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REPORTS FROM THE COASTAL ZONE MANAGEMENT SCIENTIFIC AND TECHNICAL WORKSHOP SERIES

A REFERENCE MANUAL

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BASED ON THE PROCEEDINGS OF
THE SCIENCE AND TECHNICAL WORKSHOP SERIES
FOR GOVERNMENT PERSONNEL
RESPONSIBLE FOR
COASTAL RESOURCE MANAGEMENT

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When it passed the Virgin Islands Coastal Zone Management Act (VICZMA) in 1978, the V.I. Legislature determined that one of the basic goals of the Virgin Islands for its coastal zone shall be to "assure the orderly, balanced utilization and conservation of the resources of the coastal zone, taking into account the social and economic needs of the residents of the Virgin Islands." The legislation sought to ensure that environmental quality is fully considered in the decision making process.

One significant vehicle established to achieve this is the Environmental Assessment Report (EAR), a formalized means of giving environmental quality careful consideration in the permit and decision making process. The VICZMA requires an EAR for any major CZM project and any minor project involving public trustlands or other submerged or filled lands. This document must include information such that the responsible government personnel can make a knowledgeable permit decision based on a thorough evaluation of the anticipated short and long term environmental impacts. The scientific and technical impact analysis of a proposed project and the available options can then be combined with analyses of the historic, aesthetic, cultural and socioeconomic aspects to arrive at an overall assessment of its effects.

This Reference Manual is intended to assist in the scientific and technical assessment required in the CZM process and, more specifically, in the preparation and review of an EAR. It is the result of a series of one day, in-service science and technical training workshops held for three consecutive weeks in November 1985 at the University of the Virgin Islands, St. Thomas campus. The workshops were conducted by the Virgin Islands Marine Advisory Service (VIMAS) of the University of Puerto Rico Sea Grant Program and sponsored by VIMAS and the Coastal Zone Management Program of the Department of Conservation and Cultural Affairs.

The workshops were held for government officials who play a role in the coastal zone management permitting and marine resource management processes. The chief objective was to assist government professionals and para-professionals to more effectively analyze and judge an EAR in their permit decision making. Training was provided in the field techniques, methodology, and background information which form the basis of a sound and comprehensive EAR. The workshops focused on how decision makers can (1) identify and assess whether an EAR contains comprehensive scientific and technical assessment performed by qualified experts and (2) reach a decision based upon the information presented. Emphasis was placed upon growth management along the coast, stressing the importance of making the best objective use of advancing science and technology.

It is essential that decisions on any project be made in the best overall public interest, taking advantage of the best possible quantitative and qualitative information. Coastal planning should design and allocate territorial development in such a fashion that hydrological, biological, geological, and other natural characteristics are analyzed and classified in order to yield a controlled placement, kind, and amount of new development. Proper investigation and assessment of the ecology of an area by *qualified* experts enables them to more accurately predict the favorable and adverse outcomes of alteration and to suggest mitigative measures. As a consequence, the certainty of decision makers can thereby be increased, and fewer decisions will be based on subjective reasoning. A synergistic approach to determining the structure and carrying capacity of ecosystems more fully guarantees the long term success of the project.

The first two papers of the Reference Manual address the biology of Virgin Islands coastal settings as it relates to their potential for development. Dr. LaVerne Ragster presents the different types and sensitivities of coastal ecosystems in the Virgin Islands. Mr. John Matuszak discusses aspects of terrestrial biology in the CZM permitting process.

In his paper, Dr. Kenneth Haines describes the types and sources of pollution which can arise in the CZM permitting process and various means of pollution detection, prevention, and control.

Dr. Henry Smith discusses aspects of hydrology to consider in environmental assessment. He examines the basic principles of hydrology and water resource management and the impact that development activity on the water supply in the Virgin Islands.

Coastal development projects in the tropics present special problems in sampling techniques and assessment. In his paper, Dr. William Gorham presents some of the equipment, instrumentation, and techniques which can be used in environmental assessment studies. He discusses how to collect and interpret information to better understand the biological, chemical, and physical processes at work in the marine environment.

The final paper included by Dr. Dennis Hubbard is twofold in purpose. First, he discusses the physical processes (e.g., waves, currents, runoff) to consider in an EAR. In the second half of the paper, Dr. Hubbard examines the EAR process, identifying areas of concern and recommending certain types of scientific studies which should be performed to assess the impact of the different types of development projects.

This publication should prove very useful as a desk reference for government professionals and paraprofessionals with coastal permitting and planning responsibilities. In reviewing development projects in order to determine which should be approved and which should be modified or rejected, they, along with the developers, are accountable as trustees of the coast for succeeding generations.

In addition, the reports can assist developers in knowing what studies to perform and what information to include as they prepare Environmental Assessment Reports. Civic groups may also find it beneficial in their review of upcoming projects. Additional copies can be acquired through the Virgin Islands Marine Advisory Service.

ACKNOWLEDGMENTS

I would like to offer special recognition to a number of persons who helped to make the workshop series and proceedings possible. I would first like to thank Dr. LaVerne Ragster, Chairperson of the Science and Mathematics Division at the University of the Virgin Islands, who conceived the idea of holding science and technical workshops for government personnel. I greatly appreciate the efforts of the participating scientists for their contributions of time and knowledge to steepen the learning curves of those who attended the workshops and of those who are readers of the Reference Manual. I extend my thanks to Commissioner Angel LeBron, Department of Conservation and Cultural Affairs (DCCA), for his approval and allocation of CZM funds to hold the workshop series. Finally, CZM Program Director, Mr. Benjamin Nazario, and Senior Planner, Ms. Debra Brown, deserve special thanks for their help in coordinating activities between DCCA and the VIMAS.

THE VIRGIN ISLANDS MARINE ADVISORY SERVICE

The Virgin Islands Marine Advisory Service (VIMAS) is part of the National Sea Grant College Program in the United States. Sea Grant is a federal/ state and territorial partnership administered through local academic institutions. It is designed to promote the wise use and development of the nation's coasts and oceans through a program of applied research, education, and advisory service. Sea Grant programs are located in all the coastal and Great Lakes states, Guam, Puerto Rico, and the U.S. Virgin Islands.

VIMAS is an inter-institutional project. It is part of the University of Puerto Rico Sea Grant Program and administered locally through the University of the Virgin Islands and West Indies Laboratory of Fairleigh Dickinson University.

Marine research, technology, and information are not especially useful unless there exist means of getting that knowledge to the people. Marine advisory services basically operate under the philosophy of transferring skills and knowledge to the marine community. They act as an outreach program to such marine user groups as fishermen, coastal zone management personnel, boaters, the marine industry, and youth who are interested in the sea.

VIMAS, housed at the University of the Virgin Islands, brings together the diverse talents, expertise, and facilities of its associated academic institutions and members of the V.I. community. It can also draw upon the expertise and information networks available through Sea Grant nationwide.

VIMAS activities include one-on-one advisory services, the distribution of materials, and larger scale projects, such as workshops, a marine camp, reports and publications, radio and television spots, and news columns related to marine concerns.

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COASTAL ZONE MANAGEMENT SCIENCE AND TECHNICAL WORKSHOP SERIES:

VIRGIN ISLANDS COASTAL ECOSYSTEMS ENCOUNTERED IN THE CZM PERMITTING PROCESS

Presenter

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INTRODUCTION

The coastal waters of the Virgin Islands and other Caribbean islands are filled with productive, complex systems. These natural systems or ecosystems, get their identities and their ecological roles from the interactions of a diverse set of biological and physical components. Observations and studies have indicated that the land and the open sea both impact the conditions and activities present in coastal ecosystems, and that they in turn are influenced by the status of the very same ecosystems.

Observations have also shown that if a modification is made in one part or process of an ecosystem, there will be a reaction in other parts of the system. The size of the response can vary, but external stimuli will cause a change in natural systems. Human manipulation of the natural environment must include consideration for the interdependency of the biological and physical components of an area, and their roles in maintaining the character of that area.

The Virgin Islands is fortunate to be able to point to the existence of at least six major types of coastal area ecosystems. Each system has its own unique characteristics, weaknesses and ecological role to play in relation to land. Of course, organisms living on rocky shorelines, or beaches, or coral reefs must each adapt to the conditions of their habitat. Nevertheless, generally one finds a decrease in productivity and massiveness of communities, a decrease in the height of dominant organisms, and a reduction in the percentage of area covered when moving from favorable to extreme environments in all ecosytems. Adaptation could mean timing growth to favorable times, or evolving a tolerance for changes in moisture, or adapting to the quality and quantity of light available. Rapid, excessive and/or long-lasting changes in environments usually cause drastic, even fatal, alterations of ecosystems.

Additionally, although it is possible to describe each ecosystem separately, in nature many ecosystems intergrade with others, making definitive boundaries extremely difficult to find. Also, most ecosystems are usually found associated with particular systems. (The associations found most frequently in the V.I. will be discussed later.) The end result, as stated previously, is a chain of islands surrounded by seawater containing many complex and diverse systems.

The physical aspects of the marine environment, which are obviously a part of marine ecosystems, are often as complex as the biological components. For example, the direction of water flow in a bay which affects nutrient availability, sediment movement and dispersal of organisms is determined by the strengths and interactions of tides, winds, waves, swell, external currents, and the shape and size of the shoreline. Although tidal ranges (0.24m - 0.4m average) and changes in water temperature (25°- 29°C) and salinity (34‰- 36.2‰) are not usually very drastic in the Virgin Islands, each ecosystem will still have its own set of physical and chemical parameters, and these will affect the behavior and physiology of the biotic part of the system.

The following is a cursory review of six ecosystems often encountered in the CZM permitting process: salt ponds, beaches, mangrove habitats, coral reefs, rocky shorelines and sea grass beds. A statement concerning utilization and necessary precautions is included for each ecosystem. The charts and much of the information in this section are to be found in references 1 and 2 produced by Department of Conservation and Cultural Affairs and the Island Resources Foundation.

SALT PONDS

Salt ponds develop when a shallow bay or part of a bay is closed off by mangroves or coral reef growth. The berm is maintained by sand and rubble tossed onto the shore by storms. When a pond is closed, runoff and sediment from the land become trapped in it, and nutrients and water are slowly released to the bay. Sea water may enter the pond if the berm is porous enough, thereby increasing the salinity of the shallow water.

Salt ponds are dynamic systems with high rates of evaporation, rapid and large salinity changes, high temperatures, high turbidity, low dissolved oxygen and high concentrations of hydrogen sulfide. The hydrogen sulfide is produced by certain species bacteria in the sediments and is also the cause of some of the unpleasant odors often associated with this ecosystem. Rain, heat, and sea water from storm waves are three major causes of the rapid changes in parameters that occur in salt ponds.

Due to the extreme conditions found in this type of ecosystem, there are limited types of organisms present. The major inhabitants of salt pond ecosystems include microscopic algae, some bacteria, fiddler crabs, land crabs, insects, brine shrimp, and birds like stilts, kingbirds, martins and swallows. The pond may dry up, and crystals of salt could form, but when water is available again, organisms that can tolerate the dry conditions or move away during the dry period return.

This dynamic ecosystem is usually associated with watersheds and beaches in the Virgin Islands where it helps to decrease the fluctuations in salinity and turbidity in bays by trapping runoff and sediments. It has been shown that opening the berm allows large surges of nutrients and sediment into adjacent bays, thereby increasing the probability of algal blooms and the imbalance of existing benthic communities. The extent to which this can be a problem depends on the dynamics of a particular bay.

BEACHES

A beach can be defined as a rock platform on the coastline covered with a veneer of sand, gravel and other debris. The sediments making up V.I. beaches include light colored, eroded minerals and gravel on land, and coral, calcareous algae and mollusk shells from the sea. As would be expected, the type of sediment found on a beach depends on the source, the rate of supply, and waves and currents in the bay. Virgin Islands sand contains a large marine contribution, especially calcareous algae and coral skeletons.

Sediment motility is determined mainly by waves, currents and tides. Heavy swells with strong backwash take sediments out to sea while breakers with long swash return sediments to the shore. Beaches usually have sloping foreshores and flattened backshores with the slope being dependent on the width of the beach, and the time of the year. For example, high exposure and winter usually produce the steepest slopes on V.I. beaches.

Each section of the beach has characteristic organisms. The BACKSHORE and COASTAL DUNE are usually covered with salt tolerant plants that stabilize sand and insects associated with the vegetation. On the other hand, the area between the BACKSHORE and OFFSHORE provides habitats for small crabs, clams, worms, sand dollars and benthic diatoms. The OFFSHORE region is a site of diversity where complex communities like sea grass beds can be found.

Beaches are more than places of recreation and fishing. They are also a natural buffer for the land and coastal property from destructive storm waves. Building structures (e.g., groins) across the beach can interfere with the normal movement of sediment in the bay and cause changes in the topography and/or communities of the bay. Additionally, mining of sand encourages the often destructive redistribution of sediment while dredging too close to shore can cause severe erosion or loss of sediment to the dredged hole. It is also apparent that beach sediments and bay waters are susceptible to runoff and pollution from the land.

SEA GRASS BEDS

Sea grass beds are sandy offshore areas covered with thick growths of sea grasses and algae. Grass beds thrive if enough light for photosynthesis is available, and if wave energy, currents and grazing by herbivores are moderate to low. These are extremely productive areas; when conditions are right the plants are able to saturate the bay's water with oxygen released from photosynthesis. The productivity level in sea grass beds can be as high as the level reported for tropical forests.

Thalassia testudinium , turtle grass, is the predominant species in the Caribbean. As is the case with all sea grasses, it is a true flowering plant related to the lily family. Manatee grass (*Syringodium filiforme*) and shoal grass (*Halodule wrightii*) are also present in many parts of the region.

In addition to the expected uptake through roots, sea grasses have been shown to take up nutrients directly from the water through their blades. This means the plants will respond (by growing faster) to nutrient loading from external sources like sewage discharges. If the nutrient level gets too high the system becomes balanced in favor of auxotrophic algae. The plants also have an extensive network of tangled roots and rhizomes (horizontal stems) which serve to hold the sediment in place and create a nutrient-rich environment in the bed sediment. The blades which are not usually more than 8 inches tall, help to slow down water movement in bays and to increase sedimentation of organic and inorganic materials in the grass beds. These physical characteristics allow the grasses to increase and maintain water clarity of bays contain large sea grass beds.

Sea grasses serve as attachment sites for large numbers of algae and small invertebrates, and as a source of food for some invertebrates (conch, starfish, sea urchins) and some vertebrates (parrotfishes, surgeonfishes, green turtles). The presence of other animals and algae makes for complex and varied food chains based on sea grasses. Eels, wrasses, crabs (Kinghelmet crab eats white sea urchins), shrimps, razorfishes, barracudas, jacks and stingrays all frequent grass beds. It has also been shown that many small animals like sponges, tunicates, sea anemones, and corals use the grass beds for shelter.

In addition to green, photosynthesizing blades being the basis for food chains, decaying blades of sea grasses also provide food for detritus feeders - sea grass beds are complex systems. For example, if some grazers are removed, or grasses are removed or killed, algae can and usually do become dominant. This change in the balance of the ecosystem often causes a decrease in the productivity and diversity of the system. Productivity of sea grass bed ecosystems can also be negatively impacted by increases in turbidity due to runoff and dredging, or by the loss of rhizomes and roots as a result of boat anchors and dredging. Recovery occurs extremely slowly, if at all, and other species (algae etc.) become established, making the bay less productive and the water less clear.

MANGROVE HABITATS

Mangroves are flowering plants that have adapted morphologically and physiologically to saline conditions. They are most successful in habitats near the shore in salt or brackish soils. The closer the plant grows to seawater, the more stress it must face, and the more special adaptations become necessary. Thick leaves, salt glands for getting rid of excess salt, layers of tissue under the epidermis that hold water, and special roots for anchoring in soft, silty sediment or for feeding in low oxygen sediments are all adaptations utilized by mangroves. Red mangroves (Rhizophora mangle), white mangroves (Laguncularia racemosa), black mangroves (Avicennia germinans) and buttonwood (Conocarpus erectus) are found in the Virgin Islands.

Optimum growth in these special angiosperms requires temperatures that do not drop below 68F (20C) in the winter, soft sediments high in organic matter, sea water (they grow slowly in fresh water), and a large tidal range (shallow slope) for seedlings. Red mangroves are characterized by prop roots growing in the water, seedlings that grow to 15cm on the tree (vivipary), and roots that trap sediments and debris. Rhizophora is well known for its ability to "make land". Black mangroves are usually found in swampy areas, often behind the red mangroves. The leaves excrete salt to the surface through structures called hydathodes and special roots grow up towards the surface to allow for respiration (pneumatophores). The white mangrove which lives in drier areas and also exhibits vivipary, has leaves with salt glands at the base. Buttonwood grows farthest inland and has no vivipary.

Mangroves, especially the red, often create lagoons or semi closed areas where waves are the chief driving force for flushing. These shallow, saline (can be very high in salinity) areas are usually very productive and contain many food chains, including detritus based chains. Mangrove lagoons and forests function as a significant habitat for many animals and plants, and as a nursery for fishes and birds (e.g., egrets, doves, pigeons, pelicans, fish hawks). Sponges, algae (5-10 species/root), tunicates, tube worms, sea anemones, snails, whelks, crabs, shrimps, angelfishes, tarpons, snappers, lobsters, and conchs are all members of mangrove-associated communities.

In addition to serving as a major habitat for many organisms, mangroves buffer the shore from high energy waves and deter long shore currents. They create shelter for boats, and protect coastal waters from fresh water and sediment runoff. Salinity levels that are too high or too low for long periods of time, or low concentrations of oxygen can inhibit growth and eventually kill the trees. Mangrove plants will respond positively to increased nutrient levels in the water or sediment, but the nutrients may cause imbalances in the communities associated with the plants and a decrease in the diversity of the system.

ROCKY SHORELINES

Rocky shorelines are areas along the coast with sparsely vegetated steep slopes and cliffs. The area is defined by exposure to high levels of wave activity, water, sun and wind eroded substrates, very few plants, and turbulent, well aerated waters. Fissures and crevices created by the elements provide microhabitats for plants and animals that need to withstand the harsh environmental conditions.

Organisms in the spray zone and intertidal must be able to take the pounding of waves or hide if they are going to survive in this area. Massive hard corals are often found in the well-aerated clear waters of rocky shores which often have high nutrient levels due to runoff and weathering of rocks. Mollusks (chitons, mussels, gastropods), barnacles, encrusting red algae and small urchins are found in crevices and on rocks. Rocky shorelines are prone to erosion and are difficult areas to construct structures.

CORAL REEFS

Coral reefs are complex, diverse, extremely productive ecosystems based on the invertebrate called coral. The small marine invertebrate builds elaborate structures using calcium carbonate it extracts from the surrounding seawater. Reef building corals are animals that live in intimate association with one-celled algae called zooxanthellae. In this symbiotic relationship zooxanthellae use light to drive photosynthesis during the day, and then the animal uses this extra food to supplement its nocturnal feeding. Even with the extra help, growth is still relatively slow, only a few centimeters a year in most species.

Most hard corals are colonial animals whose larvae need a clean, hard substrate to settle on when beginning a new colony. The form of the calcium carbonate rock skeleton is species dependent and new growth as a result of asexual budding is formed on top of the old coral skeleton. Corals require warm (75F-80F), clear (light needed for the zooxanthellae), oxygenated, salty (30-36‰), swift moving (cleans the coral and brings plankton for food) water if growth of reefs based on hard corals is to occur. The type of reef present in an area is dependent on the physical properties of the site: small to moderate reefs at the base of most headlands and cays; patch reefs in bays; and barrier reefs that develop on submerged island platforms (e.g., Long Point/Cas Cay, Buck Island).

Coral reefs create a large number of habitats as there are many hiding places and lots of food available. Octopuses, coweries, limpets, barnacles, lobsters, featherduster worms (sabellid), sea anemones, sponges, sea urchins, algae, fishes, (parrotfishes, triggerfishes, damsels, groupers, snappers, squirrelfishes, eels, grunts etc.) and soft corals (not a calcium carbonate skeleton, more horn like) are only a small example of the organisms associated with coral reefs.

Reefs also provide food for humans, contribute to sand (the skeleton is broken by waves, animals that eat polyps, etc.), and provide protection for the shore by absorbing wave energy. Corals cannot tolerate reduction of light levels and siltation; they release their zooxanthellae if stressed enough and eventually die. This complex ecosystem is also sensitive to chemicals in the water.

ECOSYSTEM ASSOCIATIONS

In nature, it is common to find certain ecosystems asssociated with each other. Three major ecosystems often found in the Caribbean region are listed below.

A. Rocky Shoreline Associations

cactus-agave scrub/coral reef community/sea grass and algae

B. Mangrove Lagoon-Reef Associations

salt pond/mangrove shoreline/sea grass flat/mangrove cay/back reef flats/fringing reef

C. Sand Beach Associations

salt pond/beach/sea grass bed/coral reef

Each of the ecosystems discussed in this paper is susceptible to damage and imbalance. The complexity and relationships between components in these systems result in a situation where a change in one aspect of any system will cause a response somewhere else in the system. The fact that many ecosystems are linked to each other physically, or through organisms, means the response to changes in one system can be very extensive. How negative, or positive, or how large the response will be is obviously dependent on many factors. Nevertheless, if sound resource management is to occur baseline information is needed on ecosystems in question before major manipulations are undertaken.

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ASPECTS OF TERRESTRIAL BIOLOGY TO CONSIDER IN THE CZM PROCESS

John Matuszak

This chapter is about vascular plants, for that is the area of my expertise. Most of what will be discussed regarding unique organisms, communities and habitat is equally important regarding wildlife, but a qualified specialist should be consulted. There is no one biologist capable of either writing or reviewing all the material on plants, wildlife and marine organisms necessary for a complete Environmental Assessment Report (EAR) in the Virgin Islands.

The information to be included in the EAR should give you a thorough understanding of what already exists. This should be in the form of a species list which includes the habitat of each species (herb, vine, shrub, tree, etc.) the relative abundance and other pertinent factors. Absolute or total numbers of more than the most unique species are unnecessary and impractical. If the area being assessed is large enough, it should be broken down into ecologically distinct areas (ridge, leeward slope, gut, saltpond, basin, etc.). The EAR should then inform you of what effects the planned development will have on the existing environment and what plans are proposed to mitigate environmental degradation resulting from the proposed development.

Fragile areas which are particularly sensitive to damage upon removal of the vegetation (beach berm, gut, steeply sloping areas, etc.) should be specifically dealt with if alteration is planned. Measures to mitigate damage should be included. These measures may include cutting of vegetation (rather than bulldozing) to leave roots intact to hold the soil. Establishment of a new cover before removal of original vegetation and the use of mulches, terraces, contour strips or other erosion control practices should be enumerated. Seasonality and timing of activities should be scheduled so that soil is not exposed and heavy equipment not used on clayey soils during periods of heavy rainfall.

Also important for inclusion in the species list and explanatory narrative is information on all endemic, endangered, and rare plants. In areas which include a high number of endemic and native plants, a plan should be included to maintain germplasm by saving mature plants in situ. This plan must be very specific including the number, size and location of said plants. Transplanting mature tropical plants must be viewed sceptically as it has proven time after time to be a failure. More important is the establishment of a nursery to propagate these native plants for use in revegetating the area. In addition to mitigating environmental damage, such a plan will create long term jobs where training of personnel and evaluation of material will benefit the entire community.

ENDEMIC PLANTS

The vegetation of the V.I. is unique and complex. We have a higher number of endemic plants per square mile than any of the 50 states. I will use the term endemic in this paper to refer to plant species which occur in the wild only in the V.I. (annotated in appendix 1). We are, via Vieques and Culebra, a part of the P.R. archipelago and share with them most of our natural history. Even the recently listed endangered species, Zanthoxylum thomasianum named after St. Thomas, occurs in two small (under 10) populations in P.R., in addition to larger populations. They were here before humans inhabited these islands and represent the product of thousands and thousands of years of natural selection and isolation. This has made them unique. If we destroy them they are gone forever for, by definition, they occur in the wild only here. Once destroyed they cannot be recreated!

Not all endemic plants are rare or endangered; still, their uniqueness behooves us to learn as much as we can about them, including an evaluation of their numbers and information on their uses and culture. Among the endemic plants which are not rare are the century plant, Agave missionium, and the tyre palm, Coccothrinax alta. Both of these plants have historic cultural uses. Both can be used as ornamentals and left in situ in landscaping and in natural areas.

Especially in commercial tourist related developments, the unique flora and fauna can provide an attraction for the visitor who is interested in a culturally and environmentally sensitive alternative to the Miami Beach clone which can now be found on almost every island.

Natural areas also reduce maintenance costs and reduce the risks inherent in the introduction of foreign germplasm.

Other endemics may not be of immediate use for landscaping to the developer. The reasons for protecting them are, however, well documented in both the popular and scientific press. (See Meyers, A Wealth of Wild Species, Prance, Extinction is forever, & "Bioscience" Dec.'85). In the V.I. we have endemic species which are related to more commonly cultivated plants. These could potentially provide genes for disease or stress tolerance or be utilized for hybrid vigor to improve quality or yield.

This is the case with the endemic Chrysophyllum paciflorum which is a quality lumber. It is a close relative of the caimito, C. cainito, with which it could potentially be crossbred. Another example of a valuable endemic is the mountain guava, Psidium amplexicaule, which bears an edible fruit. This could be improved by itself or used to improve the common guava P. guajava. (See Appendix 1 for a complete list of endemics).

ENDANGERED SPECIES

A number of endangered wildlife species frequent these islands. In addition to protection of the individual members of these species, critical habitat necessary for their well-being must be protected. The federal and territorial Divisions of Fish and Wildlife can supply additional information; both should always be included in the EAR review process. Review by federal F&W is in fact required by the U.S. Endangered Species Act.

The V.I. now has two plants listed on the endangered species list. One species is Zanthoxylum thomasianum. The major population of this species is found in Estate Frenchmans Bay/Flag Hill area on St. Thomas, with small populations in St. John on the east face of Gift Hill and north of the entrance to the Saltpond Bay Trail. The other species, Buxus vahlii, was believed to have been collected on St. Croix near Salt River by Eggers in the late 1800's but has not been found since. There is some question if in fact the plant Eggers collected was Buxus vahlii . In addition, status surveys of three other species considered in imminent danger of extinction are being negotiated. A status survey is required for any species before national listing can occur. These species are Calyptranthes thomasiana, Galactia eggersii and Sida eggersii. Other studies being considered are on Tillansia lineatispica, erythrina eggersii, Agave eggersii, Citharexylum spinosum, Chrysophyllum eggersii, Manilkara pleeana, Calicarpa ampla, Maytenus cymosa, Lyonia rubiginosa, Cocolobba rugosa, and Solanuum mucrotum. Some of these plants were originally named or listed from St. Thomas long ago but have not been found here in 50 years. This unfortunate state of affairs is due primarily to the fact that, until recently, there have been no systematic botanical inventories or practicing botanists working in the U.S.V.I. since the 30's. The recent survey of St. John by Woodbury has demonstrated the floristic richness of these islands. In addition to the plants currently listed or under consideration, he has found five rare plants which he believes may prove to be new species. The process of verifying this is complex and time-consuming; however, if these plants are determined to be valid new species, they would become immediate candidates for listing. (See appendix 1 for a list of endangered plant species and rare endemic plants considered for additional protection and their known occurences).

Little protection is offered plants on private land except in cases where federal permits, programs or funds are involved. The Federal Register 13021, Feb. 27, 1980 states "Title 50 subpart 1-17.94 Critical Habitats (a) The areas listed in 17.95 (fish and wildlife) and 17.96 (plants) and referred to in the lists at 17.11 & 17.12 have been determined by the Director to be Critical Habitat. All Federal Agencies must ensure that any action authorized, funded, or carried out by them is not likely to result in the destruction or adverse modification of the constituent elements essential to the conservation of the listed species within these defined critical habitats." In other words, any use of federal funding, even flood insurance, requires protection of endangered species. CZM is a federal program and approval of projects which fail to protect endangered species could jeopardize continued CZM funding. This is also true of the USDA-SCS (Soil Conservation Service and the Soil Conservation District) which reviews and approves all earth change permits in the V.I. for the Department of Public Works.

RARE PLANTS

There are occasional plants which occur both in the V.I./P.R. and beyond but are rare wherever they occur. These also need to be considered in an EAR. Finally, there are also plants which have a wide range and are not rare elsewhere but may be represented in the V.I. by only a few specimens. Examples of this are the bulletwood, Manilkara bidentata, and mastwood, Mastichodendron foetidissimum. These two trees can be found in many other islands of the Caribbean and beyond and are believed at one time to have been abundant in the V.I. Because of their excellent lumber characteristics, however, they were virtually eliminated by harvesting. Owing to the lack of remaining seed sources and the ecological changes which occurred as a result of harvesting, these plants were unable to compete with other weedier species and are now rare in the V.I. (A publication with notes on identification and distribution of "Endangered, Endemic, and Rare Plants" is currently being compiled by the CVI-Cooperative Extension Service - Natural Resources Program).

ETHNOBOTANY

Virgin Islanders have a long tradition of wild plant use for medicinal, culinary and cultural purposes. Among the traditional plants used for medicine is the black wattle, Piper amalago, which is now very difficult to find in the V.I. Culinary plants regularly used include guavaberry, Myrciaria floribunda, maubi, Colubrina eliptica, & papalolo, Corchorus siliquosus. Examples of culturally used plants include hoopvines, Tricostigma octandra

& Serjania polyphylla, hatpalm, Sabal causiarium, and birch for fishtraps, Eugenia sp. As green space and wild areas are eliminated for commercial and private development, these resources which are necessary for culturally unique small businesses are being lost. If we, as a people, want these traditional enterprises to continue, information on these plants must be included in an EAR. If loss of these resources is inevitable, it may be necessary to require that these resources be harvested rather than bulldozed and made available to the public or to vocational or cultural education programs.

FLORAL HISTORY

Shortly after the system of binomial classification of organisms was put into use by Linnaeus in the mid-1700's, botanists began visiting the V.I. to collect plants for inclusion in literature and universal ordering of organisms on a scientific basis. Collectors in the late 1700's included Charles Plumier and Hans West. Many plants from the Virgin Islands serve as "type specimens", plants used in the description of new species. An example is the guavaberry, which was named in 1800 from a specimen collected by West on St. Croix. Other plants, especially the rare or endemic ones, carry the V.I. in their specific epitaphs (e.g.,Pilea sanctae-crucis and the endangered Z. thomasianum).

The first systematic survey of all the plants in the V.I. was written by the Danish Baron H.F.A. Eggers and published by the Smithsonian in 1879. Britton & Wilson of the New York Botanical Garden published a more complete flora of P.R. and the V.I. in the 1920's and 30's. This included more species, as well as keys and descriptions for identification. Eggers identified over 800 species while Britton & Wilson brought the number to over 1200.

A recent study by Prof. Roy Woodbury brought the total on St. John alone to 800, including the 5 plants believed to be new species. When taken with the additions listed by Dr. R. Raymond Fosberg for St. Croix, the current total for native and naturalized plants is estimated near 1500. In addition, there are possibly 2000 cultivated species. However, these are not of concern in an EAR, except when new or weedy species are proposed for introduction or use.

The complexity of this flora and the breadth of knowledge necessary to enumerate and analyze it severely limits the number of individuals capable of providing this information. Even the most capable botanist, if not experienced with the V.I./P.R. vegetation, would find it necessary to collect specimens of nearly all species in fruit and/or flower. He would require days or weeks working through multiple identification keys and/or access to herbaria with the complete V.I. flora represented. Currently only the Smithsonian and NYBG herbaria meet this requirement. Even the herbaria at the CVI is not currently in possession of specimens of all V.I. species, although we have made great progress in the past few years.

There are a handful of botanists with extensive experience in the V.I. and P. R. who are familiar enough with the flora to require flowering or fruiting specimens of only the rarest plants. Fruit and flowers are necessary for the use of any key to plant identification! (see Britton & Wilson 1920-30 or Little et al. 1974 for examples of floral keys). Some rare and endangered plants also require flowers or fruit to distinguish them from closely related species, even by an expert! To obtain the specimen material necessary for identifications often requires several visits during different seasons in order to obtain the reproductive parts of the questionable species.

PLANT ECOLOGY

Vegetation is long term and dynamic. Plants must be evaluated as part of a community which is interactive with other physical and biological factors in the landscape.

Because of this complexity, most changes are irreversible: what a bulldozer can do in one day could take decades or centuries to reestablish. Any recovery potential is limited and will be possible only if there are seed sources saved nearby! In fact, because of the extensive clearing in the past for plantations, we will never know how many species there were or what we may have lost.

Thus far I have spoken mostly about the components of the plant community, stressing the need to save the few representatives of native endemic vegetation which remain here. For most areas in the V.I., however, species composition is not a critical factor because the areas have been cleared in the past. The existing vegetation is secondary, weedy species. (Weed is used here to designate any species which is fast to colonize open land, usually deterring the reestablishment of native plants by monopolizing water, nutrients and sunlight.) Whenever possible, we should encourage the concentration of development in areas of secondary growth, protecting the small bits of native vegetation which still exist. There are, however, other factors, especially the soil interface, which need to be considered in any plan to alter or clear vegetation.

SOIL

Soil is the result of climate, slope and biota acting on parent material over time. It has both physical and chemical properties which affect what successfully grows on it, its susceptibility to erosion, and what kinds of development activities it can support. The Soil Survey of the V.I. of the U.S. documents the various soils found in the V.I. and classifies their capacities for engineering and other uses. The classification is based primarily on physical factors. Additional information on chemical composition, organic matter and topsoil is necessary to determine what vegetation they will support. Each soil is different and the number of different soils which can be found in a small area is demonstrated in the map of the CVI-St. Thomas campus. This area includes 9 different soil types some of which can be further divided by the degree of slope. The Aguilita gravely clay loam, for example, offers fair stability as a foundation for low buildings while the Dorothea and Jaucas soils both show poor stability as foundations. Very sandy soils can shift excessively, while heavy clay soils can shrink and swell wiht moisture. It is also extremely difficult to transplant vegetation into or out of heavy soils. Soils can change dramatically within a few feet. It is important that those planning a development realize this and the effect which changes can have on construction and landscaping plans.

One factor that is universal to all soil types is that "the data show that soil cover is the predominant factor affecting erosion, in spite of differences of slope and rainfall." (Sanchez p.118). Raindrops impact the soil at over 20 mph and soil particles may be splashed over 2 ft. high and 5 ft. horizontally. Once soil particles are dislodged from the soil structure, they are carried by water moving on the soil surface and deposited below in either the basin or the nearshore marine environment. This process is referred to as splash erosion.

The three other categories of sheet, rill and gully erosion are also affected by the vegetative soil cover and the binding, aggregating effects of plant roots. This binding effect of the roots indicates that simply covering the soil with a mulch, although necessary, is often not sufficient. If possible, vegetation should be cut to allow roots to remain until new vegetation can be established. If total clearing is planned a program to plant a quick growing cover crop must be required and enforced if erosion is to be minimized. In addition, exposed soil should immediately be covered by a mulch with the new plantings in narrow horizontal rows minimizing the exposed areas. The best mulching program is to grind and utilize the existing vegetation. This is especially important in the tropics because most of the accumulated nutrients necessary for plant growth are stored in the existing vegetation rather than in the soil. If this vegetation is used as the mulch, it will cover and protect the soil; prevent unwanted weed growth, excessive heat and moisture fluctuation; and provide a slow release nutrient source to the new vegetation. It is estimated that it requires 100 years to create 1 inch of topsoil. Topsoil houses most plant roots and is the source of most plant growth. The cost of replacing topsoil is exorbitant when measured in either time or money.

Other mulches can be utilized to provide the soil cover and may be of organic materials, plastic screen or sheet. Care must be exercised if impermeable material such as plastic sheet is used, as it can concentrate runoff and cause gully erosion.

FRAGILE AREAS

Soil protective measures are most important in the parts of the landscape subject to high energy impacts from wind or water. These include the sloping areas, the guts, exposed ridgetops, the beach berm and coastline. The carrying capacity of water increases very rapidly with an increase in velocity. Doubling the rate of the flow of water allows it to carry particles sixty-four times the size of those it previously carried. High water volume and velocity require that gut areas should not be disturbed! On sloping areas scheduled for development, the buildings themselves can be utilized as terrace faces, reducing and interrupting water flow. However, care must be taken to protect and reinforce any areas where water will be concentrated. The beach and ridge are also important since they receive a high energy impact from winds and/or waves. Once their integrity is disturbed, their constituent parts multiply the energy effects on less stable parts of the ecosystem.

TIMING

For the above reasons, the timing of activities which alter vegetation and expose soil is a critical factor. Plans for clearing should be scheduled at the beginning of the dry season. Clearing with heavy equipment on clayey soils during wet periods not only eliminates the soil cover and binding effect of roots but will cause severe compaction. It could result in the loss of entire horizons of soil. If mulch is going to be used, a shredder/chipper to process the existing vegetation or the materials themselves should be on hand before clearing begins. This is also true if new ornamental plants or turf are planned. A nursery to propagate new plants or maintain material purchased elsewhere should be established before clearing begins if environmental degradation is to be minimized.

TRANSPLANTING AND NURSERIES

Very little is known about how to successfully move tropical trees. Experience from other areas has demonstrated that to be successful, the process of root pruning must begin approximately a year before the actual move. The move itself must be carefully planned with the new area prepared in advance to prevent unnecessary exposure.

The diversity of vegetation in the tropics is approximately four times that found in temperate zones. Yet the vast majority of information about the growth, development and horticultural practices required for plants is about temperate zone plants. Using the proper procedure of root pruning in advance and careful handling does not ensure success. A plan to save endangered, rare or endemic plants by transplanting must therefore be examined carefully. If destruction is inevitable, certainly every effort should be made to move them. More preferable is a plan which will leave a critical number of mature plants undisturbed and then attempt to propagate them both sexually and vegetatively.

Efforts to leave natural areas with mature vegetation and to establish nurseries to propagate native plants are the basis for development which is both economically and environmentally sustainable. Natural areas can spare the developer the maintenance labor required for landscaped areas (weeding, mowing, etc.).

It is often cheaper to obtain landscaping materials from outside the V.I. Material obtained this way, however, provides no employment in the territory. It can result in the introduction of plants which will become weedy, displacing the unique resources of these islands. An example of this phenomenon in the V.I. is tan tan, Leucaena leucocephala which was brought here as animal feed. In addition, with the wholesale importation of plants, there can be other latent pests or diseases which could do damage throughout the islands.

The establishment of nurseries to propagate native plants can provide employment and training potential. It can also increase the overall knowledge base as to how our native plants grow and develop and what the most appropriate horticultural techniques to use with them are.

SUMMARY

The vegetation found in V.I. ecosystems is highly complex. There are unique aspects of the vegetation which have a significant impact on both tourist-related and other types of development requiring an EAR.

Developers must be aware of these critical aspects of the V.I. coastal zone. This awareness should be reflected in the EAR. A complete EAR should therefore contain the following information:

1. a complete species list with common names; a designation of relative abundance for each ecologically distinct zone; and designation of special status, including endemism, ethnobotanical and potential horticultural use;

2. acknowledgement specifying any endangered species which might exist in the area and a statement documenting active exploration and results;

3. specification of critical areas within the development which are subject to erosion and other environmental degradation.

To be complete, the EAR must then specify what detrimental effects on the aformentioned topics might be precipitated by the planned development.

Finally, the EAR should include what measures will be taken to mitigate potential detrimental effects. Mitigation could possibly include:

1. the establishment of nurseries to propagate endangered, endemic or rare plants and to provide training and jobs;

2. undisturbed areas to leave important plants in situ or to maintain existing vegetation in fragile areas or critical habitat;

3. harvesting or making available ethnobotanically used plants;

4. use of erosion control measure such as mulches or the establishment of new vegetation before eliminating standing plants;

5. a specific timetable which acknowledges the rainy season and tries to minimize soil exposure;

6. the maintenance of seed sources for all endangered, endemic and rare plants.

Development is a desirable process when it is carefully planned and executed. Success and sustainability depend upon the awareness and use of the unique ecological parameters specifically found in this environment. Ignorance or neglect of these processes and the resulting organisms will surely result in longterm failure.

APPENDIX 1

ENDANGERED PLANT SPECIES

Zanthoxylum thomasianum Krug & Urban
syn. Fagara thomasiana Krug & Urban; Torina spinosa Desv.
St. Thomas - Est. Frenchmans Bay; Flag Hill-top and south slope
St. John-Gift Hill-east face; Salt Pond Trail - north of entrance. Also P.R.

Buxus vahlii Baill
St. Croix-Stoney Ground historically recorded; not found recently

PLANTS NEW TO SCIENCE

Byrsonima sp.
St. John-White Cliffs; Maria Bluff-south slope

Eugenia sp.
St. John-Europa Bay-hillside to the west

Malpigia sp.
St. John-Salt Pond

Machionia sp.
St. John-east end on trail to bay; Gift Hill-east face

Psidium sp.
St. John-Maria Bluff-below the peak

RARE ENDEMIC PLANTS CONSIDERED FOR ADDITIONAL PROTECTION

Galactia eggersii Urban
St. John & St. Thomas north coasts

Malpighia infestissima Vivaldi
St. Croix-Rust Up Twist; Buck Island

Calaptranthes thomasiana Berg
St. Thomas-Bolongo Hills; St. John-Bordeaux

Maytenus cymosa Krug & Urban
syn. Maytenus elaeodroides
St. Croix-Fair Plain; St. Thomas; Virgin Gorda; Vieques

Agave eggersiana Trel
St. Croix-eastern district; used ornamentally on St. Croix & St. Thomas

Abutilon virginianum
syn. *Sida eggersii* E. G. Baker
St. Thomas-perhaps; Tortola;Jost Van Dyke; Culebra historically

Lyonia rubiginosa (Pers.) G. Don

Psidium amplexicaule Pers.

Acrocomia media O. F. Cook
syn. *Acrocomia fusiformis* Krebs

Coccoloba rugosa Desf.
syn. *Cocoloba latifolia* Krebs
St. Thomas according to de Candolle; not found by Britton & Wilson

Reynosia guama Urban Guama
syn. *Renosia latifolia* Krebs
St. Thomas; St. John; Virgin Gorda common in dry thickets on all islands

Manilkara pleeana (Pierre) Cronq

Calicarpa ampla Schauer

Solanum mucronatum (O. E. Schulz)

Cordia rupicola

Operculina triquetra

Pilea richardii Urban
St. Thomas collected by L.C. Richards; not found by Britton & Wilson

Solanum conocarpum
rare species native beyond (nonendemic)

Ilex urbaniana Loes.

Enallagama latifolia (Mill.) Small
St. Thomas-uncommon in Solomon Gut; St. John in guts

Rochefortia acanthophora (DC) Griseb

Sapium caribaeum Urban
St. John-upper Cinnamon Bay watershed; Tortola

Malpigia linearis Jacq.
St. John-Hawksnest, Yawsi Point; St. Thomas-southeast coast; Water Island

Licaria triandra (Sw.) Kosterm
St. John-Bordeaux Mountain

Miconia domingensis (Tuss.)
St. Croix-recorded historically

Tetrazygia angustifolia (Sw.) DC.
St. John-Bordeaux Mountain; St. Thomas-Upper Dorothea, Upper East Caret

Cedrela odorata L. commercial (threatened)

Schoepfia schreberi J. F. Gmel
very rare

Chione venosa (Sw.) Urban

Rondeletia pilosa Sw.

Allophyllus racemosus Sw.

Picrasma antillana (Eggers) Urban

Solanum polygamum Vahl cakkalaka-berry uncommon elsewhere; common in St. Thomas & St. John

Zanthoxylum flavum Vahl Yellow Heart
Historically recorded from St. Croix and St. John-Bordeaux Mountain. (This precious wood is now believed to be extinct in the V.I. and worthy of reintroduction.)

Zanthoxylum spinifex (Jacq.) DC.
Buck Island off St. Croix

Ternstroemia peduncularis DC.
St. John-Bordeaux Mountain

Guaiacum officinale L., lignumvitae, commercial (threatened)

ENDEMIC SPECIES

Cordia rickseckeri Millsp.
not uncommon throughout V.I.; Vieques & Culebra

Croton rigidus (Muell. Arg.) Britton
not uncommon throughout V.I.; Vieques & Culebra

Sabinea florida (Vahl)
common on St. John; uncommon on St. Thomas; also BVI, Culebra & Vieques

Miconia thomasiana DC.
named for St. Thomas but not found by Britton & Wilson or since; Tortola

Eugenia sessiliflora Vahl.
not uncommon in coastal areas of St. Thomas & St. John

Psidium amplexicaule Pers.
St. Thomas historically; St. John-Bordeaux Mtn. Camelberg Peak & west face of ridge to the north.

Neea buxifolia (Hook. f.)
St. John; St. Thomas historically

Curatea littoralis Urban
St. John-Bordeaux Mtn.; St. Thomas historically

Coccothrinax alta (O. F. Cook) Beccari
common in St. Thomas & St. John; BVI; St. Croix-3 trees

Roystonea borinquena O. F. Cook
uncommon in guts on all three islands; planted

Reynosia quama Urban
St. Thomas & St. John-dry, low elevation decidious forests.

Chrysophyllum pauciflorum Lam.
St. John-uncommon; St. Thomas very rare in Magen's Bay Basin

Antherium sellosum C. Koch
St. John-common; St. Thomas-one plant in Canaan

Pilea santea-crusis Liebm
St. John-common

ASPECTS OF POLLUTION IN THE CZM PERMITTING PROCESS

by

Kenneth C. Haines, Ph.D.
President, Coastal Consultants

INTRODUCTION

One of the primary goals of the CZM permitting process is protecting the coastal environment from pollution. Pollution can be defined as any substance added to the environment as a result of man's activities which has a measurable and generally detrimental effect upon the environment (Ketchum, 1967). Historically, the coastal environment has been the site for most of man's societal development. The shores of rivers, bays and estuaries were the first land areas to be developed because of the ease with which commerce could be conducted by ship on these waterways. These waterways were also found to be convenient places in which to dispose of wastes from man's society. However, the capacity of the environment to absorb pollutants is not infinite, and for this reason the U.S. Environmental Protection Agency (EPA) has set limits for discharges of specific substances into the air and into water.

In many cases, because of their hazardous nature, discharges of some pollutants is no longer allowed. Instead, they must be disposed of in specially designed, leak-tight landfills. An example is PCBs (polychlorinated biphenyls), the insulating fluid used in electrical transformers prior to 1978. The Virgin Islands does not have a hazardous waste disposal site for disposal of hazardous waste, so it must be shipped off island.

Discharges of pollutants into receiving waters or into the air require permits from the Division of Natural Resources in the Department of Conservation and Cultural Affairs, and, depending on the magnitude of the discharges, may require permits from EPA.

The purpose of this contribution to the workshop is to give brief guidelines for CZM staff and others to use in evaluating CZM permit applications for potential environmental impacts due to pollution, and, after the CZM permit has been issued, to use in evaluating compliance with environmental regulations or CZM permit conditions.

Types and Sources of Pollution

In addition to the obvious forms of pollution, such as visible emissions from smokestacks and wastewater flows from an unpermitted facility, there are other forms of pollution that may not be recognized because they are indirect, or not easily observed. Examples of these are groundwater contamination by pollutants, and illegal discharges of hazardous wastes to receiving waters.

The effects of pollution can be short term, long term, or both. An oil spill in coastal waters, for example, will have an immediate effect on man's use of those waters, and require an expensive cleanup effort. Aquatic birds and other animals and plants associated with the littoral fringe are probably the most heavily impacted members of the biological community. If the spill is not cleaned up properly, then a longer term effect is possible if the oil gets incorporated into sediments or beach sand. The longer the oil is in contact with the environment, the greater the impact. The greatest impact is seen early in the life of a spill, before the low molecular weight compounds in the oil evaporate or are biologically degraded. The impact of oil spills in tidal waters usually persist for years if the cleanup is not done thoroughly. A spill of 12.5 million liters of oil in 1971 from a tanker on St. Croix's south shore killed approximately 5 hectares of mangrove forest on the Port Alucroix channel and showed little or no regeneration seven years later (Lewis and Haines, 1980). Many of the 86,000 red mangrove (Rhizophora mangle) seedlings planted in the impacted area show severely stunted growth or high mortality rates; in the areas with poorest growth, an oily sheen appears on the surface when the sediments are disturbed .

Detection of Pollution

The key to controlling pollution through the CZM permitting process is by a clear understanding of the potential impact of the applicant's project. If the applicant is proposing to build a chemical processing plant, then CZM must ask for details of the nature of the process and all byproducts or intermediate products that will be found at the plant. After the plant is built, then CZM may require as a condition of the permit that monitoring of certain physical or chemical parameters be done by the applicant on a routine basis. An example could be automatic, composite sampling of a waste stream at hourly intervals. CZM might also require the applicant to to carry out monitoring of the environment receiving the plant's effluent, to determine if there is any long-term impact of the effluent on organisms in that environment. This would require a determination of what the biological community is like under baseline conditions, before discharge of the effluent.

There are some indicator organisms in local waters that are useful as indicators of pollution by sewage or other sources of organic pollution; notable among these are the benthic (attached) algae Enteromorpha, Ulva and Centroceras. Biological diversity is also a useful indicator of pollution; high diversity (large numbers of species, but few individuals of each species) is typical of unpolluted waters, while low diversity (low numbers of species but high numbers or biomass of a few species) is typical of polluted waters. In pollution-impacted waters, sensitive species are eliminated, while the pollution-tolerant species thrive. Severely impacted environments, may lack any benthic organisms. This is the case near the outfalls of many powerplants that lack cooling ponds.

Prevention/Control of Pollution

Whenever possible, CZM should try to enforce "zero discharge" of pollutants by CZM permit holders. Zero discharge can be achieved through collection of a pollutant and disposal in an acceptable way that is approved by CZM, or through treatment to render the pollutant inocuous. Treatment by dilution in a seawater or other stream should not be accepted ("dilution is no solution"), and applicants should be encouraged to explore alternative or innovative methods of waste treatment or disposal. The Bacardi rum plant in Puerto Rico developed a treatment process for converting noxious rum stillage (the residue from the distillation process) into into methane gas, which is used as boiler fuel.

If damage to the environment occurs as a result of negligence in plant operation or a willful violation of permit conditions, then the permitte should be required to mitigate the damage through environmental restoration work.

Putting "teeth" in the existing laws requires adequate numbers of trained enforcement and technical staff to uphold the existing CZM and other environmental laws, many of which are not being enforced. It also requires consistency on the part of the CZM staff and management, and steadfastness in the face of political pressure to bend the CZM laws in favor of development.

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ASPECTS OF HYDROLOGY TO CONSIDER IN AN ENVIRONMENTAL ASSESSMENT REPORT

by

Henry H. Smith, Ph.D.

Man has been, presently is, and will forever continue to be a slave to water. All of man's activities are influenced by the availability of this resource. It is crucial then that all analysis of development plans take a very serious and comprehensive look at how water is considered.

Hydrology can be defined in general terms as the science which deals with the waters of the earth, their distribution on the surface, underground and the cycle involving evaporation, precipitation and flow to the seas. All components of this cycle are of equal importance. The linkages between subsystems in the hydrologic cycle are illustrated in Figure 1 while the hydrologic cycle and associated water quality parameters are illustrated in Figure 2. This overview of aspects of hydrology to consider in the CZM permitting process will briefly look at all components of the hydrologic cycle but will be more detailed when discussing those that may be more influenced by development activity in the Virgin Islands.

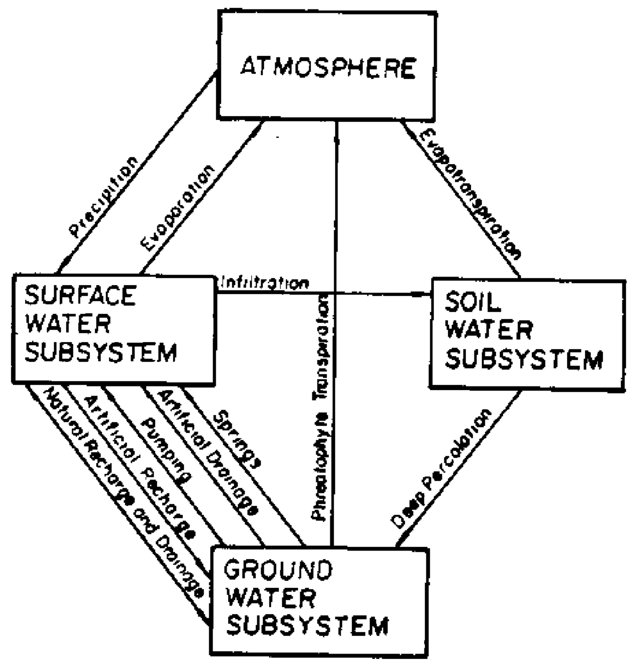

Figure 1. Linkages Between Subsystems in the Hydrologic Cycle
(From: McWorther and Sunada, 1981)

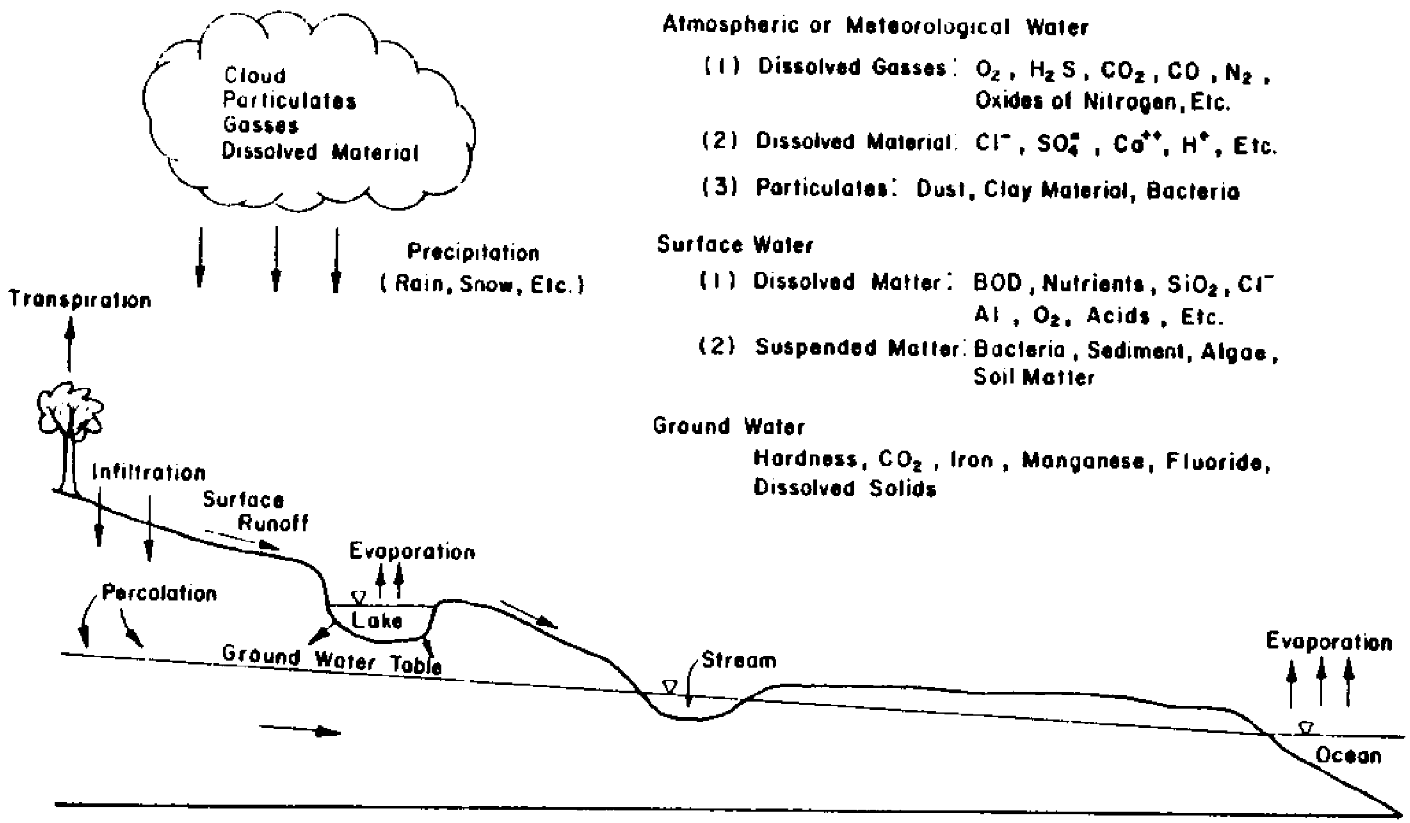

Figure 2. The Hydrologic Cycle and Associated Water Quality Parameters
(From: Sanders, 1980)

Of the average annual rainfall in the Virgin Islands (38-45 inches), it has been estimated that 87% returns directly to the atmosphere as evapotranspiration, 5% goes to groundwater recharge and 8% occurs as runoff. In Figure 3 the movement of water through the hydrologic cycle for an average year in the Virgin Islands is illustrated. It is indeed a challenge then with our high slopes, cooling ever present tradewinds and limited flat areas, to intercept for use as needed the maximum possible amount of water that can be feasibly withdrawn from each source. Current water usage in St. Thomas is summarized as shown in Figure 4.

<u>Surface Water</u>

Because of the mountainous relief and high evaporation rates, surface water in the Virgin Islands is very limited. Streams are for the most part ephemeral - they go dry during periods of little or no rain. Steep slopes and clayey soils lead to rapid runoff.

Several methods are used to estimate discharge of water from an area. For the most part they are all based on the rational formula

$$Q = ciA$$

where Q is the discharge in cubic feet per second (cfs), c is a runoff coefficient, i is the rainfall intensity in inches per hour and A is the watershed area in acres.

While the rational method provides an easily computed estimate of discharge from an area, there are certain factors

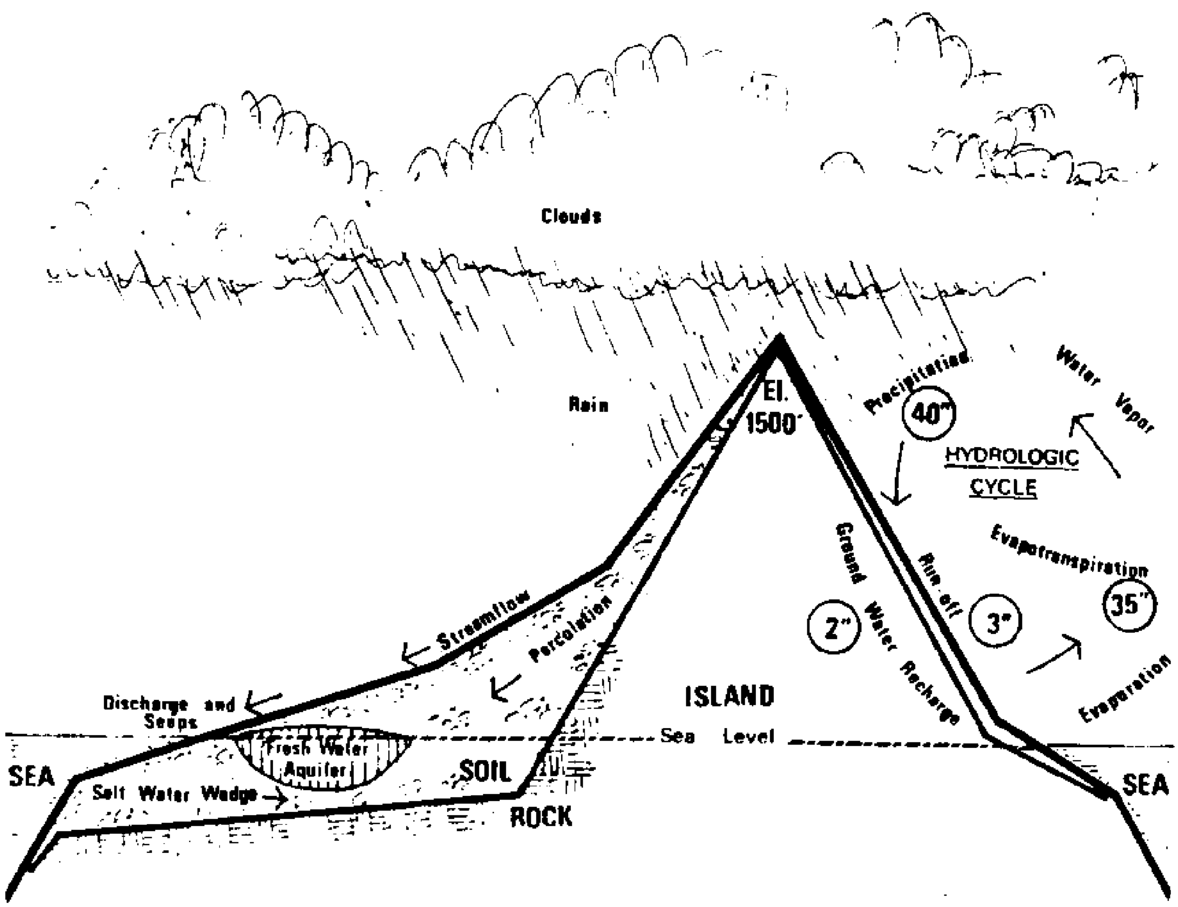

Figure 3. The Virgin Islands Hydrologic Cycle
(From: Peebles, 1979)

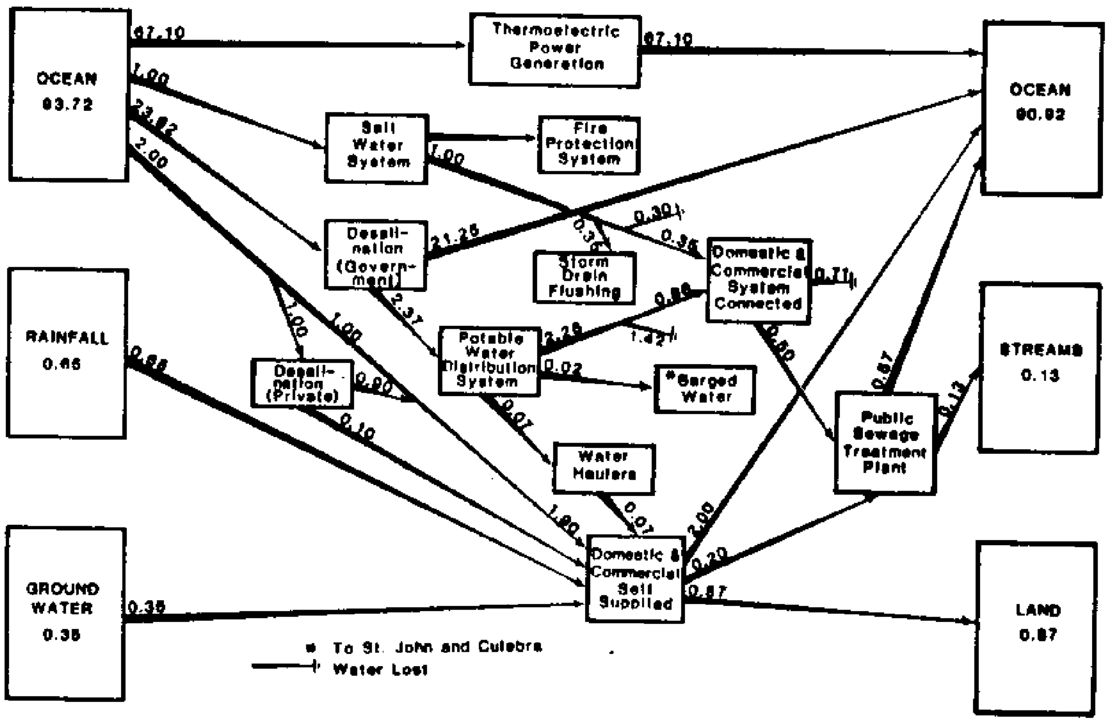

Figure 4. Water Sources, Uses, Disposition, and Amount in St. Thomas (in million gallons per day) (From: Torres-Sierra and Dacosta, 1984)

associated with its use that must be considered. Most importantly, results obtained are greatly influenced by the size of the watershed being considered. Both the rainfall intensity and the runoff coefficient can be expected to vary as the size of the area increases. Values used in the formula then should be an average value and thus the estimated discharge is significant only as an estimate for the whole area and results should not be used to approximate conditions for a smaller area in the watershed. A commonly used 'Rule of Thumb' is that the rational method should not be used for watersheds greater that 200 acres or where there is a great variation in the value of the runoff coefficient.

Runoff from an area may also be calculated using methods suggested by the Soil Conservation Service and described in a publication popularly referred to as Technical Bulletin No. 55.

Flow discharge in an open channel may be estimated using the Manning formula

$$Q = (1.49/n)AR^{(2/3)}S^{(1/2)}$$

where Q is the flow discharge in cubic feet per second, n is a roughness coefficient available from several handbooks, A is the cross-sectional area of the channel, R is its hydraulic radius and S is the slope.

Streamflow duration curves and rainfall-storm runoff relationship curves are often presented to demonstrate the influence of development on the discharge from an area.

These should be handled by the reviewer with caution and only accepted as valid when their methods of development have been satisfactorily explained. Explanations should include simulation procedures used if any, assumptions on vegetative cover, slope and other basin characteristics used fully justified, and most importantly the return period used in their development. The return period is also known as the recurrence interval, or frequency and may be defined broadly to be the average interval of time within which the magnitude of an event will be equaled or exceeded.

While there are several small livestock ponds in the islands, Creque Dam on St. Croix is the only dam in the Virgin Islands constructed to serve for municipal supply. This dam was constructed by the U.S. Navy in 1920 and is a concrete arch dam with a design capacity of 9 million gallons. Creque Dam is 40 feet high and 200 feet long. It is presently not in use.

Steep slopes also make erosion a concern. All development should include measures for erosion control during construction as well as after completion of the project. Estimates can be made of the potential soil losses using the universal soil loss equation

$$A = R\ K\ LS\ C\ P$$

where:

A = average annual soil loss (tons/acre)

R = rainfall factor expressing the soil erosion potential of average annual rainfall in the vicinity.

K = soil erodibility factor. The average soil loss per unit R and is a function of soil type and percent organic material. K ranges from 0.02 for sand with 4 percent organics to 0.60 for silt with less than 0.5 percent organics.

LS = a dimensionless topographic factor that represents the combined effects of slope length and steepness. For a slope length of 300 feet, LS varies from 0.18 for a 1 percent slope to 31 for a 50 percent slope.

C = cover and management factor. A ratio of the soil quantities eroded from land that is cropped under specific conditions to that which is eroded from clean tilled farrow under identical conditions. C ranges from 0.001 for a well managed woodland to 1.0 for tilled continuous fallow.

P = factor for supporting practice. No supporting practice, i.e. contouring or contour terracing, P = 1.0.

Use of this equation will give an estimate of soil erosion per year due to rill and sheet erosion but should not be used as an estimate of the sediment delivered to the channel since much of the eroded material will be redeposited before reaching the channel. To determine the amount of sediment reaching the channel, the sediment eroded is multiplied by a sediment delivery ratio factor which has been found to be a function of drainage basin area. Detailed discussion on this process can be found in the manual "Control of Water Pollution from Cropland" by W. C. Walton.

Groundwater

Groundwater supplies approximately 17% of the daily potable water demands in the Virgin Islands. On St. Croix the water supplied from aquifers is greatest at about 0.8 million gallons daily or 19% of daily demand.

During a rainfall event, certain abstractions occur before there is any direct runoff from the ground surface. These initial abstractions include interception storage by the covering vegetation and depression storage due to surface unevenness. A schematic representation of this process is presented in Figure 5.

Rainfall that enters the soil suffers from one of three fates:

a. It may evaporate directly from the soil
b. It may be transpired by vegetation
c. It may enter the saturated zone

In the upper strata of the soil, the openings are only partially filled with water. This zone of aeration is divided into three belts - the belt of soil water, the intermediate belt, and the capillary fringe. The belt of soil water furnishes most of the water for plant growth. The intermediate belt is principally a passage for water from the soil belt to the capillary fringe. The capillary fringe holds water above the zone of saturation by capillary force acting against the force of gravity. Phreatophytes, which grow without dependence upon the belt of soil water, get their water from the capillary fringe and the water table. In the saturated zone, the pores spaces are filled with water. The transition between these belts and zones is gradual and their thickness varies according to local geology, the availability of pores or openings in the formations, the recharge and movement of water within the zones from areas of recharge toward points or areas of discharge. The general subsurface

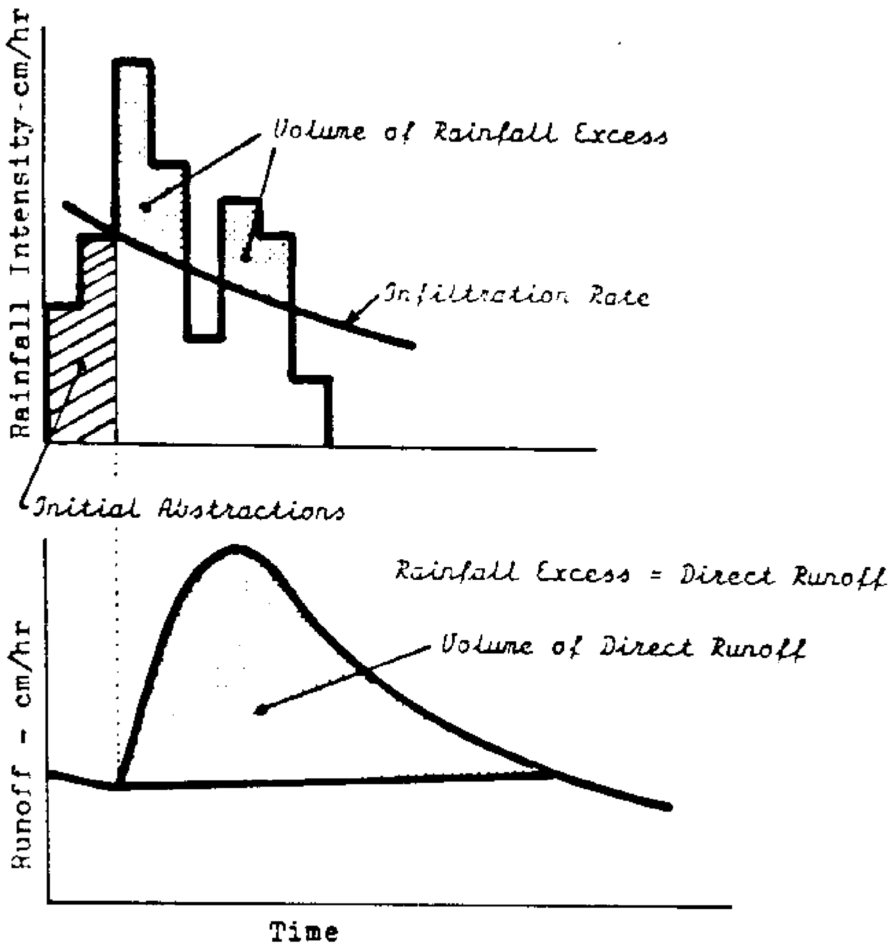

Figure 5. Relationship of Rainfall, Runoff, Infiltration and Initial Abstractions
(From: Schulz, 1978)

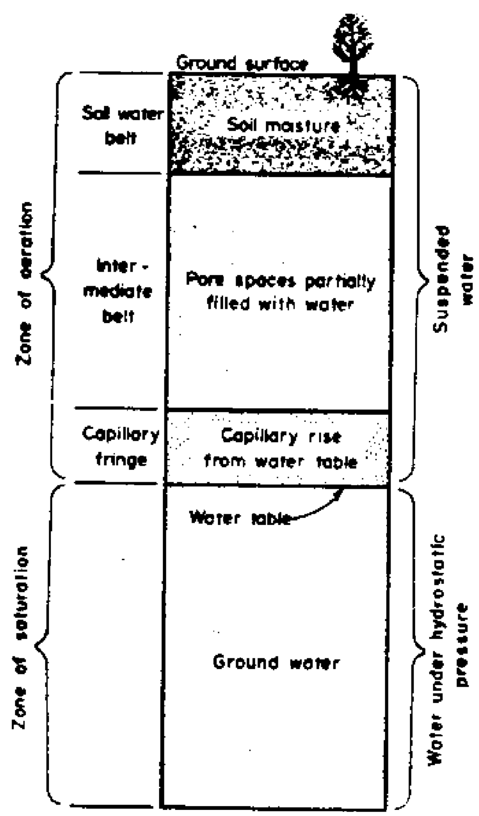

Figure 6. Subsurface Distribution of Water
(From: Johnson Division, UOP Inc, 1982)

distribution of water is illustrated in Figure 6.

In the Virgin Islands, soils are for the most part relatively shallow with high clay contents and cap a rock base. Groundwater recharge on an average amounts to 5% of the annual rainfall. The occurrence of feasible extractable water is summarized in the following table.

Table 1. Estimated Yield of Virgin Islands Aquifers

Aquifer Characteristics	Potential Yield*
Thin sand and gravel bed	10 - 30
Solution cavities	20 - 60
Fractured rock	2 - 5

* gallons per minute

In St. Thomas the major aquifers are located at Turpentine Run and Bonne Resolution and are capable of supplying 0.4 million gallons per day (mgd). On St. John the principal aquifer is located at Adrian and has a potential daily yield of 0.01 million gallons. Eight well fields sited in Adventure, Barren Spot and La Grange on St. Croix with a total of 37 wells produce 0.8 million gallons of water daily. This is 20% of St. Croix's water needs.

It is useful to examine the definition of several of the terms most commonly used in discussions of groundwater. The <u>porosity</u> of a soil is the proportion of its volume not occupied by solid material. An <u>aquifer</u> is a water saturated geologic unit that will yield water to wells or springs at a sufficient rate so that the wells or springs can serve as practical sources of water supply. While porosity represents the amount of water an aquifer will hold, it does not indicate how much water the porous material will yield. The specific yield of a soil is the quantity of water that a unit volume of the material will give up when drained by gravity, while the corresponding volume retained is its specific retention. The capacity of a porous medium for transmitting water is its permeability. The rate at which water may be withdrawn from an aquifer without depleting the supply to such an extent that withdrawal at this rate is no longer feasible is the safe yield.

In their initial development, wells are tested by pumping under controlled and well monitored conditions to determine the productive capacity of the completed well and to provide data on which the selection of the pumping equipment to be used can be based (Refer to Figure 7). The static level of the well is the level at which water stands in the well when no water is being removed from the aquifer. This level is normally expressed as the distance from the ground surface to the water level in the well. The pumping dynamic level is the level at which water stands in the well when pumping is in progress. When pumping stops, water in a well rises and approaches the static water level. At any particular time during this recovery period, the distance at which the water level is found is the residual drawdown. The volume of water per unit of time discharged from a well is the well yield. The yield of a well per unit of drawdown is known as the well's specific capacity.

Groundwater levels are commonly monitored by piezo-

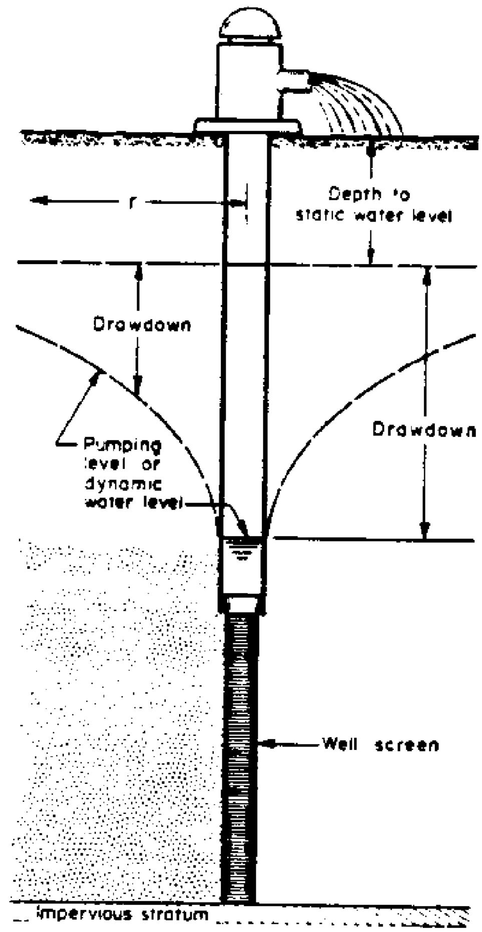

Figure 7. Measurements Related to Well Performance and Pumping Tests of Wells and Aquifers
(From: Johnson Division, UOP Inc, 1982)

meters, observation wells and production wells. These are shown in Figure 8. A piezometer consists of a casing, perforated near the terminal point only, that is installed in such a way that the casing fits tightly against the geologic formation. The height to which water rises in the piezometer is the water-pressure head at the terminal point of the piezometer. The observation well is a perforated casing simply placed in a bore hole with no attempt to provide a seal in the aquifer. In installing the observation well, care is taken not to penetrate the underlying confined aquifer in order that the observation well properly indicates the position of the water table. The production well may penetrate any confined layers present and indicates an average water-pressure head.

<u>Rain Water Harvesting</u>

Rain water harvesting has been the traditional source of water in tne Virgin Islands and still is the preferred source of water for most residents. On each of the islands the greatest annual rainfall occurs in the northwest and the least on the southeastern coasts. As can be seen from Figure 9 which shows average rainfall data for a location in St. Croix, February and March are the driest months and September is the wettest. Almost half of the average annual rainfall occurs between August and November. Generally, rainfall occurs as brief intense showers of less than a few tenths of an inch.

Methods utilized to determine the amount of rainfall

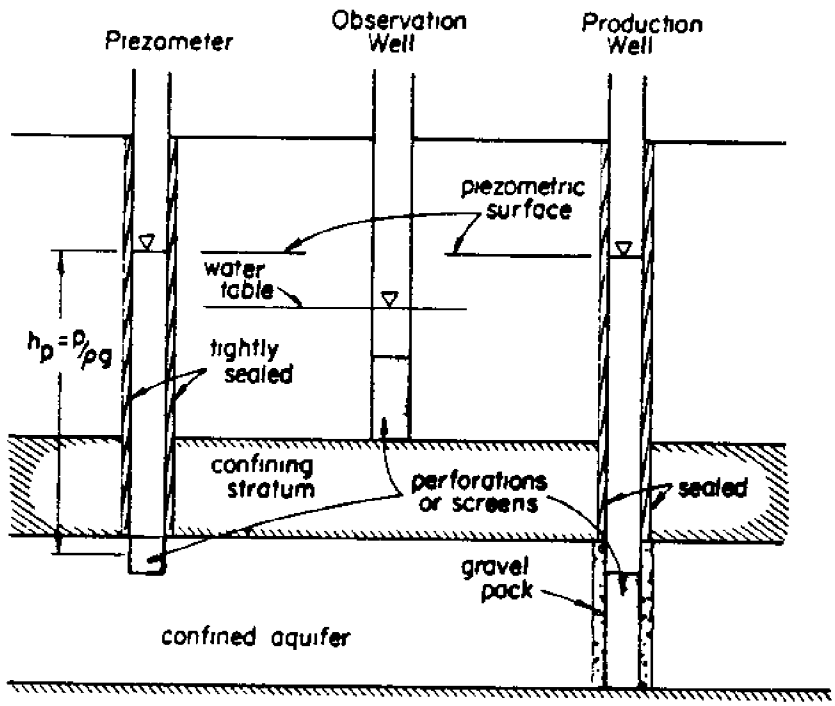

Figure 8. Common Facilities for Observing Water Levels in Aquifers
(From: McWorther and Sunada, 1981)

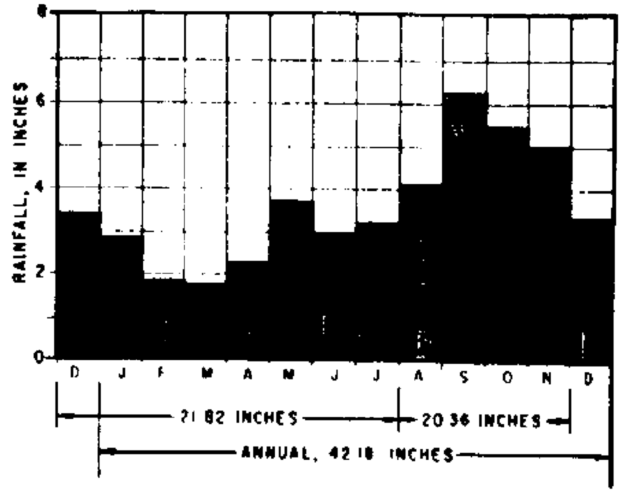

Figure 9. Mean Monthly Rainfall at Anna's Hope, St. Croix, 1920 - 1967)
(From: Jordan, 1975)

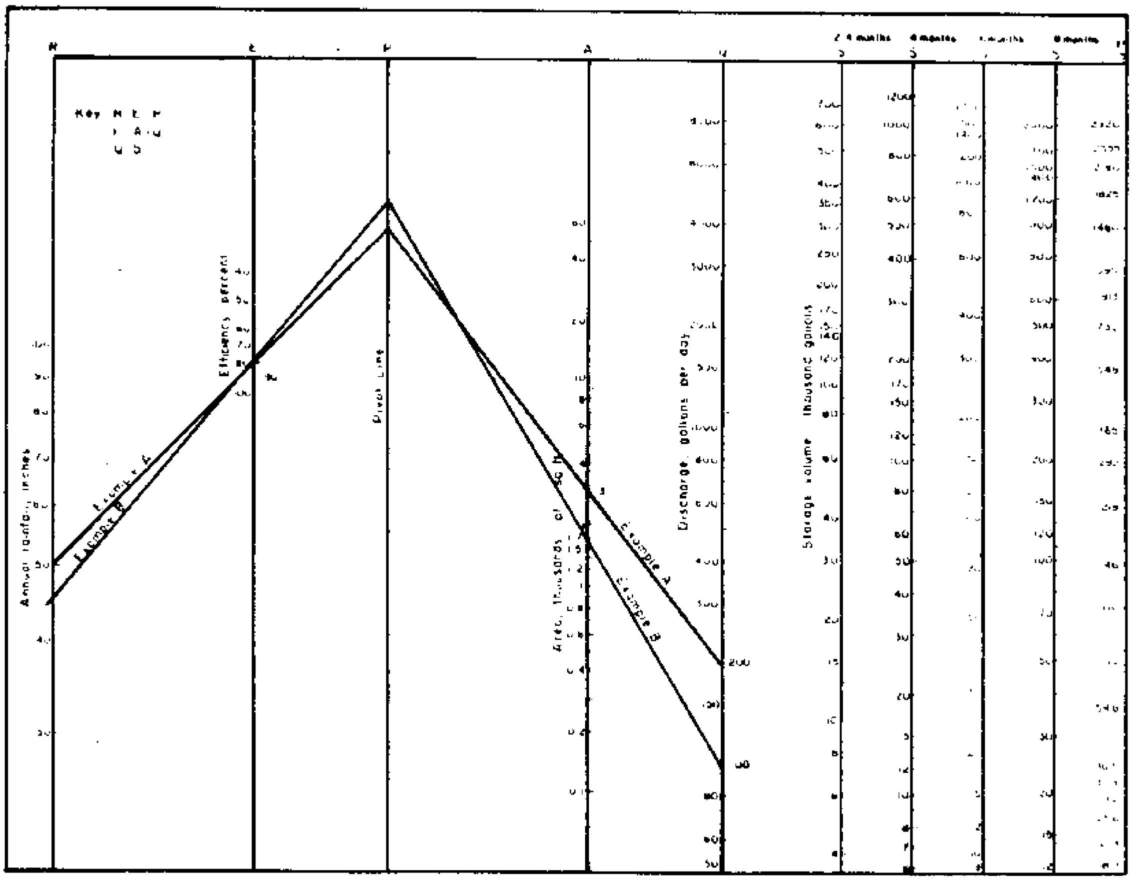

Figure 10. Nomograph of Rainfall and Runoff from Catchments
(From: Cosner, 1972)

that may be harvested from a purpose built catchment use essentially the same approach as those to determine runoff from other surfaces. Results obtained are often expressed in nomographs (Figure 10) or design curves (Figure 11).

Cisterns are required by law in the Virgin Islands and sizing requirements are presented in the table below.

Table 2. Cistern Sizing Requirements in the Virgin Islands

Type of Structure	Required Cistern Size*
Single story dwelling	10
Multi-story dwelling	15
Churches and warehouses	4.5
Other buildings	Exempted

* gallons per square foot of roof area

In St. Thomas, rainfall harvesting satisfies 20% of the daily potable water demands and in St. Croix and St. John 13% and 75% of the respective demands are satisfied by rainfall harvesting.

In considering rain harvesting schemes it is again crucial to know what assumptions were made in developing the proposed project. The length of the rainfall period is very important here as well as the characteristics of the rainfall events included. Though the average of the rainfall used in the simulation might be consistent with the observed average, the patterns, return period and magnitudes might not be realistic. Evaporation must be considered as well as the drainage characteristics of the catchment area.

Measures to preserve the quality of rain harvested water must also be taken into consideration. The catchment sur-

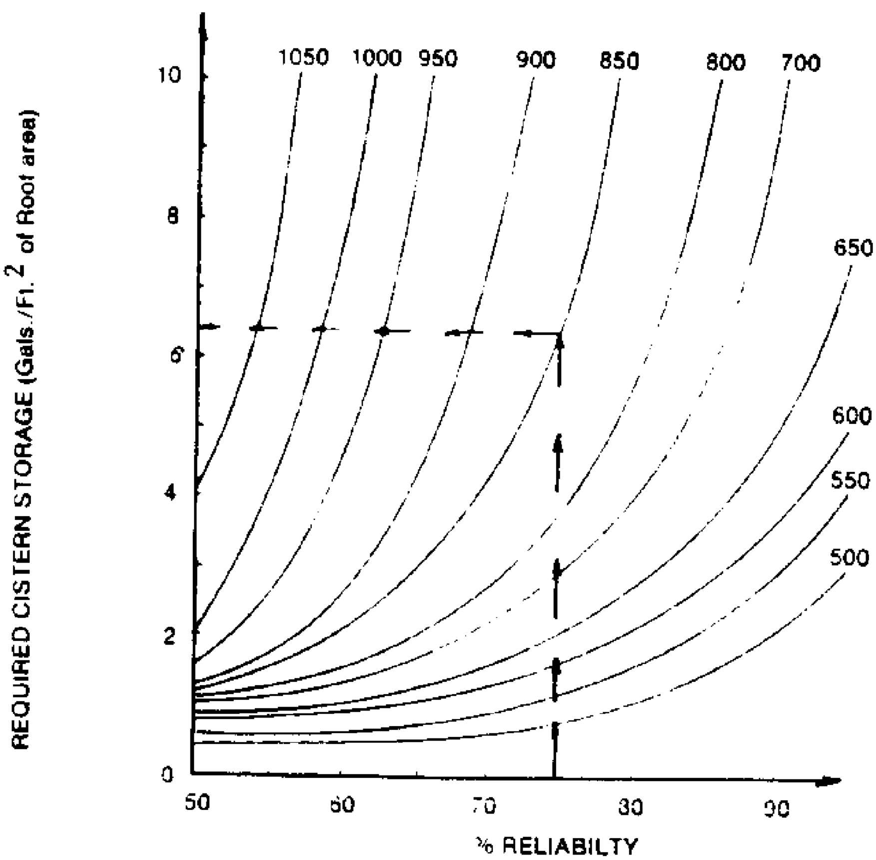

Figure 11. Cistern Sizing Curves for Sprat Hole, St. Croix
(From: Smith, 1981)

faces should be protected as much as possible from direct contamination by animals as well as overhanging trees. Storage structures must be located such that they are not flooded by storm runoff while at the same time accessible for periodic cleaning and maintenance.

Desalination

The sea surrounding the Virgin Islands provides a vast quantity of water which can supply water above and beyond needs. Desalination of this water is an attractive alternative because of the ready availability of the raw resource and the reliability which can be expected. The principles of the two most popular saline-water conversion processes, reverse osmosis and multistage flash distillation, are illustrated in Figures 12 and 13 respectively.

The energy requirements of all desalination processes are high and consequently desalination is expensive. Projects proposing to utilize desalination should also propose in detail strategies for withdrawal of the raw water (withdrawal through wells may ruin neighboring aquifers) as well as plans to dispose of the reject brine. Adequate storage should be provided to meet demands when the desalination plant is not in operation.

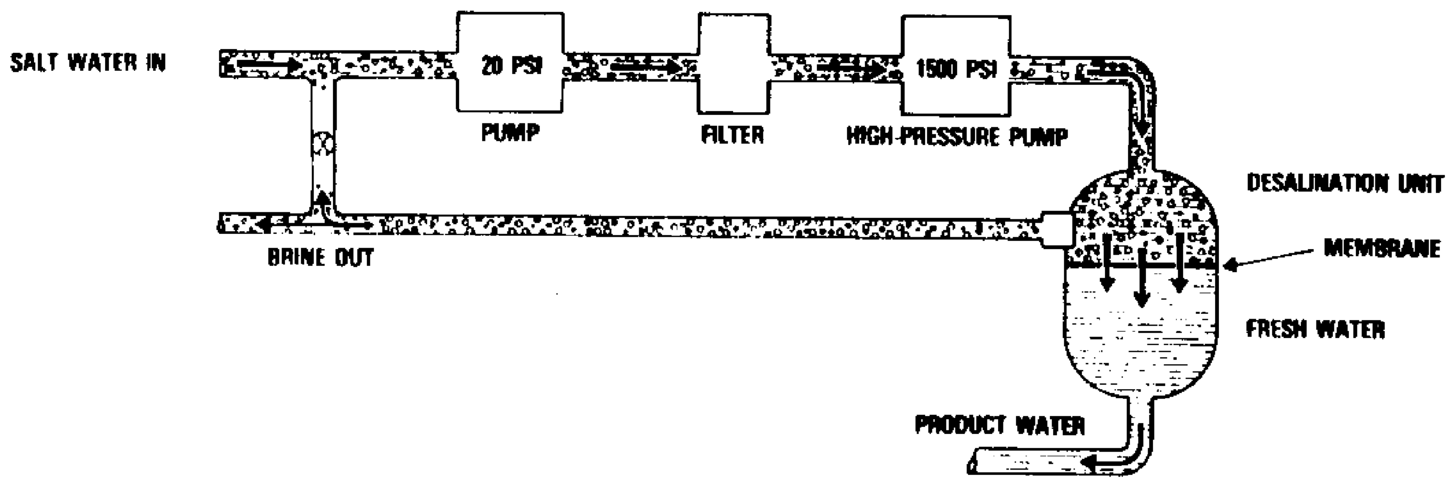

Figure 12. The Principle of Reverse Osmosis
(From: Office of Water Research and Technology)

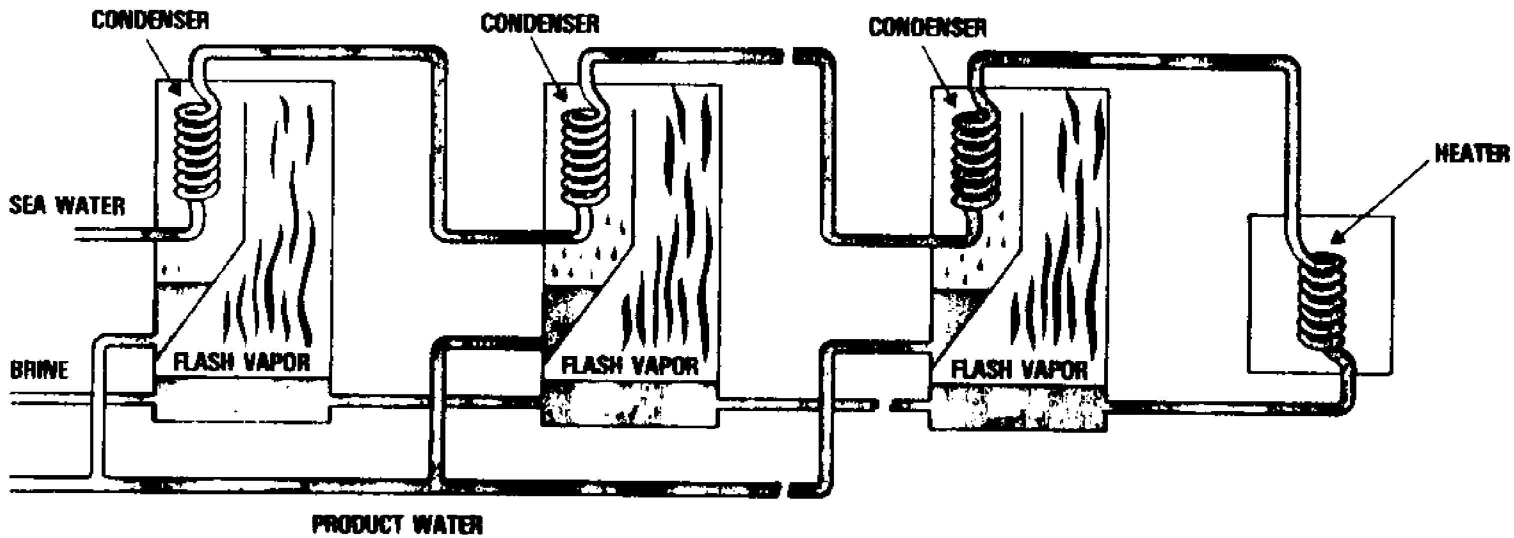

Figure 13. The Principle of Multistage Flash Distillation
(From: Office of Water Research and Technology)

Summary and Conclusions

An overview of the aspects of hydrology which should be considered in the CZM review process was made. The more conventional sources of water, surface water, groundwater, and rainfall were examined in greater detail than the other commonly used source, desalination. It was shown that there are advantages and disadvantages associated with each approach towards provision of a safe and sufficient water supply. While the basic hydrologic principles were presented it was repeatedly stressed that assumptions made in the formulation of plans should be thoroughly investigated. While there may be several approaches to solving a water provision problem, each approach is at most only as valid as the assumptions made in its development.

It is strongly recommended that reviewers scrutinize very carefully the aspects of all development plans which relate to water. On our small islands the frequent water shortages and less frequent surpluses affect us all in one way or the other. Arthur W. Lewis, a native of St. Lucia and winner of the 1979 Nobel Prize in Economics, writes in Development Planning: The Essentials of Economic Policy (New York: Harper and Row, 1966): "One simple test of the quality of a development plan is to see what it says about water." What Mr. Lewis said then applies with critical importance now to us here in the Virgin Islands.

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Methodology for Assessment of Environmental Factors
Coastal Zone Management Science and Technical Workshop
13 November, 1985 - College of the Virgin Islands

William T. Gorham

INTRODUCTION

Simply put, the objectives of environmental assessment reports (EAR's) are to determine what are the environmental conditions of an area and how these conditions might change because of proposed actions. Conditions to be considered include biological, chemical and physical factors. Often determining the current environmental status of an area is easy relative to predicting the effect of the proposed actions. In the first section of this chapter, methods for determining densities of organisms in different communities are presented. The second section deals with chemical analyses which may be routinely conducted as part of EAR's. The third section covers analyses of physical factors appropriate to EAR's.

In this chapter a large number of techniques are presented and, as a result, only a superficial treatment of each is possible. The information is aimed at the CZM commissioners and staff members who are not professional scientists. Sufficient information is presented so a non-scientist can understand how much of the data on the marine environment may have been collected for an EAR. For the professional scientist associated with CZM the presentation should serve as a refresher on many techniques and as a reference to several excellent general sources of material. These sources provide detailed discussions about how to conduct specific analyses and the limitations and cautions related to those analyses. The information presented here is not intended as a complete catalog of methodology, but rather as an overview of many typical techniques. Omission from this report does not imply that a particular method is necessarily inappropriate to an EAR.

The methods presented in this chapter are mainly applicable to the marine environment. The techniques typically require that the investigator either uses a boat equipped with the appropriate sampling gear or collects samples and data by hand using skin diving or scuba diving gear.

BIOLOGICAL SAMPLING

In sampling for the living organisms of an area one must determine what species live in an area, how commonly each species occurs, and in what assemblages or communities they live. The types of plants and animals to be assessed as well as the substrate they live on or in will strongly dictate what techniques can be used. Methods for determining large benthic (bottom dwelling) animals and plants in open areas will be examined first. Topics such as transect lines, quadrats, and appropriate numbers of samples are widely applicable to many types of sampling and are thus discussed in the first section. The determination of infaunal animals, those living in the substrate, is considered next, followed by a brief treatment of assaying for fish and planktonic organisms such as phytoplankton, zooplankton, and bacteria.

There are several good general resources for establishing sampling programs and collecting data. Southwood (1966) published a work of ecological methods which emphasized terrestrial techniques but in which he also discussed general considerations for beginning ecological studies. While the text is 20 years old, it still provides many good points about sampling in general. Gonor and Kemp (1978) published a book through the U.S.E.P.A. which considered methods for the quantitative assessment of intertidal environments. They specifically considered factors which were important to environmental assessments such as an EAR. Finally, a reference particularly appropriate locally would be one published by U.N.E.S.C.O. (1978) on coral reef research methods. This latter book presents many methods for conducting research into a variety of aspects of coral reefs.

Large Benthic Animals and Plants

Prior to surveying an area some sort of reference point or line must be established. Frequently the reference is a transect line. The nature of the transect will be determined by the size of the area being considered and the parameters being studied. The simplest type of transect to prepare and sample is a belt transect. In this method, a reference line is placed on the bottom in the study area. The investigator swims the length of the transect counting all appropriate organisms a given distance on either side of the line. Normally, a pole of 1 or 2 meters is used to determine the width of the belt. Organisms lying beneath the area covered by the pole are counted, those outside of the belt area are ignored. The data are presented in densities per square meter as the sum of all animals counted divided by the area surveyed.

The length of the line is dictated by the size of the study area and the organism's sizes. Practical considerations as to how long a line can be handled in the water also limit the transect length. Common lengths are 10, 30 and 50 meter lines. The 10 meter lines are usually marked at 1 meter intervals, while the longer lines are marked both at 5 meter intervals with one symbol and at 1 meter intervals with another symbol.

In a large, shallow area where clean water allows for good, long distance visibility and the organisms being studied are large and easily identified, a compass heading without a specific rope or line on the bottom may suffice as a transect line. The main advantage of such a transect is that little gear is required for its implementation. Its primary disadvantage is that there are no ready references for measuring distance or maintaining straight lines along the transect. Additional disadvantages include surveying areas previously covered and defining the width of a belt if a belt method is used. By surveying the entire length or width of a study area, or by traversing between clear demarcations within the study area the first disadvantage can be avoided. The second problem may also be minimized either by using transects which are sufficiently far apart to eliminate overlap or by using statistical methods which are unaffected by duplication of sampling sites. The third disadvantage may be avoided by using a rod of defined length as described above. Attempting to count all appropriate organisms within the limit of visibility is unacceptable because visibility underwater normally varies and is difficult to determine. Where visibility is reduced, where compass headings are difficult to use, or where distances are short and/or difficult to determine, a line must be placed on the bottom for reference.

Where organisms are small or difficult to see, quadrats are normally required. A quadrat is a device which encompasses a specified area. Quadrats are usually squares although other shapes are equally appropriate. When using a quadrat, it should be placed randomly in the study area. A transect line with secondary lines perpendicular to it produces a grid which allows for the specific placement of the quadrat anywhere within the selected area. Pairs of random numbers are selected, usually from a random number table, and are used to determine where the quadrats need to be positioned within the grid.

As with the transect line, the size of the organisms and the size of the study area will dictate the quadrat size. For specimens several centimeters or more in length and in relatively low abundance a quadrat of from 1/10 of a meter to 1 meter square would be appropriate. The tendency should be that the more animals and the smaller they are the smaller should be the quadrat. A single large quadrat, e.g. 1 meter square, can be made more useful by placing lines at regular intervals, e.g. 10 cm, thereby creating a grid within the quadrat. Such a grid allows one to survey carefully, and completely a large sized quadrat. Alternatively, one can census subquadrats within each large quadrat and estimate total densities without having to count all the organisms within the quadrat.

Quadrats are commonly square and are usually made from either steel or PVC pipe. Steel or other metal quadrats are convenient because they normally stay where they are put on the bottom. They may rust and large ones may be difficult to deal with in the water. Quadrats of PVC pipe are often easier to use than metal quadrats because they are lighter and may be designed to be assembled and disassembled under water easily. Their main disadvantage is that they are nearly neutrally buoyant and hence move easily in surge or currents when placed on the bottom. An additional problem is that the pipes can trap air when initially submerged making them float rather than sink. Drilling holes along the pipe or otherwise allowing the air out alleviates this problem. A reasonable alternative to a fixed, square quadrat is a round one made of two weights attached by a line of set length. This type of quadrat is readily transported and, in the proper situations, can be quite effective. It is used by placing one end at the center of the desired location then swinging the other end in a circle. Any organisms within the area of the circle are counted. The area covered in this circular quadrat is determined from

$$\text{Area} = \text{pi} * \text{radius}^2$$

where pi = 3.14 and radius = the length of the quadrat line.

Corals and Macroalgae

Corals and macroalgae both present special problems. Simply counting the number of individuals in an area may not accurately reflect their importance or abundance. Some individuals may be very large while others may be quite small, yet they may all be adults. Additionally, in coral and rocky areas as well as within algal communities, organisms exist in a three dimensional array. Simply looking at surface area from a horizontal plane could strongly bias the results. One convenient method for determining the percentage of a substrate covered by an alga or coral is to use a transect line with length but no width. The line is marked at short intervals; a light chain with large links is particularly handy. The number of intervals (links) which are over each species of coral or alga is counted. That number is divided by the total number of intervals (links) in the line (chain) to yield a measure of the percentage of the line underlain by each coral or alga and thus the percent cover for each organism. Since corals and algae can grow under other corals or algae, organisms under other organisms must be counted and added to the total. By such a determination it is possible to have a coverage of over 100%. A variation on the use of a straight line over coral or a rocky area is to have the line follow the contour of the substrate. This procedure allows the estimation of the total surface area of an organism rather than simply its horizontal surface area. It is particularly useful for encrusting forms or pillar-like corals.

A common question raised when sampling is "How many samples should be taken to accurately reflect the environment under consideration?" Properly, the number of samples varies with the abundance of each type of organism, the specific questions being considered, and the level of precision which is desired. Preliminary sampling of an area is required to determine the variability of the data. Where the variability is high, more samples are needed. If the abundance of only the most common animals or plants is required then fewer samples are needed. If a higher degree of statistical reliability is desired, more samples are required. Statistics books such as Biometry by Sokal and Rohlf (1980) present methods for determining appropriate sample sizes. Typically samples should be taken until the cumulative variability of the entire set of samples reaches some relatively stable value or until the rate of encountering new species in successive samples falls to an acceptably low value. Obviously, it is the observers discretion as to what are acceptable values.

Infaunal Animals

Sampling for infauna, animals within the sediment, requires many of the same techniques discussed above. Samples should be taken at defined stations with specific sampling sites randomly selected. Using transects and grids are often required.

Sampling sediment and infaunal animals can be accomplished by dredges, grabs, or cores. Dredges are pulled behind a slowly moving boat and scrape up sediment and organisms from the bottom. They tend to have a rectangular boxlike front with a heavy cutting edge at the bottom. Trailing behind is a heavy mesh bag which allows most sediment picked up to be lost while retaining most animals and plants. Dredges are normally good for a rapid, qualitative survey of a large area. Because it is difficult to define exactly its sampling area and/or sampling depth, i.e. depth into the sediment, quantitative analysis is difficult.

Grabs produce a small but quantitative sample of sediment and organisms. Although variable in appearance they work by essentially the same method. They are readied for sampling by opening the jaws and setting a trigger mechanism, then lowering them into a stationary position on the bottom. A sample is collected by closing the jaws of the grab thereby retrieving material from a known surface area of the bottom. The depth of substrate which the grab collects can be estimated although it varies with different types of grabs and with position within the grab, i.e. from the edge to the middle of the sample. Following collection, samples are washed through one or more screens to remove the sediment. Animals of interest are collected from the screens and preserved. The mesh size used in the screens is set by the researcher; a 2 mm mesh is commonly used. Information received is expressed in densities per unit area.

Two common types of grabs are the Peterson grab and the Ekman grab. The Peterson grab works by using its own weight to close the jaws once it lands on the bottom. The act of landing on the bottom releases a catch which holds the jaws open. As the grab is lifted off the bottom its jaws draw shut picking up the sample. Peterson grabs commonly enclose 0.1 m^2 surface area. They are simple to use although they tend to be quite heavy. In some ways the Ekman grab is easier to use than the Peterson grab because the Ekman grab is much lighter. The jaws on the Ekman grab close by spring action. Thus while the Ekman is easier to use, it also is more likely to malfunction and is more dangerous.

The advantage of grabs over dredges is that the grabs are more quantitative. Also, the samples can be collected from a stationary platform so a boat capable of towing a dredge is not required. The main disadvantage of the grabs is that they sample from a considerably smaller area than does a dredge.

The third general type of devices for sampling the infauna, is cores. Cores are most effective for sediment analyses and other geological sampling, although they can provide some biological information. Basically a core is a heavy, hollow tube which is quickly lowered to the bottom, usually at close to free fall velocity. There is typically a sleeve which fits within the outer main core. As the core penetrates the sediment, a flap at the upper end allows water to escape from the tube. As the core is removed, the top flap closes producing a suction and retaining the sediment within the inner sleeve of the core. On the boat the inner sleeve is removed from the outer core and stored for future analysis. Subsamples are removed from the core sleeve in layers and analyzed for sediment characteristics and for organisms present in each layer. Cores have the advantages of providing deeper samples than grabs or dredges, being quantitative for surface area, and, most importantly, of preserving the vertical profile of the sediment. The primary disadvantages are that they sample from a small surface area and the samples require a large storage space.

Plankton

Sampling for plankton, small plants and animals in the water column, is achieved by pulling nets through the water. Nets can vary in mesh size for sampling different types of organisms. Smaller meshes allow smaller zooplankton and phytoplankton to be captured, although they also require slower speeds and shorter towing times. Fine nets produce a relatively large "bow wake" in front of them. This "bow wake" coupled with the necessary slow towing speed means that fast swimmers escape from in front of the net and avoid being caught. Obviously large mesh size misses the smaller plankton but allows for faster towing speeds, collection of more active swimmers, and longer tows. A major drawback to all plankton tows is the destruction of fragile forms. Another difficulty is quantifying the sampling effort. Opening/closing nets, e.g. Clark Bumpus nets, or covered/collapsing nets, operate by preventing water from entering the net until it is at the proper depth. At depth a messenger is sent to the net, the cover is removed or diverted and the sample is taken. Following the appropriate interval, another messenger is sent to the net and either the net is collapsed or the opening is otherwise closed. Commonly in such quantitative sampling nets an impeller is used to measure the amount of water actually passing into the net. Using standard formulae and the information of the boat's speed, amount of tow wire out, and angle of tow wire, the net's approximate depth can be determined. By reading the information from the flow counter, the amount of water sampled can be determined. Results can be expressed in numbers of organisms per unit volume, species per unit volume, or biomass density.

Vertical plankton tows offer an alternative to horizontal tows. In this type the net is lowered to depth then returned to the boat. No information is available as to relative depths of the organisms found although the biomass per volume of water sampled can be determined readily. A vertical tow is easily performed since there is no need for a moving boat capable of towing a net. The applicability of either a horizontal tow, qualitative or quantitative, or a vertical tow is dependent on the information sought. A relatively simple sampling of total planktonic biomass should be relatively easily accomplished with the vertical tow.

Fish

Methods for determining fish stocks include stationary netting, mobile netting, trapping in fish traps, swimming transects, collection by hand, and others. The specific method is strongly dependent on the type of fish being assayed. Where a narrow channel with a predictable current is available, placing a net part way or entirely across the channel will capture some or all the fish moving past the net during a given time interval. The size of the fish is limited by the size and type of netting. A gill net traps fish as they attempt to swim through it. Small fish can pass through the net; moderate sized fish get caught up in the net; larger fish may simply "bounce" off the net. Sometimes the net may be set up as a funnel to direct the larger fish into a trap where they are caught. This type of stationary stream sampling provides mainly qualitative data unless details of the stream currents, stream size, migratory behavior of the fishes, and other related data are available.

In larger areas where stationary nets are unfeasible or inappropriate, an effective method for sampling fish is a trawl, e.g. an otter trawl. In this method a net is towed slowly behind a boat. The net has boards on either side which pull the sides open to their fullest extent. The upper portion of the net has floats and the lower portion has weights, both of which combine to keep the mouth fully open vertically. The otter trawl is a useful technique for a quick, qualitative assessment of the bottom fishes in an area. It is limited to areas of flat bottom topography without obstructions. Further, as was the case with the plankton nets, faster swimming animals can swim away from the front of the net and escape capture. Other types of moving nets include beach seines or seines deployed from boats.

One note is appropriate at this point. For any fish counting method except visual, discussed below, one needs to avoid collecting a significant portion of the fish in an area for the sake of a complete census. There is little to be said for a study which reports exactly how many fish there had been in an area before the researcher killed them all.

Where visibility allows it and where fish are abundant enough, swimming a defined course and counting the fish within a specified volume of water is another effective method for fish censusing. If a compass course is used as the transect line, factors relating to making the study quantitative must be considered as mentioned above. Related methods involving collecting and tagging of fishes or identifying specific fishes are available but would probably go beyond the scope of most EAR studies.

Bacteria

Determining bacterial concentrations can be of particular importance when considering waste treatment plants or similar sources of human (or other animal's) wastes. Normally, bacteria in the Coliform group are associated with humans. They are a well studied group of organisms for which exist good techniques for their examination and enumeration. The American Public Health Service Standard Methods of Water and Wastewater Analysis 1980, 1985 have extensive sections on the application of these methods.

Sample collection involves techniques similar to those described later in the water chemistry section. The primary considerations are using sterile collection vessels and methods as well as quickly analyzing the samples. For enumeration, generally one of three methods are used. In the first method, MPN (Most Probable Number), serial ($1/10^{th}$) dilutions are made of the test sample. A sufficient number of dilutions are performed to produce some tubes with many bacteria, some with few bacteria, and some with no bacteria. Assuming the initial sample had one million bacteria per ml, after 6 serial dilutions, the concentration should be 1 cell per milliliter; after 7 dilutions it should be 0.1 cell per ml; and after 8 dilutions it should be 0.01 cells per ml. If the incubation tubes hold 10 ml each, then there should be one bacteria in each #7 dilution tube and, on the average, one bacterium in only one of ten #8 dilution tubes. The medium used allows one to observe the production of gas by the bacteria. Each #7 dilution tube should produce gas since, statistically, they should each have started with one bacterium. By a similar rational, only one of ten #8 dilution tubes should produce gas. By statistically analyzing the results of how many tubes at each dilution showed gas production, one can calculate a value as to the most probable number of bacteria in the original sample.

A variation on the MPN method is direct plating. Again serial dilutions are made from the original sample, but in this method, the diluted subsamples are put onto agar plates (enriched bacterial growth medium) and incubated for a standard length of time. Since each individual bacterium should produce a separate colony, the number of colonies on a plate indicates how many bacteria were in each diluted subsample. Plates which become fully overgrown must have been inoculated with subsamples which were not sufficiently dilute. The subsample contained too many bacteria and individual colonies could not be determined. Plates which have no growth thus must have been inoculated with subsamples which were too dilute, i.e. they contained no bacteria. Appropriately diluted subsamples will produce a moderate number of distinct colonies on the plates. The number of colonies and the number of dilutions to produce that number of colonies are used together to determine the concentration of bacteria in the original sample. These two methods, MPN and direct plating, are useful for determining bacteria which are capable of active growth in or on the defined medium. As mentioned the growth of bacteria in the Coliform group in fresh water is well studied. Growth of marine bacteria is not similarly well known. Marine bacteria in non-Coliform groups are not as reliably picked up by the MPN or direct plating techniques.

In the third method actively growing bacteria are stained with one of two compounds which selectively stain genetic material. Water samples are mixed with the stain, either acridine orange or DAPI, then filtered onto pretreated filter pads, and finally the bacteria are counted directly under a microscope using epifluorescence microscopy. The method is fast and easy and it gives absolute numbers of bacteria in a given sample. However, different types of bacteria are not readily defined and the relative metabolic activity of the bacteria, i.e. fast growing or slow growing, can not be determined. In samples where total bacterial concentrations are required or in situations where the growth requirements of the bacteria are not known, e.g. in sea water, this method offers a good alternative to culture techniques.

Identifying bacteria to the genus or species level normally goes well beyond the scope of any EAR. Techniques for identifying most bacteria are more sophisticated than those mentioned here and require a more elaborate laboratory setup.

WATER CHEMISTRY

Chemical information required to make reasonable estimates of effects of environmental changes include data on oxygen, nutrients, organic material, and trace metals. Which specific analyses would be required will be dictated by the specific type of development. For a project requiring dredging or filling where sediments would be resuspended, data on organics, nutrients, and trace metals in the sediments would be particularly important. For a less extensive impact on the marine environment, fewer factors could be examined. As with biological sampling, once it is determined which factors need to be sampled, the next step is to determine from where the samples should be taken. Techniques similar to those described in the biological sampling section are appropriate to choosing and locating sampling stations. Next, the specific technique for collecting, holding, and analyzing the samples must be defined. For any factor, different analytical methods have different requirements for use, different levels of precision and require different assumptions. Before selecting any specific analytical method, the number of samples required to be analyzed, the necessary precision of the data, and the equipment available for analyses must be evaluated. This section contains general information on many of the more common analytical techniques as well as references for more detailed information. Principles concerning sample collecting and storage are presented first and are applicable to most analyses.

Sample collecting

Water samples must be collected from a defined depth without contamination. Common samplers are Niskin or VanDorn bottles which are basically a tube with plungers at each end. The bottles are prepared by removing the end seals (plungers) and securing those to the bottle's side. The bottles are secured to a hydrocast line, lowered to the appropriate depth, and closed by messengers sent down the line. Niskin-type bottles are useful for collecting samples for analysis of oxygen, nutrients, pH, trace metals, temperature, phytoplankton, turbidity, and other factors. Once the sampling bottles are on board the samples must be placed in special bottles and often fixed or specially stored. Delay or improper fixation of samples may ruin them and can produce worthless results. Similarly, delaying the analysis or improperly storing the samples may also ruin them. Major considerations will be presented with each analysis discussed below.

Detailed requirements are available in either of several general references dealing with water analyses. The Standard Methods of Water and Wastewater published by the American Public Health Service (1980, 1985) provides a wealth of information especially relating to determining a wide variety of factors in both fresh water and waste water. The Environmental Protection Agency (1978) has also produced a handbook which gives an excellent detailed treatment of typical chemical analyses of water and wastes. For sea water analyses, an older but excellent reference is by Strickland and Parsons (1972). This latter book has been used widely and many analyses have become standards. While many of their techniques have been modified and improved, it provides an excellent starting point for many techniques.

Oxygen

Oxygen can be determined by either chemical or electronic means. The chemical method is more precise but it is more expensive and requires more analytical skills. Electronic determinations are easy and fast, providing data as the sample is collected. It is inexpensive once the machine is purchased. Its primary disadvantages are its lower precision and potential lower accuracy.

The typical chemical analysis for oxygen in water is the Winkler Method. A water sample is drawn into either special Winkler bottles or BOD (biological oxygen demand) bottles; special care is taken to avoid introducing air bubbles into the sample. Two reagents, manganous sulfate (or manganous chloride) and alkaline iodide, are added in sequence to complex all molecular oxygen. In the lab, the sample is acidified causing a series of reactions leading to the production of free iodine. Since the iodine occurs in the same proportion as the oxygen did originally, and since the iodine concentration can be determined easily, the oxygen concentration can be calculated. The method is calibrated with samples containing known amounts of iodine and produces a direct chemical measure of the original oxygen concentration. With this technique, oxygen concentrations can be determined with a precision of 0.05 mg/L (~PPM) (0.005 mg/L if a special apparatus is used). For highly polluted samples or waters containing chemically interfering substances, modifications to the method are available.

As mentioned, the technique for measuring oxygen electronically is much easier to use than the Winkler method, however, it provides one to two orders of magnitude (10 - 100x) less precision. The oxygen probe contains two electrodes between which a small current flows. The magnitude of the current corresponds directly to the amount of oxygen in the solution between the electrodes. The electrodes are separated from the surrounding environment by a thin membrane permeable to oxygen. As current passes between the two electrodes oxygen is consumed. The rate at which it is replaced is directly related to how fast it passes across the membrane which is directly related to the concentration in the surrounding medium. Because oxygen is consumed in the process of evaluating a sample, it, the sample, must be well mixed as the data are being read. Layers of low oxygen can be produced next to the membrane and cause falsely low readings or may contribute to apparent drift in the machine. Drift can also be inherent within the machines. To accommodate machine drift, probes must be calibrated regularly, i.e. from tens of minutes to hours.

Electronic sampling procedures are quite simple. The probe and machine are first calibrated by reading the oxygen concentration of the surrounding air. Since that reading is affected by atmospheric pressure, machines usually contain one or more tables indicating the proper oxygen concentration for the prevailing conditions. Before a sample can be analyzed its salinity must be determined within 1 ‰ (part per thousand). Unless samples are estuarine where salinity can vary widely, salinities are usually measured only once, the machine is set to that salinity and all samples are tested. Following calibration of the machine, the probe is placed into a sample and the oxygen concentration is read from the machine. As mentioned, while reading the sample, special care must be taken to stir the sample very well but without injecting bubbles into the sample.

This method is both convenient and reliable if the machine is operated properly and calibrated regularly and if the samples are stirred well. As a proper backup and to confirm the validity of the machine's operation in water, occasional samples for chemical analyses of oxygen should be taken. The electronic method is particularly useful for quick analyses where the researcher wishes to identify areas of special interest or to indicate if major changes have occurred.

Because oxygen concentrations can change quickly and significantly, oxygen samples should be the first taken from a water sample. Where the chemical oxygen analyses are to be conducted, the sample must be drawn into the proper bottle very carefully assuring no bubbles enter the water. The sample must be fixed immediately. If using the electronic method, best results come from sending the probe, with an attached stirrer, down with the sampling bottles and reading oxygen concentrations while the probe is at the proper depth. Returning the sample to the surface is acceptable but provides more chances for error.

Environmental parameters related to oxygen concentration include oxygen saturation and biological oxygen demand (BOD). Oxygen saturation is simply the amount of oxygen in a sample compared to the total amount which could be there given the temperature and salinity of the water. BOD is a measure of how much organic material is in the water as indicated by how much oxygen would be required to oxidize that organic material. High BOD levels indicate that to oxidize most of the organic material much of the available oxygen would be used. If the oxygen is used for degradation of particulate and/or dissolved organic materials, it is unavailable for the respiratory requirements of the animals. High BOD levels suggest that animals in the environment may become stressed by lack of oxygen if conditions prevent the continued introduction of new oxygen to the water. While high BOD levels are not necessarily associated with low oxygen concentrations or low oxygen saturations, they do indicate the potential for serious problems.

<u>Nutrients</u>

Because growth of algae and other marine plants is often kept in check by low ambient concentrations of nutrients, changes in the concentrations of these substances can have dramatic impacts on areas. The nutrients most commonly of interest are inorganic phosphorous, as phosphate, and nitrogen, as nitrate and nitrate. They are determined by similar techniques and will be discussed together here. Phosphates are determined by reacting the water (and thus the phosphates) with a complex solution of substances and measuring the resulting reddish blue color. The intensity of the color is directly proportional to the original concentration of phosphate in the water. For nitrite analyses, water samples are reacted with another dye which produces a blue color whose intensity is again directly proportional to the original concentration of nitrite. Nitrate is determined after nitrite is determined. Part of the water sample is passed over a column of catalyst which causes nitrate to be turned to nitrite. The sample is then analyzed for nitrite. The difference in nitrite concentration before and after converting nitrate to nitrite yields a measure of the nitrate in the water. To determine properly the amounts of color produced in the analyses, the reacted samples must be measured using a spectrophotometer. Samples are easily collected with routine care being exercised to prevent contamination. Samples should be analyzed within hours of collection or be stored frozen.

Organic Material

Both particulate and dissolved organic materials may be of interest in an EAR. Particulate material is usually defined as that retained by a filter pad with 0.45 um pores or by a standard glass fiber filter pad. Simple determinations can be made either by evaporating the water from a sample in a crucible (dish) or by collecting the filterable material on a filter pad. Oven temperature of roughly 105° C or 180° C are used. The sample is weighed following drying to a constant weight or for a predetermined time, then burned to ash residue in a muffle furnace (~450 - 500°C) and reweighed. The difference in weights is the ash-free dry weight of the organic material in the sample. Samples collected on a filter pad represent particulate (filterable) organic material while samples determined by evaporation represent total organic material. Where information on dissolved and particulate fractions is required, samples can be filtered with the pad and filterate being analyzed individually as above. As an alternative, the dissolved organic carbon and nitrogen can be determined by oxidizing the sample to either carbon dioxide or nitrite. Carbon dioxide can be determined using an infrared spectrophotometer while nitrite determination is as was discussed above.

Trace Metals

Trace metals normally occur in quite low concentrations. While they are important to the normal functioning of all organisms, most are toxic when they occur in high concentrations. Organisms may accumulate these substances by passing them up the food chain from producer to consumer until the metals occur in high concentrations. Projects where the potential for trace metal contamination exists should determine ambient concentrations of trace metals and should suggest likely effects of the trace metals to the environment. Analysis is performed by atomic absorption spectrophotometry following burning of the sample or digestion of it in one or more solvents. Determination of the metals in sediment or biological tissues is easier than determining them from samples of the water column where concentrations tend to be much lower. For routine applications trace metal analyses of sediments or water are probably unnecessary. For applications dealing with dredging or filling where metals which have accumulated in the sediments over years or decades could be resuspended in large quantities, the EAR should consider trace metal contamination.

PHYSICAL PARAMETERS

The third type of information required of an EAR is on physical parameters such a temperature, salinity, water flows, turbidity, etc. This type of information is important in determining such things as where discharges or runoff might go, the magnitude of salinity or temperature changes, or the likely residence time of runoff from construction activities. The methods discussed in this section are in fairly common use. Additional information would be available from many general oceanography texts.

Temperature

The simplest parameter to determine is temperature. For surface waters, using a thermometer in a bucket of freshly collected water is sufficient. For deeper samples a thermister, a thermally sensitive resistor, on a long wire is useful. Often oxygen meters have thermisters integrated into the probe and temperature can be read from the oxygen meter. Temperatures taken at specific depths can indicate different layers of water; this information can be important in considering water flow and circulation.

Salinity

Salinity is basically a measure of the amount of material dissolved in water. Because the major constituents of sea water are essentially constant, it is possible to measure for one of them, chloride, and calculate the total salinity of a solution. Also, because the constituents are ions, their conductivity can be used to determine salinity. Finally because the physical characteristics (colligative properties) of water change with the amount of material dissolved in it, factors such as density or refractive index can be used for routine analyses.

Commercial packages are available which combine instruments to measure salinity, temperature, and depth as well as a variety of other factors. Electronic methods such as these can produce continuous readouts on a real time basis, i.e. right now. Alternatively, samples may be collected into salinity bottles and then analyzed electronically in a laboratory. Real time electronic analyses are less precise than lab electronic analyses but are easier, once set up, as well as being less time consuming. In addition, real time analyses can provide good continuous records for preparing profiles of different water masses. Lab analyses are much more precise, although the increased precision is more appropriate to oceanographic studies than EAR's.

Chemical analyses involve determining the amount of chloride in the sample by complexing it with a known amount of silver nitrate. While the analysis can become routine if many samples are to be analyzed, it is a sufficient amount of work so it is not the best method for EAR's.

An easier method for determining salinity is to measure the density of the solution with a hydrometer. The temperature and specific gravity of the sample are determined. This information is used to look up the salinity of the sample in a set of standard tables. While the method is easier than the chemical method, it is less precise and does require more sophisticated instruments and attention to certain details.

The simplest method is also the least precise. The refractive index of the sample is determined using a refractometer. The quantity of material in the solution is directly related to its refractive index. Precision of this method is roughly 0.5 $^{0}/_{00}$ while the precision of the other methods is from 10 times greater (hydrometer method) to easily 100 times greater (chemical and some electronic methods). Depending on the requirements of the specific EAR, the use of a refractometer is often sufficient for determining salinities.

Turbidity

Another indication of the amount of material in the water is the turbidity. Most methods involve determining the amount of light scattered by the materials suspended in the sample (as opposed to dissolved in it as with salinity). A simple, albeit crude, method is to look at the color of the water. Rich, blue deep water or clean, clear shallow water indicates little suspended material. Green or brown water suggest different types of materials, phytoplankton and sediment respectively. The analysis can be improved somewhat by the use of standardized color scales, although this method is still qualitative.

A more common method for indicating turbidity is the use of a Secchi disk. In this method a white or black and white disk is lowered through the water column until it just disappears from view. It is then raised until it just comes back into view. The depth to the disk is determined by measuring the amount of line put out; this depth is called the Secchi depth. The method is useful where the bottom is not visible, a rare situation in most shallow bays of the Virgin Islands.

A more quantitative measure of turbidity is determined using a nephelometer. Light is shined through the sample and the amount of light scattered at 90° to the incident beam is measured. As turbidity increases scattered light increases proportionally. Blocks producing known amounts of scattering are used to standardize and calibrate the machine in nephelometric units.

Current Flows

The water currents around the Virgin Islands are produced primarily by tidal action and wind generated waves. While the daily variation in tidal height is small, tidal influences can be quite important. Measurements of tidal heights is accomplished variously. Tidal charts are published for many areas and can be adjusted for considerably more places. Direct measurements can be made and can range from the simple, e.g. regular observations on a marked stick or pole secured on the bottom, to the complex, e.g. establishing a sophisticated, recording tide gauge. While the latter technique may be necessary in situations where tide tables are not available or are insufficient, the former method are often sufficient. Such periodic observations allow one to compare the local data to data from the nearest continuous recording tide gauge and thereby produce a local adjustment factor. Once that factor is established further observations should be unnecessary provided tide tables are available.

Whether due to tides or waves, currents can be measured by a variety of methods. For weak currents either drifters or dyes may be appropriate. Drifters are put into the currents and their positions are noted on a regular basis. Drifters with surface floats and under water "sails" can be observed from shore or a boat to measure short term movement. Longer term observations can use drifters with cards attached which either float at the surface or sink to the bottom. Some drifters wash onto shore eventually and are found by people. The postage paid, self addressed cards are then returned to the person who originally distributed the drifters. The finder notes the location and date of where the card was found. This method is more applicable for long term major current studies, although could be appropriate in very large specialized projects.

Dyes are useful for localized current studies. Basically, a dye is placed in the water and its spread from the site of introduction is monitored. Because many dyes would need to be very concentrated to be observed visually, and could cause damage in and of themselves, dyes which fluoresce are widely used. Samples are taken at regular intervals, both spatially and temporally, following the introduction of the dye. Fluorescence of the sample is measured in a fluorometer. The rate of appearance and disappearance of the dye in samples from different areas allows one to quantify reasonably well, the localized currents.

In areas where currents are strong, dedicated current meters may need to be used. Current meters vary in their sensitivity, i.e. the lowest current they can measure, although increased sensitivity is likely to carry an increased cost. If currents are only in one direction and of sufficient velocity, inexpensive meters are appropriate. If, however, the currents shift with time, such as would be the case often with tidal currents, current meters with the capacity to indicate current direction as well as current speed would be required. Such sophistication would probably be beyond the needs of most EAR's.

IMPACT ASSESSMENT

Determining the overall impact of any given project is extremely difficult. Once the physical, chemical, and biological factors are described, deciding on what will happen to the community requires information (and speculation) on how the proposed activity will affect the physico-chemical balance. Once that change has been decided upon, the expected effect of these changes must be estimated. Such estimation requires studies of how the plants and animals in the community respond to the stress to which they are likely to be exposed. Standard methods of bioassays are available (USPHS 1980, 1985) for a wide variety of organisms, although many of those organisms are not found commonly around the Virgin Islands. Good data on how local, tropical organisms respond are often not available. In the absence of good data on local organisms two options are available to the person preparing the EAR. Either the appropriate studies on how the local species respond to specific conditions should be conducted, or reasonable estimations of the organisms responses based on closely related species must be presented.

It would be nice to see an EAR give detailed evaluations of the potential changes in the identified communities as a result of the identified (or speculated) effects. The simplistic off handed dismissal that no damage will occur is certainly insufficient. Unfortunately though, because of the dearth of information on local species' responses and because of the cost in time and money to conduct appropriate experiments on the local species and ecosystems, good predictions of likely impacts to specific communities due to specific actions are difficult to produce. However, such limitations notwithstanding, efforts to predict effects must improve. Saying that there will be no further degradation of the environment by some project (because it's messed up so much already) is insufficient to allow the project. Rather, it would be nice to see that a project would be expected to cause no significant effect to a pristine environment such as occurred as recently as 10 to 20 years ago. Such a requirement would allow the environment to attempt to clean itself up and restore its proper balance.

CONCLUSION

This chapter has presented a sampling of methodology appropriate to the analysis of biological, chemical, and physical conditions in the marine environment. Several general sources of additional information were indicated.

Because the objective of EARs is not to conduct new research in the ecosystem, requesting detailed information on all impacts of a project is unreasonable. However, if the Virgin Islands is to protect the natural beauty for both the present and future generations of Virgin Islanders, strict attention must be paid to what is being done to the land and sea and at what cost. While EAR's need not produce lots of new data, neither should they contain poor science excused because of expense. The environment must be protected now because it can not be replaced at any expense.

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EVALUATION OF
THE ENVIRONMENTAL ASSESSMENT REPORT
WITH RESPECT TO THE PHYSICAL ENVIRONMENT

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INTRODUCTION

The purpose of this discussion is two-fold. First, it is intended to outline the major points of concern when evaluating the physical impacts of development. As is the case in any consideration of marine or near-marine environments, it is difficult to separate physical and biological effects. Therefore, there is likely to be some overlap between this section and others in this handbook. The distinction, however, is that this discussion will deal primarily with impacts at the systems level, that is the larger scale. Impacts on individual organisms or processes should be adequately covered elsewhere.

The second purpose is to provide some very general guidelines for assessing the completeness of specific Environmental Assessment Reports. The discussion is aimed primarily at those individuals reviewing those documents, but it can likewise serve as somewhat of a guide for those preparing EARs as well. It is impossible to adequately deal with every eventuality that might arise in the course of EAR evaluation, but some general guidelines can be suggested nevertheless. Specifically, three recommendations are made. First, a revised EAR outline is included which more closely groups subjects of similar character together. Secondly, the possibility of adding an "environmental summary" into the EAR format is discussed. And finally, a table is included which lists the types of concerns that should be addressed for various kinds of development. The table cannot completely cover every kind of development, but it does represent a starting point, a preliminary shopping list if you will, for designing studies to evaluate the impacts of various kinds of development.

Physical Impacts of Development

Marine Systems - For purposes of discussion, development has been divided into MARINE and TERRESTRIAL. In the Virgin Islands, these are inseparable, but this distinction is useful in general terms. Therefore, the reader must keep in mind the interelationship between these two areas, especially in terms of the impact of land-based development on adjacent marine systems.

The most frequent types of marine development involve: 1) dredging of the bottom for whatever purpose, 2) filling in nearshore areas for the purposes of creating fastland, or 3) the placement of some structure on the sea floor. In any of these cases, the concern is three-fold: 1) what will the impact be on organisms living in the immediate area of the project, 2) what will the impact be on "downcurrent" biota, and 3) how might the proposed project in any way modify the physical system (e.g. will it change current flow, cause beach erosion, degrade water quality, etc.?).

The impact on local biota can be addressed by a variety of means outlined elsewhere in this manual. Generally, the impact can be characterized by removal or covering of benthic organisms. It is crucial that the individual studying these effects have a sufficient background to address not only the uniqueness of the organisms affected, but the impact of their removal on surrounding systems as well. Look carefully at the credentials of the person preparing the EAR - a strong background in biology (or preferably ecology) should be evident.

A knowledge of the physical environment is equally important to understanding biological impact. First, the local current structure must be understood before it can even be determined where the "downstream" environments are located. All too often, an EAR will discuss the impact on organisms that are not even in a position to be affected, while ignoring those that will receive some heavy level of stress from the proposed project. The problem in this case generally involves a lack of knowledge of basic principles of physical oceanography. In this respect, the preparer of the document should demonstrate either formal training in oceanography, or else practical experience beyond just having lived and worked around the ocean. It is amazing how many people live around the ocean and do not understand its physical dynamics.

The other physical concern is the impact(s) of the project on the existing physical regime. For instance, dredging in a channel will generally slow down the current flow. Removal of high areas (especially reefs) can allow previously focused waves to pass through and cause severe erosion on the shorelines beyond. Placing various structures in the ma rine environment can change the flow patterns of local currents or block them altogether. And dredging too close to a once-stable beach can doom it to long-term erosion problems. All these impacts are extremely complex, and should be left only to an individual with formal training in physical oceanography or a related discipline.

The CZM regulations state that the developer shall hire a "qualified marine professional". Interpretation of this term lies at the crux of the problem. Make sure that the individual preparing the EAR is a marine professional who is qualified in the <u>specific</u> area he or she is evaluating. Do not fall into the trap of thinking that just because someone is a trained professional in one element of marine studies that they are qualified in all. Biological measurements and interpretations should be made by biologists; oceanographic measurements and interpretations should be made by oceanographers; and engineering decisions are the realm of engineers. In some cases, individuals have experience outside their trained discipline (e.g. some marine scientists have been cross-trained in several areas). I cannot count the number of EARs that I have seen that contain critical flaws that would be obvious and easy to avoid by simply involving an individual with the prop er training. And do not let anyone tell you that the expertise is not available. Qualified individuals live in the islands, and have for some time. Somewhere in the EAR, there should be a section outlining the training of the individuals <u>involved in the preparation of the report</u>.

To summarize, when reviewing an EAR on a marine project, there should be some discussion of the physical processes (waves, tides, currents, etc.) that presently exist in the area. This should <u>not</u> be limited to a generalized section copied out of some book or other report. Rather, it should be a well-conceived discussion of the present environment and <u>how it relates to the development at hand</u>. Once the EAR describes the present suite of physical processes, it should discuss two things: 1) how do these processes bear on the existing biological environment, and 2) how will the proposed project alter these processes in a way to have adverse effects elsewhere in the physical or biological system?

Terrestrial Systems - The major physical impacts for land-based projects fall into two categories: 1) What physical and biological environments will be removed by the project, and 2) what impacts will the proposed project have on runoff. The biological questions are addressed elsewhere. This discussion will, therefore, focus on runoff.

With the flashy nature of our rainfall, the watersheds of the Virgin Islands are subject to intense runoff. This is further complicated by the steep slopes on most of the island shores. In general, development impacts runoff in two ways. First, removal of vegetative cover from upland areas substantially decreases the ability of those watersheds to absorb water and hold soil. Therefore, serious upland erosion and the introduction of large quantities of sediment into nearshore waters result. Erosion causes the loss of topsoil. In the ocean, this material reduces the penetration of sunlight so critical to many organisms and can smother many others.

Alterations in the lower portions of the watersheds compromise the ability of the land to buffer the detrimental effects of runoff. Shallow ponds, a favorite target of developers serve to slow down runoff and trap sediment before it reaches the ocean. In addition, they often represent valuable feeding or refuge areas for wildlife. Filling or opening of these areas should raise immediate concern on the part of the CZM.

Impacts of land clearing can sometimes be mitigated. The placement of settling ponds to trap sediment, weirs to slow down flow, and berms to stop or retard runoff are among a host of tools at the disposal of the concerned developer. All too often, however, the Sedimentation Control Plan consists only of attempts to divert the runoff around the development. The builder obviously does not want his project flooded by all that extra water he has allowed to come down from above. But, he does not care what happens to it beyond his property line. All to often one of those boundaries is the ocean.

Beware of statements like: "Catastrophic siltation is most likely during construction, but will be controlled effectively, or totally avoided", or: "...continual or frequent episodes may kill many of the corals and other organisms. However, careful planning and construction will prevent such an occurrence". These statements from actual EARs accepted by CZM are meaningless without a discussion of the specific planning and construction practices that will be followed.

The EAR should contain some specific discussion of erosion and sedimentation-control measures to be used. The argu ment that such a discussion is premature at the CZM stage is nonsense. It is the heart of the process as it represents probably the greatest single source of impact in the project. The argu ment that such studies are too costly are equally ridiculous. You don't see developers backing out of these projects because wood costs too much. They spend the extra money that is necessary and pass it along in the total cost. A developer who accepts the higher costs of building in the Virgin Islands must likewise accept the added responsibility of development in a small insular system where environmental consequences are more immediate and dramatic than in a place like Florida, or even Puerto Rico.

The EAR - What to Look For

The remainder of this discussion will center around specific recommendations that should make the evaluation of the EAR a simpler task. It must be recognized that the individuals reviewing these documents have a wide variety of backgrounds and skills. The suggestions below have been made with this in mind.

Revisions to the EAR format - The following discussion deals with the specific format of the EAR, and how it can be designed to help the CZM staff in its efforts. Table 1 is a revised TABLE OF CONTENTS. This restructuring serves two purposes. Of less importance, it groups the subjects covered in the EAR in a more logical sequence. But more important, it highlights several critical elements that you will want to review, and should force the individual preparing the report to address the problems in a way that can be easily evaluated by individuals with a wide variety of skills.

Sections 6.01 and 7.01 would require a discussion of the potential impacts of the type of development proposed as they relate to the specific project. This discussion should be developed in general enough terms that the reviewer only needs a general knowledge of environmental systems to follow a well-constructed logical argu ment.

These sections serve two functions. First, they allow both less-technical staff members as well as the more highly trained specialists who review the report to evaluate the consultant's ability to grasp the crucial elements of the proposed development and its potential impacts. Secondly, it represents a checklist by which the reviewer can look for answers to these critical questions later on in the EAR. The reviewer should prepare a checklist from these sections, and then look for good answers to those questions and reliable data or solid logic to back them up. Thus, the reviewer (no matter what his or her level of expertise) has two opportunities to evaluate the general quality of the report.

Section 9.00 (MITIGATION) highlights specifically what the developer proposes to minimize the impacts discussed earlier in the report. If no mitigation is proposed, then those impacts had better be listed in sections 11.00 or 12.00 on UNAVOIDABLE IMPACTS. Again, the latter are highlighted, rather than being lost in a jumbled discussion of less critical items. And finally, section 13.00 would specifically require the individuals who prepared the report to justify their status as a "qualified marine professional". The discussion (or list) of qualifications should indicate either formal training in the various disciplines

Table 1. Recommended EAR Table of Contents

Section Number		Section Name
1.00		NAME AND ADDRESS OF THE APPLICANT
2.00		LOCATION OF THE PROJECT
3.00		ABSTRACT
4.00		PROJECT OBJECTIVES
5.00		DESCRIPTION OF THE PROJECT
5.01		Proposed Dates of Construction
5.02		Drawings and Maps Required
5.03		Project Workplan
6.00		IMPACTS ON THE PHYSICAL AND BIOLOGICAL ENVIRONMENT
6.01 ***		Summary of Environmental Concerns
6.02		Climate and Weather
6.03		Geology and Soils
6.04	(Land)	Landforms, Runoff and Erosion
	(Water)	Flooding and Beach Erosion
6.05		Fresh Water Resources
6.06		Oceanography
6.07		Marine Resources
6.08		Terrestrial Resources
6.09		Wetlands
6.10		Rare and Endangered Species
6.11		Air Quality
6.12		Accidental Spills
7.00		IMPACTS ON THE CULTURAL ENVIRONMENT
7.01		Summary of Cultural Concerns
7.02		Visual Impacts
7.03		Social Impacts
7.04		Economic Impacts
7.05		Impacts on Historical and Archaeological Resources
7.06		Impacts on Public Services
7.07		Waste Disposal
7.08		Recreational Use
7.09		Public Access
7.10		Conflicts With Other Uses of the Area
7.11		Relationship Between Short-term and Long-term uses of Man's Environment
8.00		ALTERNATIVES TO THE PROPOSED PROJECT
9.00		MITIGATION OF IMPACTS

Table 1 (cont.)

10.00	PHYSICAL AND BIOLOGICAL IMPACTS THAT CANNOT BE AVOIDED
11.00	CULTURAL IMPACTS THAT CANNOT BE AVOIDED
12.00	BIBLIOGRAPHY
13.00	INDIVIDUALS INVOLVED IN PREPARATION OF THE REPORT AND THEIR QUALIFICATIONS
14.00	OTHER PERSONS AND ORGANIZATIONS CONSULTED

required for the studies undertaken, or else describe factors that otherwise qualify them to address subjects outside of their area of formal training. A listing of other EARs they have prepared is NOT a list of qualifications. It is potentially just a list of other reports they had no reason to be writing either. Table 2 lists the type of training that you would likely expect the preparers to have had to discuss various aspects of environmental impact.

<u>Your shopping list</u> - Table 2 provides a very general list of the types of projects you might have to evaluate and the types of studies that might be expected. It is by no means exhaustive, but it does provide a starting point. The types of individuals who should have been somehow directly involved in the preparation of the report are also shown. The relative importance of each item is also indicated by an "x" (of likely importance), "+" (definitely important), "++" (extremely important and cannot be ignored), or "-" (only of limited importance under certain circumstances).

Table 2a. Recommended studies for various types of development

TYPE OF STUDY / PROJECT	Land Flora	Birds	Land Animals	Watershed Char.	Runoff Now	Runoff Later	Emissions	Effluent	Spill Potential	Marine Flora and Fauna on-site: Water Column	on-site: Benthos	on-site: Infauna	downstream: Water Column	downstream: Benthos	downstream: Infauna	Shore Stability	Traditional Use	Compatibility	Currents Waves: Now	Currents Waves: After	Sediment Character: Naturl Sediment	Sediment Character: Borrow Sediment	Sediment Character: Sed Behavior	Sub Bottom Char	Sed Chemistry	Water Quality: Now	Water Quality: After	Water Quality: Monitoring Req.
Land																												
Hotel/Condo	x	x	x	+	+	x	-	x								x	+	+						+				
Agriculture	x	x	x	+	+	+								x	x			+			+					x	x	-
Industry	x	x	x	+	+	x	+	+	+				x	x	x		+	+						+	+	x	x	x
Earth Change	x	x	x	+	+	+								x	x						+			+		x	x	-
Single Home	-	-	-	-	-	-																						
Track/Tennis	x	x	x	x	x	x											x	+										
Development < 100 ft from shore *	x	x	x	x	x	x				x	x	x	x	x	x	+	+	+	-	-	+					+	+	x
Marine																												
Mangrove Fill	x	+	x	+	+					x	+	+	-	x	x	x	x		+	+		+	-		x	+	+	-
Mangrv Dredge	x	+	x	x	x					x	+	+	-	x	x	x			+	+	+			+	x	+	+	x
Open pond Fil	x	+	x	+	+					x	+	+	-	+	+		x		+	+		+	+			+	+	-
O pond Dredge	x	+	x	x	x					x	+	+	-	+	+	x			+	+	+			+	x	+	+	x
Closed pond F	x	+	x	+	+					x	+	+	-	x	x		x					+				+	+	
Closed pond D	x	+	x	x	x					x	+	+	-	-	-	x									x	+	+	
Op. Marine Dr										x	+	+	x	+	+	+			+	+	+			+		+	+	+
Op. Marine Fl										x	+	+	x	+	+	-			+	+	+	+	+		x	+	+	+
Structures																												
Marina/Port	x	x	x	x	x	x	x	x	+	+	+	+	x	+	+	x	+	+	+	+	x	x		+	x	+	+	+
Dock								x	x	+	+	+	-	x	x	-		+	x	x				-		x	x	-
Seawall										-	-	-	-	-	-	+		+	+	+				-		x	x	-
Groin										-	-	-	-	-	-	+		+	+	+				-		x	x	-
Beach Nourishment										-	+	+	-	+	+	+			-	-	+	+	+	-	-	x	x	-

* Note: these types of study are <u>in addition to those listed above by project</u>

Table 2b. Areas of concern for various types of development

AREA OF CONCERN	Habitat Loss	Visual	Public Access	Drainage: During Constr	Drainage: After Constr	Drainage: Runoff	Fresh Water Use	Sewage	Jobs	Infrastructure	Endangered Species	Turtles	Birds	Proj on Erosion	Erosion on Proj	Changes: Circulation	Changes: Wave	Changes: Water Quality	Pollut Intro: On Site	Pollut Intro: Off Site	Downstream Impact	Spill Potential	Loss of Ecol Fn	Expertise[*]: Biologist	Expertise: Oceanographer	Expertise: Geologist	Expertise: Engineer
LAND																											
Hotel/Condo	+	+	+	+	+	+	+	+	+	+	+			+	+				-		x		-	x		x	x
Agriculture	+		-	+	+	++					x				++				x	+	+		-	-		x	
Industry	+	+	+	+	+	+	+	+	+	+	+				+				+		x	+	-	x		x	x
Earth Change	-			+	x	+					-			+	+			+			x			-		x	
Home		x		x	-	-					x													General			
Track/tennis	+	x	+	+	x	x	-	-	x	x	-			+	+						x			x		x	x
Development < 100 ft from shore **				+	-	-					+	+	+	+	+									x	x	x	x
Marine																											
Mangrove Fill	++	-		+	+	+					+	-	+			-		+	x		x		+	x	x	x	
Mangrv Dredge	x			x	x	x					+	-	+			-		+			-		x	x	x	x	
Open pond fil	+			+	+	+					+	-	x			+		+	x		x		+	x	x	x	
O pond Dredge	x			x	x	x					+	-	x			+		+			-		x	x	x	x	
Closed pond F	+			+	+	+					+	-	x						x				x	x	x	x	
Closed pond D	x			-	-	-					+	-	x										x	x	x	x	
Op. Marine Dr	+								x						+	+	+	+	-	-	+		+	x	x	x	
Op. Marine Fl	+								x		x	x	x		x	+	+	+	+	x	+		+	x	x	x	
Structures																											
Marina/Port	+	+	+	+	+	+	+	+	+	+	-	x	x	x	x	+	+	+	+	x	+	+	+	x	x	x	x
Dock		x					x	-	-	-				-	-	-	-	-	-	-				x	x		x
Seawall		+									-	+	-	+	+		+			x				x	x		x
Groin		+									-	+	-	+	+	+	+			+	+			x	x	x	x
Beach Nourishment											-	+	-	+	-		-	-		x	x			x	x	x	x

*Note: the geologist is generally concerned with sediment character, behavior or stability
**Note: these areas of concern are in addition to those listed above by project