bay

I. INTRODUCTION

This report is a summary of the results of bacteriological tests conducted from May 31, 1994 to June 27, 1994 at Kailua and Waimanalo beach. The intent of this project was to complement volunteer surveying and sampling in the streams.

The bacteriological tests were conducted so that results would be comparable to Federal and State water quality regulations. These water quality standards are used by the United States Environmental Protection Agency (USEPA) and the State of Hawai'i Department of Health (DOH) to assess the sanitary quality of recreational waters. Water quality standards are rules and principles used to regulate water quality. The basis of a water quality standard is a water quality criterion, which is the scientific evidence of the effect pollution has on the environment.

Currently, the State and Federal water quality standards for recreational waters are based on levels of indicator bacteria densities. Traditionally, the concept of using bacterial indicators was originally developed as a sensitive measure of possible sewage contamination of drinking water supplies. Bacterial indicators, such as enterococci, occurs in greater concentrations in human fecal wastes than pathogenic bacteria. Indicator bacteria are not necesarily pathogenic; they are only indirect measures of the likelihood of the presence of pathogens. The incidental ingestion of water when swimming forms the premise for using bacterial indicators to assess the health risks associated with recreational water use. In studies conducted by the USEPA, *E. coli* and enterococci best correlated with incidences of gastroenteritis in recreational water users (Cabelli *et al* 1982).

The Federal water quality standards set forth by the EPA limit the monthly geometric means in stream waters to less than 33 CFU (colony forming units) enterococci per 100 ml or 126 CFU *E. coli* per 100 ml, and for marine waters to less than 35 CFU enterococci 100 ml. Regulatory authority for the implementation of the water quality standards in Hawai'i is delegated by the Federal government to the Hawai'i State Department of Health. The DOH adopted recreational water quality standards that apply to all stream and coastal waters of the state. These water quality standards limit the monthly geometric means in stream waters to less than 200 CFU fecal coliforms per 100 ml, and in ocean waters to less than 7 CFU enterococci per 100 ml.

II. METHODS

The Advisory Group selected four sampling sites, two that were periodically monitored by the DOH, and two that they felt may need to be monitored by the DOH. The two DOH sites selected are at Kalamas Beach in Kailua and at Bellows Air Force Station in Waimanalo. The other two sites are at the Lanikai Boat Ramp in Kailua and off the beach lots in Waimanalo near Hilu Street. Table 1 lists the site location designations.

Table 1. Site Location Designation

Site	Location
K1	Kailua Bay at Kalama Beach, DOH Station: 207
K2	Kailua Bay at the Lanikai Boat Ramp
W1	Waimanalo Bay at Bellows AFS at Jetty Lane, DOH Station: #6 Lifeguard Stand
W2	Waimanalo Bay at the Beach lots off Hilu Street

Each site was sampled 5 times in 30 days allowing direct comparison with state and Federal Water Quality Standards. The samples were collected roughly once a week between May 31, 1994 and June 27, 1994. Our sampling dates were set up to correspond with DOH sampling dates. Four samples were collected with DOH personnel. The samples were immediately stored on ice and analyzed within 4 hours.

Three species of indicator bacteria were tested: fecal coliforms, enterococci, and *C. perfringens*. The fecal coliforms and enterococci were tested using the membrane filtration technique as specified in *Standard Methods*. *Clostridium perfringens* were tested using membrane filtration as described by Bisson and Cabelli (1979). The salinity was measured using a salinity refractometer.

III. RESULTS

The indicator bacteria densities were generally quite low, at most sites, levels rarely exceeded 5 CFU / 100ml. However, indicator bacteria densities varied considerably between sampling stations and sampling dates.

Figure 1a-1d presents the fecal coliform densities at all four sampling sites through the entire course of the 30-day sampling period. Fecal coliform densities were usually under 10 CFU/100 ml except on one occasion at Site K2, and twice at Site W1.

Figure 2a-2d presents the enterococci densites at the four sampling stations. Again, typical levels of enterococci were under 10 CFU/100 ml, except on May 31 at Site K2.

Figure 3a-3d shows that *C. perfringens* concentrations at all sampling stations remained below 2 CFU/100 ml for the entire 30-day samping period at all sampling stations.

Figure 4 presents the 5-day geometric mean for the three types of indicator bacteria at the four sampling stations. The fecal coliform and enterococci levels at Sites K2 and W1 are somewhat higher than those at K1 and W2. The *C. perfringens* 5-day geometric means are, in contrast, the same at all four sampling sites.

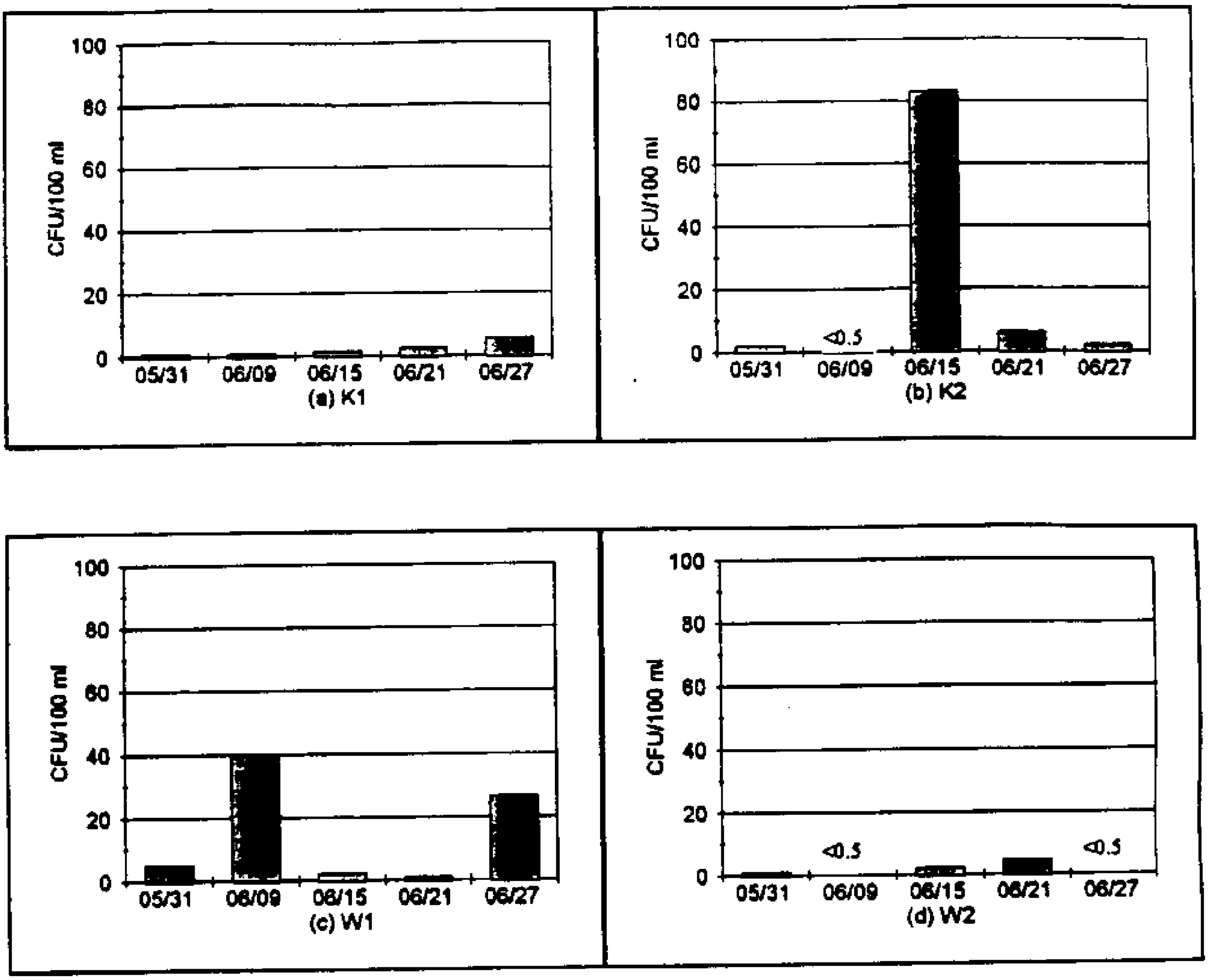


Figure 1. Fecal Coliform densities at Sites K1, K2, W1, and W2 from May 31, 1994 to June 27, 1994.

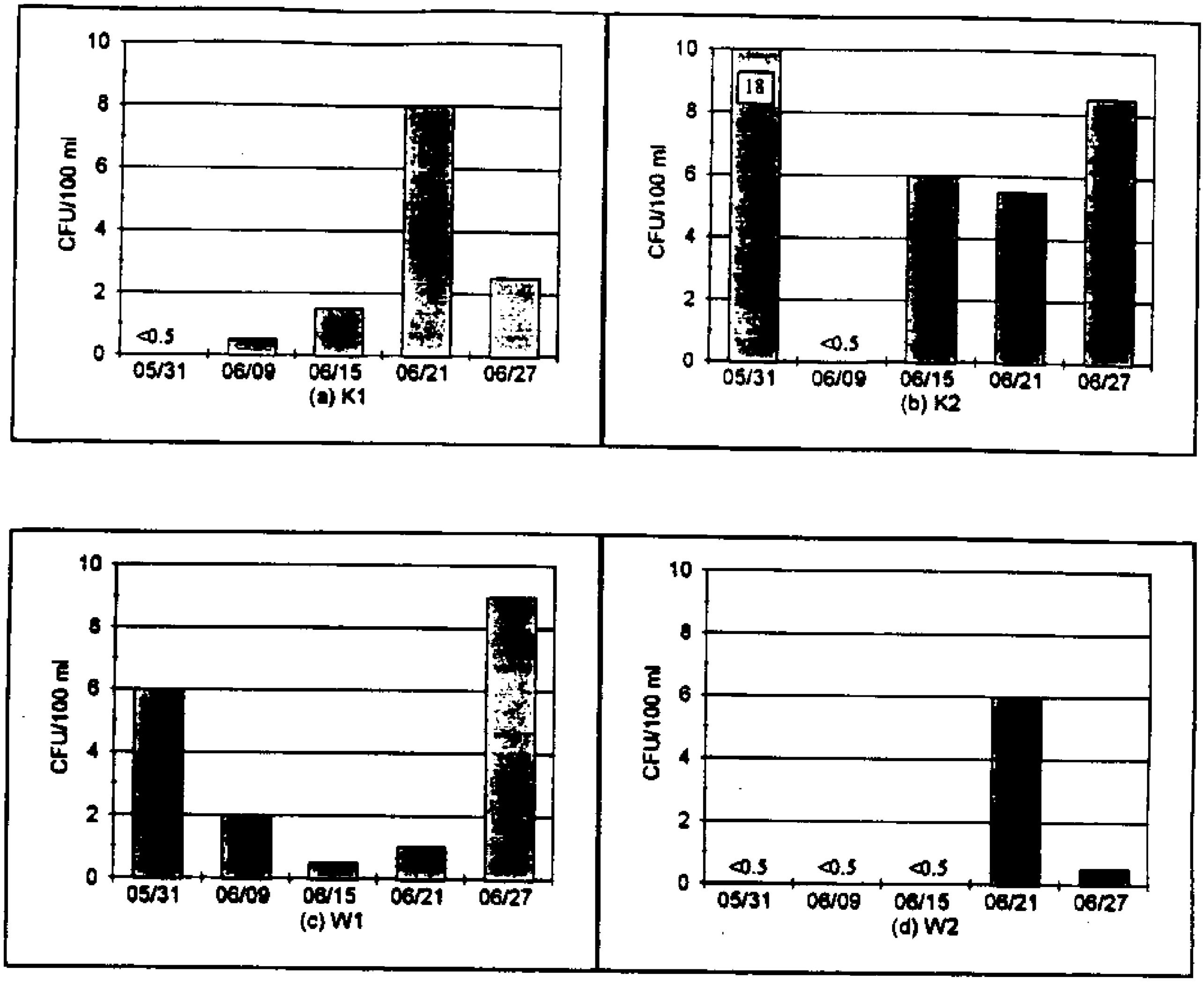


Figure 2. Enterococci densities at Sites K1, K2, W1, and W2 from May 31, 1994 to June 27, 1994.

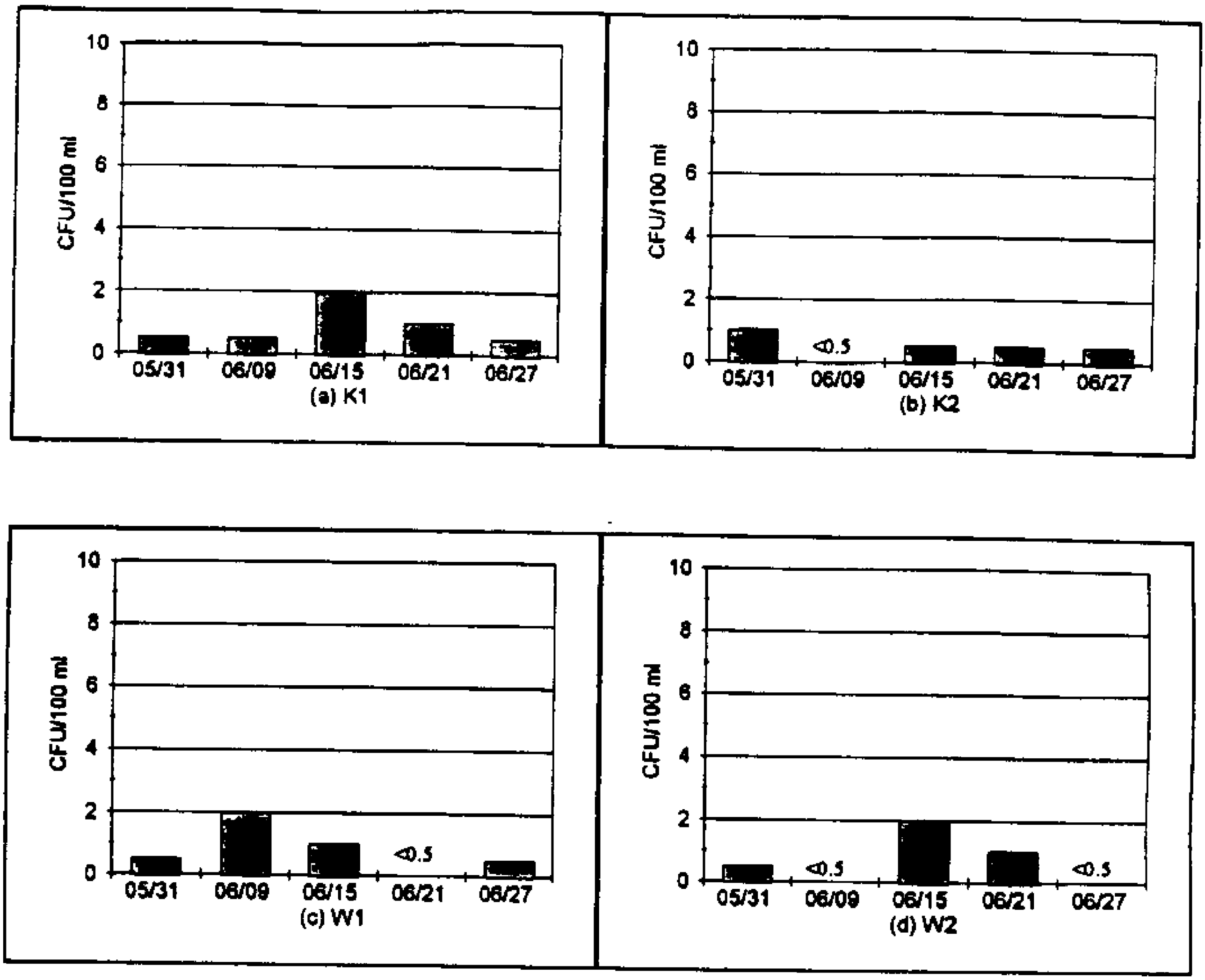


Figure 3. *Clostridium perfringens* densities at Sites K1, K2, W1, and W2 from May 31, 1994 to June 27, 1994.

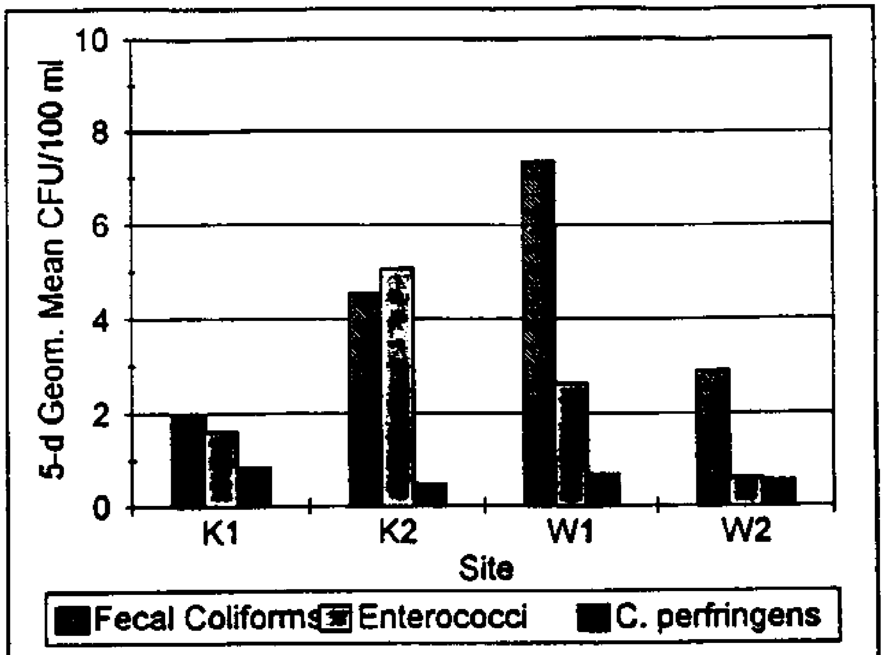


Figure 4. The 5-day geometric mean of indicator bacteria densities sampled between May 31, 1994 and June 27, 1994, at Sites K1, K2, W1, and W2.

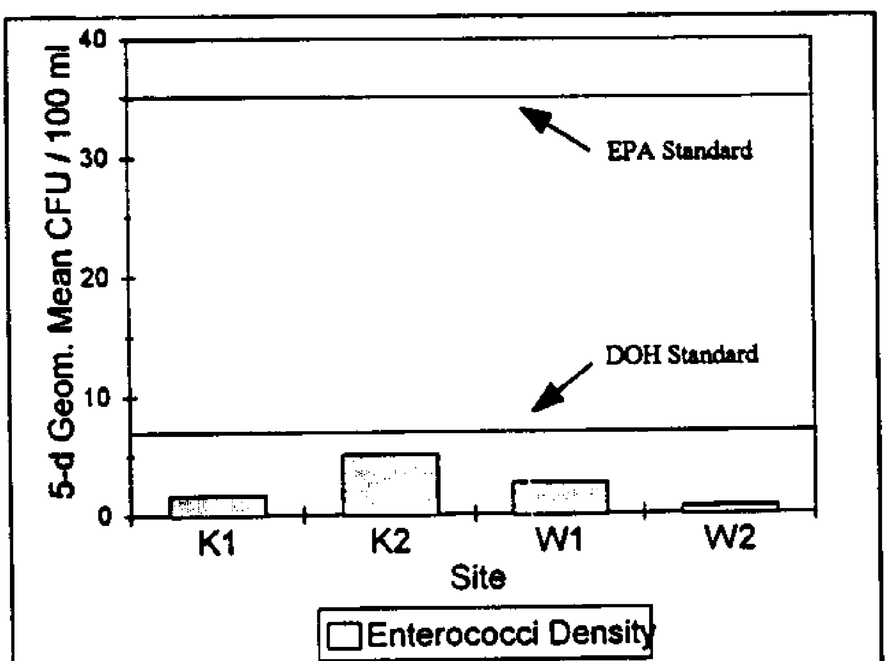


Figure 5. A comparison of the 5-day geometric mean of enterococci densities at Sites K1, K2, W1, and W2 sampled between May 31, 1994 and June 27, 1994, with the State and Federal water quality standards.

IV. DISCUSSION

Indicator Bacteria Levels and their Proximity to Stream Mouths

The relatively higher fecal coliform and enterococci densities shown in Figure 4 at Sites K2 and W1 may be due to their proximity to stream mouths. Site K2 is located about 0.25 miles from the mouth of Kaelepulu Stream and Site W1 is found less than 200 yards from the mouth of Waimanalo Stream. In contrast, Sites K1 and W2 are both located considerablely further away from stream mouths.

This is consistent with the results of some recent studies on Kailua Bay (Ahuna 1992, Roll 1992) that have shown elevated indicator bacteria densities increasing at the stream mouths of Kaelepulu Stream and Kawainui Canal. Ahuna and Roll both concluded that the sources of indicator bacteria densities at the stream mouths are probably primarily due to nonpoint sources such as soil, storm waters, and animal feces. The sampling site at the Lanikai boat ramp (Site K2) also appeared to be more turbid than the others, perhaps due to sediment stirred up by boats entering and leaving the water. There is also more human influence at the boat ramp than at the other sampling sites.

That *C. perfringens* levels remained below 2 CFU/100 ml at all the sampling sites may be due to the nonpoint sources of the indicator bacteria. Fujioka and Shizumura (1985) found that *C. perfringens* concentrations were extremely low in waters influenced by only nonpoint sources of pollution.

Compliance with State and Federal Water Quality Standards

Figure 5 presents a comparison of the 5-day geometric mean of enterococci levels at all the sampling stations with the State and federal water quality standards. Figure 5 shows that for the sampling period between May 31, 1994 and June 27, 1994 all four sampling stations complied with the State and Federal water quality standards.

Long Term Trends of Indicator Bacteria Densities

The DOH monitors the waters of Kailua Bay and Waimanalo Bay regularly. Their data is presented in Figures 6 and 7 for their sampling sites at Kalama Beach on Kailua Bay and at Bellows AFS on Waimanalo Bay, respectively. Due to budget cutbacks, the frequency of the DOH's water quality monitoring has decreased over the past two years: from sampling every week to about two to three samples monthly. This reduction in sampling is readily apparant in both Figures 6 and 7. Therefore, the DOH is not able to assess the health risks to recreational users following the State and Federal water quality standards because they no longer collect five samples within a 30-day period.

Nonetheless, Figures 6 and 7 are useful in viewing the longer term trends in indicator bacteria concentrations. In Figure 6, the running geometric mean (since the five samples are not confined to a thirty-day time period, the geometric mean is calculated using the last five samples, be it a 35, 45, or 55-day time period) remained under the DOH standards of 7 CFU enterococci /100 ml from January 1992 to about February 1994. The 5-day geometric mean shown in Figure 5 corresponds to this baseline enterococci density. The sharp rise in enterococci levels at Kalama beach during March 1994 coincided with the heavy rains that turned Kailua Bay brown. The DOH closed the beaches along Kailua Bay following the March 1994 storms. Figure 7 shows that levels of enterococci at Site W1 remained for the most part under 7 CFU/100 ml at Bellows AFS. Thus, despite the proximity of Site W1 to the mouth of Waimanalo Stream, the density of enterococci appears to be at a safe level. The 5-day geometric mean of enterococci levels at Bellows AFS shown in Figure 4 also corresponds to the baseline levels shown in the DOH data.

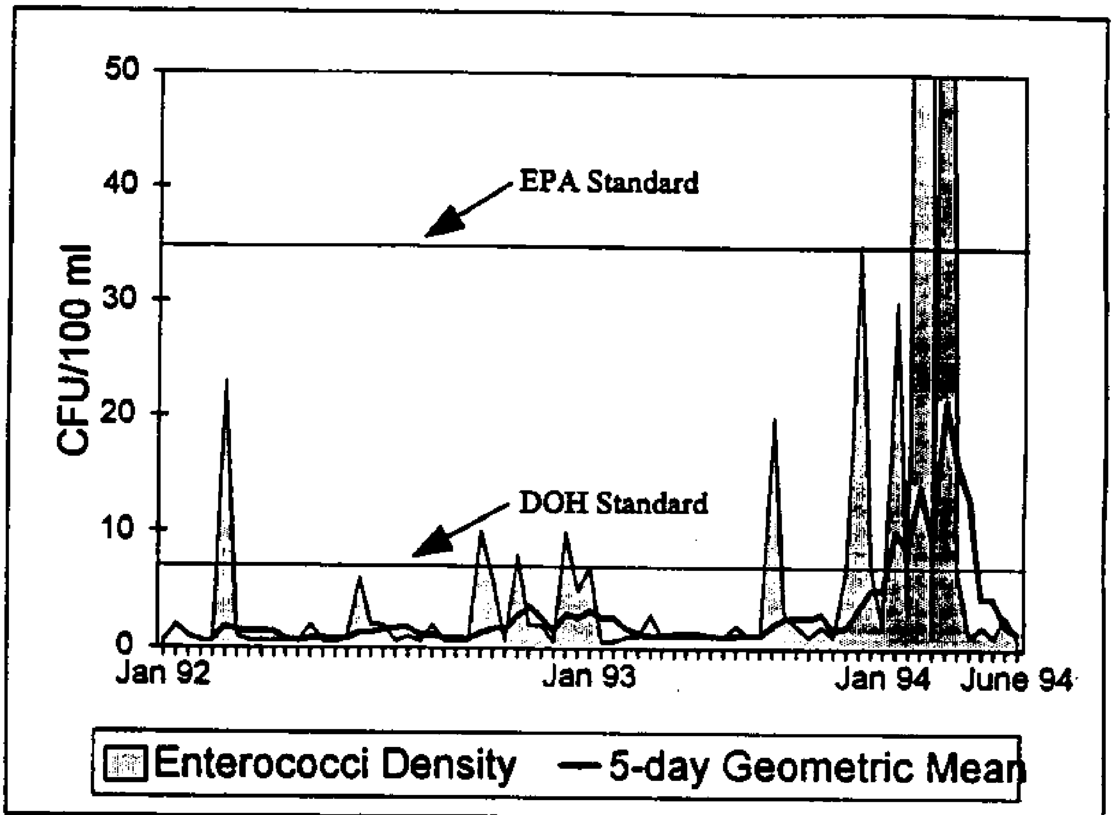


Figure 6. Enterococci densities and the 5-day running geometric mean of enterococci densities at Site K1, Kailua Bay at Kalamas, DOH Station: 207, from Janauary 1992 to June 1994. (Source: Teruya, DOH 1994)

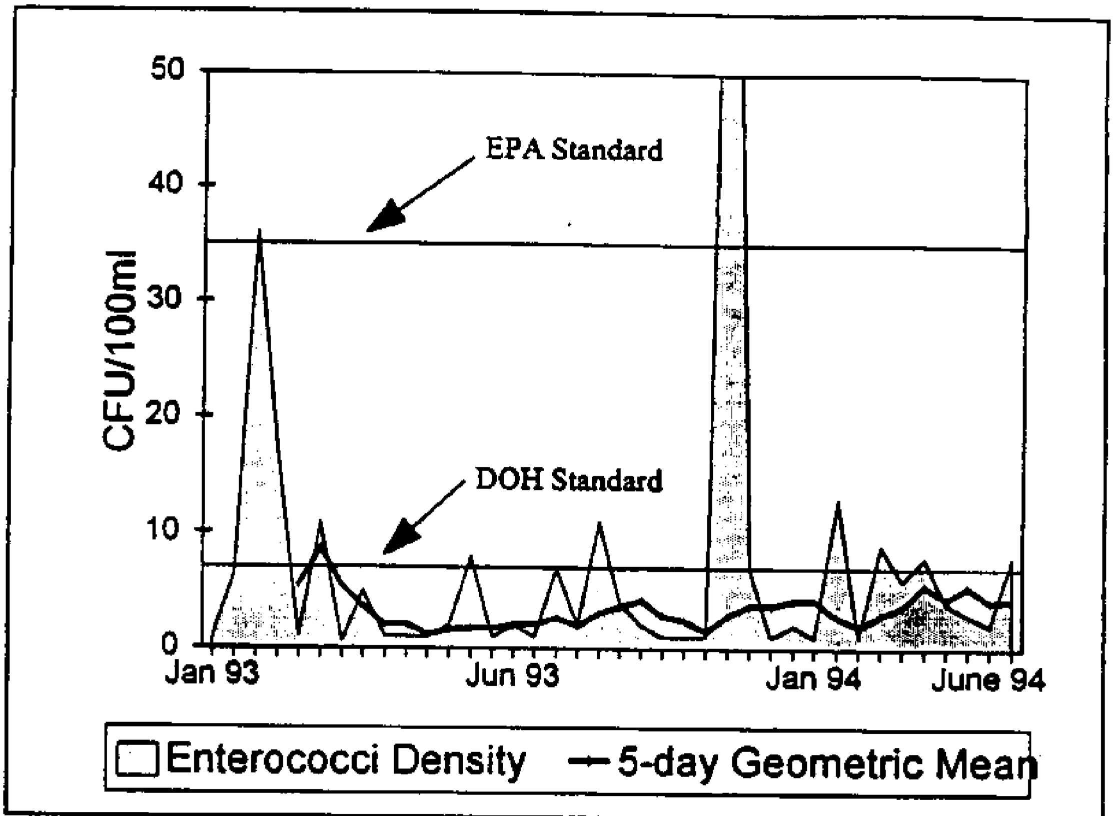


Figure 7. Enterococci densities and the 5-day running geometric mean of enterococci densities at Site W1, Waimanalo Bay at Bellows AFS, DOH Station: #6 Lifeguard Stand, from January 1993 to June 1994. (Source: Teruya, DOH 1994)

V. CONCLUSIONS

The indicator bacteria densities measured at Kalama Beach (Site K1) and the Lanaikai Boat Ramp (Site K2) in Kailua Bay, and at Bellows AFS (Site W1) and off the beach lots (Site W2) in Waimanalo Bay were generally low. The levels of enterococci and fecal coliforms at Sites K2 and Site W1 were slightly higher than those at Sites K1and W2. This maybe attributed to the relative proximity of Sites K2 and W1 to nonpoint sources of pollution introduced by Kaelepulu and Waimanalo Streams, respectively. The levels of enterococci density measured in this study were within baseline levels measured by regular DOH water quality monitoring over the last one and two years.

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VI. APPENDIX

Table 2. Indicator bacteria densities, salinity, and collection time at Site K1, Kailua Bay at Kalamas, DOH Station: 207

CFU/100 ml	5/31	6/9	6/15	6/21	6/27
Fecal Coliforms	1	1	1.5	2.5	5.5
Enterococci	<0.5	0.5(1)	1.5	8(3)	2.5
C. perfringens	0.5	0.5	2	1	0.5
Salinity (ppt)	ND	35(35)	35	35(35)	35
Collection Time	0840	0815	0810	0800	0920

ND - Not Done
( ) - DOH test results

Table 3. Indicator bacteria densities, salinity, and collection time at Site K2, Kailua Bay at the Lanikai Boat Ramp

CFU/100 ml	5/31	6/9	6/15	6/21	6/27
Fecal Coliforms	2	<0.5	83	6	2
Enterococci	18	<0.5	6	5.5	8.5
C. perfringens	1	<0.5	0.5	0.5	0.5
Salinity (ppt)	ND	35	35	35	35
Collection Time	0825	0833	0800	0740	0910

ND - Not Done

Table 4. Indicator bacteria densities, salinity, and collection time at site W1, Waimanalo Bay at Bellows AFS, DOH Station: #6 Lifeguard

CFU/100 ml	5/31	6/9	6/15	6/21	6/27
Fecal Coliforms	5(7)	40	2	1	26.5(26)
Enterococci	6(3)	2	0.5	1	9(8)
C. perfringens	0.5	2	1	<0.5	0.5
Salinity (ppt)	ND(34)	33	35	35	35(34)
Collection Time	0715	0916	0840	0720	0745

ND - Not Done

Table 5. Indicator bacteria densities, salinity, and collection time at site W2, Waimanalo Bay at the Beach lots off Hilu Street

CFU/100 ml	5/31	6/9	6/15	6/21	6/27
Fecal Coliforms	1	<0.5	2	4.5	26.5
Enterococci	<0.5	<0.5	<0.5	6	0.5
C. perfringens	0.5	<0.5	2	1	<0.5
Salinity (ppt)	ND	35	35	35	35
Collection Time	0738	0856	0855	0700	0800

( ) - DOH test results
ND - Not Done

Table 6. The 5-day geometric mean of indicator bacteria densities for the time period between 5/31/94 through 6/27/94 for four beaches along Kailua and Waimanalo Bay.

Site	5-d Geometric mean, 5/31 - 6/27 (CFU/100 ml)		
	Fecal Coliforms	Enterococci	*C. perfringens*
K1	1.96	1.60	0.83
K2	4.56	5.07	0.47
W1	7.35	2.63	0.68
W2	2.90	0.60	0.55

KAILUA & WAIMANALO VOLUNTEER WATER QUALITY MONITORING PROGRAM

Established By:
The Hawaii State Legislature
Act 292, House Bill #1536

Coordinated By:
The University of Hawaii
Sea Grant Extension Program
for the Hawaii Department of Health

Are you concerned about the condition of our streams? Do you think the waters in our bays are as clean as they should be? If you are interested by these questions and want to be more informed, read on. If you want to make a difference, get actively involved and join the Kailua & Waimanalo Volunteer Water Quality Monitoring Program.

GOALS:

The goals of the Volunteer Water Quality Monitoring Program are:

1. To help develop educated and involved community members that are committed to preserving and protecting Hawaii's water resources.

2. To organize community volunteers to collect usable water quality information relating to the local watershed and bays.

3. To develop community-based solutions to pollution problems.

4. To develop a program that can be replicated elsewhere in Hawaii.

WHAT IT IS:

This program is not a vigilante program, rather it is a partnership between government, private landowners, the University of Hawaii, and concerned volunteers. The program is being carried out in close cooperation with the Hawaii Department of Health (DOH), Department of Land and Natural Resources, the Water Commission, City and County of Honolulu Dept of Public Works and Dept of Waste Water Management, and other relevant government agencies. The monitoring is being done in collaboration with related monitoring and research programs involving the University of Hawaii.

IMPLEMENTATION:

In a series of publicly announced meetings, interested members of the Kailua and Waimanalo communities identified the goals for the program as listed above. An initial set of volunteers has received the required training and has begun characterizing selected streams and obtaining and testing water samples. Any permission required for accessing private land has been or is being obtained by contacting private landowners (either directly or through the University of Hawaii).

THE NEED:

Hawaii's 376 perennial (year-round flowing) streams are a vital resource, providing habitat for unique flora and fauna, irrigation water, hydroelectric power, and recreation. The citizens of Hawaii recognize the need to balance increasing human use of the state's streams with environmental protection.

Water quality at certain sites in Kailua and Waimanalo Bays varies daily from clean to chemically and/or biologically polluted. It has been determined that non-point source pollution (i.e., pollution which does not generally come from a specific location, for example: soil run-off containing insecticides and fertilizers, and storm drain discharge containing oil, grease and household toxins) is a major contributor.

Frequent sampling of the streams, ponds, and bays in the Kailua and Waimanalo watershed areas is required to provide baseline data on the sources of pollution. These data can then be used to develop short-term and long-term strategies to prevent and/or reduce water pollution in the watershed areas.

Unfortunately, the State does not have the funds necessary to provide the long-term, statewide education and sampling programs required.

THE RESPONSE:

In order to complement existing DOH coastal water quality monitoring programs and to establish a pilot program that can be used throughout the state, the Kailua and Waimanalo Volunteer Water Quality Monitoring Program was established by Act 292, House Bill #1536 in 1993.

An Advisory Council was formed to help direct the program. It consists of representatives from various Departments of the City and County of Honolulu as well as community groups such as, The Neighborhood Boards, Save our Bays and Beaches, Surfrider, Windward Community College, Kawainui Heritage Foundation, Save Mt Olomana Association, Kalaheo High School Environmental Club, Sierra Club, and the Ohana Council.

The program, which is being jointly developed by the UH Sea Grant, DOH, and the community, provides regular training, proper equipment, supervision, and timely laboratory analysis. Community volunteers will:

—Actively participate in water quality monitoring through a central core of trained water samplers.

—Actively work to educate other residents, schools, and businesses on methods to prevent water pollution.

IN THE FUTURE:

In the future, given regular monitoring of a watershed area, the DOH will be able to:

— Develop a comprehensive, statewide community volunteer based monitoring plan.

—Develop an educational program for the communities to help reduce pollution in the state's watershed areas.

—Achieve the goals of the Clean Water Act.

HOW YOU CAN HELP:

To volunteer your time, technical expertise, or contribute financial support to this program, call the University of Hawaii Sea Grant, School of Ocean and Earth Science and Technology at 956-8475.

[illegible]

September 30–October 6, 1993 Windward Sun Press A-9

UH group wants to oversee water project

Sea Grant seeking contract to monitor Windward's water

By ELOISE AGUIAR
News Editor

WINDWARD — The University of Hawaii's Sea Grant Extension Service is seeking a contract to oversee the state's water-quality monitoring project for Kailua and Waimanalo bays.

David Tarnas of Sea Grant will present the proposal at a meeting set for 7 p.m. Monday at Kailua Elementary School cafeteria, said Rep. Jackie Young, who has been coordinating the project's meetings.

In the Volunteer Water Quality Surveying and Sampling Pilot Project, non-professionals will collect water samples that will be used to establish data about water conditions in Kailua and Waimanalo, said Young, D-51st District (Waimanalo-Kailua).

The Legislature appropriated $45,000 this year for the project, which the state Department of Health will [illegible].

Work on the project is scheduled to begin in October. The proposal calls for Sea Grant to meet with an advisory council, select sites, establish a training schedule and set up procedures.

The advisory council would be made up of members from the neighborhood boards, Save Our Bays and Beaches, Surfrider Foundation, Outdoor Circle, Lions clubs, Rotary clubs, Windward Community College, Kawainui Heritage Foundation and others.

Training would take two months, with sampling to begin in January and the project ending in September. Reports would be made to community groups, the Legislature and DOH.

The health department will be soliciting community response to the proposal before a decision is made to award the contract, Young said.

Kailua and Waimanalo volunteers met Aug. 10 to implement the project, she said. However, Waimanalo residents wanted to use some funds to pursue a project under way in their community.

But the bill had a different intent, Young said. The legislature [illegible] work with the [illegible].

Participants [illegible] August meeting [illegible] keep the water clean and safe through a program that can be replicated in other communities, she said.

Objectives were based on the assumption that water quality varies daily, sampling will provide baseline data. DOH doesn't have the resources to provide frequent sampling and people are willing to be trained as volunteer water samplers, Young said.

With a good monitoring program, she said, DOH will be able to reduce levels of contamination, identify potential sources of pollution and achieve the goals of the Clean Water Act.

Kailua Water Quality Monitoring Project

The Department of Health has contracted with the University of Hawaii Sea Grant Extension Service to coordinate a volunteer Water Quality Monitoring Project in the Kailua and Waimanalo watershed and costal areas. Sierra Club has been asked to be a participant in the project. Tom Shields, of the Sierra Club, Oahu Group Executive Committee, has volunteered to represent the Club on this project.

The project consists of some twelve proposed activities that could be used to monitor water quality. Tom Shields has suggested to the Project coordinator that the Sierra Club, Oahu Group might be able to help on two of the twelve activities. One involves picking up litter along beaches and streams in Kailua and cataloging the type, amount and identifying its source, if possible. This might lead to better management of preventing or reducing litter and illegal dumping.

The other activity would be a Kailua beach survey and the analysis of plastic litter impact on debris along the shore. The beach survey would attempt to record processes of accretion and erosion along the beach. This would employ making visual and photographic records of the beach frequently and from a constant vantage point.

The plastic litter impact portion of this activity would involve taking sand samples along the beach and analyzing for plastic content. Plastic has been turning up in the tissue of some fish. Perhaps this part of the project will determine how this happens.

If you are interested in spending a little time in helping on these activities, please contact Tom Shields at [illegible]. If this project is successful, it may be extended to other areas in the State.

Malama I Ka Honua
Journal of the Hawaii Chapter, Sierra Club
Feb/Mar 1994

Windward Sun Press Feb 10-16 1994 p8

Volunteers to study coastlines, streams

By ELOISE AGUIAR
News Editor

WINDWARD — Members of the Windward water-quality monitoring project decided last month to survey the physical characteristics of coastlines and streams and to map watersheds in Kailua and Waimanalo.

The project's Advisory Group chose the two options from 12 possibilities at a Jan. meeting in Waimanalo. The next water-quality project meeting is scheduled for 7 p.m. Feb. 22 at the Waimanalo Public & School Library meeting room. The meetings are open to the public.

"The project is at an exciting stage," said David Tarnas, project coordinator. "Its plans are crystallizing, and the time is approaching for training and volunteer monitoring."

The state Legislature created the Volunteer Water Monitoring Program last year to operate a pilot water sampling program in which volunteers would collect samples from Kailua and Waimanalo bays.

After the preliminary mapping and surveying, the project volunteers will sample coastal waters during algae blooms to determine if they are natural events or are caused by man, Tarnas said. At the same time, a microbiological analysis of water and soil will be conducted. Dates haven't been set for either project.

Volunteers from the Sierra Club and the Surfrider Foundation have offered to carry out a third option: cataloging the types and amount of litter found on beaches and along streams. The litter pickup will probably be carried out on a quarterly basis and involve the city.

Another group of volunteers will survey beaches and analyze sand samples for plastic content, Tarnas said.

The Advisory Group, made up of members from various community organizations, has decided the project needs salaried community liaisons, one from each community.

The group also decided the project needs a paid trainer, and it is seeking Arvin Wu, a trainer for another water-quality monitoring project being conducted in Waimanalo. He will be able to coordinate both projects, Tarnas said.

[illegible] News August 1994

Rare Native Hawaiian Moorhen discovered in Waimanalo

Notes on a Native Bird

Such findings of native animals are important as they show that our streams' habitat is still not too degraded. The streams can still make a home for such sensitive species which are an important part of our heritage.

Adam Rose

Volunteers from the Kailua and Waimanalo Water Quality Monitoring Project have unexpectedly discovered a nesting population of the rare Hawaiian Moorhen in a Waimanalo Stream. This is the first recorded sighting of this Federally listed endangered species in the Waimanalo area, and is a very exciting find for the community stream team members who are involved in the monitoring project.

Sharp eyed volunteers from the Kahawai and Waimanalo Streams teams first noticed this reclusive bird in late June, while they were conducting stream surveys and monitoring the water quality of the Kahawai Stream near Bellows Air Force Base. "We saw this bird moving through the reeds at the edge of the stream," said Greg Field, a member of the Kahawai Stream team. "We got a good look at it but didn't know what it was. We got real excited when the description matched that of a native Moorhen."

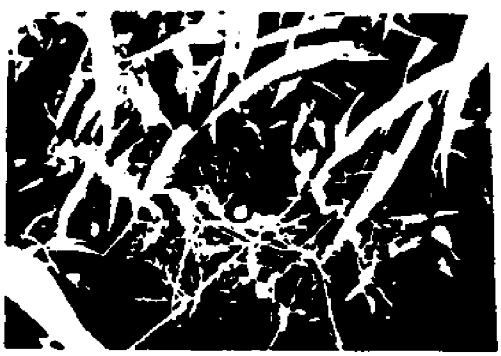
The project coordinator contacted a wildlife biologist from the US Fish and Wildlife Service. The biologist confirmed that the bird seen by the volunteers was indeed a native Moorhen. That same day another volunteer who was doing testing in the same area discovered a Moorhen nest with seven brown eggs in it.

The Hawaiian Moorhen, or 'Alae'ula', is a medium sized, grey domestic waterbird which frequents freshwater ponds, streams and marshes. It has a white rump and long yellowish legs, and a distinctive red and yellow beak. This secretive bird is very shy and tends to keep well hidden among the marginal aquatic vegetation where it lives and nests. As a result, it is more common to hear its clucks like croaks and high pitched peeps, than to actually see this endangered bird.

This species has Hawaii State protection. It is also on the US Endangered Species list, which means it is protected by the US Endangered Species Act. According to Section IV (D) and Section IX of the Act it is illegal to "harm, harass, hunt or pursue" the bird and that it is an offense to significantly modify or degrade its habitat.

The Moorhen, or 'Alae'ula', is also important in Hawaiian legend: it is the bird that brought fire from Pele and gave it to the people.

The Moorhen is not the only exciting animal the stream teams have found in Waimanalo streams. They have also found two species of native fish: O'Opu Nakea and O'Opu Naniha, living in certain parts of the Kahawai and Waimanalo streams. Such findings of native animals are important as they show that our streams' habitat is still not too degraded. The



streams can still make a home for such sensitive species which are an important part of our heritage.

But will these native fish and birds still be able to survive in our streams in the future for our children to see? Native Hawaiian stream animals are under threat as our streams continue to deteriorate due to the pressures of development and water pollution. Native fish, for example are being displaced by growing numbers of alien introduced fish species. Tilapia, Mosquito Fish, Swordtails and others may feed on O'Opu and compete against them for resources, food and space.

Possibly the biggest threat to our streams and bays is non point source pollution. This type of pollution does not originate from a single, identifiable source. It is caused by more general factors such as land use, roads, storm drains and animal waste. Residential areas are the major contributors of non point source pollution, especially in places where lots of people live, like Oahu.

We can make a difference. By learning more about our streams we will become more aware of the kinds of threats that they face, and we may learn to treat them with more care and respect. We may streams and pouring domestic wastes and oil down storm drains are some of the activities that are very harmful to water quality and stream life. They are also practices which we could easily avoid.

The Kailua and Waimanalo Volunteer Water Quality Monitoring Program has been running for almost a year now. Interested community members have volunteered and joined stream teams which are responsible for conducting water quality analyses and stream surveys. We have a lot of fun and are also doing valuable work while monitoring our local streams. We are working in a collaborative manner with the state and federal government, the University, landowners and the community. The project aims to monitor our local aquatic water quality problems and work together to address and improve any problems we may find. If you would like to join the fun and volunteer, call the coordinating team at UH, Sea Grant, 956-8475. ■

Adam Rose is the Project Coordinator of the Kailua/Waimanalo Water Quality Monitoring Program. He has a degree in Environmental Science from Plymouth University, United Kingdom.

Star-Bulletin 3/-/94

By Kathryn Bender, Star-Bulletin

State biologist David Smith surveys the Kawainui restoration project area.

Star-Bulletin

Kawainui work makes way for the birds

By Melissa Vickers
Star-Bulletin

If you see bulldozers digging up the undergrowth and mangrove trees along Kawainui Stream in Kailua, don't worry. The land won't be developed.

Some area residents feared the critical wetland habitat was being used as a carrot to gain state approval for a retirement home planned for Kaneohe Ranch land mauka of the wetland.

"We do not have any approvals for it at this time, and don't plan to pursue it until the developer that is supposed to do it finishes the home they're working on now, Hale O Malia on the Star of Sea campus," said Kaneohe Ranch spokesman Randolph Moore.

It will take about four years to get needed permits once the retirement home is started, Moore said. "And we haven't done that yet."

Stripping the land is the first step in restoring the habitat for four species of native Hawaiian birds on state and federal endangered species lists.

The restoration project, which could start as early as Monday, was made possible by the donation of 227 acres by Kaneohe Ranch, money from federal grants and donations from Ducks Unlimited.

Ducks Unlimited, which signed the lease for the property this week, will turn it over to the state for management once the area is restored, probably by October, said Jim Wolf, regional spokesman.

The Hawaiian duck (koloa), moorhen, coot and stilt were plentiful in the area until non-native plant species established themselves, said David Smith, a biologist and wildlife manager for the Department of Land and Natural Resources.

"Once the mangroves took hold, they were all over. You can't rip them out fast enough once they take hold in an area you're trying to keep clear ... and no one was even managing that land."

The mangroves were accompanied by the proliferation of a thorned, flowered shrub that is also hard to kill, Smith said.

"What's here now ... is only 10 years of growth," he said. "Already, none of the birds are nesting anymore. They can't."

The gradual choking off of the stream and the shallow ponds in the area by introduced vegetation did more than take the birds' preferred open-water habitat.

"Once the area became overgrown, the birds weren't safe to nest because predators like the mongoose and feral cats and dogs came in and killed everything."

Ducks Unlimited, a mainland group started so hunters could increase game bird population by purchasing and restoring their habitats, has become more preservation-oriented over the years, Wolf said.

"In cases where we work in Hawaii, it's always a purely conservation effort because hunting the animals there is illegal. You have unique species out there found nowhere else in the world, and we just think they should be preserved," he said.

Smith said he wants to assure residents the restoration will not harm the animals.

"One thing that always happens when we do this is that people think we are allowing someone to ruin the environment. What we're doing here is good for the area. And it could ... help cut back flooding downstream, once this overgrowth is taken out."

HOUSE OF REPRESENTATIVES
SEVENTEENTH LEGISLATURE, 1993
STATE OF HAWAII

H.B. NO. 1563 H.D. 2 S.D. 2 C.D. 1

A BILL FOR AN ACT

TO ESTABLISH A PILOT PROGRAM TO CREATE AND TEST A MODEL OF WATER QUALITY SURVEYING AND SAMPLING USING VOLUNTEERS.

BE IT ENACTED BY THE LEGISLATURE OF THE STATE OF HAWAII:

SECTION 1. The legislature finds that clean water is essential to sustaining life and has a tremendous impact on the well-being of the State. However, due to limited resources, there has been much public concern regarding the inadequacy of the current water quality monitoring program administered by the department of health.

The legislature also finds that along with the commitment to protect our surface and coastal waters, there must also come the recognition that our state resources are under great strain and must be utilized with great care. Accordingly, creative efforts that can maximize the rich and varied resources of the State need to be developed and implemented. In this regard, the legislature recognizes that carefully constructed programs which utilize volunteers are being implemented in many areas in the United States and are increasingly cost-effective. These programs also serve as educational alternatives to traditional methods.

The United States Environmental Protection Agency (EPA) encourages the use of volunteers in water monitoring, and has produced a practical guide, Volunteer Water Monitoring: A Guide for State Managers, to help the states implement volunteer water quality monitoring programs. At least twenty states have implemented volunteer programs.

The EPA report recommends and the legislature finds that a pilot program is a necessary starting point in a carefully designed effort towards better and more efficient water quality monitoring. The legislature therefore finds that the establishment of a pilot volunteer surveying and sampling water program to examine water systems and sources of contamination would be an invaluable investment that could supply necessary water quality monitoring data while providing immediate as well as long term savings.

The legislature further finds that much of the coastal and surface waters draining into and surrounding Kailua and Waimanalo bays on Oahu meet EPA guidelines for a target location for pilot program establishment. This includes having an available pool of people willing to participate, as well as physical and legal access to the water.

The purpose of this Act is to: (1) empower the department of health to establish a pilot program for surveying and sampling water quality utilizing volunteers at a selected water system in the coastal and surface waters draining into and surrounding Kailua and Waimanalo Bays on Oahu; and (2) provide a report to the legislature on the long-term feasibility and economic benefit of a state-wide volunteer water quality surveying and sampling program.

SECTION 2. (a) There is established within the department of health a pilot program to test a model of volunteer water quality surveying and sampling. The target area of the program shall be a water system in the area of the coastal and surface waters draining into and surrounding Kailua and Waimanalo Bays on Oahu. In conjunction with the foregoing, the department of health shall:

(1) Establish a pilot water quality surveying and sampling program using volunteers to examine one or more watershed systems in the State and possible sources of contamination;

(2) Determine those aspects of the State's coastal and surface water quality surveying and sampling program that:

(A) Can be performed by volunteers; and

(B) Will produce meaningful and useful data with regard to monitoring environmental quality;

(3) Provide for the training of a cadre of volunteers, including the following:

(A) Volunteers from one or more environmental organizations with experience in conducting volunteer water quality surveying and sampling programs, such as the Surfrider Foundation and the Isaak Walton League of America;

(B) Volunteers from educational institutions, such as windward community college and the Hawaii Loa campus of Hawaii Pacific University;

(C) Volunteers from other interested organizations; and

(D) Other interested individuals;

(4) Provide for the acquisition of surveying and sampling equipment and supplies to carry out the purposes of this Act;

(5) Provide for the periodic collection and analysis of samples to evaluate the sampling and monitoring practices of volunteers; and

(6) Provide for the acquisition of laboratory, statistical, and other technical services to analyze samples and interpret data.

(b) The department of health may contract for the services of organizations and laboratories to carry out the purposes of this Act.

(c) The department of health shall work with the statewide volunteer services office and other agencies and organizations, as may be appropriate, to carry out the purposes of this Act.

(d) The department of health shall prepare and submit a report to the legislature no later than twenty days prior to the convening of the 1994 regular session which documents the effectiveness of the pilot program and the feasibility of implementing additional volunteer water monitoring programs.

SECTION 3. There is appropriated out of the general revenues of the State of Hawaii the sum of $45,000 or so much thereof as may be necessary for fiscal year 1993-1994, for the purposes of this Act. The sum appropriated shall be expended by the department of health.

SECTION 4. This Act shall take effect on July 1, 1993.

SECTION 3

SCIENTIFIC FINDINGS AND PROJECT EVALUATION

SCIENTIFIC FINDINGS AND PROJECT EVALUATION

I. RATIONALE

In the final phase of the program (January 1995 through June 1996), a small scientifically based water quality monitoring program was established with the objectives of (1) providing accurate albeit limited baseline information with regard to water quality in the areas being monitored by the volunteers as well as (2) to utilize these data in a quality assurance/quality control for the volunteer monitoring. Other objectives in this phase were to (1) develop a series of topographical maps for the Waimanalo area depicting infrastructure for field use by volunteers, (2) undertake a preliminary program of heavy metal/pesticide analyses in the lower reaches of the Mauanwili watershed to Kailua Bay, (3) continue support of the active volunteers in their water quality monitoring, and (4) develop this final report which analyzes the scientific value of using volunteers in water quality monitoring and provides recommendations for future activities.

II. METHODS

Our assistance and guidance to the volunteers during the January 1995–June 1996 period took several forms. We organized community meetings and scheduled speakers who presented information in their areas of expertise. We continued the newsletter and flyers which served as a means of distributing pertinent information regarding stream and marine water quality as well as upcoming events to the community. We also accompanied volunteers in the field to assist them in their monitoring and to answer questions as they arose. Some of the cooperative field work was done by collecting split samples where the University team took one-half of the water sample and the volunteers retained the second half. This split sampling allowed the completion of the quality assurance/quality control (QA/QC) program for the volunteer efforts.

A. METHODS USED BY THE UNIVERSITY PROGRAM

Samples were collected from sites previously established by the volunteer monitoring groups, as well as from a number of other locations selected by the University group, to obtain a better understanding of any inland-to-the-sea (*mauka-makai*) gradients that may exist. Insofar as the University water quality samples were concerned, samples were collected in acid-rinsed, one-liter polyethylene bottles which were triple rinsed with sample water prior to filling in the field. These samples were immediately placed on ice until further sample processing could be completed (within 2 hours of collection). All sample collection and processing followed methods as outlined in Standard Methods (1995). The one-liter samples were split into subsamples for various analyses. Subsamples for nutrient analyses were filtered in the field through Whatman glass fiber (GFF) filters into 125 ml acid-washed, triple sample rinsed, polyethylene bottles and placed on ice. Filters were retained for chlorophyll-a analyses. Subsamples for salinity and turbidity were placed in 125 ml polyethylene bottles. In-situ field measurements included dissolved oxygen and water temperature using a field meter (YSI Oxygen meter, Model 58 with a readability of 0.01 mg/l) and a hand held thermometer with a readability of 0.1°C. pH was measured using a field meter with a readability of 0.01 pH units (Hanna field model HI 9025).

Analyses for nitrite-nitrate nitrogen, ammonium, orthophosphorus and silica were performed using a Techicon AAII system, with standard procedures modified for high-precision analyses (Techicon Industrial Systems; Industrial methods for water, seawater and wastewater analysis). Total nitrogen and total phosphorus were analyzed in a similar fashion following ultraviolet (UV) digestion. Dissolved organic nitrogen (DON and dissolved organic phosphorus were calculated as the difference between total dissolved and dissolved inorganic N and P, respectively.

Turbidity was determined on a 60 ml subsample fixed with HgCl2 to terminate biological activity using a Monitek laboratory nephalometer (Model TA1). Salinity was determined using an AGE laboratory salinometer (Model 2100) with a readability of 0.0001 ppt. Chlorophyll-a was measured by filtering 200 ml of water through glass fiber filters; pigments on filters were extracted and assessed fluorometrically.

Most of the laboratory analyses were performed by the SOEST Analytical Services Laboratory. The Analytical Services Laboratory is a research grade facility that provides the highest possible precision and accuracy in nutrient analyses. The Analytical Services Laboratory was chosen as one of the 12 most distinguished labs in the International Council for the Exploration of the Sea (ICES) Fourth Intercomparison Exercise for Nutrients in Seawater. This laboratory routinely participates in the U.S. Geological Survey round-robin analytical comparisons.

Sediment samples were collected from a number of the routine sample sites for pesticide and heavy metal analyses. These samples were collected in precleaned 500 ml glass jars. Samples were immediately placed on ice and air shipped to an EPA approved laboratory in California for analyses. Analyses were performed for three screens: total organic halogens, organophosphorus pesticides and chlorinated pesticides. The rationale for selecting these three screens was that they cover a broad range of pesticides, some of which have been commonly used in Hawaii, and the costs of sample processing were within our limited scope and budget. The total organic halogen screen includes a number of trihalmethanes, organic solvents such as trichloroethene, tetrachloroethene, and other halogenated alkanes and alkenes as well as chlorinated and brominated pesticides and herbicides; polychlorinated biphenyls or PCBs, chlorinated aromatics such as hexachlorobenzene and 2,4-dichlorophenol and high-molecular-weight, partially chlorinated aquatic humic substances. The total organic halogen screen was carried out using EPA method 9020. The organophosphorous pesticides include diazinon, disulfoton or disyston, demeton or systox, parathion methyl, malathion, parathion ethyl, ethion, azinphos methyl or guthion, chlorpyrifos or dursban, dichlorvos, mevinphos or phosdrin, naled or dibrom, phorate or thimet, dimethoate or cygon and EPA method 8140 was used to measure these compounds. The chlorinated pesticides include aldrin, a-BHC, b-BHC, c-BHC or lindane, d-BHC, chlordane, 4,4'-DDD, 4,4'DDT, dieldrin, endosulfan I, endosulfan II, endosulfan sulfate, endrin, endrin aldehyde, heptachlor, heptachlor epoxide, toxaphene, PCB-1016, PCB-1212, PCB-1221, PCB-1232, PCB-1242, PCB-1248, PCB-1254, and PCB-1260, and EPA method 8080 was used to determine the presence of these compounds. Heavy metal analyses included those for antimony, arsenic, barium, cadmium, chromium, copper, lead, nickel, selenium, thallium, and zinc using EPA method 6010, and mercury using EPA method 7471.

B. METHODS USED BY THE VOLUNTEER PROGRAM

Prior to the changeover in University personnel January 1995, a decision was made among the volunteers and leaders to undertake a water quality monitoring program of selected streams in the Kailua and Waimanalo watersheds. As outlined above (Section 2), the volunteers used low-cost methods in processing water quality samples. High equipment costs and necessary in-depth training that goes with sophisticated equipment precluded its use in the volunteer program. Part of the rationale for the volunteer program was to determine if low-cost equipment used by trained volunteers could provide useful monitoring data for state and other agencies, thus explaining the rationale for the methods used.

Once trained in the use of the equipment, volunteers formed teams ranging from three to eight individuals to work in the field. Each individual was trained in all aspects of the monitoring protocols so that if absences were to occur, someone else could "fill in." Water samples were collected and processed on-site as dictated by the test equipment used and where feasible. Parameters measured by the volunteer program included temperature, dissolved oxygen concentration, pH, salinity, nitrite+nitrate nitrogen, and orthophosphorus. At each station, stream teams also noted any aquatic macrobiota seen, riparian vegetation, approximate stream flow and any unusual condition in the vicinity of the sampling station.

Temperature was measured using a hand-held thermometer with a readability to 0.1°C, salinity with a refractometer read to 1 ppt, pH with a Hach 17N wide range pH kit (No. 1470-11), dissolved oxygen concentration with a Hach OX-2P dissolved oxygen kit (No. 1469-00), nitrite+nitrate with a Hach NI-14 low range kit (No. 14161-00) and orthophosphorus with a Hach PO-19 orthophosphate kit (No. 2248-00).

As noted above, the University sampling using scientifically accepted equipment and methods served as the basis for the QA/QC program for the volunteers.

III. RESULTS AND DISCUSSION

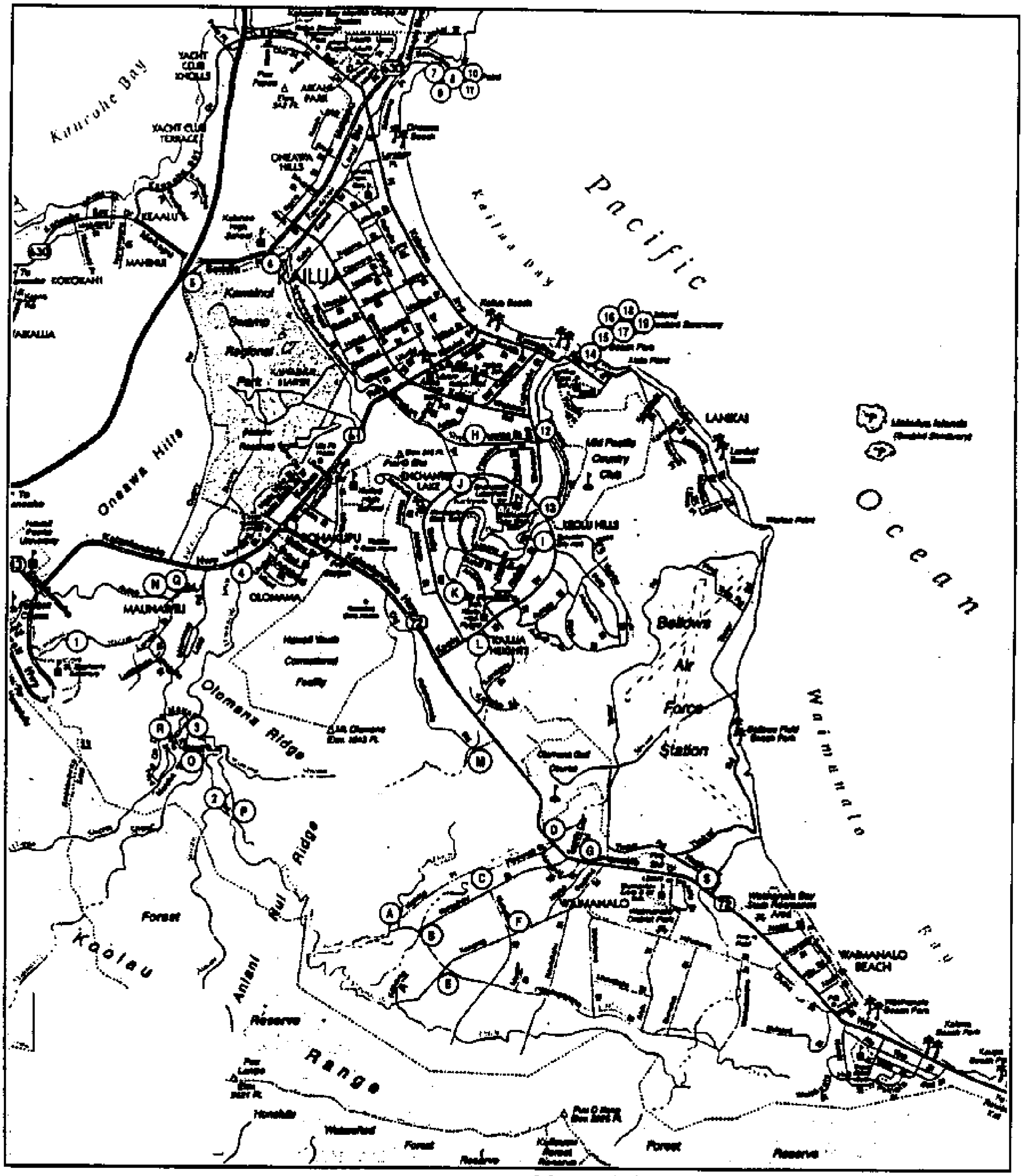
A. VOLUNTEER PROGRAM

There were four volunteer stream teams formed during the course of the project. Two of these teams worked in the Kailua area (the Maunawili and Kaelepulu teams) and two in the Waimanalo area (the Kahawai and Waimanalo teams). The Maunawili stream team focused primarily on Maunawili Stream and tributaries as well as sections of Kawainui Marsh into which the Maunawili watershed drains. The Kaelepulu stream team sampled Kaelepulu Pond, as well as an intermittent stream that flows into this pond and Kaelepulu Stream below or seaward of the pond. The Waimanalo stream team centered their sampling on Waimanalo Stream and tributaries while the Kahawai stream team sampled Kahawai Steam and tributaries.

The locations of stream team sample sites are given in Figure 1. Numbered sample sites were those routinely sampled by the University of Hawaii team. In some cases, the stream teams and the University team sampled the same sites but not all of the numbered sites were sampled by the volunteers, and similarly, not all of the lettered sites were sampled by the University team (see Figure 1). For the quality assurance/quality control program a subset of sites were sampled as identified below.

The data received from the four teams are presented in Appendix A. To our knowledge, these data represent the full sampling effort of the stream teams insofar as nutrient sampling is concerned; all data received from the teams is given in Appendix A. In some cases not all parameters were sampled during a sampling event or at a particular site and these omissions are shown in the Appendix as blanks.

The Maunawili stream team sampled 11 sites through the course of the project; of these, six continue to be sampled (Figure 1, sites 1, 2, 3, 4, 5, 6) and five sites were sampled on a much



Map copied with permission from GTE Hawaiian Tel

Figure 1. Map of the Kailua-Waimanalo watershed showing the approximate locations of the 36 stations sampled by the volunteer program as well as University of Hawaii personnel in this study. Scale: 1 inch = 2.3 km.

more sporatic basis (Figure 1, sites N, O, P, Q and R). The Maunawili stream team began sampling on 17 November 1994 completing 17 sample periods through 17 June 1996. The Maunawili team has continued sampling using not only adult volunteers from the community but also a number of high school students from Kalaheo High School. These "second generation" volunteers have much enthusiasm and the program provides an educational opportunity as well as a chance to make a positive contribution to the community.

The Kaelepulu stream team had five sites (Figure 1, sites 12, H, I, J and M) that were sampled on eight occasions between 15 June 1994 and 13 July 1994. The Waimanalo stream team sampled four sites (Figure 1, sites A, B, C and D) on seven occasions from 17 June 1994 through 14 January 1995. Similarly, the Kahawai stream team sampled that drainage at three sites routinely (Figure 1, sites E, F and G) and at one location (Figure 1, site S) once. Field sampling was carried out on four occasions between 15 January 1994 and 14 January 1995.

The sampling efforts were primarily in freshwater because the test kits will not accurately measure nitrite-nitrate nitrogen concentrations in saline waters. Evidently, the salts responsible for salinity interfere with the nitrate nitrogen test leading to poor results (personal communication with a chemist at Hach Company, 25 February 1995). Only the Kaelepulu stream team encountered measurable salinities at all but one of their sampling stations. As noted above, the data from the volunteer stream teams are presented in Appendix A. It should be noted that the equipment used by the teams for the determination of nutrient concentrations does so to a level of mg/l which is sufficient for some applications such as teaching secondary students. In general, the results vary considerably through time and space. This high variability may be a reflection of the precision and resolution of the test kits used in determining nutrient concentrations. Also apparent are the relatively low concentrations as measured by the teams for most locations and sample periods. High nitrate nitrogen concentrations were recorded at site G on Kahawai Stream during June and July 1994 and at site M (the unnamed intermittent stream near Kalanianaole Road) as sampled by the Kaelepulu stream team on four occasions in June and July 1994. Relatively high concentrations of orthophosphorus were encountered on occasion at many of the sample locations and at different times. Most stream sites at one time or another showed some increase in orthophosphate concentration. The high within site variability suggests that (a) there is considerable variability in the source of orthophosphate, or (b) the test equipment measuring orthophosphate creates variability due to lack of sensitivity at the concentrations encountered in this study (see below).

Mean concentrations of nitrate nitrogen and orthophosphate as sampled by the volunteer stream teams are plotted in Figure 2. Given in this figure are the means by sample location and the associated standard deviations. In general, sample locations are arranged from more inland (*mauka*) to more seaward (*makai*) sites to depict any gradients in concentration that may be present. In some cases, the standard deviations are smaller than the point depicting the mean for that station, which results in no vertical standard deviation bars being visible. Figure 2-A presents the mean concentration of nitrate nitrogen at six stations routinely sampled by the Maunawili stream team as well as one site (site N) sampled on three occasions. This plot does not suggest any obvious input of nitrate nitrogen at the sample sites. On the other hand, the Waimanalo stream team noted higher mean concentrations of nitrate nitrogen at station C (at bridge northwest of junction of Kumuhau and Mahaiula Streets) where a mean of 0.68 mg/l (681.94 ug/l or 48.71 uM) was measured (Figure 2-B). However, by the time this water reaches site D (Waimanalo

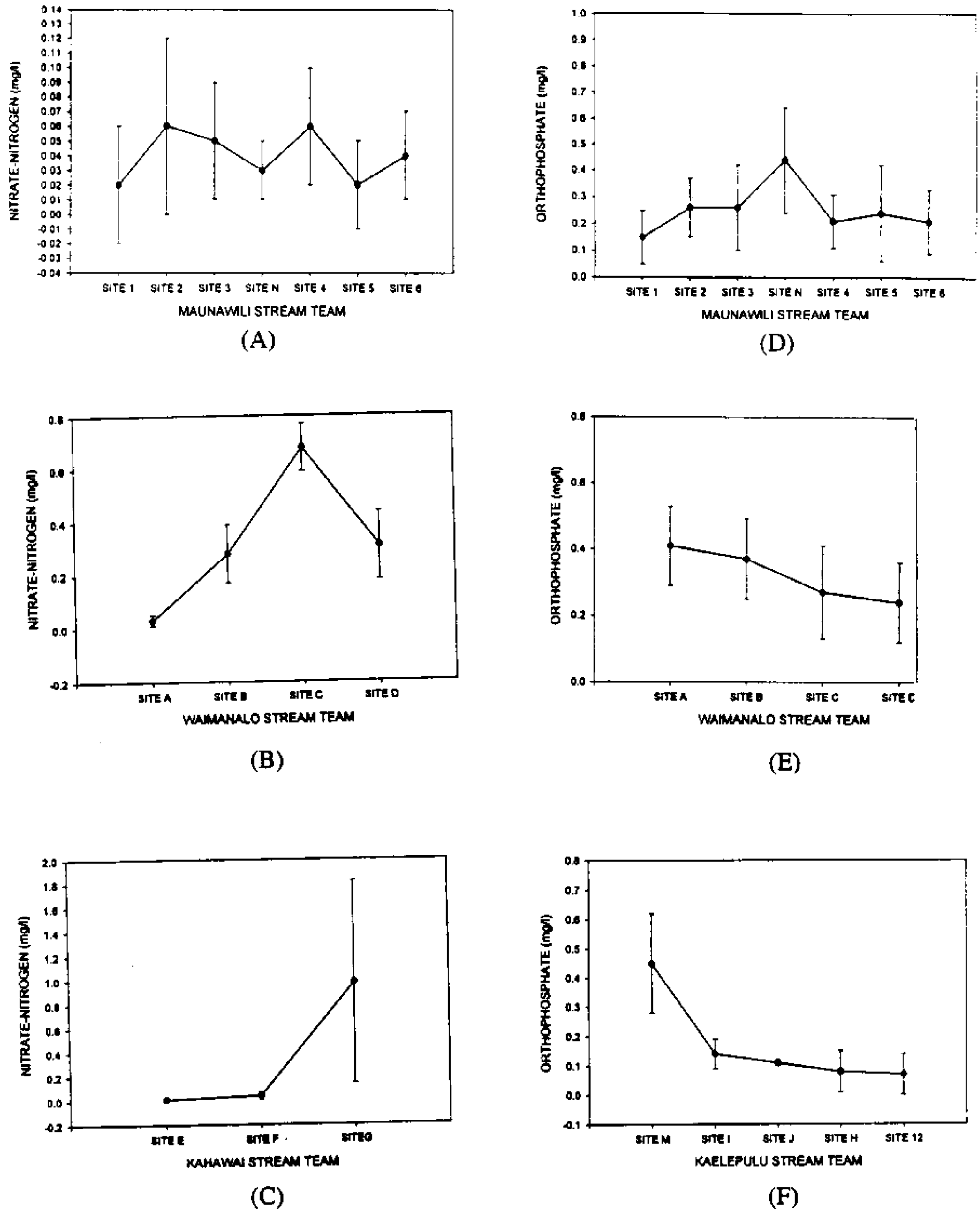


Figure 2. Nitrate nitrogen and orthophosphorus as measured by the Maunawili team (A and D above), the Waimanalo team (B and E), the Kahawai team (C), and the Kaelepulu team (F). Standard deviations of these data are shown as vertical bars.

Stream bridge at Kalanianole Highway) the mean concentration has decreased. The mean nitrate nitrogen concentrations at three sample sites along Kahawai Stream are given in Figure 2-C. Nitrate nitrogen concentrations are elevated at site G (Kalanianole Highway bridge at Kahawai Stream) where a mean of 0.97 mg/l (975.94 ug/l or 69.71 uM) was measured. The reason(s) for this greater mean concentration at site G are unknown. Because the measurement of nitrate nitrogen is inaccurate in brackish water using the test procedures available to the volunteers we have not plotted out any Kaelepulu stream team nitrate nitrogen data. The Kaelepulu stream team recorded nitrate nitrogen at one freshwater site (site M) which was not plotted. Mean nitrate nitrogen concentration at site M was 1.84 mg/l (1,834.98 ug/l or 131.07 uM).

Figure 2-D presents the mean concentration of orthophosphate at the six sites routinely sampled by the Maunawili stream team as well as at site N (Kahanaiki Stream at Auloa Road bridge). Highest mean concentration was encountered at site N (sampled on three occasions only; mean = 0.44 mg/l or 440.00 ug/l or 31.42 uM). The mean orthophosphate concentrations from the four routinely sampled sites along Waimanalo Stream are given in Figure 2-E. This plot shows a rather steady decline in orthophosphate concentration from the most inland points toward the sea suggesting uptake or dilution of this nutrient as the stream water moves toward the ocean. Figure 2-F presents the mean concentration of orthophosphorus at the five sites monitored by the Kaelepulu stream team. Again, the mean concentrations appear to decrease as water flows toward the sea, which is probably related to uptake and/or dilution. The volunteer monitoring data for both the Waimanalo and Kaelepulu drainage systems suggest little input between the *mauka* and *makai* sampling sites. In contrast, the mean concentration of orthophosphate in Kahawai Stream shows a very slight increase as water moves toward the sea, which may suggest (a) some input or (b) no uptake and/or dilution.

B. UNIVERSITY PROGRAM

1. Nutrients and Non-Specific Criteria

The University field sampling program had two main objectives: the first was to provide accurate analyses of water quality parameters from samples split with the volunteers, such that the data could serve as the basis of a quality assurance/quality control program; the second was to obtain quantitative information on the quality of water in the watershed and entering Kailua Bay. Nineteen stations sample the Kailua watershed and bay and these are shown in Figure 1. The QA/QC effort sampled some of the alphabetically as well as numerically marked stations as given in Figure 1. Station 1 through 6 also were monitored routinely by the Maunawili stream team, so these along with stations A through G plus site N were sampled for the QA/QC program.

There are costs associated with the collection and processing of water quality samples. To minimize these costs and maximize the return of useful data, the sampling strategy employed here focused on a sampling schedule that would provide the greatest return of data for the funds expended. Many aquatic borne pollutants are carried to the sea during periods of high rainfall, which serves to "flush" them from the drainage basin to the sea. It follows that during periods of low stream flow conditions (i.e., low rainfall periods), there is less opportunity for pollutants to enter a stream and be carried to the sea. Thus sampling during periods of low rainfall, as well as during (or just after) high rainfall events, should provide data on the envelope of variability that may be expected for the sampled parameters This was the strategy followed in this study.

Field sampling was carried out on five occasions: 14 January 1995 which represented a QA/QC run with the three of the four volunteer groups, 11 March 1995 which was a QA/QC run with the Maunawili stream team, 10 November 1995 and 17 June 1996 which represented a full sampling of the Kailua watershed and bay under dry conditions as well as a QA/QC run with the Maunawili stream team. The 26 January 1996 sample effort was undertaken during a period of heavy rainfall with as much as 18 inches (457 mm) falling in the 36 hours just preceding our sampling effort. The January 1996 field survey sampled 18 of the 19 stations in the Kailua watershed and bay. Station 2 was eliminated because it was located on private property and required presampling contact through an intermediary for permission to enter the property; although the caretakers were very amenable to our entry and sampling, the effort and lead time was excessive.

The data collected by the University team is presented in Appendix B. Twenty-nine of 73 total samples collected were matched with volunteer stream team samples for QA/QC. Inspection of the data in Appendix B shows considerable variability among the different sites (expected) and some variability at each sites through time. A few sites suggest some problems exist (nutrient pollution): the high nitrate and ammonia nitrogen values encountered at site G on 14 January 1995 and nitrate nitrogen at site 13 on 26 January 1996, as well as the elevation of ammonia nitrogen at sites F and 5 (during dry periods). Interestingly, during the January 1996 high rainfall event, ammonia nitrogen was relatively low and nitrate nitrogen was high at site 5. Ammonia nitrogen is a product of metabolism and/or decomposition. The high ammonia nitrogen values encountered at station 5 are due to these processes as well as to the probable poor circulation of water at this site. Oxygen concentrations were low at site 5 during low rainfall sample periods, which is indicative of decomposition suggesting that this is the source of much of the ammonia nitrogen at this location. The January 1996 flooding probably "flushed" the ammonia from the system as well as carried in additional nitrate. The concentration of orthophosphorus was elevated at site 13 during dry periods and showed considerable elevation during the January 1996 rainfall event. Other than the anomalies noted above, the concentrations of nutrient parameters given in Appendix B appear to be in the usual range as found in Hawaiian streams.

The U.S. Geological Survey annually compiles data on Hawaii's freshwater resources which includes some measurement of water quality parameters (i.e., nitrate nitrogen, ammonia nitrogen, orthophosphorus and total phosphorus) at some stream sites (see Matsuoka et al. 1995). These data may serve as a comparative measure of stream water quality. Kahakuloa Stream in the West Maui watershed is situated in an undeveloped drainage basin and is representative of an undeveloped windward watershed. Besides nutrient data, the USGS collects information on stream flow; during the low flow period (dry season = 7.5 cubic feet/sec) mean nitrate nitrogen = 117 ug/l, mean ammonia nitrogen = 23 ug/l, mean orthophosphate = 17 ug/l, and mean total phosphorus = 27 ug/l. During the rainy season the mean stream flow is about 42 cubic feet/sec and mean nitrate nitrogen = 60 ug/l, mean ammonia nitrogen = 13 ug/l, mean orthophosphate = 10 ug/l and mean total phosphorus = 17 ug/l. Comparing the dry or low-flow period mean values to the geometric means at stream stations in Table 1 we find that most of them are close but there are instances where the streams sampled in this study yield greater values, i.e., the geometric mean for nitrate nitrogen at station 4 is slightly greater than found at Kahakuloa Stream (130 ug/l versus 117 ug/l), orthophosphorus is elevated at station 2 (22.8 ug/l versus 17 ug/l), total phosphorus is greater than the Kahauloa Stream mean at station 5 (31.7 ug/l versus 27 ug/l) and the geometric mean for ammonia nitrogen at station 5 is much greater (1362 ug/l versus 23 ug/l). A second comparison may be made using data from Luluku Stream in the Kaneohe watershed at a point below the large banana grove fronting Likelike Highway (elevation 220 feet). The mean annual flow of this stream is 8 cubic feet/sec and mean nitrate nitrogen = 230 ug/l, mean ammonia nitrogen = 350 ug/l and mean total phosphorus = 270 ug/l. These mean values are elevated over those encountered in the undeveloped watershed; the drainage basin of Luluku Stream supports agriculture and urbanization as well as being undeveloped in the upper reaches.

TABLE 1. Summary of the geometric means from stations sampled more than once by the University team in three groups: streams, estuaries and marine sample sites. Geometric means are calculated for each parameter over all sample periods. In the body of the table are given the geometric means for each parameter at each sample site. All data are presented in ug/l unless otherwise noted. The complete dataset upon which these geometric means are based is given in Appendix B. Underlined values exceed the state "dry" standard as applicable. Table continued on the next page. ND = below limits of detection.

Station	NO3	NH4	TN	PO4	TP	DON	DOP	Si
STREAMS								
1	26.56	1.78	108.56	6.64	11.82	59.57	4.74	14806.09
2	106.78	1.84	164.48	22.83	27.97	44.38	4.74	13121.80
3	49.27	4.32	147.41	2.75	10.47	64.71	6.41	11411.99
4	130.58	17.26	253.40	7.79	15.60	86.76	6.22	12888.16
5	79.29	1362.09	4555.48	4.26	31.74	736.95	19.77	12962.65
ESTUARIES								
6	6.07	34.67	572.63	22.26	32.66	430.94	5.21	9091.56
12	21.89	28.32	641.59	12.44	44.39	465.81	20.95	1608.69
13	43.50	68.59	819.88	40.11	64.89	479.69	21.43	1158.39
14	9.79	10.84	602.14	10.38	37.10	392.21	16.43	1182.34
MARINE								
7	33.48	16.94	289.41	9.86	20.86	210.30	10.72	2011.40
8	10.90	13.73	226.05	6.90	19.43	170.31	11.81	588.46
9	7.79	11.14	228.03	5.48	15.92	173.58	8.90	305.42
10	5.19	10.91	211.86	6.25	17.32	160.26	9.48	316.39
11	4.18	4.65	167.88	4.95	15.05	132.65	9.41	242.79
15	6.03	14.55	284.78	9.25	25.89	187.02	12.22	293.47
16	1.73	3.70	126.37	2.85	11.78	113.03	8.54	105.89
17	1.34	3.90	110.16	2.75	11.37	96.37	8.08	50.77
18	1.99	3.19	118.57	2.93	11.63	100.81	8.16	51.27
19	1.78	3.49	118.27	3.11	12.74	104.97	8.97	48.39
STREAMS								
1		ND	1.26	0.031		21.5	7.96	7.28
2		ND	2.81	0.096		21.1	9.25	7.64
3		ND	3.09	0.495		23.2	9.47	8.08
4		ND	4.65	0.062		22.4	7.40	7.23

TABLE 1. Continued.

Station	Salinity (ppt)	Turbidity (NTU)	Temp Chl-a	Oxygen (oC)	(mg/l)	pH
5	1.034	44.76	2.272	24.1	2.34	7.34
ESTUARIES						
6	0.975	19.30	0.313	23.6	3.20	6.94
12	12.885	4.87	1.147	26.3	4.56	7.66
13	11.671	19.94	0.789	26.9	5.55	7.53
14	15.057	6.26	1.531	26.8	5.95	7.75
MARINE						
7	8.153	7.93	0.601	25.5	5.25	7.51
8	12.230	9.52	0.221	25.1	5.71	7.49
9	16.985	9.20	0.169	25.1	5.87	7.66
10	14.839	6.89	0.172	25.1	5.80	7.66
11	28.908	5.51	0.211	25.5	6.94	7.86
15	17.196	5.06	0.307	25.6	6.37	7.76
16	34.618	1.07	0.199	25.9	6.43	7.99
17	34.637	1.31	0.182	25.9	6.48	8.01
18	34.420	1.13	0.140	25.9	6.54	8.03
19	34.737	3.79	0.152	25.9	6.55	8.04

Chlorophyll-a is a measure of phytoplankton biomass. Phytoplankton are microscopic plants that often give pond water a "green" appearance; high chlorophyll-a values are indicative of high phytoplankton abundance. Relatively high chlorophyll-a values (i.e., greater than 5 ug/l) were encountered at stations D and G in January 1995 and at station 5 during November 1995 and June 1995 surveys. Not surprisingly, phytoplankton abundance was low during the high rainfall event in January 1996 but turbidity was elevated at many stations due to the runoff.

The State of Hawaii has numerical standards for many of the water quality parameters that are routinely monitored. Among others, specific standards have been developed for streams, estuaries and open coastal waters. Geometric means are calculated for each water quality parameter for samples collected over time at a specific site, and these geometric means are used in assessing compliance to the state standard. The calculated geometric means of all parameters measured by the University team in this study are given in Table 1. In this table, sites are separated into stream, estuarine or marine, and the state standards for each of these are given in Table 2 for streams, Table 3 for estuaries and Table 4 for open coastal marine waters. Underlined values in Table 1 indicate the parameters for each site that do not meet the applicable state standard. In this analysis, we have assumed that the Kailua-Waimanalo coastline is classified as a "dry" coastline and that samples were collected during the "dry" season (the most stringent conditions). It is apparent from an inspection of Table 1 that nitrate nitrogen and turbidity in streams were not in compliance with the standards at four of five stations. Similarly, nitrate nitrogen, ammonia nitrogen, total nitrogen, and total phosphorus were not in compliance at estuarine stations, nor were these parameters in compliance at many of the marine stations.

At estuarine and marine stations turbidity was always out of compliance and chlorophyll-a was out of compliance at all but one marine station. The lack of compliance with state standards is not surprising considering that most stations sample waters in, and immediately adjacent to, a developed or urbanized watershed and also encompass both wet and dry conditions.

2. Pesticide/Heavy Metal Analyses

Sediment samples for pesticide/heavy metal analyses were collected at six locations during the 17 June 1996 field survey. These analyses are costly thus not many compounds or locations could be sampled under this program. The sample sites selected are shown in Figure 1 and include station 4 (in Maunawili Stream at the bridge to Royal Hawaiian Country Club), station 5 (in the ditch below the Kailua Landfill along Kapaa Quarry Road), station 9 (in the northern part of Kailua Bay approximately 100 m offshore of the mouth of Kawainui Channel at a depth of 2.5 m), station 13 (at the Keolu Drive bridge crossing Kaelepulu Stream), station 14 (at the mouth of Kaelepulu Stream in Kailua Beach Park) and station 17 (in the ocean approximately 100 m offshore of the mouth of Kaelepulu Stream at a depth of 3.5 m).

TABLE 2. Specific criteria specified by the Department of Health water quality standards for streams as amended in 1992.

Parameter	Geometric mean not to exceed the given value	Not To Exceed the given value more than ten percent of the time	Not To Exceed the given value more than two percent of the time
Total Nitrogen (ug/l)	250.0* 180.0**	20.0* 380.0*	800.0* 600.0**
Nitrate + Nitrite Nitrogen (ug/l)	70.0* 30.0**	180.0* 90.0**	300.0* 170.0**
Total Phosphorus (ug/l)	50.0* 30.0**	100.0* 60.0**	150.0* 80.0**
Total [Nonfilterable Residue] Suspended Solids (mg/l)	20.0* 10.0**	50.0* 30.0**	80.0* 55.0**
Turbidity (N.T.U.)	5.0* 2.0**	15.0* 5.5**	25.0* 10.0**

* Wet Season - November 1 through April 30.
** Dry Season - May 1 through October 31.
l = liter
N.T.U. = Nephalometric Turbidity Units. A comparison of the intensity of light scattered by the sample under defined conditions with the intensity of light scattered by a standard reference suspension under the same conditions. The higher the intensity of scattered light, the higher the turbidity.
ug = microgram or 0.000001 grams.

TABLE 3. Specific criteria specified by the Department of Health water quality standards applicable to all estuaries except Pearl Harbor as amended in 1992.

Parameter	Geometric mean not to exceed the given value	Not To Exceed the given value more than ten percent of the time	Not To Exceed the given value more than two percent of the time
Total Nitrogen (ug/l)	200.00	350.00	500.00
Ammonia Nitrogen (ug/l)	6.00	10.00	20.00
Nitrate + Nitrite Nitrogen (ug/l)	8.00	25.00	35.00
Total Phosphorus (ug/l)	25.00	50.00	75.00
Light Extinction Coefficient (k units)	0.40	0.80	1.00
Chlorophyll-*a* (ug/l)	2.00	5.00	10.00
Turbidity (N.T.U.)	1.50	3.00	5.00

k units = the ratio of light measured at the water's surface to light measured at a particular depth. l = liter.

TABLE 4. Specific criteria specified by the Department of Health water quality standards for open coastal waters as amended in 1992.

Parameter	Geometric mean not to exceed the given value	Not To Exceed the given value more than ten percent of the time	Not To Exceed the given value more than two percent of the time
Total Nitrogen (ug/l)	150.00* 110.00**	250.00* 180.00**	350.00* 250.00**
Ammonia Nitrogen (ug/l)	3.50* 2.00**	8.50* 5.00**	15.00* 9.00**
Nitrate + Nitrite Nitrogen (ug/l)	5.00* 3.50**	14.00* 10.00**	25.00* 20.00**
Total Phosphorus (ug/l)	20.00* 16.00**	40.00* 30.00**	60.00* 45.00**
Light Extinction Coefficient (k units)	0.20* 0.10**	0.50* 0.30**	0.85* 0.55**
Chlorophyll-a (ug/l)	0.30* 0.15**	0.90* 0.50**	1.75* 1.00**
Turbidity (N.T.U.)	0.50* 0.20**	1.25* 0.50**	2.00* 1.00*

* "Wet" criteria apply when the open coastal waters receive more than three million gallons per day of freshwater discharge per shoreline mile.

** "Dry" criteria apply when the open coastal waters receive less than three million gallons per day of freshwater discharge per shoreline mile. Applicable to both "wet" and "dry" conditions: pH units – shall not deviate more than 0.5 units from a value of 8.1, except at coastal locations where and when freshwater from stream, storm drain or groundwater discharge may depress the pH to a minimum level of 7.0.

These samples were analyzed for 13 metals and three pesticide "screens." These pesticide screens provide information on the presence of a number of chemically related compounds but, if present, will not identify which compound(s) from the group is present. The results of the analyses are given in Table 5. None of the more than 50 compounds that the three screens (total organic halogens, organophosphorus pesticides or chlorinated pesticides) can identify were detected in the sediment samples from these six locations. The analysis of metals from these sites showed that other than mercury and cadmium, all were detected at some of the stations. Despite the detection of these metals, only two (i.e., antimony and selenium) exceeded the expected natural ranges of these elements based on data from soils in the United States (see below).

TABLE 5. Results of the pesticide and heavy metal analyses from six sediment samples collected at sites in the Maunawili watershed, bordering Kaiwainui Marsh and into Kailua Bay on 17 June 1996. In the body of the table are given the constituent, its detection limits and the concentration (in mg/kg = ppm dry wt.) measured in the sample. ND = below the limits of detection.

	Detection	Station Numbers					
Constituent	**Limits**	**4**	**5**	**9**	**13**	**14**	**17**
Heavy Metals							
Antimony	1.81	5.75	9.99	5.75	9.72	30.8	21.7
Arsenic	0.20	2.93	ND	2.93	0.52	1.84	2.97
Barium	0.39	10.2	72.1	10.2	5.26	6.42	4.84
Cadmium	0.18	ND	ND	ND	ND	ND	ND
Chromium	0.48	12.1	65.7	12.1	49.0	4.92	6.57
Copper	0.60	8.53	59.6	8.53	57.2	11.2	1.45
Lead	0.10	2.07	3.14	2.07	4.86	2.83	2.62
Mercury	0.05	ND	ND	ND	ND	ND	ND
Nickel	0.57	14.7	57.9	14.7	46.0	4.25	10.3
Selenium	0.20	2.37	ND	2.37	ND	4.79	4.76
Thallium	0.14	1.88	11.5	1.88	12.3	ND	0.71
Zinc	0.20	8.6	44.4	8.6	41.0	26.9	ND
Screens							
Total Organic Halogens	5.0	ND	ND	ND	ND	ND	ND
Organophosphorus Pesticides		ND	ND	ND	ND	ND	ND
Chlorinated Pesticides		ND	ND	ND	ND	ND	ND

A number of metals which are considered priority pollutants do occur naturally in the environment, often at relatively high concentrations. Usually these metals are complexed or bound to sediments and/or organic particles and often do not move readily into solution in the aquatic environment. Under these circumstances these bound or complexed metals pose little threat to most aquatic species, and it is only when the pH shifts toward a more acidic setting that some of these forms will move into solution and become more readily accessible to aquatic biota. Insofar as this sampling program is concerned, there are a number of anthropogenic sources for the metals that could be partially responsible for the concentrations encountered at the sampled stations. Municipal wastes and sewage sludge are placed in the Kailua Landfill. These wastes are a known source for copper, zinc, cadmium, chromium and nickel. Fertilizers, sprays and agricultural practices can locally increase copper, zinc, cadmium and nickel (phosphate fertilizers). A source of lead is from automobile emissions (leaded gasoline) and paints (Spencer et al. 1995), nickel from the combustion of coal (not here) and oil, and antimony from reclamation of lead-acid batteries. An anthropogenic source of thallium is from the cement industry and there is a cement manufacturing operation at nearby Kapaa Quarry. A major anthropogenic source of arsenic is from arsenical sprays (herbicides). Volcanism and the exhalations from volcanic vents are a natural source for arsenic and selenium (see Kabata-Pendias and Pendias 1992). Chilvers and Peterson (1987) calculated that at least 60% of the atmospheric global inputs of arsenic are derived from natural sources such as volcanoes.

As noted above, other than mercury and cadmium, metals were detected at all stations in this study. Only selenium and antimony were above the expected natural range for these elements as based on data from soils in the United States. Antimony has a relatively high mobility in the environment. Jones et al. (1990) reviewed the data on antimony in soils and provided a natural range from 0.3 to 9.5 ppm (dry weight) with a grand mean of about 0.9 ppm. Anthropogenic sources of antimony include copper smelters which may bring antimony levels in soils up to 200 ppm (Crecelius et al. 1974). Soils from battery reclamation sites are reported to contain up to 857 ppm of antimony (Trnovsky et al. 1987). The elevated antimony values encountered in this study were at station 5 (at the foot of the Kailua Landfill) and at station 13 at Keolu Drive bridge where it crosses Kaelepulu Stream. The high value from the landfill site is not unexpected because of the proximity of the landfill, as well as the former Kailua Auto Wreakers site which was located approximately 200 m northwest of this sample site. The Kaelepulu Stream drains Enchanted Lake which is surrounded by urban development, thus, urban activities could be responsible for the elevation at this site.

Selenium above the reported natural background levels for U.S. soils was encountered at two stations in this study: station 14 at the mouth of Kaelepulu Stream (in Kailua Beach Park) and at station 17 which is in the ocean approximately 100 m offshore of the mouth of Kaelepulu Stream at a depth of 3.5 m. The only gross point of commonality between these two samples is that they were primarily comprised of coralline beach sand and were collected within 140 m of one another.

Selenium often occurs in sulfur and sulfide minerals where it may be concentrated up to 200 ppm (dry weight). During chemical weathering of rocks selenium is easily oxidized and the state of its oxidation, as well as its solubility, are controlled by the oxidation-reduction regime and by pH of the environment. Selenite ions resulting from oxidation processes are stable and may migrate until they are adsorbed on mineral and organic particles. As a consequence, the selenium levels may be increased in coals as well as in clay sediments (Kabata-Pendias and Pendias 1992). In the United States selenium occurs naturally in sandy soils in the range from 0.005 to 3.5 ppm (dry weight) with a mean of 0.5 ppm. In a variety of other soil types the natural range is from <0.1 to 4.0 ppm with a mean of 0.31 ppm. Anthropogenic sources of selenium include the combustion of coal, as well as from metal smelting operations. Plants readily take up selenium and Gutenmann et al. (1976) reported that legumes grown on coal ash contain selenium at concentrations up to 200 ppm. A major natural source of selenium is from volcanism, which could explain the selenium levels encountered in this study.

AECOS, Inc. (1989) reported the concentrations of a number of metals from stations surrounding and in Kawainui Marsh. Only one AECOS station was close to any of ours; AECOS station 3 was situated about 400 m southeast of our Station 5. They sampled their station 3 on two occasions and the mean dry weight values obtained were as follows: arsenic AECOS = 1.43 mg/kg, this study = ND (= non-detectable); cadmium AECOS = 0.35 mg/kg, this study = ND; copper AECOS = 35.4 mg/kg, this study = 65.7 mg/kg; chromium AECOS = 55.0 mg/kg, this study = 59.6 mg/kg; mercury AECOS = 0.07 mg/kg, this study = ND; nickel AECOS = 50.5 mg/kg, this study = 57.9 mg/kg; lead AECOS = 12.2 mg/kg, this study = 3.14 mg/kg; and zinc AECOS = 33.0, this study = 44.4 mg/kg.

Lau et al. (1973) reported metal concentrations in sediments from Kahana Stream, as well as from adjacent Kahana Bay on Oahu. The Kahana watershed is relatively undeveloped and probably representative of natural levels of these heavy metals in Hawaiian settings. In the Kahana Stream, sediments measured concentrations were: arsenic from 3-12 mg/kg (dry weight), cadmium from non-detectable to 2 mg/kg, chromium from 47 to 147 mg/kg, copper from non-detectable to 160 mg/kg, mercury from non-detectable to 0.2 mg/kg, nickel from non-detectable to 350 mg/kg, and lead from 5 to 34 mg/kg. In the Kahana Bay marine sediments the concentrations were: arsenic from non-detectable to 29 mg/kg, cadmium from non-detectable to 10 mg/kg, chromium from 1 to 122 mg/kg, mercury from non-detectable to 2 mg/kg, lead from 5 to 58 mg/kg, and zinc from non-detectable to 105 mg/kg. In no case did the concentrations of heavy metals measured in the present study exceed the range of values found by Lau et al. (1973) for Kahana Stream and marine sediment samples.

The State of Hawaii has developed acute and chronic standards for both freshwater and seawater environments for some priority pollutants including many of those sampled for in this study. There are no standards for sediments which were sampled here. In general, the concentration of many priority pollutants will be considerably greater in sediments due to adsorption or in organisms residing in polluted habitats due to bioaccumulation than found in the aqueous portion of the environment. Thus data from sediment samples usually provides the "worst case" for many pesticides and heavy metals in a given habitat and, hence, the rationale for sampling sediment in this study.

Many of the heavy metals present in Hawaiian soils and sediments may be attributed to the local geochemistry as well as the volcanic source of the parent rocks. However, urban pollution may be a significant contributor of heavy metals to some estuarine sediments (Jonasson and Timperley 1975). Local examples where this has occurred may be found in the Ala Wai and Kapalama Canals (Department of Health 1978; DeCarlo and Spencer 1995; see also Pacific Science 49[4]).

In summary, the results of the priority pollutant sampling suggests that the concentrations of most pollutants are within the ranges encountered in undisturbed soils of the United States and for sediments from an undisturbed Hawaiian watershed and coastal system. In addition, the results of the present study are similar to those of a previous study done in Kawainui Marsh more than six years ago.

3. Quality Assurance/Quality Control With The Volunteer Program

One of the objectives of the University sampling was to analyze the resolution, precision and accuracy of the data collected by the volunteer program. This assessment provides information to agencies concerned with water quality monitoring on the value of (1) the techniques and methods used by the volunteer program and (2) on using volunteers to obtain field data.

Quality assurance/quality control (QA/QC) programs rely on comparative analyses; to meet this objective, we worked with some of the volunteer groups in the field collecting water samples in a common container and "splitting" each sample between the University team and the volunteer stream team for analysis. Since each sample is unique, data are compared on a one-to-one basis below. It should be noted that the University equipment has much greater resolution (four orders of magnitude greater) but to make the data visually comparable, the University data has been scaled to mg/l which is the level of resolution of the nutrient test equipment available to the volunteers in this program. As noted above, all data collected under this program are presented in the appendices. Plots below are scaled to match the volunteer data; thus, much of the resolution of the University data is lost. For example, in the first pair of points in Figure 3-A (site A) the volunteer reading was 0.06 mg/l nitrate nitrogen (Appendix A) and the University team reading was 26.04 ug/l or 0.03 mg/l nitrate nitrogen (Appendix B), yet in Figure 3-A these two points appear close together.

The visual comparisons for nitrate nitrogen are given in Figure 3-A through 3-F. In general, the volunteer test kit results follow the University team results, but there are exceptions. Occasionally, the results from the volunteer kits diverged; Figure 3-B, site G is one example. In that case, the University team found a very high nitrate reading (7868.64 ug/l or 562.05 uM = 7.86 mg/l, see Appendix B) while the volunteer reading for this site was lower, i.e., 0.26 mg/l (or 260 ug/l or 18.57 uM). In other instances the volunteer kits provided a higher reading than probably existed; one example is in Figure 3-C at site Q where the University team obtained a nitrate nitrogen reading of 3.22 ug/l (or 0.23uM or 0.003 mg/l, Appendix B) while the volunteer team kits provided a nitrate nitrogen estimate of 0.10 mg/l (or 0.0001 ug/l, Appendix A). At the level of resolution available with the test kits used, the volunteers frequently obtained nitrate nitrogen results that were reasonably close to the University results as given in Figure 3-A, 3-D and 3-E.

The results of the comparisons between the volunteer and University results for orthophosphate concentrations are given in Figure 4-A through 4-F. Visual inspection of these figures shows that in all but two instances (Figures 4-E and 4-F, site 1) the volunteer readings were consistently higher than the University estimates. The worst case example is seen in Figure 4-D, site N where the volunteer team obtained an orthophosphate estimate of 0.60 mg/l or 600 ug/l (Appendix A) and the University measured orthophosphate at 1.82 ug/l or 0.0018 mg/l (Appendix B). The graphical evidence suggests that the orthophosphate test kits used by the volunteers provide consistently higher estimates of orthophosphorus than is present.

The other parameters measured by the volunteer program (i.e., oxygen, temperature and pH) are in close agreement with the University QA/QC results and are not plotted here. This result is in agreement with Christman and Frease (1993) where a volunteer water quality monitoring program produced acceptable salinity, pH and oxygen estimates. Although the pH test kits are reasonably accurate, the use of litmus paper, which was used on some occasions, is not.

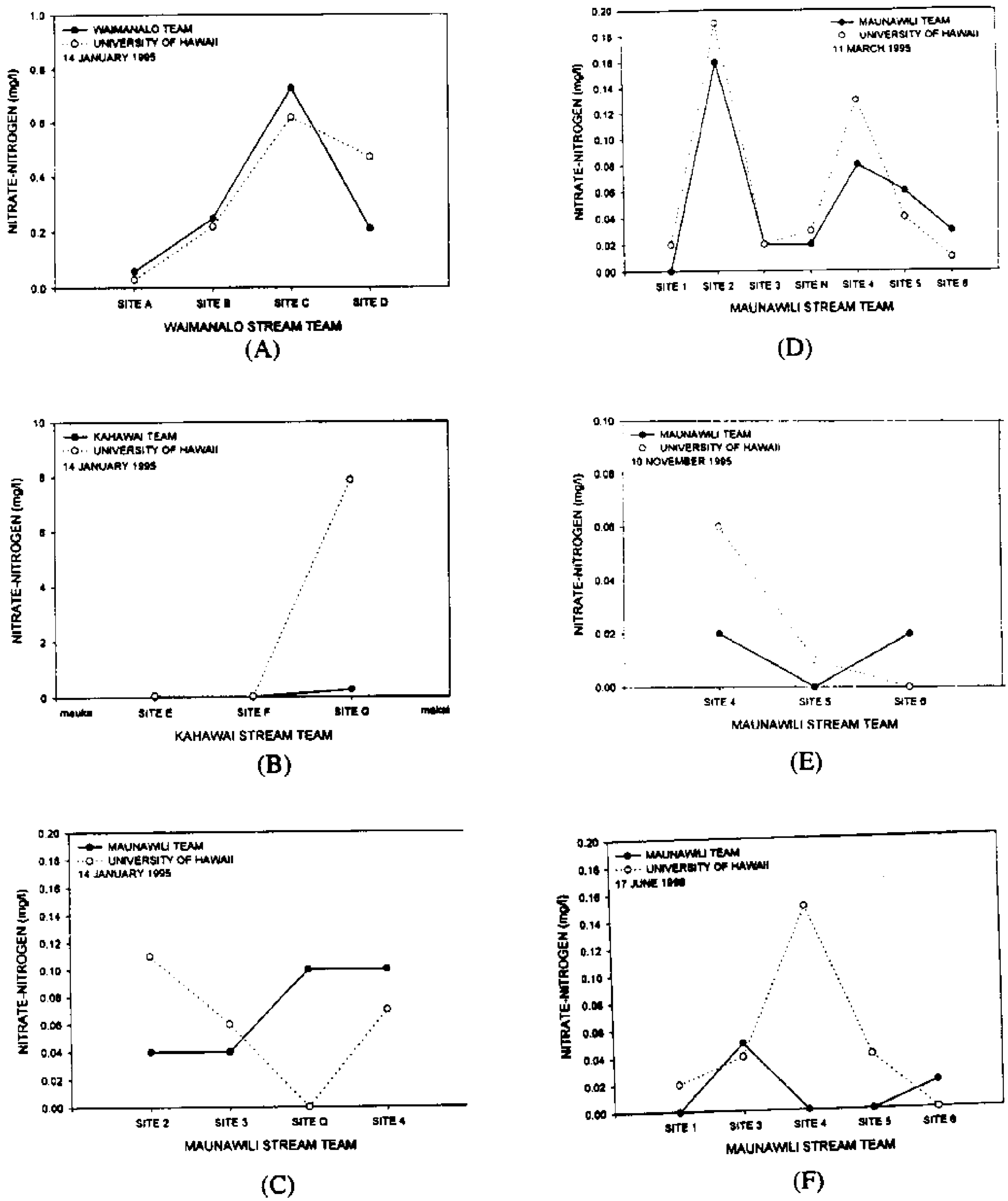


Figure 3. Comparative nitrate nitrogen results for the Waimanalo (A), Kahawai (B), and Maunawili (C through F) using split samples with the University team for QA/QC analyses carried out on different dates.

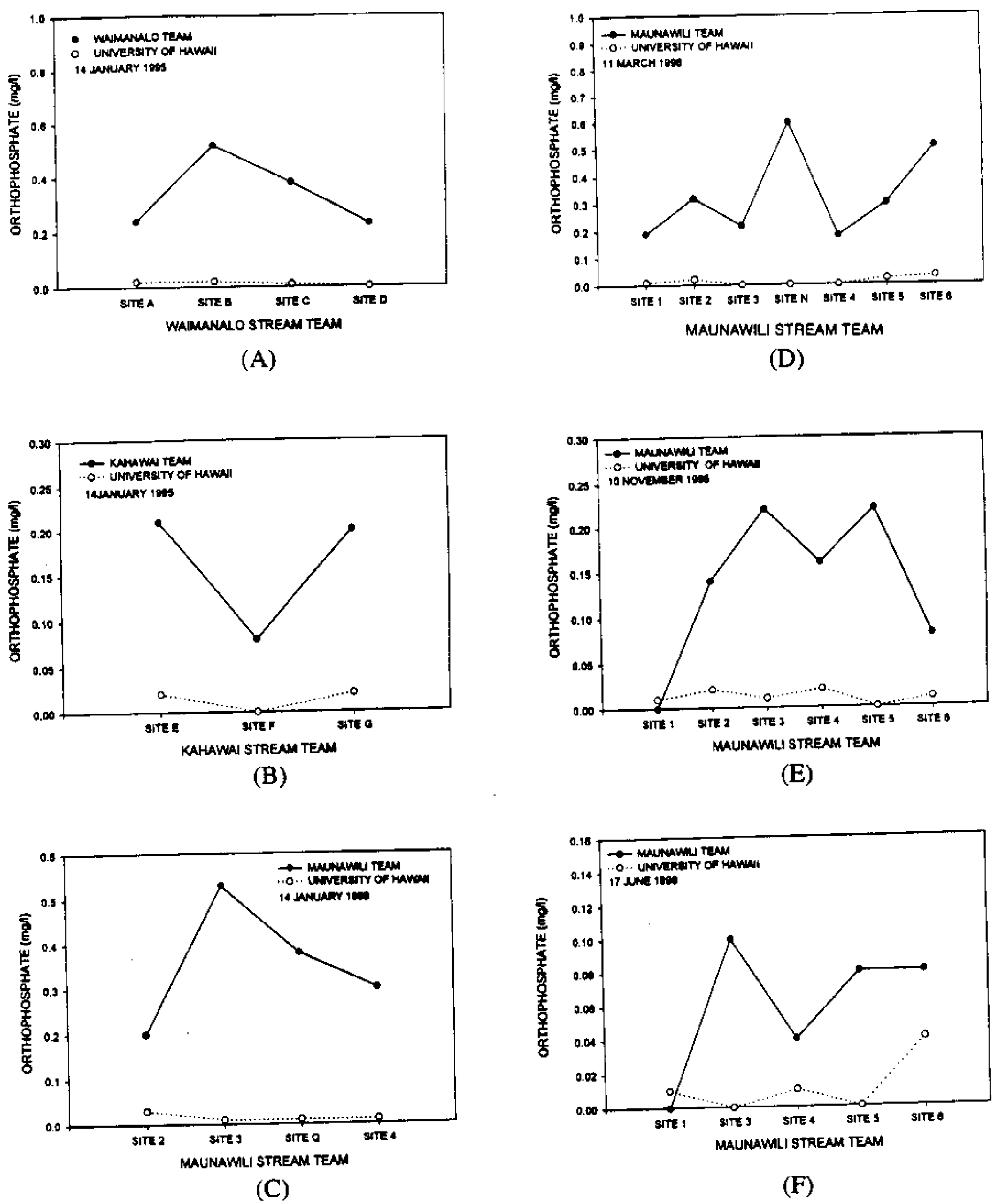


Figure 4. Comparative orthophosphorus results for the Waimanalo (A), Kahawai (B), and Maunawili teams (C through F) using split samples with the University team for QA/QC analyses carried out on different dates. (Appendix B). The graphical evidence suggests that the orthophosphate test kits used by the volunteers provide consistently higher estimates of orthophosphorus than is present.

We recommend that portable, temperature-compensated, ditigal pH meters be considered for any volunteer program. These meters are not expensive and provide pH as well as temperature measurements.

Summarizing the results of the QA/QC program, we note that the use of the low-cost test kits used provided a reasonable low-resolution estimate for nitrate nitrogen. The resolution in estimating concentration with the kit used by the volunteers in this study allows one to determine if the concentrations were either high or low; utilizing these data to draw further conclusions beyond this "high or low" level is probably not appropriate. The orthophosphate kits used by the volunteers provided a poor estimate of the concentration of this material. The QA/QC data suggest that orthophosphate should not be measured with this kit. Despite the lack of resolution with the kits used by the volunteers in this project, these kits are inexpensive and are relatively easy to use. The kits probably have their greatest utility as teaching instruments rather than for determining concentrations of materials in streams. It should be noted that the volunteers appeared to be well trained and followed the directions for their test kits. The problems encountered in the QA/QC program appeared to be related to the limits of the equipment used, not the people using it.

4. Thoughts on Citizen Volunteer Monitoring Programs

Volunteer water quality monitoring programs have been successfully established in various parts of the country. Section IV of this manual presents some information on how to successfully establish a volunteer program. The reader interested in doing this is urged to take the time to read what has been done elsewhere. A word of advice regarding volunteer programs and water quality monitoring is that these programs are successful because of the efforts of the volunteers in the program. There may be regional differences in public perception and motivation to be a volunteer in a water quality monitoring project, thus not all of the information based on experiences in other parts of the United States may have application in Hawaii. Furthermore, Hawaii's terrestrial and marine environment is quite different from the temperate counterpart where most of this literature originates, hence not all scientific explanations from the temperate perspective have application in the Hawaiian setting. One example may be with the natural levels of nitrate nitrogen found in some Hawaiian coastal groundwater — the naturally occurring concentration of this nutrient may be at levels considered to be polluted in some temperate fresh or brackish waters.

A successful volunteer water quality monitoring program should first develop a series of realistic goals and objectives. An important element of these should be a list of questions to be addressed by the monitoring activity. To monitor for the sake of monitoring is probably not a good use of time and resources. Monitoring to obtain data to answer a scientifically valid question is appropriate. Questions such as "What is the temporal variability in the important inorganic nutrients leaving this watershed?" or "Are there important previously undocumented sources of nutrients coming from this watershed?" are all appropriate. These questions should be developed with the help of individuals familiar with water quality monitoring so that realistic expectations are in place. The goals, objectives and any questions posed must be consistent with the funding levels, equipment and expertise available to assist the volunteers.

We will not address the funding requirements, sources or structure of a volunteer program but the program must have one or more individuals who will be responsible for the program.

Usually a monitoring program will require some level of funding and the administration of those funds must be carefully considered. Ideally, a volunteer water quality monitoring program should have access to individuals with expertise in water quality monitoring and who are willing to share their time with the volunteers and the program. Having a governmental agency willing to "work with" the community and the volunteer program increases the chances of a program to be successful.

An important component to any volunteer water quality monitoring program is that of safety. Whether a volunteer is collecting water samples from a stream or is handling the reagents used in some of the test procedures, all safety precautions should be rigorously followed. The use of a "Waiver of Liability" form may be one way to decrease liability exposure of the program, but an attorney should be consulted with respect to this aspect.

Recruitment of volunteers may best accomplished through exposure of the program in the local community. This may be done through presentations at local neighborhood boards or other community meetings, television and radio exposure, as well as writing stories for local newspapers. The degree of exposure attained will be limited only by the energy and ingenuity of those doing the organizing. Once recruited, volunteers must be kept informed, given meaningful tasks and made to feel that their individual contributions are important to the success of the program. Regular meetings help keep the interest alive in the volunteers but the meetings should only be called when there are meaningful matters to be presented and discussed. We found that having presentations by professionals in water quality, aquatic biology, resource management, and from government agencies help to broaden the perspective of the volunteers and make the meetings more interesting. Overloading volunteers with work will often result in individuals quickly "burning out" and leaving the program. Work must be shared but for many volunteer programs the workload may be heavy, especially in the formative stages of the program requiring time commitments beyond the levels that may be expected by volunteers alone. Programs with these attributes require a sufficient funding base to hire someone to serve as the coordinator . Otherwise the program will probably not come to fruitition. The successful coordinator has the talents of an organizer, teacher, mediator, is well known and respected in the community, and has a strong background in water chemistry, natural resource management and report preparation.

Besides establishing and overseeing the running of a volunteer water quality monitoring program, the coordinator will be responsible for the training of the volunteers. The training undertaken is dependent upon the questions being addressed by the program and the equipment available. Training not only involves the taking of samples and use of the equipment, but also safety as well as QA/QC. Periodic "refresher" training should occur to insure that volunteers are adhering to standards.

The perception of what a volunteer water quality monitoring program is should be broadened to include more than just water quality monitoring. These citizen volunteers can be organized to do important tasks, such as organizing and carrying out the clearing of debris from streams (i.e., stream clean-ups), working with state and county agencies, as well as landowners, to replant existing exotic riparian vegetation with appropriate native and other better soil holding species, working with neighbors and local businesses to curtail the dumping of trash into streambeds, conducting beach clean-ups, assisting in the education of landowners for appropriate land use practices, and helping local schools with their science educational programs.

Perhaps one of the largest benefits to participants in citizen volunteer programs is that of being better informed individuals. By participating, interested citizens learn more about what the real problems and issues are, and how best to solve them. We believe that the Kailua-Waimanalo Volunteer Water Quality Monitoring Program not only demonstrated that citizen groups can carry out scientific monitoring but most importantly, in doing so, these citizens became more informed and thus could make better decisions regarding the future of their communities. Probably one of the best results of the Kailua-Waimanalo Volunteer Water Quality Monitoring Program is that one motivated high school teacher took it upon herself to involve some of her students in the program. Today there is a "second generation" of young adults carrying out water quality monitoring in the Maunawili watershed. These young adults have a much better understanding of the ecological issues and problems existing in their community. It is successes such as this that have made our involvement in this project a real pleasure.

IV. CONCLUSIONS AND RECOMMENDATIONS

Based on the data and experience with administering the Kailua-Waimanalo Volunteer Water Quality Monitoring Program, we have the following recommendations:

1. Citizen volunteer water quality monitoring programs may be successful in obtaining scientifically valid field data if volunteers are trained and equipment available to the program is of sufficient quality to produce high resolution data. Use of low-cost, low-resolution test equipment will provide "ballpark" estimates on parameter concentrations which may be adequate for some programs. The low-resolution equipment probably has its greatest utility as a teaching tool. It should be remembered that processing of water quality samples using high-resolution equipment is expensive and requires the services of a highly trained technician.

2. Any proposed volunteer monitoring program should first develop reasonable and attainable goals and objectives. Part of this effort must focus on the development of scientifically valid questions to be addressed by the program. The development of questions usually requires the assistance of an individual with the appropriate scientific background. Questions to be addressed must match available equipment and funding. All participants must be cognizant of the goals, objectives and questions to be addressed by the program.

3. In some cases, the best use of volunteer groups may not be with water quality monitoring but with the addressing of other environmental concerns. Volunteers may have a much greater positive impact working to improve riparian habitat (such as stream cleaning projects) rather than focusing on water quality issues where problems may not exist. Volunteer groups considering the establishment of a water quality monitoring program should seek advice from knowledgable individuals and governmental agencies, as well as obtain and review all background literature prior to committing resources to water quality monitoring. This recommendation should not be construed as a means of lowering the importance of water quality monitoring; prior work should be reviewed by a competent individual(s) and at a minimum, a small pilot series of samples should be taken to determine if monitoring on a larger scale is warranted.

4. To be successful, a volunteer water quality monitoring project must have committed individuals. Some of these individuals will be volunteers, but all projects should have some level of funding and have a paid coordinator (either in or outside of a governmental agency), who is responsible for overseeing the day-to-day operation of the program. Volunteers are people and must feel that they are making a contribution to the program. Programs capitalizing on citizen assistance must be cognizant of the level of effort that must go into making each and every participant feel they are part of the program.

5. Seek all expert advice and approach the perceived problems in your community with "open eyes." Lay persons and experts all have opinions; do not let opinions guide you in developing the direction(s) for your program, but use all published information. If you feel that an expert is letting his or her opinion rule his thinking, seek the advice from as many experts as is feasible in coming to a decision about the direction of your program. Points of commonality in the advice given are probably the most accurate and least biased, thus should be candidates for inclusion in your program.

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APPENDIX A. Data from the volunteer stream teams given by date of sample collection. Note that blanks indicate missing data and that nitrate and orthophosphate are given in mg/l. Locations of each sample site are given in Figure 1.

1. Maunawili Stream Team Data

Site	Date	NO3 (mg/l)	PO4 (mg/l)	Temp. (oC)	Oxygen (mg/l)	pH
Site 1	(St. Stephens Seminary)					
	11Feb95	0.13	0.18	19.0	9.00	7.50
	11Mar95	0	0.19	21.0	8.50	7.50
	15Apr95	0	0.26	21.0	9.80	7.50
	27May95	0	0.16	23.0	9.00	7.50
	29Jul95	0.02		22.0	8.80	7.50
	23Sep95	0	0.20		8.00	7.75
	10Nov95		0	22.1	7.30	7.30
	14Jan96			21.6	8.46	7.96
	11Feb96	0.04	0.30	19.2	9.40	7.32
	09Mar96	0	0	19.8	8.51	7.35
	13Apr96	0.01	0.20	21.4	8.16	7.51
	17Jun96	0	0	21.8	7.99	7.41
Site 2	(Ainoni Stream)					
	31Jul94	0.01	0.30	24.0		7.75
	11Sep94	0.12	0.36	24.0	9.00	8.00
	22Oct94	0.04	0.46	24.0	9.50	8.00
	19Nov94	0.08	0.20	21.0	10.00	7.50
	14Jan95	0.04	0.20	20.0	9.50	7.90
	11Feb95	0.02	0.30	18.5	9.00	8.00
	11Mar95	0.16	0.32	21.0	9.50	7.50
	15Apr95	0.04	0.45	21.0	8.80	7.50
	29Jul95	0.02		23.0	9.50	8.00
	23Sep95	0.02	0.10		8.10	8.00
	10Nov95		0.14	22.5	9.06	7.90
	14Jan96			21.5	8.54	8.42
	11Feb96	0.06	0.26	19.2	9.65	7.62
	09Mar96	0.02	0.14	20.0	8.60	7.61
	13Apr96	0	0.20	21.4	8.64	7.89
Site 3	(Maunawili Stream at Maunawili Road)					
	31Jul94	0.06	0.30	25.0		8.50
	11Sep94	0.11	0.24	26.0	11.00	8.50
	22Oct94	0.10	0.26	24.0	9.00	8.00
	19Nov94	0.09	0.30	22.0	9.50	7.90
	14Jan95	0.04	0.53	21.0	8.50	8.00
	11Feb95	0.09	0.26	21.0	9.80	8.50
	11Mar95	0.02	0.22	25.0	12.50	8.80

APPENDIX A. Continued

1. Maunawili Stream Team Data (Continued)

Site	Date	NO3 (mg/l)	PO4 (mg/l)	Temp. (oC)	Oxygen (mg/l)	pH
Site 1	(St. Stephens Seminary)					
	11Feb95	0.13	0.18	19.0	9.00	7.50
	15Apr95	0.02	0.70	23.0	9.80	8.50
	27May95	0.04	0.17	24.5	9.00	8.00
	29Jul95	0.04		27.0	8.80	8.50
	23Sep95	0	0.20		8.30	8.30
	10Nov95		0.22	24.5	8.72	8.52
	14Jan96			22.4	9.14	8.88
	11Feb96	0.02	0.18	20.6	10.50	8.03
	09Mar96	0	0.06	20.6	9.25	8.05
	13Apr96	0.01	0.12	24.5	9.80	8.93
	17Jun96	0.05	0.10	21.8	7.99	7.41
Site 4	(Maunawili Stream at Bridge Above Kawainui Marsh)					
	31Jul94	0.08	0.30	25.0		7.50
	11Sep94	0.14	0.28			7.50
	22Oct94	0.10	0.18	23.0	10.00	7.50
	19Nov95	0.10	0.35	22.0	11.00	7.40
	14Jan95	0.10	0.30	21.0	8.12	7.50
	11Feb95	0.05	0.19	20.0	8.30	7.50
	11Mar95	0.08	0.18	23.0	8.80	7.50
	15Apr95	0.04	0.55	22.0	9.00	7.50
	27May95	0.04	0.20	24.0	9.00	7.50
	29Jul95	0.04		24.0	6.45	7.50
	23Sep95	0	0		6.80	7.00
	10Nov95	0.02	0.16	24.0	6.03	7.32
	14Jan96			21.7	7.73	7.84
	11Feb95	0.06	0.12	19.7	9.90	7.28
	09Mar96	0.08	0	19.7	8.0	7.30
	13Apr96	0.02	0.24	23.3	8.20	7.58
	17Jun96	0	0.04	23.7	6.54	7.29
Site 5	(Kawainui Marsh Below Landfill)					
	08Dec94	0.10	0.10	25.0	4.80	7.50
	16Feb95	0.06	0.30	23.0	2.5	7.50
	09Mar95	0.06	0.20	23.0	3.50	7.50
	20Apr95	0.08	0.45	25.0	3.00	7.50
	25May95	0.02	0.19	27.0	6.00	7.50
	22Oct95		0		4.00	7.50
	10Nov95	0	0.22		0.97	7.17
	14Jan96			23.4	1.59	7.59
	11Feb96	0.06	0.38	21.3	4.15	7.11

APPENDIX A. Continued

1. Maunawili Stream Team Data (Continued)

Site	Date	NO3 (mg/l)	PO4 (mg/l)	Temp. (oC)	Oxygen (mg/l)	pH
	09Mar96	0.02	0.18	21.2	6.36	7.39
	13Apr96	0.01	0.26	26.7	4.17	7.24
	17Jun96	0	0.08	26.1	1.2	7.30
Site 6	(Kawainui Marsh Near Dike Road)					
	17Nov94	0	0.55	25.0	4.50	7.00
	08Dec94	0.10	0.04	24.0	2.70	7.00
	16Feb95	0.02	0.20	5.30	7.50	
	09Mar95	0.03	0.51	21.0	4.70	7.30
	20Apr95	0.02	0.35	28.0	6.80	7.90
	25May95	0.01	0.10	28.0	4.80	7.50
	22Oct95		0		7.00	8.00
	10Nov95	0.02	0.08	26.8	2.58	7.07
	14Jan96			22.7	3.30	7.21
	11Feb96	0.02	0.32	22.1	4.03	6.77
	09Mar96	0	0.40	23.2	3.05	6.79
	13Apr96	0.01	0.26	26.7	4.17	7.24
	17Jun96	0.02	0.08	25.8	2.57	6.97
Site N	(Kahanaiki Stream At Auloa Road Bridge)					
	11Mar95	0.02	0.60	22.0	8.50	7.50
	15Apr95	0	0.55	22.1	7.50	7.50
	27May95	0.06	0.16	27.0	8.00	7.50
Site O	(Upper Maunawili Stream)					
	22Oct94	0.13	0.68	23.0	11.00	8.00
Site P	(Makawao Stream At Farmers Road)					
	31Jul94	0.04	0.10	25.0		7.50
	11Sep94	0.18	0.66	24.0	8.00	7.50
Site Q	(Kahanaiki Stream)					
	19Nov94	0	0.16	22.0	9.50	7.60
	14Jan95	0.10	0.38	20.5	10.00	7.50
Site R	(Omao Stream at Manuawili Road)					
	31Jul94	0.02	0.40	25.0	9.75	7.50
	11Sep94	0.12	0.44	25.0	8.00	7.50

2. Waimanalo Stream Team Data

Site	Date	NO3 (mg/l)	PO4 (mg/l)	Temp. (oC)	Oxygen (mg/l)	pH
Site A	(End of Waikupanaha at Bridge)					
	17Jun94		0.36	22.5	8.50	7.50
	28Jun94		0.57		9.50	7.50
	09Jul94	0.04	0.38	25.0	8.50	7.50
	19Jul94	0.02	0.40	25.0	8.80	7.50
	17Sep94	0	0.35			7.50
	29Oct94	0.03	0.59	20.5	8.75	7.50
	14Jan95	0.06	0.24	20.0	9.00	

APPENDIX A. Continued

2. Waimanalo Stream Team Data (Continued)

Site	Date	NO3 (mg/l)	PO4 (mg/l)	Temp. (oC)	Oxygen (mg/l)	pH
Site B (Bridge at Waikupanaha and Kumuhau, Upstream)						
	17Jun94	0.35	24.0	6.30	7.50	
	28Jun94		0.43		7.50	7.50
	09Jul94	0.40	0.29	26.0	6.50	7.00
	19Jul94	0.41	0.33	25.0	6.50	7.50
	17Sep94	0.15	0.15			7.50
	29Oct94	0.20	0.50	21.0	8.25	7.50
	14Jan95	0.25	0.52	21.0	8.00	
Site C (At Bridge Northwest of Junction of Kumuhau and Mahaiula Streets)						
	17Jun94		0	25.0	10.00	7.50
	28Jun94		0.34		10.00	7.50
	09Jul94	0.70	0.42	27.0	9.00	7.50
	19Jul94	0.53	0.29	26.0	8.00	7.50
	17Sep94	0.80	0.14	28.0		7.50
	29Oct94	0.65	0.32	24.0	9.00	7.50
	14Jan95	0.73	0.38	21.0	9.00	
Site D (At Bridge Northwest of Frankie's Drive-In)						
	17Jun94		0.02	30.0	16.30	9.00
	28Jun94		0.32		17.50	9.00
	09Jul94	0.30	0.44	34.0	16.00	9.50
	19Jul94	0.27	0.18	33.0	11.80	9.00
	17Sep94	0.20	0.20	30.0		7.50
	29Oct94	0.55	0.28	24.0	15.25	8.00
	14Jan95	0.21	0.23	23.0	15.00	
3. Kahawai Stream Team Data						
Site E (At Hawaiian Floral Nursery)						
	06Jul94	0	0.06	22.0	3.00	7.70
	27Jul94	0.02	0.14	22.0	7.50	7.50
	14Jan95	0.02	0.21	20.0	7.00	
Site F (Makai of Bridge at Mahaiula and Kakaina Streets)						
	29Jun94	0.08	0.14	23.0	2.50	7.50
	06Jul94	0	0.26	22.5	4.00	7.50
	27Jul94	0.04	0.12	23.0	5.50	7.25
	14Jan95	0.02	0.08	21.0	5.75	
Site G (Makai of Frankie's Drive-In)						
	15Jun94	0.12	0.20	27.0	6.50	7.75
	29Jun94	1.00	0.14	24.5	6.00	7.50
	06Jul94	2.50	0.12	24.5	7.50	7.25
	27Jul94	1.00	0.12	25.0	12.50	7.25
	14Jan95	0.26	0.20	24.0	14.00	

APPENDIX A. Continued

3. Kahawai Stream Team Data (Continued)

Site	Date	NO3 (mg/l)	PO4 (mg/l)	Temp. (oC)	Oxygen (mg/l)	pH
Site S	(Puha Stream Makai of Tinker Road)					
	25May94	0	0.20	25.0	5.50	7.00

4. Kaelepulu Stream Team Data

Site	Date	NO3 (mg/l)	PO4 (mg/l)	Temp. (oC)	Oxygen (mg/l)	pH	Salinity (o/oo)
Site 12	(Bridge at Wanaao Road)						
	15Jun94	0					22
	18Jun94		0.06	26.6	5.00		20.5
	22Jun94		0.18	28.2	6.00	8.50	21
	25Jun94	0.18	0	26.7	4.00	8.00	17
	29Jun94	0	0.12	25.0	6.50	8.50	18
	02Jul94	0	0	26.8	3.50	8.30	19
	06Jul94			29.5	3.20		
	13Jul94	0	0.10	29.9	4.50	8.40	20
Site H	(Hamakua Stream Near Auwina Street)						
	15Jun94		0.23				20
	18Jun94		0.06	25.0	7.00		15
	22Jun94		0.02	26.0	4.00	7.00	16
	25Jun94	0.09	0.02			8.00	15
	29Jun94	0	0.12	28.5	6.00	8.50	15
	02Jul94	0	0			8.30	15
	06Jul94			29.3	4.00		
	13Jul94	0	0.08	30.1	5.50	8.10	17.5
Site I	(Kaelepulu Stream Near Akumu Place)						
	15Jun94		0.10	27.1	8.00		24
	18Jun94		0.04	27.1	3.00		26
	22Jun94	0	0.18	28.5	7.00	8.50	25
	25Jun94	0	0.20	26.8	4.00	8.20	25
	29Jun94	0	0.12		8.10	24	
	02Jul94	0	0.20	27.4	3.00	8.30	23
	13Jul94	0	0.12	29.4	5.00	8.50	24
Site J	(Kaelepulu Pond at Ohiki Place)						
	15Jun94		0.10				26
	18Jun94		0.13				24
	22Jun94	0.12				8.50	26
	25Jun94	0	0.10	26.9	4.00	8.00	24
	29Jun94	0	0.12			8.50	
	02Jul94	0	0.10	26.9	3.75	8.30	24
	06Jul94		29.0	5.50			

APPENDIX A. Continued

4. Kaelepulu Stream Team Data (Continued)

Site	Date	NO3 (mg/l)	PO4 (mg/l)	Temp. (oC)	Oxygen (mg/l)	pH	Salinity (o/oo)
	13Jul94	0	0.12	29.5	5.50	8.60	25.5
Site M	(Unnamed Intermittent Stream at Kalanianaole Road)						
	18Jun94		0.35	23.6	6.00		0.5
	22Jun94	1.70	0.48	26.0	4.00	7.00	1
	25Jun94		0.50	23.1	4.00	7.00	0
	29Jun94	2.20	0.12	24.6	4.50	7.20	0
	02Jul94	2.43	0.64	24.5	4.00	7.00	0
	06Jul94			23.6	3.00		
	13Jul94	1.01	0.60	23.8	4.00	7.00	0.5

APPENDIX B. Summary of water quality data collected by the University of Hawaii team during the course of this project. In the body of the table are given the concentrations of parameters in ug/l unless otherwise noted. Data are presented by date; station locations are given in Figure 1. ND = below limits of detection; for salinity >0.100 ppt.

Site	Date	NO3	NH4	TN	PO4	TP	DON	DOP	Si
2	14Jan95	114.94	4.62	149.80	29.76	33.48	30.24	3.72	13016.08
3	14Jan95	55.30	6.58	112.42	8.06	11.78	50.54	3.72	11805.36
4	14Jan95	73.78	9.80	126.00	8.99	18.29	42.42	9.30	13016.08
A	14Jan95	26.04	3.22	81.34	22.94	28.83	52.08	5.89	14529.76
B	14Jan95	222.46	11.34	292.60	16.43	31.93	58.80	15.50	13924.40
C	14Jan95	620.62	6.58	777.14	12.09	23.25	149.94	11.16	14378.28
D	14Jan95	473.06	6.58	591.08	3.41	8.68	111.44	5.27	13621.72
E	14Jan95	63.98	6.58	145.32	21.08	37.82	74.76	16.74	15891.96
F	14Jan95	28.28	651.28	633.64	1.55	4.96	0	3.41	12259.52
G	14Jan95	7868.64	1869.14	8421.14	15.81	24.18	0	8.37	14983.64
Q	14Jan95	3.22	4.90	54.32	9.92	16.74	46.20	6.82	14983.64
1	11Mar95	19.88	0.14	64.68	8.06	13.02	44.66	4.96	16013.20
2	11Mar95	192.50	0.42	235.48	17.67	21.08	42.56	3.41	12975.20
3	11Mar95	20.72	0	86.38	0.31	4.34	65.66	4.03	12056.80
4	11Mar95	125.02	7.00	229.88	0	5.58	97.86	5.58	13734.00
5	11Mar95	43.40	3812.20	4130.00	21.70	40.30	274.40	18.60	14655.20
6	11Mar96	6.16	6.16	441.56	25.42	27.28	429.24	1.86	11508.00
N	11Mar95	25.90	1.82	106.12	0.93	8.99	78.40	8.06	15733.20
1	10Nov95	16.49	2.24	110.88	8.06	13.95	91.70	5.89	14786.52
2	10Nov95	55.02	3.22	126.14	22.63	31.00	67.90	8.37	13377.84
3	10Nov95	19.04	5.18	124.74	5.89	37.51	100.52	31.62	11794.16
4	10Nov95	56.42	37.66	220.50	15.81	23.56	126.42	7.75	13247.64
5	10Nov95	6.02	4195.80	5585.30	0	49.60	1383.48	49.60	14269.08
6	10Nov95	3.92	17.64	481.32	12.40	17.98	459.76	5.58	8831.76
7	10Nov95	10.22	6.72	170.52	6.51	16.12	153.58	9.61	1016.96
8	10Nov95	3.36	4.90	119.42	4.03	13.02	111.16	8.99	274.40
9	10Nov95	1.68	3.50	103.74	3.10	11.16	98.56	8.06	47.88
10	10Nov95	1.12	3.22	109.20	3.10	11.16	104.86	8.06	30.80
11	10Nov95	1.12	0.42	95.06	3.10	11.47	93.52	8.37	30.52
12	10Nov95	1.54	4.76	434.70	2.48	21.08	428.40	18.60	325.36
13	10Nov95	24.08	95.06	649.46	22.94	48.36	530.32	25.42	226.24
14	10Nov95	0	5.04	459.20	2.17	20.46	454.16	18.29	347.48
15	10Nov95	0.42	4.62	116.06	3.10	11.47	111.02	8.37	44.80
16	10Nov95	0.28	1.12	94.36	1.55	9.61	92.96	8.06	33.60
17	10Nov95	0.14	0	94.92	1.55	9.61	94.78	8.06	33.32
18	10Nov95	0.28	0.56	94.64	2.17	9.61	93.80	7.44	32.48
19	10Nov95	0.28	0.42	94.08	1.86	9.61	93.38	7.75	38.92
1	26Jan96	73.78	0.45	139.02	3.72	9.92	64.79	6.20	12835.20
3	26Jan96	375.76	0.98	447.58	4.34	9.61	70.84	5.27	9477.44

APPENDIX B. Continued

Site	Date	NO3	NH4	TN	PO4	TP	DON	DOP	Si
4	26Jan96	482.02	15.68	680.54	15.50	24.80	182.84	9.30	10800.72
5	26Jan96	3451.98	120.68	3827.32	24.49	37.20	254.66	12.71	9089.92
6	26Jan96	401.66	108.78	918.12	20.77	58.90	407.68	38.13	5563.88
7	26Jan96	312.20	109.90	804.58	26.35	44.33	382.48	17.89	5180.00
8	26Jan96	305.76	114.24	812.84	32.86	58.59	392.84	25.73	5449.36
9	26Jan96	287.00	117.46	775.32	24.49	35.34	370.86	10.85	4829.72
10	26Jan96	296.94	115.36	773.64	36.27	51.77	361.34	15.50	5086.48
11	26Jan96	155.40	61.04	452.90	17.98	31.93	236.46	13.95	2382.24
12	26Jan96	593.46	281.54	1502.62	166.78	196.85	627.62	30.07	4633.72
13	26Jan96	1221.22	82.18	1786.40	113.46	137.02	483.00	23.56	3986.64
14	26Jan96	938.98	120.40	1473.92	127.72	146.32	414.54	18.60	3446.52
15	26Jan96	931.14	110.74	1513.68	117.49	143.53	471.80	26.04	3553.76
16	26Jan96	33.04	8.26	175.00	8.06	18.91	133.70	10.85	145.88
17	26Jan96	30.66	9.38	143.50	8.68	18.29	103.46	9.61	140.28
18	26Jan96	50.54	8.26	179.20	9.30	19.53	120.40	10.23	205.80
19	26Jan96	23.94	14.70	159.18	13.02	26.66	120.54	13.64	131.60
1	17Jun96	20.02	71.82	139.30	8.06	10.85	47.46	2.79	15813.00
3	17Jun96	35.42	44.94	128.38	2.48	6.82	48.02	4.34	12165.72
4	17Jun96	151.34	37.80	240.38	13.02	15.50	51.24	2.48	13902.28
5	17Jun96	43.82	1783.18	4878.02	0.62	13.64	3051.02	13.02	14853.44
6	17Jun96	0.14	122.22	551.04	37.51	39.37	428.68	1.86	12081.72
7	17Jun96	11.76	6.58	176.68	5.58	12.71	158.34	7.13	1544.76
8	17Jun96	1.26	4.62	119.00	2.48	9.61	113.12	7.13	116.48
9	17Jun96	0.98	3.36	147.42	2.17	10.23	143.08	8.06	123.20
10	17Jun96	0.42	3.50	112.56	2.17	8.99	108.64	6.82	202.16
11	17Jun96	0.42	3.92	109.90	2.17	9.30	105.56	7.13	196.84
12	17Jun96	11.48	16.49	404.32	4.65	21.08	375.90	16.43	2761.36
13	17Jun96	2.80	41.30	475.02	24.80	41.23	430.92	16.43	1723.40
14	17Jun96	0	2.10	322.56	4.03	17.05	320.46	13.02	1380.12
15	17Jun96	0.56	6.02	131.46	2.17	10.54	124.88	8.37	158.76
16	17Jun96	0.56	5.46	122.22	1.86	8.99	116.20	7.13	242.20
17	17Jun96	0.56	6.30	98.14	1.55	8.37	91.28	6.82	28.00
18	17Jun96	0.56	7.00	98.28	1.24	8.37	90.72	7.13	20.16
19	17Jun96	0.84	6.86	110.46	1.24	8.06	102.76	6.82	22.12

Site	**Date**	**Salinity (o/oo)**	**Turbidity (NTU)**	**Chl-a ug/l**	**Temp (oC)**	**pH**	**Oxygen (%Sat)**
2	14Jan95	ND	3.05	0.381	19.9	7.52	9.19
3	14Jan95	ND	1.59	1.053	20.3	7.77	9.27
4	14Jan95	ND	3.50	0.392	20.2	7.14	8.15
A	14Jan95	ND	2.10	0.262	19.9	7.37	7.80
B	14Jan95	ND	7.15	0.237	20.5	7.24	6.88

APPRENDIX B. Continued

Site	Date	Salinity (o/oo)	Turbidity (NTU)	Chl-a ug/l	Temp (oC)	pH	Oxygen (%Sat)
C	14Jan95	ND	2.70	1.086	21.3	6.98	6.08
D	14Jan95	ND	1.32	5.860	22.4	9.54	13.55
E	14Jan95	ND	0.53	0.768	20.9	7.57	7.31
F	14Jan95	ND	18.40	0.900	21.5	6.89	4.47
G	14Jan95	ND	1.40	5.767	23.2	7.03	12.08
Q	14Jan95	ND	1.82	0.523	20.4	7.32	8.39
1	11Mar95	ND	0.87	0.025	21.4	7.51	8.16
2	11Mar95	ND	0.97	0.033	21.0	7.50	9.50
3	11Mar95	ND	1.82	0.885	25.0	8.50	12.50
4	11Mar95	ND	2.40	0.043	23.0	7.50	8.80
5	11Mar95	ND	10.80	1.968	23.0	7.50	3.50
6	11Mar95	ND	8.30	0.107	21.0	7.30	4.70
N	11Mar95	ND	2.00	0.033	22.0	7.50	8.50
1	10Nov95	ND	0.90	0.025	22.1	7.30	7.30
2	10Nov95	ND	7.50	0.071	22.5	7.90	9.06
3	10Nov95	ND	5.50	0.667	24.5	8.52	8.72
4	10Nov95	ND	5.80	0.028	24.0	7.32	6.03
5	10Nov95	6.946	25.00	6.525	25.3	7.17	0.97
6	10Nov95	7.095	6.50	0.999	26.8	7.07	2.58
7	10Nov95	31.850	.50	0.598	27.4	7.93	6.38
8	10Nov95	34.523	2.40	0.301	27.2	8.08	7.30
9	10Nov95	35.111	2.40	0.127	27.2	8.12	7.40
10	10Nov95	35.138	2.10	0.117	26.8	8.05	7.10
11	10Nov95	35.150	1.00	0.213	27.0	8.05	7.50
12	10Nov95	25.144	1.30	2.322	27.9	8.06	6.38
13	10Nov95	25.804	3.10	3.129	28.6	7.67	4.38
14	10Nov95	30.778	3.40	1.967	29.8	8.16	6.23
15	10Nov95	35.254	4.00	0.211	27.6	8.08	6.45
16	10Nov95	35.260	0.90	0.249	26.7	8.03	6.32
17	10Nov95	35.241	1.00	0.160	26.7	8.03	6.32
18	10Nov95	35.250	1.20	0.159	26.7	8.08	6.42
19	10Nov95	35.240	0.70	0.127	26.7	8.10	6.36
1	26Jan96	ND	3.20	0.028	20.6	6.92	8.42
3	26Jan96	ND	4.90	0.066	21.4	6.86	8.35
4	26Jan96	ND	17.10	0.023	21.5	6.90	7.85
5	26Jan96	ND	770.00	0.198	22.3	7.38	7.32
6	26Jan96	ND	176.00	0.176	21.2	6.46	3.37
7	26Jan96	0.554	175.00	0.413	21.4	6.67	3.51
8	26Jan96	1.522	240.00	0.297	21.4	6.51	3.54
9	26Jan96	4.007	162.00	0.231	21.5	6.79	3.96
10	26Jan96	2.702	173.00	0.191	21.5	6.87	4.17
11	26Jan96	19.965	62.00	0.248	22.2	7.41	6.71

APPRENDIX B. Continued

Site	Date	Salinity (o/oo)	Turbidity (NTU)	Chl-a ug/l	Temp (oC)	pH	Oxygen (%Sat)
12	26Jan96	3.041	27.00	0.150	22.4	7.04	3.46
13	26Jan96	2.690	360.00	0.084	21.9	6.91	6.73
14	26Jan96	4.209	38.00	1.033	22.2	7.08	6.05
15	26Jan96	4.113	36.00	0.582	22.2	7.13	6.12
16	26Jan96	33.297	3.40	0.372	23.8	7.85	6.45
17	26Jan96	33.372	4.50	0.464	23.8	7.88	6.52
18	26Jan96	32.747	1.70	0.363	23.8	7.91	6.49
19	26Jan96	33.682	13.00	0.549	23.8	7.91	6.52
1	17Jun96	ND	1.00	0.053	21.8	7.41	7.99
3	17Jun96	ND	3.60	0.727	25.4	8.60	9.02
4	17Jun96	ND	2.60	0.087	23.7	7.29	6.54
5	17Jun96	0.717	19.30	10.486	26.1	7.30	1.21
6	17Jun96	1.161	14.60	0.509	25.8	6.97	2.57
7	17Jun96	30.729	1.90	0.879	28.3	8.01	6.45
8	17Jun96	34.816	1.50	0.120	27.2	8.00	7.20
9	17Jun96	34.882	2.00	0.164	27.0	8.16	6.90
10	17Jun96	34.414	0.90	0.226	27.5	8.11	6.58
11	17Jun96	34.425	2.70	0.177	27.5	8.13	6.65
12	17Jun96	27.972	3.30	4.328	29.2	7.92	4.30
13	17Jun96	22.896	7.10	1.866	31.0	8.07	5.97
14	17Jun96	26.350	1.90	1.766	29.2	8.06	5.60
15	17Jun96	35.066	0.90	0.235	27.5	8.12	6.56
16	17Jun96	35.336	0.40	0.085	27.4	8.10	6.53
17	17Jun96	35.334	0.50	0.081	27.4	8.12	6.61
18	17Jun96	35.326	0.70	0.048	27.3	8.10	6.70
19	17Jun96	35.314	6.00	0.050	27.4	8.10	6.79

SECTION 4

BIBLIOGRAPHY OF DOCUMENTS REGARDING VOLUNTEER PROGRAMS AND WATER QUALITY MONITORING

PURPOSE

This section is a bibliography of documents that are useful for any volunteer water quality monitoring program, whether in Hawai'i or elsewhere. Many of the documents cited in this section are from state and/or federally funded programs. We have reproduced the title page, table of contents and abstract (where available) of each of these, as well as the addresses of where they may be available.

If you are starting a volunteer monitoring program, check your local library for any area-specific information that may be available. Tap all resources for information including specialists in local and state governments as well as your universities.

Guide to Environmental Issues

October, 1995

Office of Solid Waste & Emergency Response

Project Manager and Editor:
Julie Klaas Pangman

Cover photo: Bottomland Hardwoods, Yazoo National Wildlife Refuge, Mississippi, courtesy U.S. Fish & Wildlife Service.

This ***Guide To Environmental Issues*** was based in concept and format on *Citizens' Guide for Environmental Issues - A Handbook for Cultivating Dialogue* by the National Institute for Chemical Studies and U.S. EPA, 1989 and 1990.

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Note: **Bold face** terms used throughout are defined in the Glossary, Laws Section, or Government Agencies Section.

introduction

By choosing to read this Guide, you are showing your concern for the environment. Many of our daily activities can potentially alter environmental balances, but too often we ignore relationships among people, other living creatures, and our surroundings.

Environmental protection can be most effective when complex connections between all parts of an **ecosystem** and society are taken into account. No longer can we say, *"I'm too busy to be concerned with the environment—someone else can take care of it."*

citizen participation

That someone is you. Citizen participation is a key element in environmental protection. This Guide is dedicated to the enthusiastic interest and creative ideas of people across the country who are concerned about the nation's environmental health. Diverse elements of everyday life make each contribution unique. The abilities and vision of a multitude of people need to be applied to the public decision-making process.

information sources

Although protective laws respond to public needs, we need to understand how laws and regulations work in real situations. Knowing where to turn for help is sometimes as difficult as understanding which issues are addressed by specific environmental laws.

This handbook lists federal and state agencies as well as pertinent health, safety, and environmental laws, with brief comments on each law's intent.

the terminology problem

Discussing complex economic, technical, health, safety, and environmental issues can be frustrating. Many environmental conversations evolve into a series of acronyms, technical terms, and jargon that can leave you confused unless you have been previously involved with the issues. When words or phrases remain undefined, dialogue is likely to be limited. With *Guide to Environmental Issues*, we try to make specific concepts clear to all so that language and limited access to information do not hinder public participation.

When you see a term in **bold,** that word is defined in the Glossary in the back or may refer to a specific Law or Government Agency. We included terms and definitions relating to **pollution prevention**, enforcement, regulations, community involvement, and environmental **risk.** We also included a variety of technical terms and acronyms frequently used by subject matter specialists.

Please note that many terms in the text and glossary may have different meanings for different audiences. Definitions and explanations presented here provide only a general understanding of the terminology and should not be taken as full technical or legal definitions. Although much more could be said about any topic, the information provides the basics in non-bureaucratic English. We hope this Guide helps you become actively involved in community dialogue and better able to understand environmental issues.

where do I get help?

Have you ever wondered where to turn for answers to environmental problems? If so, you are not alone. In the back of this Guide we have listed four pages of EPA and federal agency telephone numbers and addresses, followed by two pages of **Hotlines** that EPA maintains for general and specific information. But protection of the environment is a big job. Federal, state, and local agencies across the nation are all involved, employing thousands of citizens who care about their health and natural resources. Every city, county, and state networks with federal groups to share and provide information. If the first person you contact can't answer a specific question, he or she will know who can.

Civic and community organizations are usually helpful too. Chances are, if you contact one group that is not involved with a particular topic, you will be steered to the correct organization. In some areas, environmental and other community groups have formed coalitions for improved communications and action on specific issues.

The literally thousands of trade and citizen groups involved in environmental issues are far too numerous to list. Your local telephone Yellow Pages contains a directory of many groups and their respective telephone numbers. You should contact those groups whose interests are similar to yours.

Rhode Island Sea Grant | University of Rhode Island | Narragansett, RI 02882

United States Environmental Protection Agency | Office of Water (4101) | EPA 841-B-94-001 January 1994

EPA

National Directory of Volunteer Environmental Monitoring Programs

Fourth Edition

Volunteer Estuary Monitoring:

A Methods Manual

U.S. Environmental Protection Agency
Office of Water
Office of Wetlands, Oceans, and Watersheds
Oceans and Coastal Protection Division
401 M Street, SW (4504F)
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Executive Summary

Overview

As concern over the well-being of the environment has risen during the past couple of decades, volunteer monitoring has become an integral part of the effort to assess the health of our nation's waters. Government agencies, often strapped by financial limitations, have found that volunteer programs can provide high quality reliable data to supplement their own water quality monitoring programs.

Along with lake, river, and stream programs, monitoring of the estuaries fringing our coastlines has grown significantly from the early programs that monitored only a few simple parameters. Although many programs still monitor a basic suite of water quality measures, others cover a wide realm of parameters.

As these programs have developed, so has the interest of the Environmental Protection Agency (EPA) which has supported volunteer monitoring since 1987. The EPA has sponsored three national symposia on volunteer monitoring, publishes a newsletter for volunteers, has developed guidance manuals and a directory of volunteer organizations, and provides technical support to the volunteer programs. Through these efforts, the EPA hopes to foster the interest and support of state and other agencies in these volunteer programs.

The EPA developed this estuary manual as a companion to three other documents: The *Volunteer Water Monitoring: A Guide for State Managers*, *Volunteer Lake Monitoring: A Methods Manual*, and *Volunteer Stream Monitoring: A Methods Manual* (in progress). This manual presents information and methodologies specific to estuarine water quality. Both the organizers of the volunteer programs and the volunteers themselves should find the manual of use.

The focus of the manual is the identification of those water quality parameters that are most important in determining an estuary's water quality. The significance of each parameter and specific methods to monitor it are then detailed in a step-by-step fashion. The manual stresses proper quality assurance and quality control techniques to ensure that the data are useful to state agencies and any other data users.

Chapter 1 summarizes the process of planning and managing a volunteer monitoring program, borrowing from the principles established in the *Volunteer Water Monitoring: A Guide for State Managers*. Chapter 2 follows with a discussion of the particular problems that afflict our nation's estuaries. Chapter 3 describes those parameters that paint a broad-brush picture of an estuary's fundamental nature and outlines how to measure them. Chapters 4 through 7 take a detailed look at the most important parameters used in describing the water quality status of an estuary: dissolved oxygen, nutrients and phytoplankton, submerged aquatic vegetation, and bacteria. Most volunteer programs measure one or more of these parameters.

Dissolved Oxygen

Dissolved oxygen, critical for the survival of most aquatic animals, is one of the best indicators of an estuary's health. Chapter 4 discusses sampling considerations, such as different methods of monitoring dissolved oxygen and where and when to sample, as well as the specific steps to measure dissolved oxygen levels using a Winkler Titration kit.

Nutrients and Phytoplankton

Of all the nutrients necessary to sustain life, phosphorus and nitrogen are the two of most concern in estuaries since an overabundance of these nutrients can trigger a chain of oxygen-depleting events. Chapter 5 discusses where to sample in the water column for these nutrients, the different types of sampling methods, and the procedures for sampling nutrients using either a test kit or preparing the sample for laboratory analysis. The chapter also covers the significance of phytoplankton and how to sample these tiny floating plants.

Submerged Aquatic Vegetation (SAV)

For those estuaries that can support the growth of SAV, these plants provide a valuable indicator of overall estuary health. Chapter 6 describes common SAV species found in the estuaries along our nation's coasts. The chapter also considers the choice of sampling sites and provides a step-by step description of how to monitor SAV using the groundtruthing method.

Bacteria

Although bacteria are natural inhabitants of estuarine ecosystems, human activities often introduce excess or pathogenic bacteria to their waters. Coliform bacteria are generally good indicators of the possible presence of pathogenic bacteria. Chapter 7 describes the reasons for monitoring fecal coliform bacteria levels either by water sampling or through shellfish monitoring. The chapter also describes bacteria sampling considerations and how to monitor bacteria levels by collecting a water sample for laboratory analysis.

The Rest of the Manual . . .

Some programs may want to add other specific volunteer tasks to their roster. Chapter 8 discusses the monitoring of marine debris, organizing a beach cleanup program, and collecting shellfish for toxic substance, bacteria, or paralytic shellfish poisoning analysis.

Training volunteers should be an integral part of any volunteer monitoring effort to ensure sound and consistent data collection techniques. Training also motivates the volunteers and impresses upon them the importance of high quality data. Chapter 9 discusses the reasons for training volunteers and the steps necessary to ensure complete and interesting training sessions.

The manual concludes with a discussion of data presentation and the importance of credible data. Chapter 10 highlights different data presentation techniques, the use of graphics, and the importance of summary statistics. A case study, using a fictitious estuary named Windward Bay, exemplifies ways to present volunteer data and techniques to interpret estuarine data.

At the end of each chapter, references and materials from existing volunteer monitoring estuary programs are listed. These references should prove a valuable source of detailed information to anyone interested in establishing a new volunteer program or a background resource to those with already established programs.

Volunteer Lake Monitoring:

A Methods Manual

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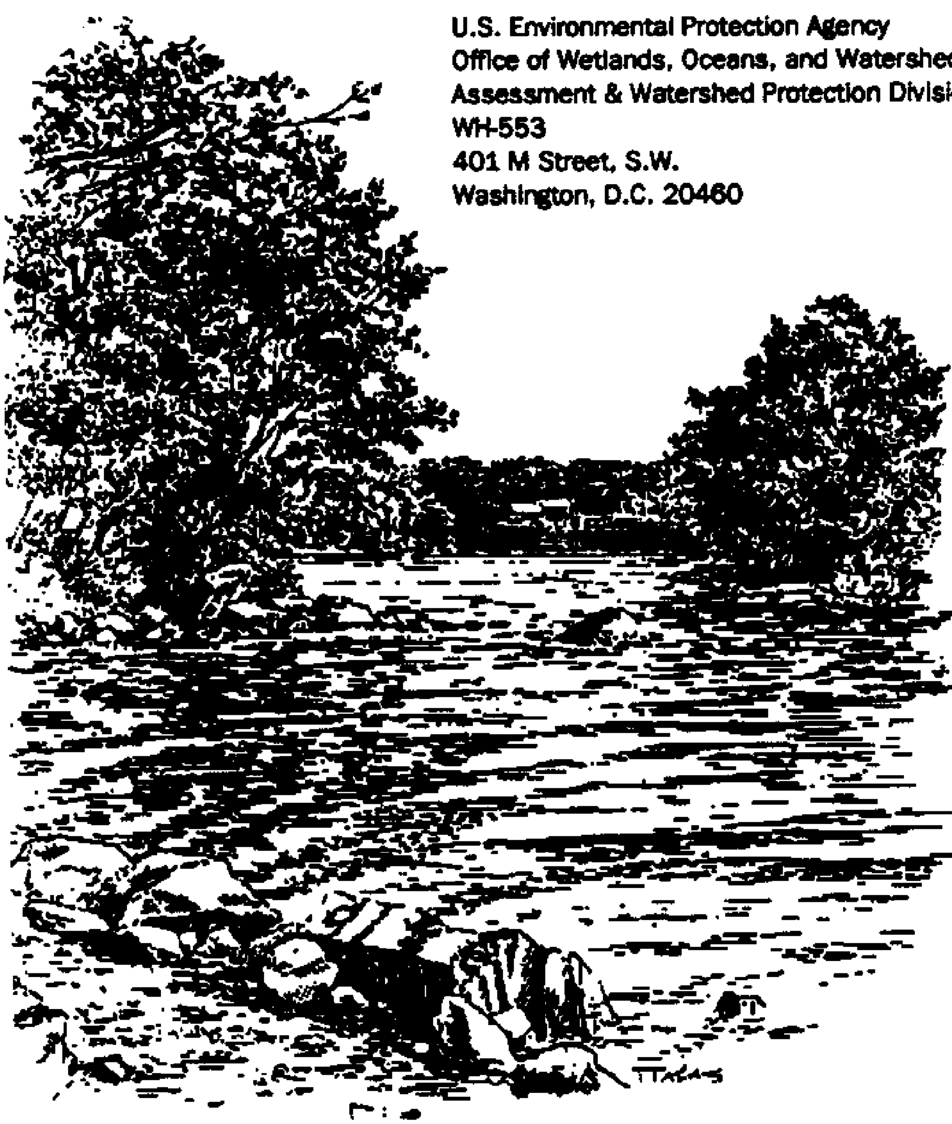

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Executive Summary

Overview

Increasingly, State, local, and Federal agencies are finding that citizen volunteers are valuable partners in programs to monitor and protect our Nation's water resources. Among the most developed and widespread of these volunteer programs are those that monitor existing or potential lake pollution problems.

The U.S. Environmental Protection Agency (EPA) has supported the volunteer monitoring movement since 1987 by sponsoring two national volunteer monitoring symposia, publishing a newsletter for volunteers and a directory of volunteer organizations, developing guidance manuals, and providing technical assistance. These activities have been designed to help State and other agencies understand the value of volunteer monitoring programs, both as potential sources of credible data and as catalysts for developing an educated and involved citizenry.

The EPA has developed this manual to present specific information on volunteer lake water quality monitoring methods. It is intended both for the organizers of the volunteer lake monitoring program, and for the volunteer who will be actually be sampling lake conditions. Its emphasis is on identifying appropriate parameters to monitor and setting out specific steps for each selected monitoring method. Careful quality assurance/quality control procedures are advocated throughout this manual to ensure that the data collected by volunteers are useful to States and other agencies.

This manual begins by summarizing the steps necessary to plan and manage a volunteer monitoring program, including setting general goals, identifying the uses and users of collected data, and establishing sound quality assurance procedures. Rather than addressing every parameter and method that might be monitored by the citizen volunteer, this manual concentrates special attention on three of the most common lake pollution problems: increased algal growth; increased growth of rooted aquatic plants; and lowered or fluctuating levels of dissolved oxygen. All three are common symptoms of human-induced (cultural) eutrophication. Other lake conditions that can be monitored by volunteers are also briefly discussed including sedimentation, turbidity, lake acidification, and bacteriological condition.

Increased Algal Growth

This manual discusses three parameters most commonly used by volunteer monitoring programs to measure the algal condition of a lake: Secchi disk transparency (a measure of water clarity and, indirectly, of algal density); chlorophyll *a* (a more reliable indicator of algal density); and total phosphorus (a measure of water fertility). Ideally, all three should be measured in a monitoring program. Step-by-step instructions are provided on sampling procedures.

Increased Growth of Rooted Aquatic Plants

Three procedures are recommended for assessing the overgrowth of rooted aquatic plants: mapping the distribution of plant beds in the lake; estimating the density of plants along a transect line in a selected part of the lake; and collecting plant specimens for professional identification. Specific procedures are outlined.

Lowered or Fluctuating Levels of Dissolved Oxygen

Dissolved oxygen conditions are best characterized by measuring the dissolved oxygen and temperature profiles of the lake (measurements taken from the lake surface to the lake bottom at set intervals).

In addition to discussing specific sampling methods and equipment, this manual outlines a specific volunteer training process. Training the citizen volunteer is an essential component of a successful monitoring program. Time and resources should be budgeted up front to plan, present, and evaluate volunteer training, both at the start of the program and as periodic follow-up and "continuing education." The payoff includes: more effective, involved, and confident volunteers; better data; and more efficient use of the coordinator's (and volunteer's) time and energy.

This manual concludes with advice on how to present volunteer-collected data. After all, a volunteer program is of little value if the generated data are not translated into information useful both to the volunteers and to the managers of the program. Hints and examples are provided on presenting data results to meet the needs and level of knowledge of the data users.

This manual attempts to provide a comprehensive overview of standard lake volunteer monitoring methods. However, it cannot claim to cover every conceivable approach. Methods and equipment other than those described here may be perfectly acceptable and meet the needs of the programs that employ them.

Reference documents and material from existing lake volunteer monitoring programs are cited at the end of each chapter to provide the reader with additional detailed information on methods, limnology, data quality considerations, and program planning. Anyone interested in establishing a lake volunteer monitoring program is strongly encouraged to consult these references and to evaluate the experiences, goals, and techniques of the many successful volunteer lake monitoring programs already underway.

Field Manual for Water Quality Monitoring

An Environmental Education Program for Schools

(Eighth Edition)

♦

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Schools interested in obtaining additional water quality educational activities are encouraged to contact the GREEN Project.

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1

OVERVIEW

As a guide to measuring water quality, this manual is a step in the long-term process of restoring the health of the world's rivers. But it is also part of an even larger task: namely, improving our educational systems, and creating new ways of thinking about ourselves and how we relate to other life forms on the planet and to nature as a whole.

More and more people are realizing that we need to find better ways to share our world's natural resources with each other and with other species to ensure that the planet can support life in the future. By allowing poison in our rivers, we are slowly drinking it ourselves. Everything we do affects our water. We are beginning to see how important each of us is to making the world a better place to live, no matter what kind of work we do or how intelligent society says we are.

This manual covers two main components of a model of education that we have found to be a useful approach to learning about river systems and many other topics. The first piece of this model, which is called action research, is the data collection component. The objective of this component is to identify community issues to study. In some cases, students will select these issues, and in others, teachers will already have identified some issues that they think students might want to examine.

In river studies, data collection is done in the form of water quality testing. In addition, students make note of the thoughts, feelings, images, sounds, and smells that strike them in their experiences with the river and its surroundings. These informal observations, or sensory impressions, are not only important, but they often motivate us to make the transition to the second component of the action research model: the problem-solving/action-taking component.

For the problem-solving component, students, teachers, and citizens team up to devise actions to raise the quality of our environment. This component links what we study in school to how we live.

As action researchers we are both learners and doers. We not only test rivers to determine the water's health, but we also prescribe "treatment" or courses of action. In addition to the water quality tests, this manual includes several examples of actions that students and other citizens have taken on behalf of their rivers.

The specific skills that this manual is designed to teach you are:

1. to understand the meaning of nine important tests for measuring water quality;
2. to become familiar with important sources of water pollution and ways to help solve those problems;
3. to learn how to run accurate water quality tests; to determine how the tests relate to each other;
4. to run the tests on the river safely; and to understand what the test results mean in terms of human uses of the river.

There are many ways to look at a river besides simply testing water quality. When we are trying to change something about a river system, all of the things that affect it must be considered. For example, we need to know what flows into the river, which requires looking at how we use the land around it.

We must expand our vision beyond that of a scientist. We need to perceive rivers in the same way as sociologists, economists, artists and politicians might. Whether we recognize it or not, each of us, regardless of occupation or perception, has a role in the decision-making process about how the river is treated. After all, it is our daily activities and land uses that determines what goes into the water.

In short, becoming a student of the world's rivers requires going beyond any one way of thinking. It calls for skills used in language arts, social studies, and other classes, as well as those employed in science, ecology or biology classes.

We hope that the river helps you to find a purpose for your studies that runs through your daily life, much like the river itself flows through and connects your community.

What does monitoring the river accomplish?

It is important to measure the quality of a river over long periods of time to detect changes in a river ecosystem, including the land around the river as well as the water in it. The data you collect about the health of the water can be used to analyze changes over time.

It is also important to collect data at different points so that water quality along the length of the river can be compared. For example, the river may be less healthy where it passes through farmlands than where it passes through upstream forested areas due to the runoff of fertilizer in rainwater.

As in a human body, not all parts of a river are equally healthy all of the time. And just as getting a physical check-up on a regular basis is important to us, checking the river at regular intervals can provide us with the information we need to maintain or improve water quality.

It is important to not only do the tests, but to let other people know about your results. Notifying community residents and officials about research results can lead to increased public awareness and action directed toward improved water management. Personal lifestyle, industry, and government policy all have an impact on water quality.

How can I best use this manual?

This manual is divided into clearly labeled chapters and sections, listed in the table of contents, so that you can pick and choose among them as needed or as time allows. However, since all of the sections of the manual are interrelated, we recommend reading the entire book if possible.

We have tried to emphasize the ways in which the different water quality tests relate to each other. Throughout the manual you will notice boxed text sections. These are specifically targeted at instructors (teachers or leaders).

Other sections of the manual have been developed based on feedback from river projects around the globe:

- The concept of a watershed is discussed in Chapter 2, as well as techniques for measuring water quality, sampling procedures, and precautions necessary for monitoring water quality.

- Chapter 3 contains precise test procedures, with the idea that substitute equipment and techniques may be required depending on such factors as your budget, numbers and experience of participants, and the unique demands of your river ecosystem.
- Methods for calculating the overall water quality of a section of a river are given in Chapter 4.
- A pilot program for testing for heavy metals and toxic substances is described in Chapter 5.
- River ecology and the many kinds of aquatic organisms (macroinvertebrates) found in rivers are discussed in Chapter 6, as well as models for sampling and monitoring water quality.
- Chapter 7 discusses land uses and their relation to water quality. This chapter also contains information on aerial photographs and satellite images, and activities useful for students in learning more about their local rivers and how they can personally influence water quality.
- Chapter 8 contains a case study describing how the interactive water quality program is handled in an interdisciplinary manner in one watershed.
- Chapter 9 discusses the international dimension of water quality monitoring. River studies around the world are accelerating. The Global Rivers Environmental Education Network (GREEN), founded in 1989 at the University of Michigan School of Natural Resources and Environment, has incorporated the principles of existing river projects. In addition, there is a movement underway to spread the worldwide effort of river monitoring to waterways other than rivers, such as lakes, groundwater, and estuaries.
- Chapter 10 discusses the opportunity to share information between schools within a watershed, or between watersheds nationally and internationally by way of computer conferencing.
- The last section contains a list of literature to supplement the information presented in this manual.

In conclusion, we cannot overemphasize the significance of creativity in planning your river study. All of the river projects that we have had the pleasure of observing or being involved in have been imaginative in their approach. They go beyond books, just as explorations of unknown territories go beyond maps. As students of rivers, we are explorers, too. We invite you to explore your local waterways and seek the most fun, creative, and educational experience possible.