South Pacific Regional Environment Programme (SPREP)
Training Manual

HOW TO ASSESS ENVIRONMENTAL IMPACTS ON TROPICAL ISLANDS AND COASTAL AREAS

Richard A. Carpenter
and
James E. Maragos

editors/authors

October 1989

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East-West Center

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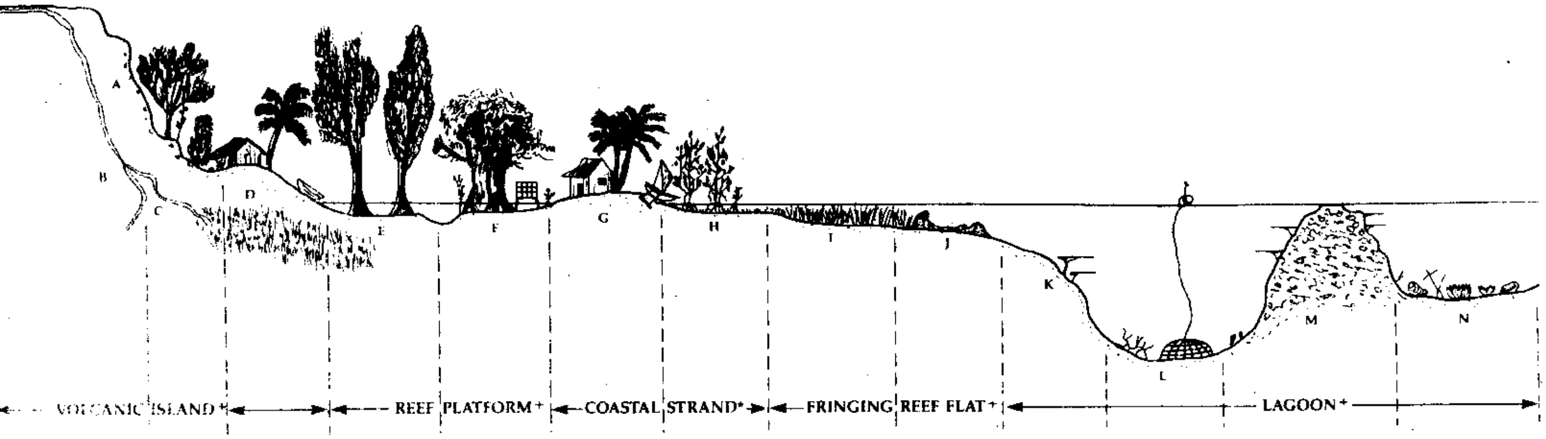
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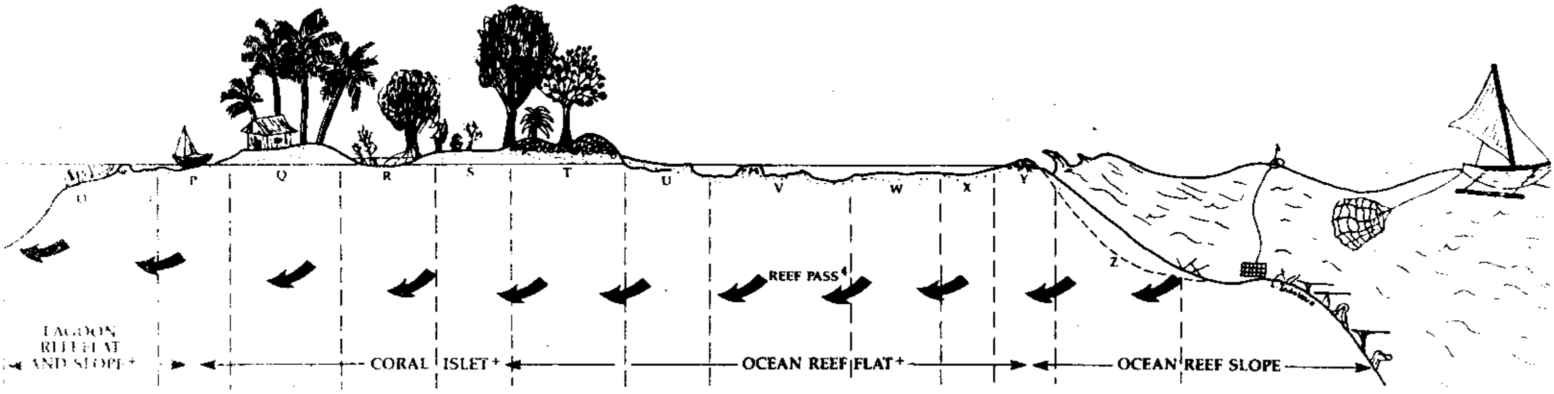
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CONTRIBUTING AUTHORS

Graham Baines, Consultant in Environment, Conservation, Natural Resource Management, Australia

Daniel van R. Claasen, University of South Pacific, Fiji

William Clarke, University of South Pacific, Fiji

Rory Frampton, Environment Studies, University of Hawaii

John T. Harrison, Water Resources Research Center, University of Hawaii

Paul Holthus, SPREP, New Caledonia

Philip Hughes, University of Papua New Guinea

R. J. (John) Morrison, University of South Pacific, Fiji

S. D. Naidu, University of South Pacific, Fiji

Lauren Wenzel, University of South Pacific, Fiji

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A Training Manual
prepared for the

South Pacific Regional Environment Programme (SPREP)

Richard A. Carpenter
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James E. Maragos

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This manual was coordinated for SPREP by **Mr. Paul Holthus**, Project Officer (Scientist).

Environment and Policy Institute
East-West Center
1777 East-West Road
Honolulu, Hawaii 96848

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PREFACE

The idea for this manual has roots in more than 25 years of work interpreting and transferring scientific and technical information for use by policy and decision-makers. I was privileged to take part in the formulation of the U.S. National Environmental Policy Act of 1969 while Chief of the Environmental Policy Division of the Congressional Research Service, Library of Congress. This law called for the preparation of an environmental impact statement--an action-forcing provision aimed at American government officials. But the concept of a special analysis of the consequences to the environment of technological change has spread around the world. The most important result is the availability of information to the public and to managers about natural systems and their behavior which would not otherwise have been gathered and assessed. Now, with environmental impact assessment, decisions about using and protecting the environment are better informed, and public participation is facilitated.

Since 1977, I have worked at the East-West Center with many colleagues in Asia and the Pacific on the adaptation and implementation of EIA methods in developing countries. Often, the suggestion has been made to refine and publish the various training materials that have emerged from these collaborative studies. I have been reluctant to do so because of a firm conviction that each opportunity for assessment must be systematically and thoughtfully designed to fit the circumstances--there is no "correct" method generally applicable. Any format such as a checklist or matrix works against the tailoring of the assessment. Nevertheless, the opportunity developed with Paul Holthus of SPREP and Bindu Lohani of the Asian Development Bank in planning a Regional Training Course (held in June 1989 at the University of the South Pacific in Suva, Fiji) persuaded me that a compilation of how-to-do-it methods and techniques could be useful, if embedded in a systems approach. This manual is the result.

Since 1967 Jim Maragos has had a distinguished career working in environmental affairs in the Pacific, first with the University of Hawaii, and then with the U.S. Army Corps of Engineers. He has also been a frequent colleague in East-West Center programs and contributed significantly to this manual as co-editor, author, and originator of many of the graphics.

Authors, other than the editors, are noted in the sections which they prepared. We have drastically edited some contributions in order to fit them together and thus, with appreciation to each author, take full responsibility for the final manuscript.

A draft version of the manual was used in the Fiji training course and revised on the basis of comments from the 25 participants from 14 island nations. Other reviewers included Graham Baines, Warren Evans, Arthur Dahl, and Tor Hundloe.

The manual has benefited from an exceptional editorial support group in the East-West Environment and Policy Institute headed by Helen Takeuchi. Her expertise and dedication show through on every page. Laura Miho and Linda Shimabukuro processed words with skill and patience, assisted by Joy Teraoka and Karen Hee. Laurel Lynn Indalecio prepared graphics and art work. To all of them, to co-editor Maragos, and to my author colleagues, I offer a heartfelt mahalo.

Richard A. Carpenter
Environment and Policy Institute
East-West Center
Honolulu, Hawaii 96848
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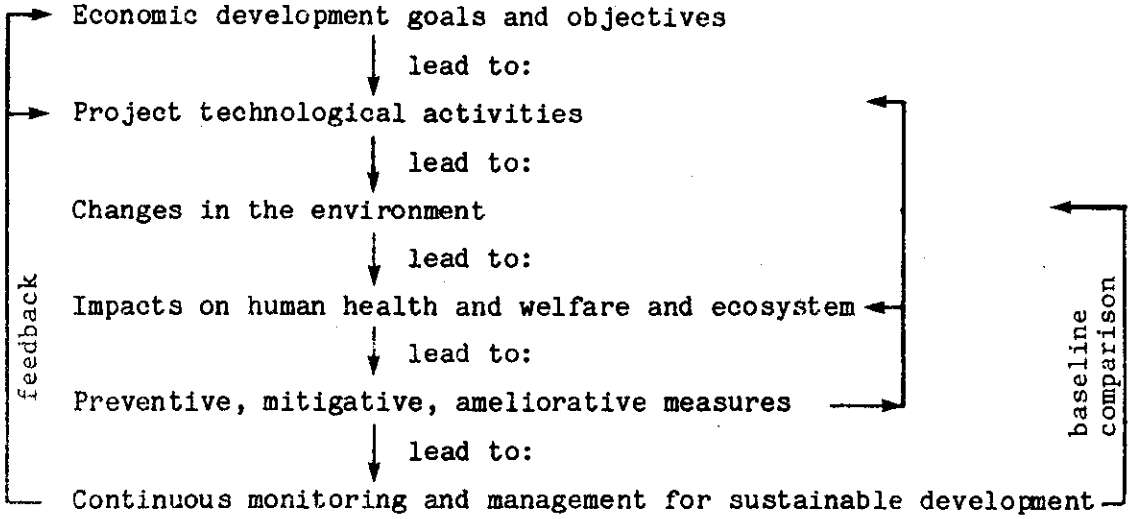
HOW TO USE THIS MANUAL. There is no best method for performing environmental impact assessment (EIA). This manual contains many examples of useful techniques for gathering, analyzing, and communicating information about the consequences of development activities. However, the overall method recommended here is to think through each specific management question and to design an EIA process to fit the need and the time and resources available for assessment.

This systematic approach requires scientific understanding to predict the impacts of alternative development strategies and practices. The most likely changes in the environment and consequent impacts on human health and welfare are explained. Section V reviews the basic relationships of ecology and related environmental sciences. The sensitivity and vulnerability of different ecosystems are explained so that the assessment may begin with these considerations of siting, if that is the issue. Sections II and III present proven techniques for organizing and analyzing the data that make up the assessment. Section IV and the Appendix of Asian Development Bank guidelines enable the reader to begin the assessment design from experience with the type of development in question.

The theme of the manual is prediction of future environmental conditions as a result of economic development and technological change. Uncertainties and surprises are accepted as unavoidable. However, this EIA method will help prevent and remedy many unwanted adverse consequences and may also generate new alternatives for achieving development goals, together with sustaining environmental quality and renewable natural resources.

Intelligence and interest are the traits of a good assessor. Environmental impact assessment does not necessarily require advanced education, complicated models, or detailed data in order to help managers and decision-makers. Qualitative assessment can be quite useful (see Chapters II.B and III.A). Preliminary site and project evaluations often lead to important changes that are relatively easy to make at an early stage.

Throughout the manual, the concept of sequential cause-effect relationships is taught and illustrated:

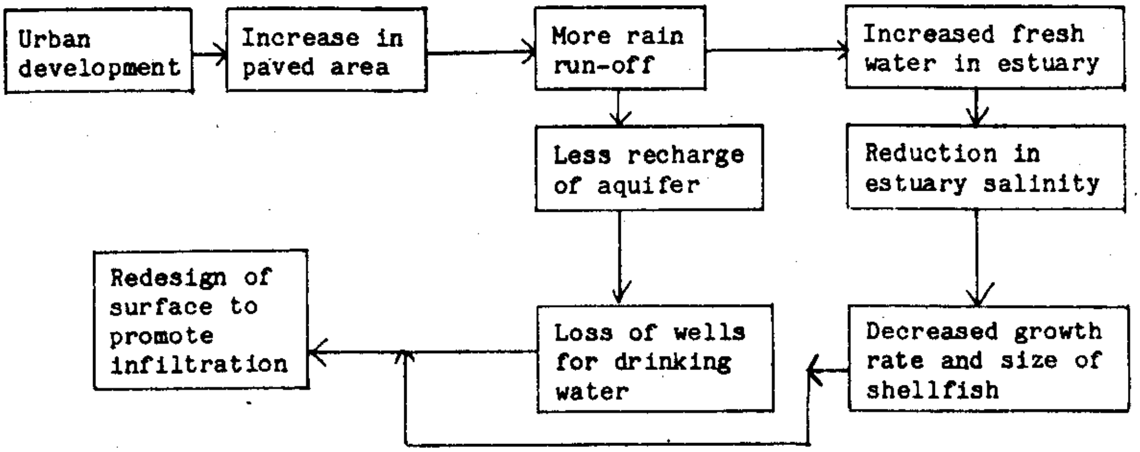


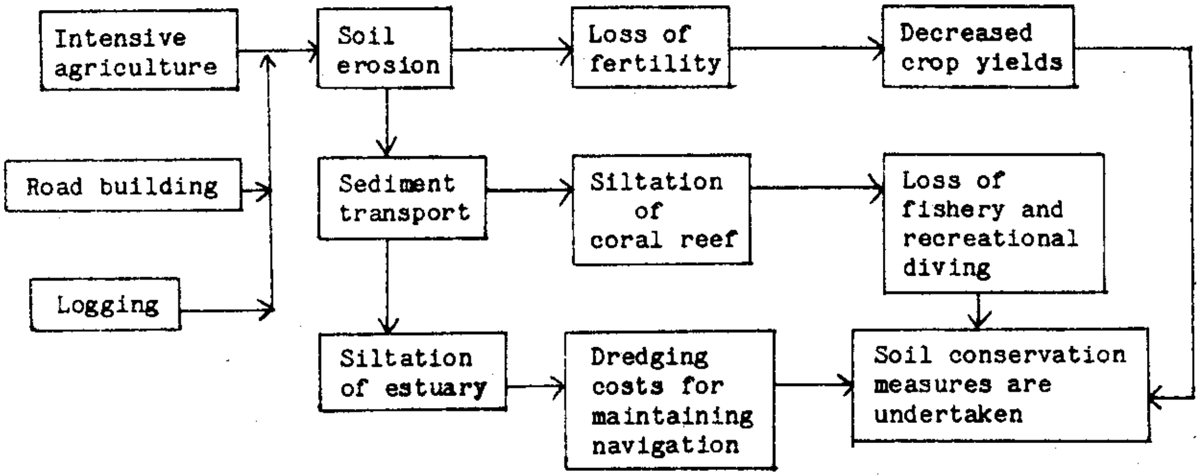
Some specific examples of sequence charts are shown on the next page. Branches or cascades of effects must often be dealt with. The economic valuation of impacts, including those external to the main development objective, allows a more comprehensive benefit-cost analysis. Uncertainties are quantified as probability distributions to give a sense of comparative risks. The entire process is to assist management in making better decisions and trade-offs for more successful development.

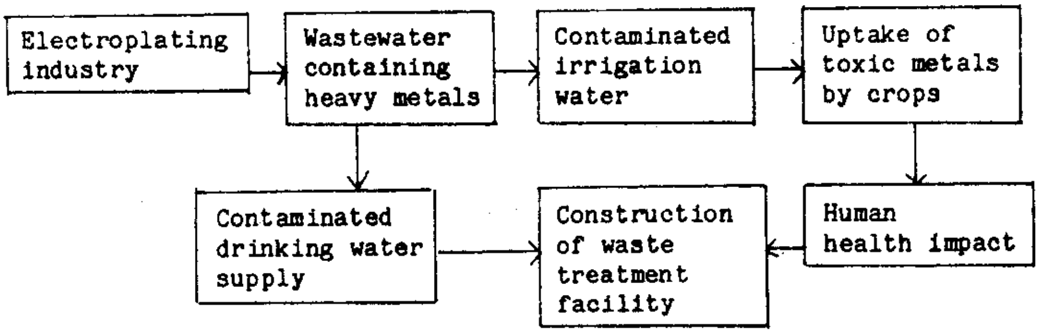
The manual shows how to design an assessment and, when used with suggested reference materials (e.g., Munn 1979; Dixon et al. 1988; Carpenter 1983; ADB Guidelines, various years) also shows how to perform a complete assessment. Two other important tasks can be accomplished through using the manual. Review of EIAs is aided by comparing a draft assessment with the suggested contents and predictive techniques in the manual. Terms-of-reference spelling out the work to be done by consultants may be prepared by using the framework in the manual for the particular type of development. These examples also assist environmental officers in negotiating with developers to produce a more useful EIA, rather than simply accepting or rejecting what is provided.

The manual is also a desk reference with definitions of terms and examples of many impacts and mitigative measures. It is, however, a "living document" and should be continuously augmented by the actual experiences of assessors in each country as the use of this important management tool grows.

THREE EXAMPLES OF THE SYSTEMS APPROACH FOR EIA







I. INTRODUCTION: EIA ASSISTS SUSTAINABLE ECONOMIC DEVELOPMENT

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I. INTRODUCTION

ENVIRONMENTAL IMPACT ASSESSMENT ASSISTS SUSTAINABLE ECONOMIC DEVELOPMENT

Planning and managing economic development require a continuous flow of information to decision-makers. Environmental Impact Assessment (EIA) has become a useful process, as well as format, for acquiring, analyzing, and reporting the facts and understanding about the natural environment. EIA complements and supplements the knowledge in economic and engineering studies of development projects and strategies. The initial letters E, I, and A also represent three essential characteristics of proper assessment (see Figure I.1):

Early: The EIA begins at the inception of development planning in order to identify opportunities and constraints in natural systems and thus guide the design of projects;

Integrated: The EIA is linked directly to engineering and economic studies, not performed separately or at a later time;

Always: The EIA process continues to accumulate data throughout the project cycle, monitoring the implementation of environmental protection measures and suggesting mid-course corrections to management.

I.A. MULTIPLE NATIONAL GOALS REQUIRE TRADE-OFFS AND PRIORITIES

Most nations have many urgent needs and objectives, some of which are mutually conflicting. Resources are always insufficient to do everything at once. A clean, healthy environment and the conservation of natural resources are goals of all societies. Jobs, foreign exchange, national security, and improved living standards are other goals that compete with the environment. In many projects, immediate economic gains appear to require the degradation of environmental quality; sometimes, ingenuity can achieve economic growth and protect the environment but the conflict is often real. Some countries (e.g., Japan) have knowingly taken a development path of "grow rich dirty, then clean up." Whether that was wise remains to be seen, but it illustrates the need by development managers for information about the impacts of projects on the environment and the use of environmental resources in projects. That is what EIA is all about.

Because many environmental impacts are subtle and do not appear immediately, the conventional project planning neglects these effects. In the early 1970s, led by the United Nations Conference on the Human Environment at Stockholm and the United States National Environmental Policy Act, many development agencies began to order special studies

ENVIRONMENTAL	**E**	EARLY
IMPACT	**I**	INTEGRATED
ASSESSMENT	**A**	ALWAYS

Figure I.1. The meanings of EIA.

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on environmental aspects of projects. All too often these reports came along only after commitments were made as to site, design, and technologies. Changes or additions to plans in order to avoid environmental damage were disruptive, delaying, and were seen to be extra costs. The EIA concept got a bad name.

Projects that had proceeded without concern for the environment, however, often resulted in unacceptable damage to air and water quality, valuable plants and animals, and human health. In some instances, irreversible harm such as pollution of groundwater or gross soil erosion has occurred. Some projects were suspended or terminated on the basis of unforeseen adverse consequences.

I.B. PROBLEMS IN IMPLEMENTING EIA

While learning how to assess impacts, it is worthwhile to consider some of the recognized problems in EIA almost 20 years after its beginnings. The methods of this manual are intended to overcome many of these shortcomings.

1. Lateness in the development sequence. If the EIA is begun only after major decisions have been made, then it often is seen as causing delays. This is not necessarily true, but the perception is widely held. In any case, the EIA should begin <u>early</u> and, if possible, should not lag behind other elements of the development process.

2. Lack of follow up during development. As has been stated, EIA should <u>always</u> be contributing information to management, not just during the feasibility stage of projects. Otherwise, environmental concerns may be forgotten and newly uncovered problems will not be addressed. If there is no post-audit or monitoring, implementation of mitigating measures and verification of predictions may not occur.

3. Beneficial impacts are ignored. EIA should reveal opportunities and benefits, not simply raise warnings. Design changes on the basis of predicted environmental consequences may save the success of a project (e.g., avoiding seawalls that would cause beach erosion at a resort).

4. Lack of consideration of alternative sites, technologies, designs, and strategies may weaken the effectiveness of EIA.

5. Bias in the tone and language of the EIA reports (either toward the project or toward environmental values) will decrease their credibility.

6. Participation of all interested and affected parties in the EIA is essential. The political will to implement recommendations comes from informed participation from local residents, non-governmental organizations, and mission agencies. The review process is especially important for allowing participation. Even if some parts of an EIA must remain confidential because of diplomatic or proprietary sensitivities, a summary of these aspects should be made public with an explanation for the lack of detail.

7. Mitigation measures are often not affordable, do not reflect appropriate standards for the level of development, and are unrealistic as to maintenance requirements or operating costs.

8. The private sector often resists EIA because it is viewed as anti-development, a nuisance imposed by bureaucrats, and unnecessary when good engineering-economic analyses have been prepared.

9. Communication of EIA findings is often awkward and unclear. Voluminous reports cannot be read by many who should understand the EIA. Reports may be too late to be on the table when decisions must be made.

10. The ad hoc, project-by-project approach of EIA makes regional and national environmental planning difficult. An increased attention to land-use planning and economic-cum-environmental planning is a trend to correct this deficiency.

11. EIAs should be managed by strengthened environmental coordination units within mission agencies as contrasted with reliance on central environmental agencies. The private sector developers should also have independent environmental units. These measures help integrate EIA into the planning process.

12. Economic valuation of impacts is inadequate even though much progress in identifying and including so-called offsite and future "externalities" has been made.

13. Modeling of ecosystems is inadequate for predictions because ecological theory is still incomplete and principles are vague.

14. Uncertainties are not treated explicitly and many assumptions are hidden. Risk assessment built on EIA can do much to remedy this problem.

Fortunately, adjustments in both EIA and development planning have been made in the past few years. The benefits of Early, Integrated, and Always-available information about the environment are now equated with efficient project management. EIA need not delay development, and the costs of prevention are usually less than those of repair or damage sustained. The environment is never the preeminent national goal, but it is one that must be adequately represented in the balancing and trade-off processes. EIA helps to make that happen.

I.C. WHY DO EIA?

The essence of EIA is a prediction of the future state of the environment, with and without the development activity. All managers and planners, whether in government agencies or the private sector, should know the consequences of their actions. They are responsible for their effects on society, environment, and other projects.

Nature is holistic--complex, interconnected, and systematic. Unfortunately, development projects are usually single events undertaken in isolation. Natural systems must be understood in order to predict the consequences of technological change. EIA is a form of systems analysis--a procedure for studying complex arrangements and events in order to manipulate them to a desired goal.

The history of economic development contains more disappointments and failures than successes, and the reasons for this are myriad. The lack of understanding and appreciation of the environment and renewable natural resources, however, is clearly to blame for many instances of economic shortfalls, premature ending of projects, depleted resources, degraded lands, and human misery. EIA is not only a rational process to warn of unwanted adverse effects but also to generate alternative approaches that improve the chances for development success. EIA does not make decisions, but it is essential for those who do.

Thus, we do EIA in order to predict the adverse consequences of development on the environment.

I.D. ECONOMIC DEVELOPMENT BASED ON RENEWABLE NATURAL RESOURCES

Much of the growth in developing countries comes from using renewable natural resources (i.e., crops, forests, water, soils, animals, fish). These natural systems also are affected by development activities such as road building, pollution, dredging, and filling. EIA points up both the dangers to environmental values and the opportunities to use these resources. It is a constructive, pro-development tool for management that improves the success of and lengthens the life of projects. EIA addresses the following issues:

1. Development that is sustainable is accepted as an essential characteristic of economic growth. Sustainable development is broadly and vaguely defined (e.g., "[sustainable development] meets the needs of the present without compromising the ability of future generations to meet their own needs") (World Commission on Environment and Development 1987:43). In this sense, development is to be sustained and not any particular technology or resource. When development strongly depends on renewable natural resources, however, the definition must be more specific: a strategy to achieve immediate economic gains while maintaining indefinitely the productive potential of the resource base. For example, the traditional conservation practice called Raui is used in the northern Cook Islands to rotate the use of atoll fisheries over time in order that they may replenish themselves. The rate of regeneration, maintenance, or repair must, over time, equal or exceed the rate of harvest, consumption, or degradation. A report from the World Resources Institute (Dover and Talbot 1987) states "productivity without sustainability is mining." EIA quantifies the factors making up sustainability and predicts the future productivity of the landscape.

2. Human health is directly dependent on a clean environment. Health concerns also are the most powerful source of "political will" needed to enforce regulations and to make necessary budget commitments. For example, safe drinking water supplies are threatened not only by pathogenic organisms but increasingly by toxic chemical compounds such as heavy metals and chlorinated organic chemical compounds. EIA specifically treats the risk to human health from technologies and urbanization accompanying development.

3. Ecosystem health includes the maintenance of habitat for wildlife, fish, shellfish, and other commercially valuable animals as well as the constant provision of the so-called "services" of nature such as watershed protection forests, pollinating insects, and soil-building organic matter. EIA is concerned with biological diversity and the esthetic/recreational values of intact natural systems.

4. Development opportunities in the landscape may be uncovered during EIA. These include untapped water resources, forest products such as medicinal plants, mineral deposits, rare wildlife species, unique scenic and recreational sites, and archaeological or cultural sites to be conserved. The surveys and inventories conducted as part of EIA may reveal unexpected natural resource values.

5. Siting of needed facilities, roads, and human settlements is often the subject of EIA. Alternative locations are judged against a variety of technical and social criteria in order to pick the site that will serve development and least disrupt other uses of the landscape.

I.E. RESOURCE USE CONFLICTS

Economic development often involves using the same natural resource in several ways that may not be compatible. For example, agricultural land is attractive for human settlements; waterways are used to dilute and carry off sewage and for fishing. EIA, especially when complemented with extended economic analysis, can point out these conflicts and reveal the trade-offs necessary to maintain sustainable development. See Section III.E for the techniques used.

An illustration is the conflict generated by logging, which increases sedimentation of coastal areas and thus damages fisheries and tourism. Countries in Oceania and the Pacific Rim with marine resources potentially at risk in this manner include Fiji, Papua New Guinea, Samoa, Solomon Islands, Vanuatu, French Polynesia, Indonesia, Malaysia, the Philippines, and Thailand. The following is excerpted from Hodgson and Dixon (1988:xi-xii).

> In 1985 a logging operation was begun in the watershed bordering Bacuit Bay (El Nido), Palawan, Philippines. Bacuit Bay is also an important resource for two other foreign exchange earning industries--tourism and marine fisheries. The effects of logging-induced sedimentation on the bay's previously pristine marine environment were the subject of a 1-year ecological study. By the end of the study, only 11 percent of the available commercial forest had been logged, but high rates of accelerated erosion due to logging had already resulted in dramatic increases of sediment transport and discharge into the bay. Sedimentation damage to bay coral reefs and associated fisheries was rapid and severe [see Figure I.2.].
>
> In order to examine the economic effects of sedimentation pollution on tourism and marine fisheries, predictions of future revenue production based on two development alternatives are presented. The development options are (1) to ban logging in the bay's watershed or (2) to allow logging to continue as planned. The first option would prevent further damage to the bay's ecosystem due to logging-induced sedimentation and thus the tourism and marine fisheries dependent on it. The second option would maximize logging revenue but reduce revenue from the other industries.
>
> The results of the economic analysis are striking and project a reduction in gross revenue of more than \$40 million over a 10-year period with continued logging of the Bacuit Bay watershed as compared with gross revenue given implementation of a logging ban [see Table I.1]. The difference is due to projected losses from tourism and fisheries. Present value analysis was performed using both a 10 and 15 percent discount rate. Even with the higher discount rate, the present value of lost revenue exceeds \$11 million under Option 2--continued logging. Sensitivity

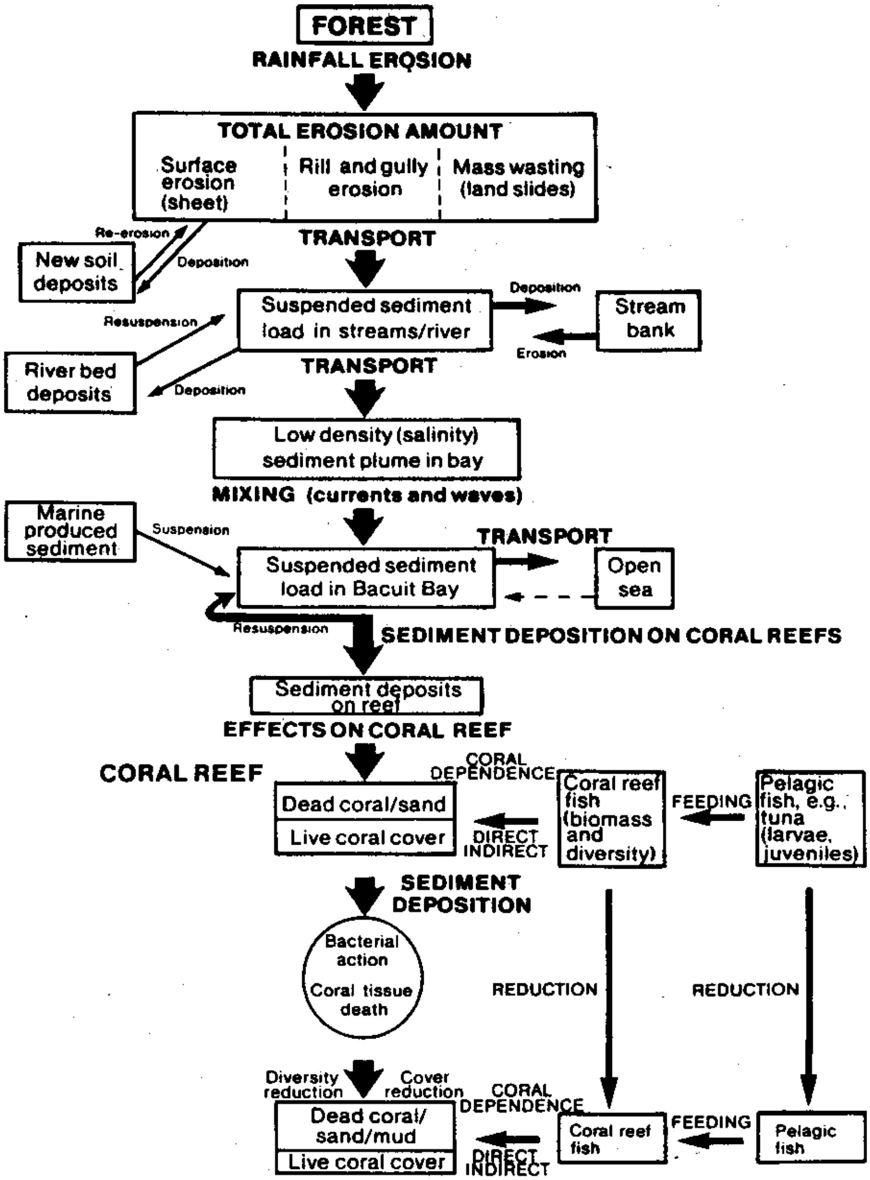

Figure I.2. The predicted pathway of soil eroded from the forest floor as it passes to the sea. Note the many locations where soil can be temporarily stored and then later rejoin the transport process. Upon reaching the sea, sediment settles to the bottom. If coral reefs are present, the living corals may be damaged by sediment deposition. Since fisheries are linked to the coral directly and indirectly, they will be reduced by losses of living coral cover (<u>Source</u>: Hodgson and Dixon 1988:5).

Table I.1. Tourism, fisheries, and logging industries: Ten-year sum of gross revenue, present value of gross revenue (x $1000) using 10 and 15% discount rates

	Option 1	Option 2	Option 1 minus 2
Gross Revenue			
Tourism	47,415	8,178	39,237
Fisheries	28,070	12,844	15,226
(with tuna)	(46,070)[a]	(21,471)	(24,599)
Logging	0	12,885	-12,885
Total	75,485	33,907	41,578
Present Value (10%)			
Tourism	25,481	6,280	19,201
Fisheries	17,248	9,108	8,140
(with tuna)	(28,308)[a]	(15,125)	(13,183)
Logging	0	9,769	-9,769
Total	42,729	25,157	17,572
Present Value (15%)			
Tourism	19,511	5,591	13,920
Fisheries	14,088	7,895	6,193
(with tuna)	(23,122)[a]	(13,083)	(10,039)
Logging	0	8,639	-8,639
Total	33,599	22,125	11,474

Source: Hodgson and Dixon (1988:58).

[a] Tuna revenues (in parentheses) are not used to calculate the totals.

> analysis shows that significant deviation from predicted effects of sedimentation damage do not alter the conclusion. In addition to these quantitative results, consideration of qualitative factors reveals that the social, economic, and environmental benefits of fisheries and tourism outweigh those of logging in this location.
>
> The study demonstrates that the combined use of ecological and economic analyses can provide useful information for government planners seeking to maximize net economic benefits while minimizing social and environmental costs.

A full EIA encompassing alternative sites and designs for logging may have led to proposals that would have avoided or reduced impacts to tourism and fisheries. In any case, the EIA would have predicted the effects of logging, which, in turn, may have led to new or revised decisions on logging.

I.F. THE PLANNING PROCESS

1. The Project Sequence

EIA is useful at every level of planning from national to regional (e.g., river basin or coastal zone) to local (e.g., industrial parks or cities). Land-use planning with an ecological basis matches appropriate uses to the inherent capability of landscape units. Sensitive areas such as steep slopes or wetlands are identified by EIA and left undisturbed as much as possible.

The timetable of planning ranges from 5-year development strategies to project scenarios to the continuously adjusting plans for long-term resource management. EIA serves all of these time horizons. For example, Table I.2 shows how EIA assists management in the various steps of a development project.

It is now recognized that development planning should be flexible with changes anticipated as the work goes forward. Adaptations to new information and unexpected consequences of the project implementation are aided by the always continuing EIA. Midcourse corrections thus can be made to assure that the project meets environmental protection standards and that measures undertaken to sustain renewable resources are actually working.

2. Comprehensive Environmental Planning

A legislative base for EIA may not always be possible (because of institutional inertia, a nation's stage of development, or political antipathy). Much of the information and analysis may be acquired through non-legislative approaches so that the same product is obtained (i.e., a prediction of the consequences of economic development for the environment). Along with EIAs that are required as a condition of loans or grants from international aid agencies, comprehensive environmental planning generates information that, in and of itself, becomes a force for the rational use of renewable natural resources. A country can thus ease into environmental planning without directly confronting entrenched bureaucracies' jurisdictions. Some of the assessment-like approaches are:

a. Regional Master Planning. Regional master planning is an innovation that provides siting information before implementation of individual projects to steer the development of a naturally defined region. A river basin, coastal zone, or an island may be the geographical setting for a master plan. In this case an EIA looks at past, present, and future developments and their interactions in the natural system. Cumulative effects in space and time are predicted. When this is done, subsequent specific projects are essentially already sited, and the EIA for them is simply an additional step of considering the exact technology. In the future as more islands and regions complete master plans with environmental components, the need for ad hoc project EIAs will diminish. The Asian Development Bank has pioneered in this approach which it calls "Guidelines for Integrated

Table I.2. EIA in the project sequence (the exact correspondence varies among projects)

Stage of the project	EIA process
1. Conception	• Screening for obvious environmental problems based on previous experience
	• Scoping of significant issues for possible EIA
2. Prefeasibility	• Review of site for ecological sensitivities
	• Application of findings of generic EIA for the technologies intended
	• Initial assessment
	• Gathering of baseline environmental data
	• Public participation in project planning
3. Feasibility	• Prediction and quantification of impacts
	• Review of EIA by public and independent experts
	• Interaction with engineering analysis for proposing alternative technologies
	• Identification of needed prevention and mitigation measures
	• Valuation of externalities
	• Benefit-cost analysis
	• Negotiation of environmental protection covenants in financing agreements
4. Design and engineering	• Detailed design of mitigation measures, refinement of impact predictions, and economic analyses including cost effectiveness
	• Monitoring program designed
5. Implementation	• Installation of mitigation measures
	• Mid-course correction based on actual performance
6. Operation and maintenance	• Monitoring for compliance and testing for accuracy of predictions
7. Completed project evaluation	• Post-audit and lessons learned for future EIAs

Regional Economic-cum-Environmental Development Planning," ADB Environment Paper No. 3 (1988e).

b. National Conservation Strategy. The International Union for the Conservation of Nature and Natural Resources sponsors surveys and inventories of wildlife, habitats, and other unique or rare natural systems. A country undertaking such a study is assisted in planning for the sustainable use of its natural endowment of biological diversity. Much of the baseline information for EIA (especially the identification of sensitive areas and endangered species) is thus acquired.

c. National Environmental Profile. The U.S. Agency for International Development, the Asian Development Bank, and other aid agencies sponsor the preparation (involving local professionals) of comprehensive descriptions of a country's environment. Renewable and non-renewable resources are surveyed, current land uses are mapped, and trends in environmental quality are traced. These profiles are updated frequently so that they can be used in economic development planning at the earliest stages to examine for potential adverse impacts.

d. Five-Year Plans or Forecasts. Many countries regularly conduct comprehensive planning in the form of "Year 2000" or Five-Year Plans. These studies should have a well-defined environmental component and thus motivate the gathering of EIA-type information. Although predominantly economic and political in content, such national examinations can be the vehicle for improving data about land and water resources.

e. Technical Assistance Grants. Environmental concerns may be the subject of special aid programs, the results of which are useful to EIA. In Thailand, for example, USAID is sponsoring the Management of Natural Resources and Environment for Sustainable Development (MANRES) Project to strengthen the country's government and non-governmental institutions. Coastal zone management programs may be the focus of grants to gather data, train personnel, and set boundaries for planning and management. The U.S. Trade and Development Program has sponsored studies of hazardous waste and other pollution problems that lead to a national strategy for coping with these issues.

f. Special Development Authority. The fragmenting of the environment by narrow mission agencies of government is a barrier to proper planning for holistic nature. This can be overcome sometimes by setting up a new agency with powers to control all activities in a certain area (i.e., a port, a river basin, or a coastal zone). Then the authority can arrange for comprehensive surveys and monitoring of all environmental matters within its purview. EIA takes place as a matter of course when the special development authority makes its operational plans.

I.G. WHAT IS EIA?

The formal <u>document</u> required by law or regulation (such as the U.S. National Environmental Policy Act of 1969) may be called an environmental impact statement, an environmental assessment, or an EIA. More important, however, is to regard EIA as a <u>process</u> that continuously generates reports, advisory opinions, and monitors information. The written documents are most often the vehicles to report on the progress of the EIA process. Although EIA will report the findings and recommendations, it does <u>not</u> make decisions, because the balancing of environmental effects with the other consequences of development is a political process. The EIA finding does not carry a veto power over a project but should be "on the table" when decisions are made.

1. <u>EIA As a Process</u>

EIA predicts the future state of the environment as a consequence of economic development activity. It is a management information process that continuously gathers, analyzes, interprets, and presents facts and knowledge for the decision-maker. It is a scientific study (i.e., objective, treating uncertainties explicitly, and providing advice, not advocacy). Prediction is intrinsically difficult, and indeed many impacts are not even identified at the beginning of EIA. That is why development must be adaptive, expect surprises, and have the information flow upon which to make midcourse corrections.

The coverage of an EIA will vary in breadth but will always focus on the natural environment or ecosystem of which human beings are a part. Because engineering and economic analyses often ignore social and cultural impacts, these concerns are also often part of an EIA.

EIA addresses the need for the project and alternative ways to achieve the goal or purpose. It describes present environmental conditions, the technology to be used, and then predicts the consequences <u>with and without</u> the project. EIA finds ways to reduce unacceptable impacts and evaluates the most cost-effective mitigation measures. It compares the net present value of all the costs and all the benefits associated with the project throughout its lifetime and the distribution among societal groups of costs and benefits--who pays and who gains.

Not every project should be subject to an EIA, although the actual screening of all development activities to decide which to study in detail is a form of assessment itself. The size and type of projects are one test of how much environmental impact there might be. As experience accumulates, the results of previous EIAs can be applied to similar projects to lessen the need for completely new studies. Developing countries just beginning EIA will often employ expatriate assessors but, by using counterpart assistants, indigenous capabilities can be built while getting on with needed assessments and accumulating experience.

A screening method identifies the major technological changes and simply applies general findings from experience. For example, the WHO Rapid Assessment Method gives expected air and water pollution loadings from standard industrial processes.

In summary, EIA addresses the constraints and opportunities that the natural environment brings to the success of development. Its aim is to discover problems at an early stage and provide for their solution so that the benefits of economic growth can be achieved without unacceptable damage to environmental values. It specifies monitoring and post-development audits to ensure that environmental predictions are accurate and that implementation of measures and precautions reduces or avoids adverse environmental effects.

2. Even Simplified EIA Is Useful

An elaborate, sophisticated EIA is not necessary in order to be useful to management. Furthermore, all EIAs are estimates and somewhat uncertain so that the value of more precise predictions is always compared with the additional cost in time and money. This manual not only presents the methods and techniques for a complete and elaborate EIA but also emphasizes that much can be done with a simple approach using the knowledge, common sense, and talent at hand. Four levels of EIA are:

a. Preliminary EA or Initial Environmental Examination: The use of similar project experience and "generic" EIAs for certain technologies will allow a fair estimate of consequences. A walk through the project area by an experienced assessor can provide a lot of useful information. This simplified approach gives the obvious characteristics of the site, identifies the probable impacts from past experience, and prescribes a monitoring program to follow environmental changes as the work goes forward. It is semi-quantitative and may miss some important impacts, but it encourages thinking about environmental values and helps to design a more quantitative EIA to be conducted later that focuses on significant issues and resources. The wisdom and judgment of experienced persons can substitute to some extent for specific biophysical data if these are not readily available.

b. Quantitative and Explanatory: Baseline data at candidate sites are collected--surveys, inventories, status, and trend information. The major natural systems (e.g., rivers, coastal waters, mangrove forests) are described. The flows of materials and energy through the system are quantified, cause-effect relationships established, and models are constructed to explain the consequences of development activities and to make predictions. Several development strategies, technologies, sites, and project designs are generated for comparison and form the basis for informed decisions on the selected project and appropriate measures to reduce or avoid adverse effects.

c. Extended Benefit-Cost Analysis: A careful search for externalities is made (i.e., the offsite, downstream, future, perhaps secondary effects sometimes omitted by setting too narrow boundaries for the EIA). All impacts and development activities are given monetary value--both negative (costs) and positive (benefits). The time stream of when these costs and benefits occur is calculated and discounted to net present value for comparison (see Section III.G). The cost effectiveness of various mitigation measures and other alternatives are calculated. Distributional effects (inequities) are explored. All effects, whether or not they can be quantified or given monetary value, are retained in the analysis for presentation with the economic data.

d. Risk Assessment: Although uncertainties about environmental information are recognized throughout EIA, they are seldom treated explicitly (i.e., expressed as probability distributions). In some EIAs (certainly not all), it is worthwhile to study two kinds of uncertainty: the frequency with which an adverse consequence will occur and the distribution of the magnitude of the impact. For example, the likelihood that a rainstorm would exceed a certain intensity and that the resulting sediment delivery, or flooding, would vary over a given range with a 95 percent confidence interval are more useful expressions than a single number (mean or central tendency). Risk assessment finds the net of both risk-reducing and risk-increasing actions. It is particularly useful in comparing two alternatives, both of which contain uncertainties of data and understanding (see Section III.H).

Whatever level is undertaken, the resulting EIA can become the basis for further studies in greater depth on specific issues or to obtain greater certainty. As noted earlier, EIA normally involves written reports that document the progress and status of the EIA process. EIA itself is not static and undergoes evolution as analyses are completed and project features become defined. Very rarely is it adequate to prepare only a single report. Often, public and peer review of draft reports offer suggestions that substantially improve the quality and scope of revised (or final) analyses and reports.

II. FUNDAMENTAL EIA METHODS

FIGURES AND TABLES

Figures

Tables

II. FUNDAMENTAL EIA METHODS

Assessment methods are usually taken to include the means of gathering and analyzing data, the sequence of steps in preparing a report and the procedure (who does what and when). The essential ingredients of description, prediction, evaluation, mitigation, and communication are universally agreed upon, but EIA techniques vary widely. This manual takes the view that a "cookbook" is not the best approach and that each development requires an EIA plan tailored to the type, size, timetable, etc., of the project and to the assessment skills, money, and time available. Therefore, what is taught here are the abilities to think in a systematic way, to understand the interactions of the environment and technological change, to meet, in a practical way, the needs of the development manager, and to follow the fundamental process of preparing a preliminary EIA. Once these skills are learned, many of the techniques recommended by various publications can be useful. The danger of adopting a particular checklist or matrix is that filling it out becomes more important than thinking about the complex trade-offs between exploiting and conserving nature. A duly completed format may even become the legal test as to whether an EIA has occurred.

For almost 20 years (the Leopold Matrix was published in 1971), attempts have been made to assess impacts by some sort of mechanistic formula. Beginning with a checklist or matrix to identify a wide number of possible impacts, a quasi-mathematical transformation is used to quantify information about the effect and to weigh one effect against others in terms of importance. Then another manipulation converts all impacts to units on a common scale so that they can be combined to produce a total impact index. This index is used to rank one project alternative (a technology or site, for example) against another (see Figure II.5).

These scaling index methods are popular with decision-makers because they appear to identify the "best" alternative, and thus its selection is a safe move. Technocrats find it easy to communicate indices to politically responsible officials and to the public.

The authors of this manual object strongly to reliance on scaling/index methods for EIA because they are actually unscientific despite their appearance of mathematical rigor. Weights and scalars hide substantial subjective judgments that often come from narrow groups of experts who may be from a different culture. Index methods are needlessly complex and thereby inhibit participation of the public and nontechnical affected groups. They artificially fragment the environment by quantifying each factor in isolation as if each was independent. The emphasis on quantification leads to extremely doubtful numbers for important factors such as aesthetics. Index methods cannot represent the reality of complex environmental systems by merely summing up changes in the components. Tempting as they may be, the assessor must resist indexing because it ultimately interferes with thinking through the development activity.

This section describes the elements of a preferred approach to EIA that enables the practitioner to design an EIA that fits each development project, decision on strategy, or management action.

II.A. THE SYSTEMS APPROACH

EIA is based on understanding how the natural world is constructed and connected, how it functions, and how social, technological, and economic forces interact with the environment and resources. Understanding allows prediction of the consequences of development--the essence of EIA and the desire of successful managers.

Development comes in project-sized packages that are set down within an already functioning system and disrupt it. A cascade of subsequent reactions and adjustments occurs, and finally impacts are felt on human health and welfare. The natural system is never static but always fluctuating with climatic and biological rhythms and evolving toward some new quasi-stable situation. Furthermore, measurement problems cause uncertainty in the value of environmental quality parameters in which we are interested. A major task of EIA is to sort out the changes caused by a proposed development activity from those future changes that are a part of natural cycles. Figure II.1 illustrates the necessary discrimination (see also Section III.C). A controlled experiment compares the changes in a parameter of environmental quality. One system is kept natural while another is subjected to treatment.

Although nature may be variable, it is not chaotic, and cause-effect relationships hold true, once they are understood. Of course, random (stochastic) events such as storms or volcanic eruptions cannot be forecast, but their frequency can be described by a probability distribution function. As complex as it may seem, nature can be studied and understood as a system; that is the only way assessment of possible environmental impacts is possible.

Any fragmentation of the EIA investigation or neglect of a component will lead to inaccurate prediction. For example, in assessing a proposal to clear a wetland, consider that a mangrove forest protects inland areas against storm surge as well as provides fish spawning areas. Similarly, harbor pollution is worsened when reduced circulation and flushing accompany construction of a new jetty.

The beginning of any EIA is a thoughtful delineation of the natural system and the technological system to be imposed on it. The development project is a manifestation of the technology employed. Again, a partial assessment must be avoided. For example, an oil-fired electric-generating plant means also oil transport and storage. Sewage treatment means also sewage sludge disposal.

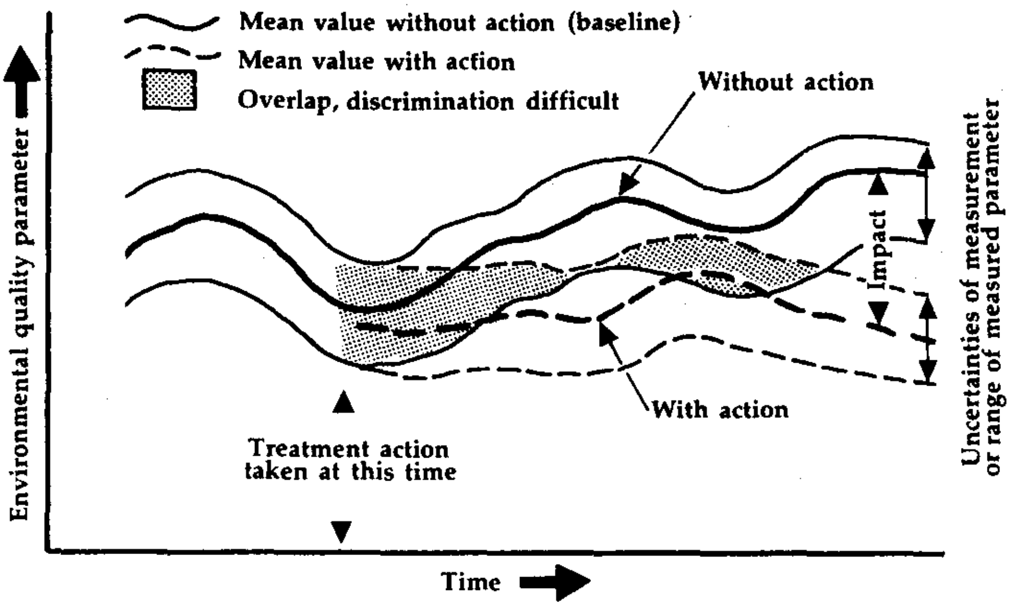

Figure II.1. Discriminating the behavior of natural systems with and without the project.

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1. Screening

Screening is the decision as to whether or not to perform an EIA. Some countries establish a list of types and sizes of projects that must always have an EIA. Others apply guidelines on a case-by-case basis. Over time, the following development activities have emerged from both approaches as most usually justifying a full-scale environmental assessment:

- large industrial and manufacturing plants;
- large construction projects--deep draft ports, highways, airports;
- water resources structures--dams, irrigation systems;
- electric power plants;
- mining and minerals processing;
- hazardous chemicals manufacture, handling, storage;
- sewerage and sewage treatment plants;
- municipal wastes and hazardous wastes;
- new human settlements;
- large-scale intensified forestry, fisheries, or agriculture;
- tourism facilities;

- military facilities; and
- large-scale changes in land use.

Smaller projects may be analyzed by applying the findings of "generic assessments." For example, rural roads and transmission lines will usually follow a pattern that can be used to predict impacts. The importance of an environmental consequence may be out of proportion to the size of a project, however. A road can make pristine forestland accessible. A small tannery or metal plating shop can release a hazardous amount of toxic chemicals.

A public report should be made for all projects as to whether an EIA is required or not, so that the screening results can be reviewed.

It is not a good idea to place a quantitative limit of some measure of project size below which no EIA is ever required. This might provide an unreviewable exemption that could be taken advantage of by unscrupulous developers. For example, in one country, hotels with less than 80 rooms did not require an EIA; as a result, 79-room units were constructed in sets and substantial environmental impacts occurred.

Some countries employ a finding-of-no-significant-impact (FONSI) as a screening mechanism. Such a finding usually requires that a project is initially designed and sited to avoid or mitigate all of the standard concerns. To merit a FONSI, the project will not involve ecologically sensitive areas or cultural sites, will not irreparably damage ecosystems or social systems, will not dislocate people or disrupt economic stability, and is not located subject to natural disasters. A FONSI is much to be desired since no full EIA (or EIS) is then necessary and it motivates the early consideration of environmental problems.

In the final analysis, common sense and discretion must be exercised in deciding whether the need for an EIA is triggered by a proposal. Some small projects may have more adverse effects than some larger projects and the "threshold" value judgment must always be applied on a case-by-case basis.

II.B. PRELIMINARY SITE AND PROJECT EVALUATION

An early evaluation of the purpose, need, alternatives, and assessment of a proposed project is extremely important to identify resources, issues, other agencies, the affected public, and directions to achieve the project purpose. Often, wise decisions made early, particularly to move project planning in a feasible direction, can help to avoid the need for expensive or time-consuming decisions to drop, resite, redesign the project, and force the need to accomplish more intensive studies or analysis. The project proponent should first accomplish a preliminary environmental assessment (PEA) to lay out what needs to be done during the full environmental assessment. In particular, this preliminary assessment should involve the following steps:

1. review all written materials on the purpose, need, or prospectus for the project;

2. perform field reconnaissance of the desired site or sites for the project;

3. interview local residents and affected communities that use resources;

4. consult with other agencies that have expertise, jurisdiction, or influence on the decision to approve, design, or site a project;

5. consult with local or regional scientists at colleges, universities, institutes, or field stations; and

6. visit local political leaders where the project may be sited.

The proponent should be able to accomplish these steps within a week or two and certainly before deciding to fund studies or hire outside consultants. The proponent of the project will then be familiar with the scope of possible issues, problems, controversies, and needs, which will help develop realistic schedules, budgets, sites, designs, and precautions for further analysis. The PEA is also a useful reference document for inclusion in the terms-of-reference for outside consultants to prepare a full EIA. The PEA helps the proponent and consultants focus on significant issues which, in turn, can save the proponent time and money allocated for consultant contracts.

1. Purpose, Need, and Scope of the Proposal

The proponent needs to respond to the following questions which we conveniently term the "seven Ws":

1. Why? Why is the project proposed?

2. What? What will the final project look like? the magnitude of the project? What design options are available?

3. When? When is the proposal to be implemented? construction? operation? decommissioning (if applicable)?

4. Where? Where are the preferred sites for the proposal? What are some possible alternative sites?

5. Who? Who is the real advocate or proponent of the project? Who will build it? operate it?

6. Whom? Which publics or communities will be interested or affected by the project?

7. How? How will the project be implemented? the phases or steps?

Answers to the preceding questions will give the sponsor a clear idea of where the project will be heading, and they can be used as background information for the scoping meeting (see below).

2. Field Reconnaissance

A preliminary visit to the project site will help to identify many of the important resources to be affected, relationship to the nearest communities, public areas, soil and vegetation conditions, for example. A site visit will uncover many unforeseen factors that cannot otherwise be anticipated. Ideally the staff of the project sponsor should participate, especially the project manager, environmental scientist, and engineer, accompanied by specialists from other agencies with relevant jurisdiction or expertise (e.g., historic resources, fish, and wildlife). Resource users at the proposal sites can also be observed and interviewed during field visits.

3. Interviews

Informal discussions with community group networks and leaders should be accomplished to gauge reaction, possible support, or opposition to the project and the reasons for such opinions. Most important, the public should be asked how the proposal should be revised to render it acceptable or supportable, and how they would like to be involved during the planning and approval processes.

4. Consultation With Other Agencies

If other agencies are unable to participate during the initial reconnaissance visit, they should still be queried by telephone or visited at their offices to determine the presence of important resources or issues and the need for approvals or permits for project construction or operation.

5. Consultation With Other Specialists

If there is a local university, college, scientific institute, museum, or research station on the island or in the region, the project sponsor should consult with them. These contacts can identify expertise that may be tapped during the study phase for the project and identify problems, issues, or resources warranting special attention.

6. Visits Or Contacts With Local Political Leaders

The views of elected officials of the region with regard to proposals are important. Political support may be voiced for some sites or designs and opposed for others. Political views inconsistent with those of affected community views also raise possible "red flags," necessitating immediate follow-up discussions. Political leaders may also be the source of funds or other support to assist the project, such as for sewage, transportation, power or water supply, if the proposal is consistent with long-range political plans for the affected areas.

Completion of the preceding steps will help to answer a number of questions, such as those listed here, for establishing realistic planning steps, schedules, and budgets.

- What special studies will be required?
- What are the preferred sites and other acceptable (alternative) sites?
- What resources or issues should be accommodated or avoided?
- What permissions or approvals are needed? and at what project phase?
- What are the roles of the politicians, and when should officials and communities participate?
- What technical assistance can be provided and possibly be supported by other agencies and institutions?
- What will the project cost? How will it be broken down for the planning, construction, and operational phases? What are the economic benefits (as well as costs)? Is the project economically feasible?
- How long will it take to implement the project?
- What are the major environmental and socioeconomic consequences of the project?

The answers and information can now be assembled and organized within a preliminary environmental assessment (PEA) prepared by the project proponents. Such an analysis will be invaluable during scoping. The PEA can be distributed to other agencies, the public, and politicians for review and comment. The PEA could then serve as the blueprint for much of the complete environmental assessment to be accomplished later. Most important, this analysis helps to track specific project details through the assessment process to a preliminary appraisal of impacts and mitigation. (See Section III.A, "Qualitative Evaluation Procedures," for more details.)

The format of the written findings of the PEA is flexible but can include the following headings:

A. Purpose and need for the proposed action

B. Alternatives (including the preferred or proposed project)

C. Environment without the proposed project (existing environment)

D. Environment with the project (environmental impacts)

E. Recommendations on future analysis, mitigation, monitoring, and coordination

II.C. SCOPING

Setting the boundaries of the assessment is the most important step of the entire EIA. Too narrow a scope will likely leave out an important factor or effect, but too broad a scope may make the analysis unwieldy or take too long a time. Other aspects of scoping are to choose the important issues to be resolved and to agree on responsibilities for performing the EIA. Figure II.2 shows the increasing difficulties of EIA as the scope is increased.

The elements of scoping include geographical boundary; time horizon for analysis; alternative actions to be considered; affected groups, institutions, agencies; significant issues to be investigated; and previously related EIAs.

1. Geographic Scope

Setting the correct boundary for analyses is essential. Consider, for example, a multipurpose dam and reservoir project in a large upland watershed (Figure II.3). A narrow financial analysis might include just the costs of the dam and hydroelectric generator and just the benefits of the power delivered to an electric grid. From the standpoint of society, however, many related effects on natural systems would be important. A cascade of consequences from the construction of the dam can be imagined to include:

- A multipurpose reservoir is created.

- Valley dwellers are displaced to uplands or to the floodplains below the dam or begin a fishery in the lake or farm the draw-down area. Wildlife habitat and cultural sites may be inundated.

- Migrants from reservoir sites add to population pressure on marginal and steep sloping lands causing soil erosion.

- Intensified upland activities (farming, forestry, agroforestry, roads, and settlements) cause soil erosion, silt, and chemical pollution of streams. Sediment is stored in the stream banks and beds awaiting storm events to be moved farther downstream.

- Sediment from eroded soil is deposited in headwaters of lake, at first causing flooding of adjacent land.

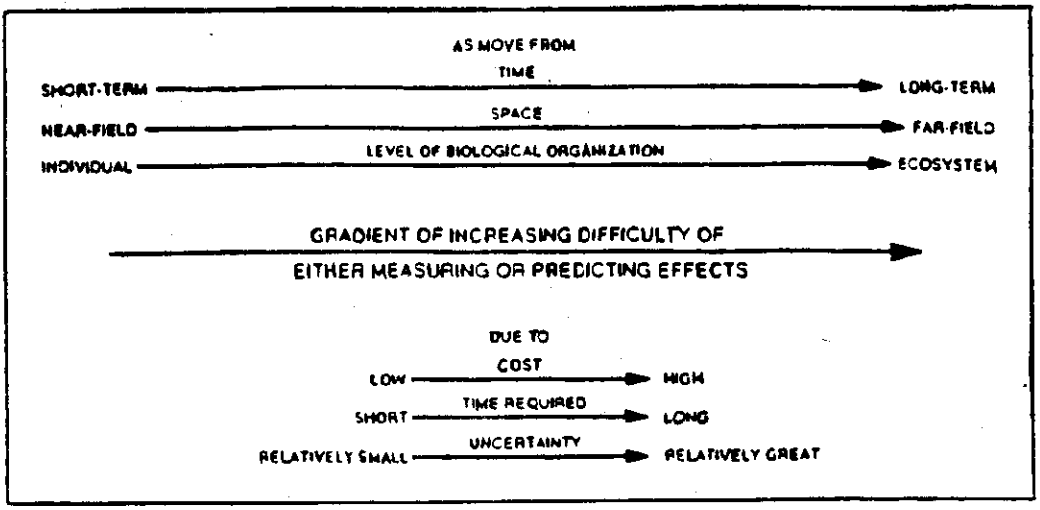

Figure II.2. Gradients associated with analyzing impacts (After Christensen et al. 1976).

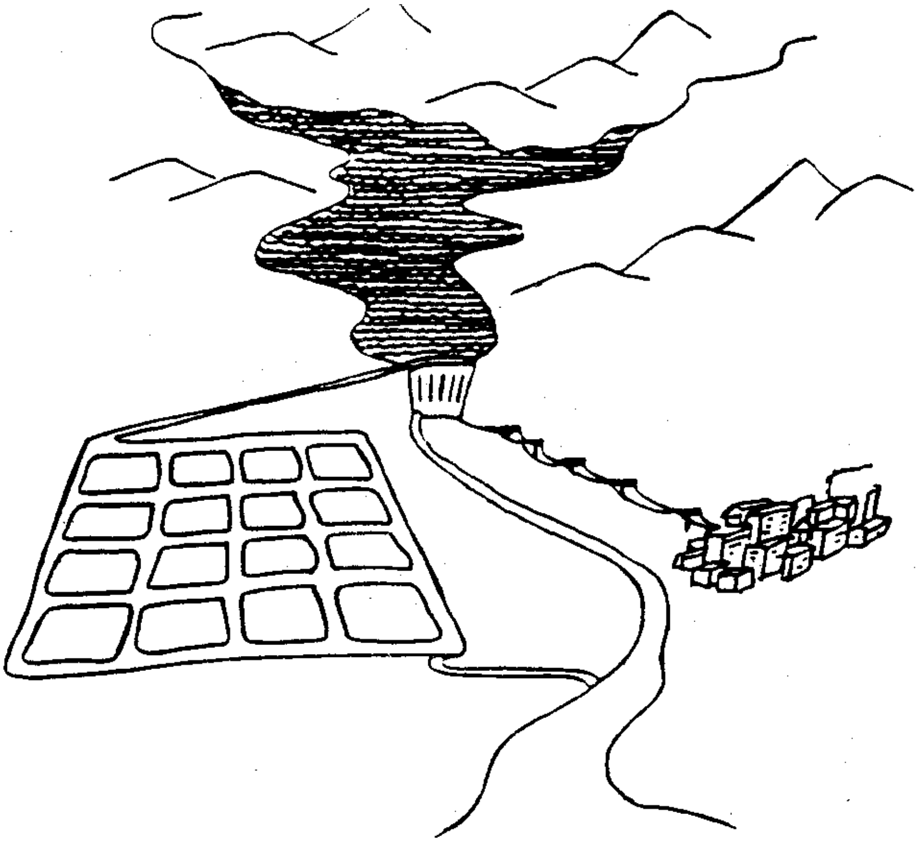

Figure II.3. What are the correct boundaries for analysis in this watershed system? (<u>Source</u>: Carpenter 1987:331)

- Turbidity increases in the lake, interfering with fishery and recreation.

- Nutrients cause eutrophication and aquatic weed problems (lowered dissolved oxygen, fouling of equipment, odors, etc.).

- Eventually, sedimentation displaces active storage capacity.

- Irrigation water is a primary benefit and dependence of agriculture on that water grows. Silt in water requires dredging of feeder canals.

- Salinization and waterlogging of soils occur from improper control of irrigation.

- Electric-generating capacity and its longevity are lost through sedimentation. Silt damage to turbines increases maintenance expenses.

- Irrigation return flow to river may carry toxic agricultural chemicals and salts, which affect downstream fisheries and other water uses.

- Severe storms require water release from flood plain damage because of reduced reservoir capacity.

- Many dependencies (e.g., irrigation, flood protection) develop upon a water management system, which may be rather short-lived.

Some of the interactions can be seen to bear directly on the success of hydroelectricity generation (e.g., erosion in the uplands can cause siltation of the reservoir and loss of storage capacity). Transfer payments may be worthwhile to subsidize soil conservation projects, thus avoiding the damage costs of siltation and also gaining additional benefits such as less turbidity in the reservoir fishery and sustained on-farm agricultural yields.

The fish catch in the Nam Pong Reservoir near Khon Kaen, Thailand, is decreasing because soil eroded from upland forests that have been clear-cut is causing turbidity and consequent low survivability of fry. Since replanting the forests appears to be less costly than the reduced income from fishing, replanting is worthwhile.

Plant nutrients often appear in runoff water from fertilized croplands when the fields are cultivated right to the edge of drainage streams. When this water reaches the reservoir, aquatic weeds are encouraged, and they may grow to such an extent that they foul turbines, interfere with boat transportation, and upon decay lower the dissolved oxygen to a point where fish die. Many reservoirs employ mechanical harvesting of aquatic weeds, the costs of which could be avoided if riparian vegetative strips were left along stream banks to trap the nutrients (and also silt).

The social costs of displaced people can be calculated in terms of employment and human settlement investments with, and without, the dam. In some cases the new opportunities such as a reservoir fishery add up to a substantial and unexpected increase in total benefits over the previous agricultural use of the flooded basin.

Engineering calculations must show a lifetime of the reservoir long enough to produce electricity sufficient to more than repay the costs of construction and operation. Watershed protection programs that ensure against siltation and loss of storage capacity can be objectively evaluated over the expected reservoir lifetime and judged as to their worth.

The advisory reports from a comprehensive analysis should suggest alternatives to management including sites, designs, and scales. In the extreme case, the externalities may be so great as to render the dam at a particular site uneconomic as a project. More usually, previously unrecognized economic justification for environmental protection will be discovered. Other conservation measures may be seen to be relatively inexpensive or even "free" (e.g., maintaining biological diversity by patches of natural vegetation, riparian buffer zones, and roadsides).

Thus, a systems approach would seek to understand thoroughly the interacting factors in the river basin under consideration and to present, insofar as possible, a comparison of management options in terms of benefits and costs. The intangible consequences such as flooding of cultural sites, threats to endangered species, and changes (good or bad) in lifestyle, would also be carefully described and presented, along with the economics, to the decision-maker. Values would still enter the decision but on a much expanded and documented basis of objective knowledge.

In the case of industrial projects, the scope should include reasonably important factors (e.g., transport of raw materials and products, worker housing, and pollution or waste discharges) extending beyond the site.

Highly imaginative indirect effects may be mentioned but need not be evaluated (e.g., civil unrest, price fluctuations in distant markets, rare natural calamities).

2. Time Horizon

All phases of the project (i.e., construction, operation, and decommissioning maintenance) should be covered. The more important question, however, is how far into the future predictions should be taken. Although their accuracy falls off rapidly with time, predictions of effects out to the expected lifetime of the project or facilities should be attempted. Instances where some sort of perpetual management is necessary (e.g., hazardous waste or radioactive materials) should be noted. If dismantling of a facility is necessary, the impacts of that activity at a future time are covered.

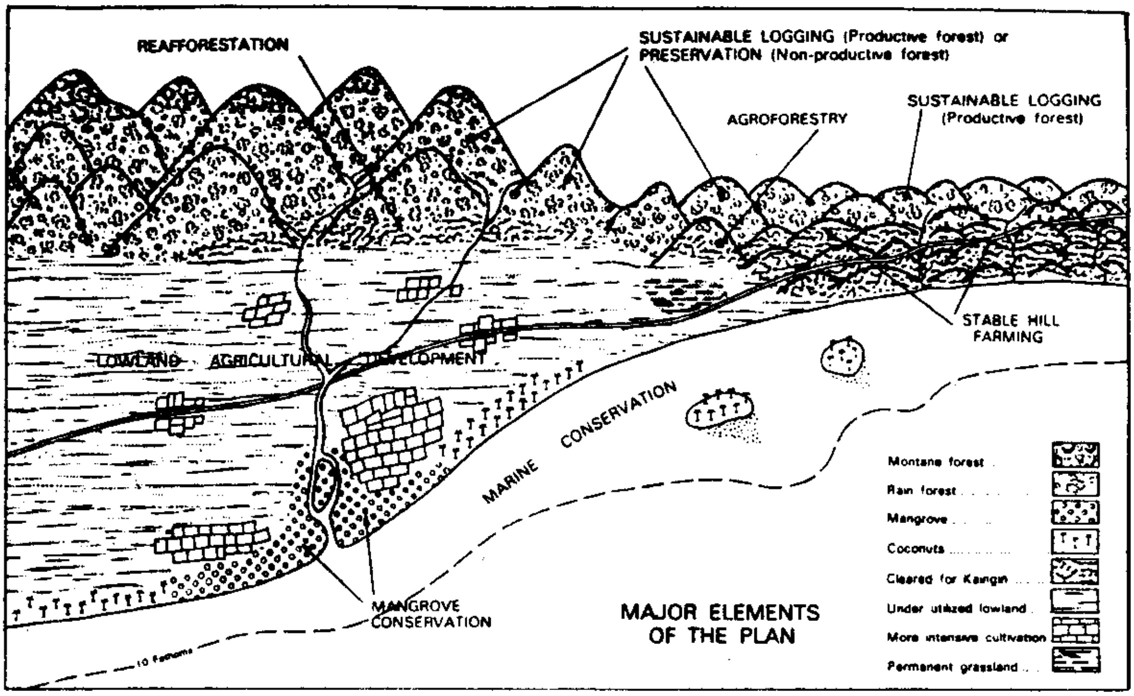

Figure II.4. A sustainable development plan for Palawan, Philippines (Source: PIADP 1985:7).

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3. The Scoping Meeting

An efficient way to plan an EIA is to meet with (1) officials responsible for the project and the site, (2) experts in the technology and environmental sciences, (3) affected groups such as local residents and businesses, and (4) representatives of other agencies with expertise or jurisdiction. Announce the meeting well ahead of time and use the PEA to describe the development objective and tentative project plan. The convenor of the scoping meeting can be either the project proponent or environmental officer. Convene the meeting and present more details. A sketch "map" of the project at about 1:10,000 scale on a large piece of paper can be used to organize the discussion (see Figure II.4). All participants are encouraged to add items to the sketch and to propose alternatives and issues to be assessed. Flows of materials, energy, and people are indicated on the sketch map. Impacts are tentatively predicted. Ecologically sensitive areas (e.g., steep slopes, flood plains, wetlands) are located. Later, a fresh version of the sketch map may be prepared; but for scoping, the purpose is to capture all reasonable ideas and comments so that neatness is not required. Specific sites may be sketched at a larger scale to allow portrayal of more detail.

The scoping meeting participants agree on responsibilities and schedules for various parts of the EIA. How much money and time are available? Where are existing data located? Who will collect what additional data? Who performs the EIA, prepares the report, pays the bills, reviews the findings, implements the recommendations?

In addition to geographic and time boundaries, the scoping group agrees on the alternatives and major issues to be addressed. Others may be added during the assessment; but by using tests of significance, urgency, and irreversibility (see Section II.C.4), the EIA is outlined.

Affected parties are identified (i.e., various users of the resources, water, and landscape; suppliers and customers of the development project; displaced people; and wildlife or recreational interest groups). If these groups are not represented, surrogates are appointed to place their concerns in the EIA planning. Conflicts, controversies, and incompatible objectives are identified. Trade-offs and compromises may be negotiated even at this early stage of assessment. For example, religious sites may be declared inviolable, or preservation status for a part of a wetland may be agreed to in return for permission to develop another part. Where great uncertainties exist, conflicting parties may agree as to the scientific effort necessary to reduce them or simply stipulate that decisions will have to be made without resolving the uncertainties. The participation of diverse interest groups at this stage helps set priorities for EIA and guards against future contentious issues being brought up, which might delay the assessment.

Finally, the scoping meeting compares the project under discussion with past similar projects to take advantage of previous EIA results. If the experience can be transferred, much time and money may be saved. Furthermore, the previous projects provide an actual history of cause-effect and success or failure of mitigating measures rather than predictions.

The scoping meeting results in a design for the EIA with the following elements:

- Environmental systems: brief description of the principal environmental and socioeconomic resources in the proposed area and at other feasible project sites, and how the systems function and interact.

- Brief description of the expected or predicted environmental changes from the project.

- Measures or procedures that could be implemented to avoid or reduce the impacts on human health and welfare.

- Alternatives including the proposed action and no action.

- Study requirements, regulatory requirements, and other coordination requirements for the proposed project.

4. How to Rank Alternatives and Set Priorities

Environmental planning and management often involve words such as "important" or "significant." These subjective, qualitative words are difficult to deal with because their interpretation depends on cultural values and specific circumstances. Even when quantitative data are available, they must be gauged against some standard and there often is none or at least none widely accepted. There are, however, some useful guides for ranking impacts and for allocating EIA resources to get more information.

Significance of an impact depends on (1) the number of people affected, (2) the duration of an effect (e.g., is it just during construction or for the life of the project?), (3) the proportion of a natural resource that is damaged or consumed, (4) the relationship to other components of the project or other projects in the region, and (5) intensity or severity of impact.

Urgency is a determinant of priorities (i.e., how fast are things getting worse, and how much time is there for remedial action?)

Irreversibilities always command attention because they signal a loss of future options. Species extinction, severe soil erosion, and habitat destruction are examples of irreversible changes. Pollution of groundwater is often essentially irreversible because of its slow movement. Urbanization of agricultural land is virtually impossible to undo once the land use trend has begun.

5. Cumulative Effects

Individual projects interact to produce different and greater impacts than are found by EIA for each one alone. The natural assimilative capacity of the environment can be overwhelmed by impacts too close together in space or too frequent in time. Table II.1 is from a research prospectus prepared by the Canadian Environmental Assessment Research Council titled "The Assessment of Cumulative Effects." A regional master plan may anticipate such combinations. Each EIA for a major project, however, should consider these interactions, and environmental managers should institute monitoring in developing regions that will measure cumulative effects.

II.D. BASELINE STUDIES

EIA predictions depend on understanding cause-effect relationships and the status and trends of environmental characteristics. Baseline studies establish the current (and sometimes past) state of ecosystems. These records are built up gradually and continuously grow in detail through systematic surveys and monitoring. Most countries have some historical data on climate and weather, soils, vegetation, and land use. Each EIA can add to this database while the "always" aspect of assessment (i.e., continuous monitoring and study) establishes time-series of

Table II.1. A typology of cumulative environmental effects

Type	Main Characteristics	Examples
1. Time crowding	Frequent and repetitive impacts on a single environmental medium	Wastes sequentially discharged into lakes, rivers or airsheds
2. Space crowding	High density of impacts on a single environmental medium	Habitat fragmentation in forests, estuaries
3. Compounding effects	Synergistic effects arising from multiple sources on a single environmental medium	Gaseous emission into the atmosphere
4. Time lags	Long delays in experiencing impacts	Carcinogenic effects
5. Extended boundaries	Impacts resulting some distance from source	Major dams: gaseous emissions into the atmosphere
6. Triggers and thresholds	Disruptions to ecological processes that fundamentally change system behaviour	The greenhouse effect: effect of rising level of CO_2 on global climate
7. Indirect effects	Secondary impacts resulting from a primary activity	New road developments opening frontier areas
8. Patchiness effects	Fragmentation of ecosystems	Forest harvesting: port and marina development on coastal wetlands

Source: CEARC and U.S. NRC (1986:161).

measurements. Environmental "profiles" are the beginning of baseline studies even if they are mostly qualitative descriptions.

The data should be compiled for naturally demarcated areas such as watersheds, river basins, or coastal zones or islands (if not too large). However, since they are often collected by areas of political jurisdiction, they must be transferred and adapted for use. Where possible, specially bounded regions corresponding to natural systems may be set up for future extensions of the data (e.g., coastal zone management district).

Detailed research is usually not possible for every area, but transfer of data from a well-studied site to another one of interest that has not been studied may allow the EIA to proceed with a reasonable degree of understanding. Areas that are already intensely managed (e.g., agriculture, forestry, or fisheries) merit less study than those that are sensitive to degradation, unique, or as yet undeveloped.

A comprehensive format should be set up regardless of present data limitations. Many years may elapse before baseline studies are complete; thus, the following framework should guide the collection:

1. Ecological information to understand ecosystems.

    a. Hydrologic cycles--a water budget

    b. Biogeochemical cycles for carbon, nitrogen, phosphorus, potassium, and perhaps sulfur, calcium, and magnesium

    c. Energy flow patterns, food chains

   d. Functions that regulate ecosystems (e.g., succession, predator/prey relations, other biotic interrelationships)

   e. Destabilization trends or irreversible effects such as severe soil erosion, groundwater pollution, coral reef sedimentation, salinization, and waterlogging of soils

2. Soils

   a. Structure, erodibility

   b. Parent geology

   c. Chemistry

   d. Fertility

3. Water

   a. Runoff and infiltration

   b. Quality, pollutants

   c. Water resources development

4. Vegetation

   a. Organization, structure, function, stratification

   b. Biomass, primary production, litter, growth rates

   c. Species diversity, endangered species

   d. Successional processes

5. Animals

   a. Food chains or webs

   b. Species diversity

   c. Endangered species

6. Biological hazards

   a. Weeds

   b. Pests

   c. Parasites

   d. Diseases

7. Human activities
    a. Settlements
    b. Land use
    c. Demographics

This suggested framework for baseline study may be modified as necessary to reflect local interests. These data are closely related to land-use planning.

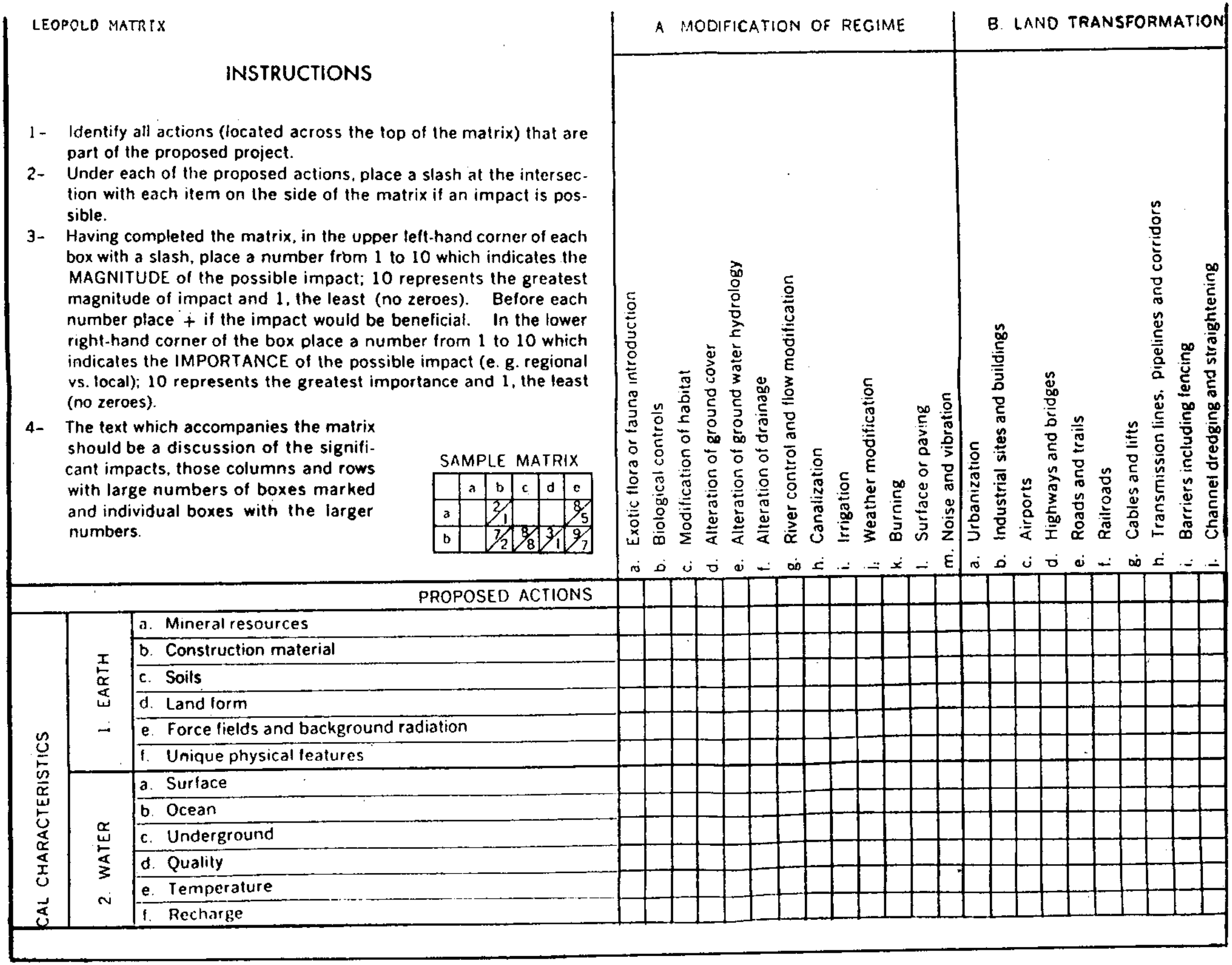
II.E. EIA FORMATS

After a systematic design and scoping of each individual EIA have taken place, there are a number of ways to format data and to proceed with analyses. These techniques do not perform EIA, which requires reasoning, understanding, wisdom, and synthesizing skills. Mechanistic approaches are useful in putting data into order and guiding the thinking process.

1. Checklists serve as a reminder of all possible relationships and impacts, out of which a set tailored for the specific assignment may be chosen. It is always possible that an important local factor may be left out of the generic checklists that appear in EIA manuals. The guidelines from the Asian Development Bank (various years) are a good example because they stimulate investigation (see Appendix). Beware of questionnaire-type checklists where the answers can be "yes" or "no." These discourage thinking and may provide a false sense of assessment. If questions are asked, they should be phrased "to what extent" and "under what conditions" and "in what ways" rather than simply "Does A result in B?"

2. Matrices relate actions to environmental characteristics so that the box at each intersection can be used to indicate a possible impact. Figure II.5 shows a portion of the most famous matrix of all, the "Leopold Matrix" named for Dr. Luna Leopold of the U.S. Geological Survey who developed it in the early 1970s. All development activities are listed across the top and all environmental components that might be impacted are listed at the side. He attempted to assign numerical ratings of magnitude and importance so that the completed matrices for alternative sites or technologies could each be summed and compared. Thousands of possible impacts can be postulated by such a matrix. While useful as a concise identification aid, the matrix can too easily be wrongfully employed to generate trivial questions and to lose meaning through aggregation of the subjective ratings assigned. Filling out a matrix is not equivalent to performing an EIA.

A matrix analysis can systematically identify potentially important effects warranting more careful attention or analysis or focus attention on possible effects that might otherwise be overlooked.



LEOPOLD MATRIX

INSTRUCTIONS

1- Identify all actions (located across the top of the matrix) that are part of the proposed project.

2- Under each of the proposed actions, place a slash at the intersection with each item on the side of the matrix if an impact is possible.

3- Having completed the matrix, in the upper left-hand corner of each box with a slash, place a number from 1 to 10 which indicates the MAGNITUDE of the possible impact; 10 represents the greatest magnitude of impact and 1, the least (no zeroes). Before each number place + if the impact would be beneficial. In the lower right-hand corner of the box place a number from 1 to 10 which indicates the IMPORTANCE of the possible impact (e. g. regional vs. local); 10 represents the greatest importance and 1, the least (no zeroes).

4- The text which accompanies the matrix should be a discussion of the significant impacts, those columns and rows with large numbers of boxes marked and individual boxes with the larger numbers.

SAMPLE MATRIX

	a	b	c	d	e
a		2/1			8/5
b		7/2	8/8	3/1	9/7

			A MODIFICATION OF REGIME													B. LAND TRANSFORMATION									
		PROPOSED ACTIONS	a. Exotic flora or fauna introduction	b. Biological controls	c. Modification of habitat	d. Alteration of ground cover	e. Alteration of ground water hydrology	f. Alteration of drainage	g. River control and flow modification	h. Canalization	i. Irrigation	j. Weather modification	k. Burning	l. Surface or paving	m. Noise and vibration	a. Urbanization	b. Industrial sites and buildings	c. Airports	d. Highways and bridges	e. Roads and trails	f. Railroads	g. Cables and lifts	h. Transmission lines, pipelines and corridors	i. Barriers including fencing	j. Channel dredging and straightening
CAL CHARACTERISTICS	1. EARTH	a. Mineral resources																							
		b. Construction material																							
		c. Soils																							
		d. Land form																							
		e. Force fields and background radiation																							
		f. Unique physical features																							
	2. WATER	a. Surface																							
		b. Ocean																							
		c. Underground																							
		d. Quality																							
		e. Temperature																							
		f. Recharge																							

Figure II.5. A portion of the Leopold Matrix.

3. Sequence diagrams show cause-effect relationships and are effective in explaining how the environment works. Usually four stages are included: (1) beginning with the development activity or human intervention and the technology employed, (2) changes in the natural system and environmental quality, (3) consequent impacts on human health and welfare and ecosystem health, and (4) avoidance or remedial actions, management alternatives, or mitigation for the unacceptable impacts--these may result in revising the original development activity or choosing different technology and thus the sequence diagram is iterative or cyclic (Figure II.6).

A similar flow chart or event chart (event tree in risk assessment language) may reveal a cascade of effects and impacts (Figure II.7).

4. The landscape map: Land-use planning is a form of EIA since proposed uses of land are assessed as to whether they are appropriate and sustainable. Predicting the suitability of landscape units for sustainable uses is facilitated by a detailed map of environmental features. A large scale (1:25,000) topographic map showing roads and settlements is the base. Aerial photographs at the same scale or larger, preferably as overlapping stereo pairs, are highly desirable. A search of the available literature is made for information on vegetation, water resources, soils, geology, and geomorphology. Past and present land use is indicated. Weather and climate information are used to make a climate diagram showing monthly variation in temperature and rainfall. Seasonal variations in winds and ocean currents are needed. A few profile diagrams along transects from sea level to high inland points give a useful third dimension to the map (see Carpenter 1981).

The objective of mapping these environmental data is to separate the region into recognizable landscape units that can be assigned certain uses based on their inherent capability to sustain such uses. Landscape units are roughly homogeneous as to soil, slope, rainfall, elevation, water supply, and vegetation. They are differentiated by margins at which these characteristics change abruptly, such as steep slope or water boundary. Similar landscape units often recur throughout the region. Examples of discrete types of landscape units include beach dunes, alluvial plains, lowland moist forests, mangrove forests, grasslands, steep slopes, desert scrub, terraced farms, eroded and degraded lands. A hypothetical map of differentiated landscape units is shown in Figure II.8. A first broad level of unit recognition is temperature and rainfall. Next, landforms are delineated by topography. A third level is soil type and naturally occurring vegetation. The overall criterion is the capacity of a segment of land to support a certain community of plants and animals on a sustainable basis.

The next step is to rate each landscape unit as to its suitability for a given use. A list of probable uses is drawn up (e.g., tourism, residential, industry, agriculture).

Development Activity	Change in Environment	Impact	Avoidance or Mitigation
Dredging	Suspended particles	Sedimentation of reef	Silt curtain
Causeway construction	Decreased circulation	Fish kills	Larger culverts

Figure II.6. Examples of the sequence diagram.

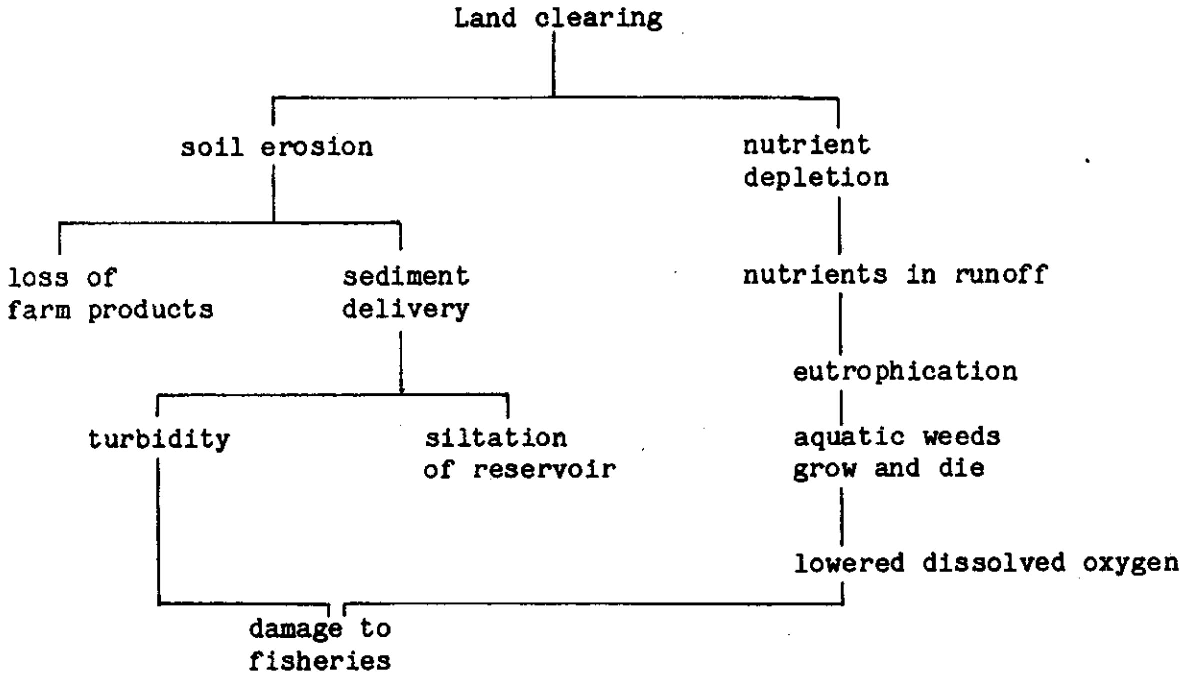


Figure II.7. Cascade of effects.

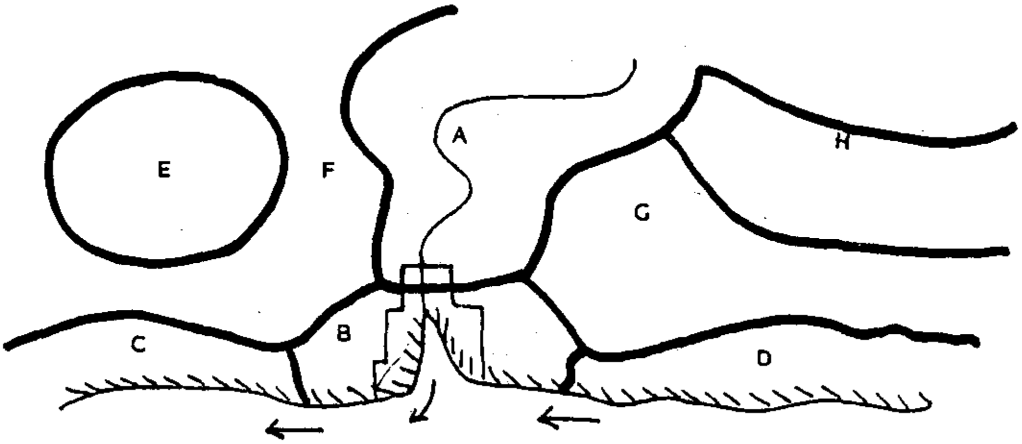


Figure II.8. A hypothetical map showing differentiated landscape units.

A rating system should employ several levels of suitability such as:

S_1 = no limitations to sustained use as proposed

S_2 = limitations that require careful management if the use is to be sustained

S_3 = marginally sustainable only if great care and maintenance are accomplished

N_1 = currently not suitable unless corrections are made

N_2 = permanently not suitable for the proposed use

Table II.2 shows suitability or capability classes for agricultural use.

The landscape units on the map are then rated for each use, usually by a panel of experts familiar with the region. It is not necessary to rate each landscape unit for each use since some combinations may be clearly not relevant (NR). The result is Table II.3. The advent of Geographic Information Systems using computers makes preparing these maps easy, but they can be done effectively by hand.

Table II.2. Soil capability classes for agricultural use according to the U.S. Soil Conservation Service

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Class I: Soils that have few limitations that restrict their use. Suitable for cultivation.

- Unit I-4: Deep, well-drained, nearly level, upland soils.
- Unit I-6: Nearly level, well-drained, silty soils on floodplains and low terraces.

Class II: Soils that have some limitations that reduce the choice of plants or require moderate conservation practices. Suitable for cultivation.

- Subclass IIe:[a] Nearly level to gently sloping soils, subject to erosion if tilled.
- Subclass IIw:[b] Moderately wet soils.

Class III: Soils that have severe limitations that reduce the choice of plants, require special conservation practices, or both. Suitable for cultivation.

- Subclass IIIw: Wet soils that require artificial drainage if tilled.
- Subclass IIIs:[c] Soils that are severely limited by stoniness.

Class IV: Soils that have very severe limitations that restrict the choice of plants, require very careful management, or both. Marginal soils.

- Subclass IVe: Soils severely limited by risk of erosion if tilled.
- Subclass IVw: Soils severely limited for use as cropland because of excess water.

Class V: Soils that have little or no erosion hazard but have other limitations that are impractical to remove and that limit their use largely to pasture, woodland, or wildlife food and cover. Level but wet.

- Subclass Vw: Soils limited in use to grazing or woodland because of poor internal drainage.

Class VI: Soils that have severe limitations that make them generally unsuitable for cultivation and limited by steepness, drought, or moisture. Suitable for grazing and forestry uses.

Class VII: Soils with very severe limitations that restrict their use to pasture or trees.

- Subclass VIIe: Hilly, steep, erosive.
- Subclass VIIs: Stony, rolling, steep, shallow to bedrock.

Class VIII: Soils with no agricultural use, mountains.

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[a] The letter "e" indicates the soil is erodible.

[b] The letter "w" indicates wet.

[c] The letter "s" indicates extreme stoniness.

Source: Ecology, Impact Assessment, and Environmental Planning, by Walter E. Westman. Copyright © 1985. Reprinted by permission of John Wiley & Sons, Inc.

Table II.3. Array of alternative uses and their suitability at various sites in Figure II.8

Mapped landscape unit	Tourism	Residential	Industry	Agriculture
A Floodplain		S^2		S^1
B Estuary	N_2		S_1	
C Beach	S_2		NR	
D Beach	S_1		NR	
E Mountain		NR		S_3
F Slopes	NR	S_3		S_2
G Upland		S_1		S_1
H Steep slopes	N_1	S_2	N_2	S_3

NR = not relevant

II.F. PREDICTION METHODS AND MODELS

The essence of EIA is predicting future environmental conditions: one situation with the proposed development and one without. A comparison of the two predicted situations is also often made with the present. This section presents some proven approaches to forecasting or prediction and suggests the most useful methods for various changes in the environment.

1. Extrapolation, Interpolation, and Analogy

If the proposed development activity is an addition to an existing situation, a correlation of impact may lead to a prediction. For example, a resort doubles the number of guest rooms, and the sanitary sewage output doubles also. But the impact on water quality may be much greater if the sewage treatment system is already near capacity. Trends and correlations may or may not be the linear and continuous; thus, extrapolation must be done with care and understanding. The shape of the dashed line in Figure II.9 determines the extrapolated impact.

Interpolation may be used to estimate the impact of a new development where the impacts of both larger and smaller similar developments are known. The result is usually more accurate than extrapolation if the assumptions of a linear correlation are true (see Figure II.10).

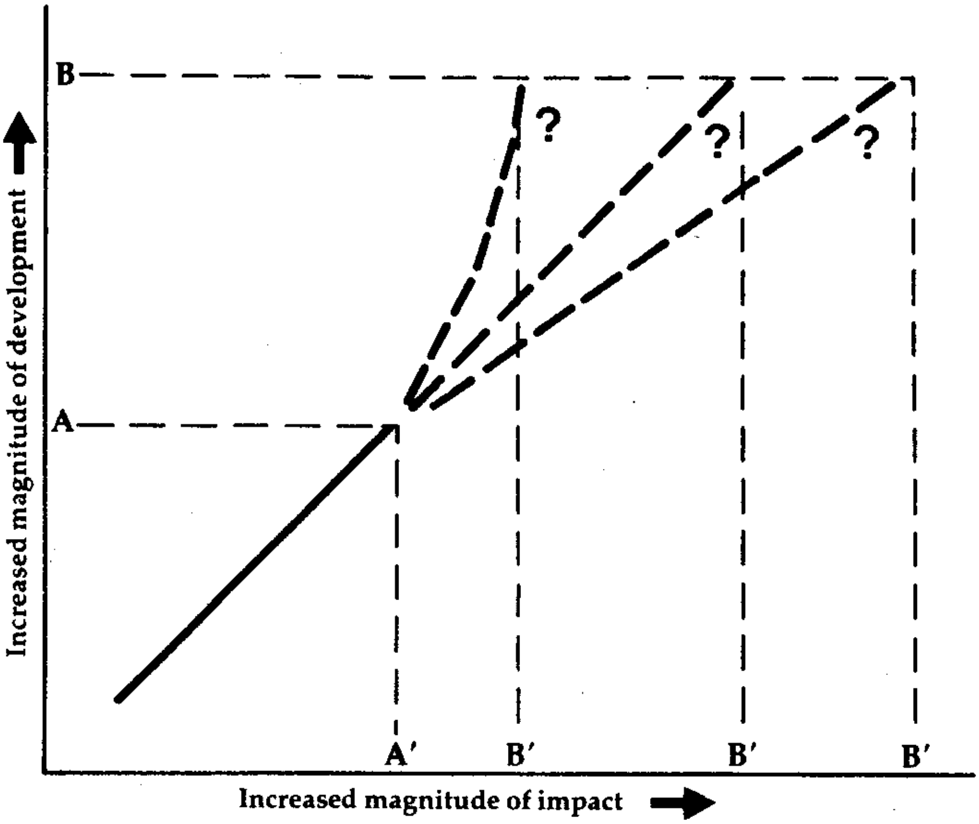

Figure II.9. Extrapolation.

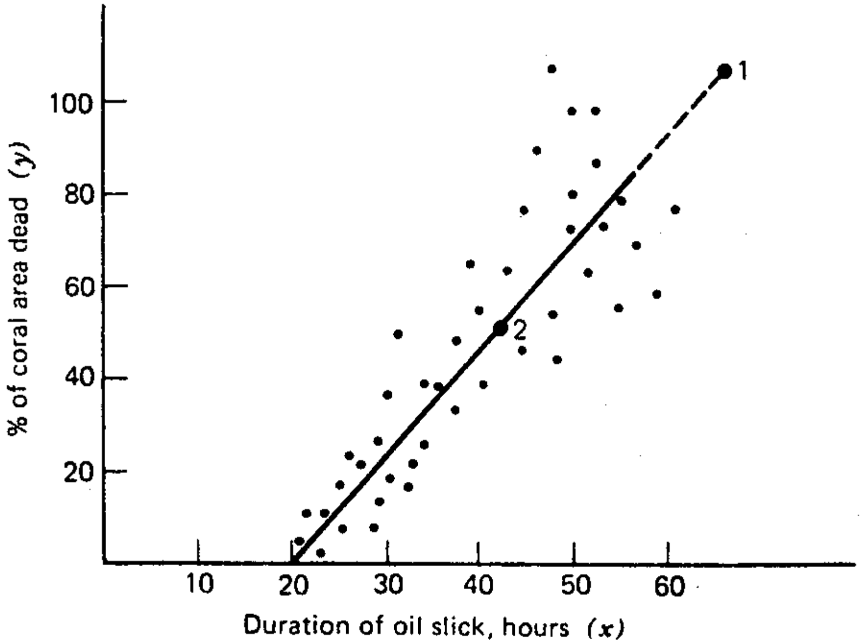

Figure II.10. Predictions by projection from past observations. The solid line is a regression line through observed events of coral death, y, under particular duration of exposure of oil, x (hypothetical data). Point 1 is predicted by extrapolation, point 2 by interpolation; both are projections from past events (Source: Ecology, Impact Assessment, and Environmental Planning, by Walter E. Westman, Copyright © 1985. Reprinted by permission of John Wiley & Sons, Inc.).

Analogy between an existing development and a new project allows prediction of impacts depending on the extent of similarity of the sites in both cases. These prediction methods anchored in actual experience are always preferred to estimates with no basis of direct observations.

2. The World Health Organization Rapid Assessment

Waste discharges (gaseous, liquid, and solid) from various industrial and municipal processes can be rapidly estimated from knowledge of typical amounts of pollutant released per unit of production or per unit of raw material. For example, a wood pulp mill using the sulfate process will typically discharge 18 kg of suspended solids for each ton of production; thus, the daily production rate x 18 yields the amount of solids discharged to receiving waters. Similarly, canning of fish will typically result in 280 kg of inedible fish parts per ton of fish processed; the solid wasteload is calculated by multiplying the daily processing rate by 280 (see WHO 1989). See also the typical effluent streams for island industries in Section IV.H, p. 219.

Thus, a proposed new factory may be quickly assessed for pollutant discharges by inquiring about its designed capacity and the efficiency of any pollution control equipment to be installed.

3. Capacity and Threshold Concepts

The environment has capabilities for carrying, withstanding, absorbing, and assimilating various development activities and their consequences without substantial adverse impacts. Knowledge of these capacities and their threshold limits is valuable for prediction. Examples are:

- Tourism can be accommodated up to a point where one or more of the following capacity limits are exceeded: crowding of beach space, noise and congestion on access roads, sanitary sewage disposal, or drinking water supplies. Quantitative per tourist requirements can be derived for these environmental values: the total available capacity can be measured and then the maximum number of tourists can be calculated for the threshold that is first exceeded.

- Wildlife habitat for some species must be a certain minimum area or contain a minimum number of animals for the community to be sustainable. If less is available, the entire area may as well be developed because the wildlife will not be preserved in any event.

- The percentage of area paved with an impervious cover is important in setting the ratio of runoff vs. infiltration of rainfall. After a certain definable level is reached, underground water supplies will no longer be recharged.

- Dissolved oxygen in a waterbody can oxidize organic matter in sewage (the "biological oxygen demand"). Once all the oxygen is expended, foul odors are detected and fish die. This assimilative capacity can be measured and used to predict the impact of fluctuations in sewage loading.

4. Limiting Factors

Similar to thresholds are those requirements for energy and materials that limit the size of biological communities (i.e., nutrients, food and predator-prey relationships in the food web/chain, light for photosynthesis, space, and water). A prediction of harvests and standing stocks can be made from knowledge of which factor is in least supply and what that supply level is.

5. Models

When structure and processes of ecosystems are understood, equations can relate essential characteristics in a predictive model.

a. The Universal Soil Loss Equation predicts erosion rates from knowledge about rainfall, slope, soil structure, vegetative cover, and management practices (see Section V.B).

b. The water budget is essentially a materials-balance equation among rainfall, evapotranspiration, runoff, infiltration, and storage in a watershed or other hydrologic system (see Section V.D).

c. The salt budget accounts for all sources of salt, movement by solution, deposition (precipitation), uptake by plants, and export by leaching.

d. Population dynamics predict the rise and fall of biological organisms and communities from knowledge of lifecycles, predator-prey relationships, food webs, and other factors affecting the lives of various species.

Other models are noted in the following sections.

6. Toxicity Models

Human beings, animals, and plants respond to toxic materials in the environment according to how large a dose they receive. Prediction of impacts can be made if this relationship is understood quantitatively. Figure II.11 shows human dose-response information in terms of exposure time at various concentrations. The chart was prepared from a variety of data including (1) tests with animals assumed to respond similarly to humans, (2) studies of workers exposed in industry where the toxic chemical may be encountered, (3) epidemiology that links health effects in a population to measured ambient levels of toxicant, and (4) studies of accidents where humans are exposed to high concentrations. Since there is always uncertainty in the response, a safety factor is used to set standards well below

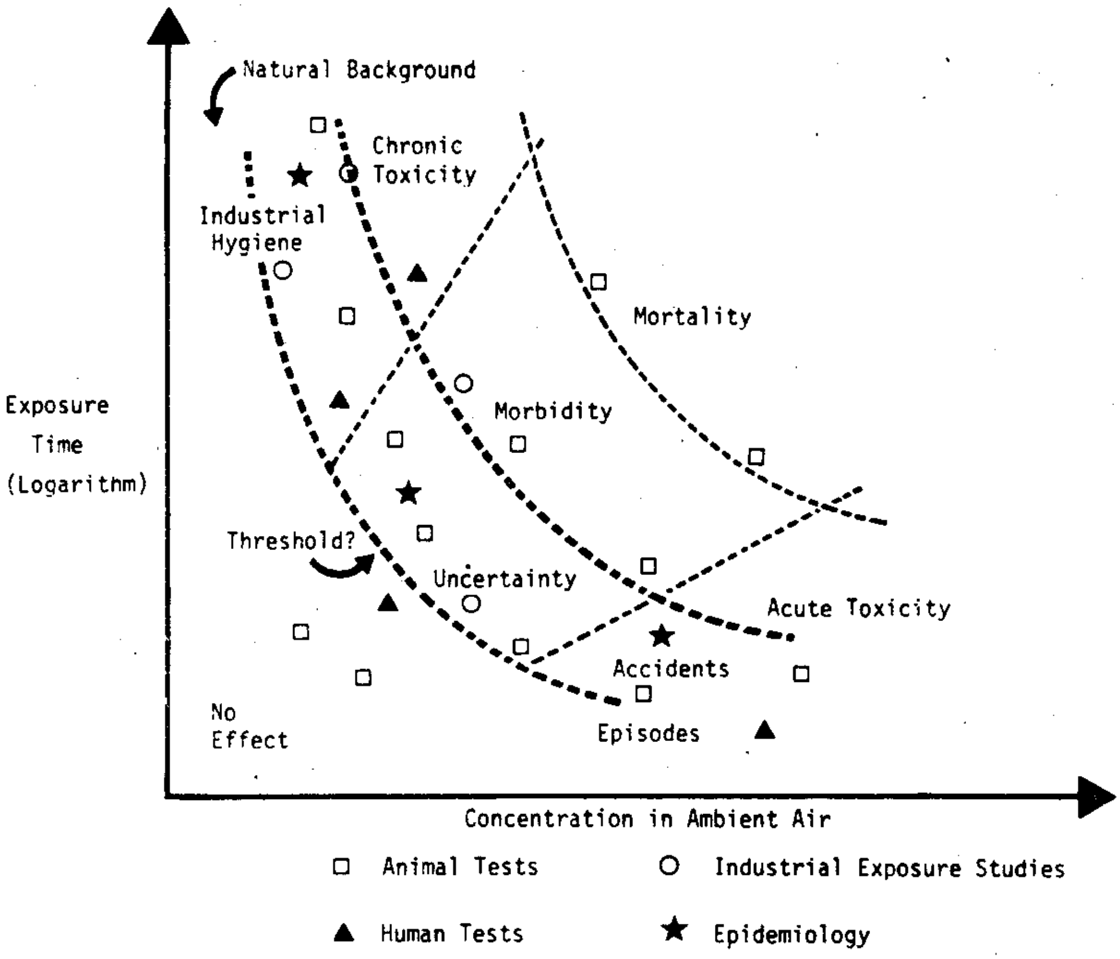

Figure II.11. Human dose-response information.

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the dose where morbidity is actually detected. Recommended exposure limits are available from the World Health Organization. For other organisms, research studies are reported in scientific literature. For fish and shellfish, tests can be run on the species in question, although the response of an entire ecosystem is what actually should be known.

Figure II.12 shows the pathways for human exposure to toxic chemicals. Health effects are most directly related to dose, and then to exposure. Quantification of these steps in the pathway may be difficult. An EIA can make a useful estimate of possible adverse health effects even if only the ambient concentration is known. And a prediction of risk may be made from just the knowledge of inventory and the probability of spills or leaks. The assessor should always seek the most closely linked data (i.e., dose) but still make an estimate from whatever information exists.

Direct dose assessment requires that the chemical, a specific metabolite, or specific biologic marker be measured in the appropriate body fluid or tissue. Organochlorines such as PCBs are a good

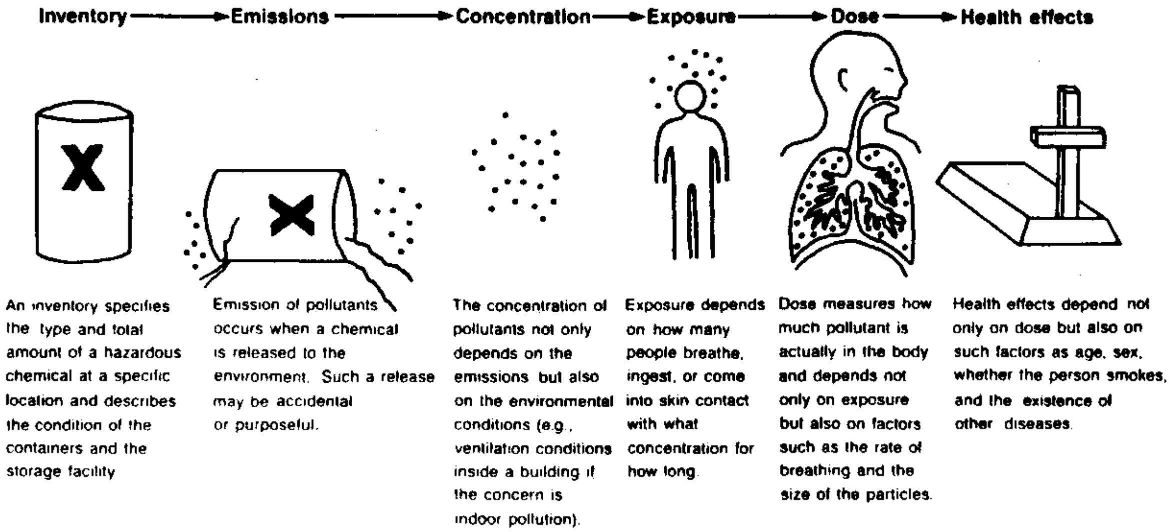

Figure II.12. This figure shows the relationship between quantity, emissions, environmental concentrations, human exposures, doses, and health effects--what is called an environmental pathway (Source: Smith et al. 1988:36).

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example. In areas where the PCB content of fish is high, there is a strong association between the number of fish eaten, as determined by dietary history, and the level of PCBs in human body fat or milk. Negligible amounts of PCBs are found in the water itself.

Basically two approaches are used to ascertain the health impacts of toxic chemicals. The first relies on extrapolation from laboratory tests, such as controlled exposures to animals. The second approach applies epidemiological investigation to human populations.

Ecosystems provide direct support for human populations as well as sustaining other species upon which society depends. For example, a pesticide may have an unexpected toxic effect upon a major predator of the target pest. Pesticide use could result in an eventual increase in abundance of the pest, leading to a detrimental economic effect upon the human population depending on this crop, and possibly a decrease in the health of people who depend on the crop as a food source. As a second example, consider the case in which a toxicant is released into the environment in diffuse low concentrations, but is accumulated to higher concentrations through the food chain. Humans who eat animals higher in the food chain may be exposed to concentrations greatly in excess of what was anticipated from the released quantities.

7. Predicting Air Pollution Effects

The Air Quality Control District Concept. Understanding the geographical region that shares an air mass can lead to a predictive capability. The most important determinant of the boundaries is air movement, and this will vary as to speed and direction with the seasons or even the time of day. A windrose is shown in Figure V.20, and this is combined with the location of emission sources and population concentrations to give an estimate of pollution problems.

Since terrain also affects air movement, a map of actual measured pollutant concentrations is desirable (see Figure V.21).

To predict pollution from a new or additional emissions source, a model of the dispersion of pollutants is necessary. A simple "box" model assumes that the wind blows through a rectangular area from a source to contact a constant speed, mixing the pollutant with the air homogeneously. A more complicated model is the Gaussian plume distribution type that considers stack height, release rate, and crosswinds (see Figure V.19). For additional discussion, see Section IV.H, "Waste Management and Pollution Control."

8. Predictions Relating to Water Quality Impairment

The uses of a body of water are often impaired by contamination, and it is this loss of use that must be predicted. For example, clarity (absence of turbidity) is essential for recreational divers and snorkelers to view coral reefs with their assortment of fishes. Turbidity may be predicted from knowledge of current patterns, sources of suspended material, and the physical characteristics of that material.

Figure II.13 shows the "oxygen-sag" model which can predict the recovery of a stream after discharge of oxygen-consuming organic wastes.

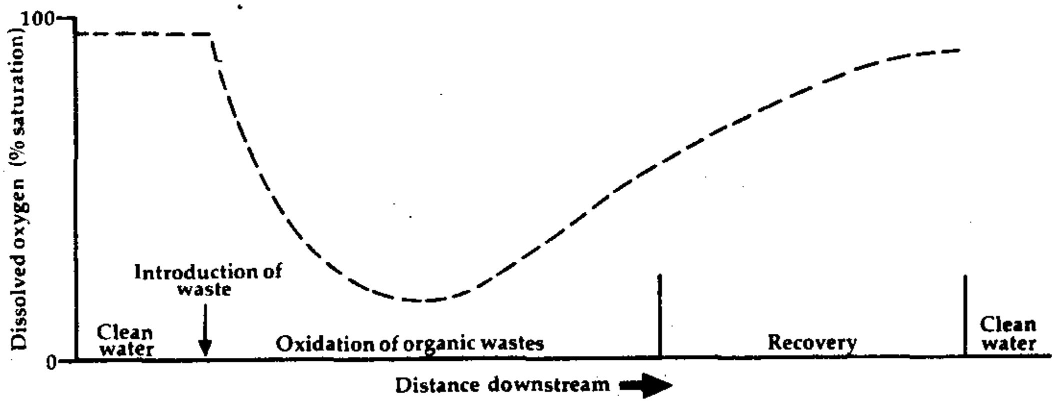

Figure II.13. Sag in dissolved oxygen and natural purification in a river following sewage discharge.

9. Prediction of Ecosystem Response

The health of an ecosystem may be predicted from effects of development activities on the major structural and functional characteristics. Structurally, the ecosystem should contain many species (diversity), have long and complex food chains/webs, not be invaded by foreign species, have strong connections to neighboring ecosystems, and have "keystone" species in strength. The functions may be evaluated as high primary productivity (energy fixation) and tight biogeochemical cycles (nutrient flow).

Stress indicators such as foliage drop, fin rot, and population fluctuations are predictors that the ecosystem is not being sustained. For example, the appearance of many marine worms indicates that the sea bottom communities of plants and animals are under stress, perhaps from sediments or toxic chemicals.

II.G. POST-AUDIT, MONITORING, AND EVALUATION

The EIA procedures should include a formal requirement to review completed projects and judge the predictions and recommendations made against actual experience. The purposes of the audit are (1) to determine whether consequences were accurately predicted and to identify additional significant effects warranting corrective action and (2) to use the results to refine the impact predictions for future projects of the same type and magnitude. In the few retrospective studies made, the findings have been disconcerting. Forecasts are admittedly difficult, but they are often so imprecise and vague that their accuracy cannot really be ascertained. Many impacts are presented as unquantified assertions without any indication of their likelihood or significance. Not surprisingly, physiographic information is usually more complete and precise than biological impact prediction. Social considerations often occupy disproportionate space (in terms of what is actually known) in an EIA, but that is a reflection of the essential political use of these documents.

The post-audit can begin at once with existing EIAs on completed projects. It is a valuable training device and also helps to find empirical evidence for cause-effect relationships that is useful in ongoing and future EIAs. Post-audit may be painful in that the performers of past EIAs are being second guessed. Therefore, it should be carried out by a group independent of the environmental agencies, perhaps a panel drawn from the academic community.

Monitoring is essential for continuing EIA inputs to management (i.e., mid-course corrections, compliance with mitigation actions, and improvement of predictions). We have seen that predictive accuracy is limited because of the scarcity of information on impacts and natural variations in the environment. All development projects should be managed with the expectation of surprising outcomes and the necessity to adapt and change implementation actions if the goals are to be met. Monitoring provides an early warning that adverse impacts (predicted or not) are occurring.

Measures recommended to mitigate the impacts of development must be actually installed, operated, and maintained. Even so, their efficacy is often uncertain; thus, monitoring is necessary to see how well they work out and how cost-effective they are. As in the case of post-audit, compliance monitoring should be somewhat independent of the project operator, or at least the data should be verified by an independent group.

The overall evaluation of EIA in a particular government should be undertaken from time to time. All participants in the process should contribute constructive criticism and judgment as to how well EIA has helped achieve sustainable development.

II.H. HOW TO REVIEW AN EIA

Review serves several purposes, each requiring somewhat different review skills. Technical accuracy and completeness are assumed by using independent experts who have no vested interest in promoting development or withholding project approval. The following questions are designed for use by high-level officials to judge the adequacy of the EIA. They are adapted from draft materials of the Organization for Economic Cooperation and Development (OECD).

1. To what extent are both the beneficial and adverse environmental effects clearly explained?

2. How are the risks of adverse consequences evaluated and what are they?

3. What is the scope of the EIA in terms of externalities and time-lag effects?

4. What (if any) are the impacts on environmentally sensitive areas, endangered species and their habitats, and recreational/aesthetic areas?

5. What alternatives are considered: no project? other sites? other technologies?

6. What lessons from previous similar projects are incorporated?

7. How do the environmental effects change the costs and benefits of the project?

8. What adverse effects are unavoidable?

9. What public participation and review of project plans or the EIA have occurred?

10. What mitigation measures are proposed, and who is responsible for implementing them?

11. What are the parameters to be monitored so that state of the environment can be studied throughout the project?

II.I. PREPARING TERMS-OF-REFERENCE FOR CONSULTANTS OR CONTRACTORS

Many EIAs are performed by consulting firms under contract to environmental agencies or project proponents. The consultant proposes a statement of work in response to a request for proposal which contains instructions or terms-of-reference (TOR). After negotiation on the scope, schedules, and price, a contract is executed. A good definition of a problem often provides much of its solution and reduces the cost of contract services. It is essential that the major environmental concerns be identified and a search for other likely consequences of development be specifically requested in the TOR. For competitively bid contracts, the consultant will seldom add tasks for fear the resulting higher costs will keep the firm from being awarded the job. During negotiations, however, additional studies may be suggested. Hence, the buyer must have an understanding of just what is needed in order to avoid paying for unnecessary services. It is also important to request the form of analysis and presentation appropriate to the use of the EIA (i.e., extended benefit-cost analysis, comparative risk assessment, cost effectiveness).

The technical contents of a TOR typically include:

1. The objective of the EIA: What decisions will be made, by whom, timetable, what kinds of advice are required, what is the stage of the project?

2. Components of the project: Sites, technologies, inputs of energy, and materials anticipated

3. Preliminary scope of EIA: geographic, region, lifetime of project, externalities

4. Major anticipated concerns about environmental changes and consequences

5. Major anticipated impacts on human health and welfare; on ecosystems

6. Mitigation measures possible. Reasonable alternative project designs for achieving development objective

7. Estimated monitoring necessary for feedback to operations, for detecting environmental consequences and judging whether mitigation measures have been implemented

8. Type of study required (e.g., benefit-cost analysis, land-use plan, pollution control regulation, simulation model, comparison of sites or technologies, risk assessment)

9. Staff level of effort, skills required, cost estimate, and deadlines for completion of tasks

The PEA prepared by the project proponent should have most of the preceding information in qualitative form and may be appended to the TOR for guidance.

Nontechnical requirements in the TOR include:

1. Stipulation of references and data to be provided by the buyer,

2. Frequency and subject of meetings and progress reports,

3. Opportunities for review and comment on draft reports,

4. Prior approval of changes in contractor personnel,

5. Payment schedules,

6. Liability, insurance,

7. Printing, distribution of reports, and

8. Coordination requirements.

II.J. COMMUNICATION OF RESULTS

Communication of EIA findings to policy and decision-makers is difficult because they are often not technically trained. The task is one of translation and interpretation from the language of the scientist into a clear and concise summary that matches the client's constraints and timetables. Another problem in using research results is the gap between the expectations of decision-makers for certainty and the probabilistic realities of science. If a scientist reveals this uncertainty, the client may reject the findings as unhelpful, whereas disguising the uncertainty may cause the scientist to lose credibility when unpredictable results do occur.

Prediction should be straightforward, logical, and systematic regardless of the completeness or accuracy of the data available. All assumptions must be explicitly stated. The users of the assessment can follow the predictive method and, if they wish, substitute alternative assumptions where factual information is lacking. A four-part format in reporting predictions is helpful in avoiding misunderstanding by the users about the uncertainty that inevitably accompanies EIA results. First, the prediction should state what is known and with what confidence--a narrative statement of the

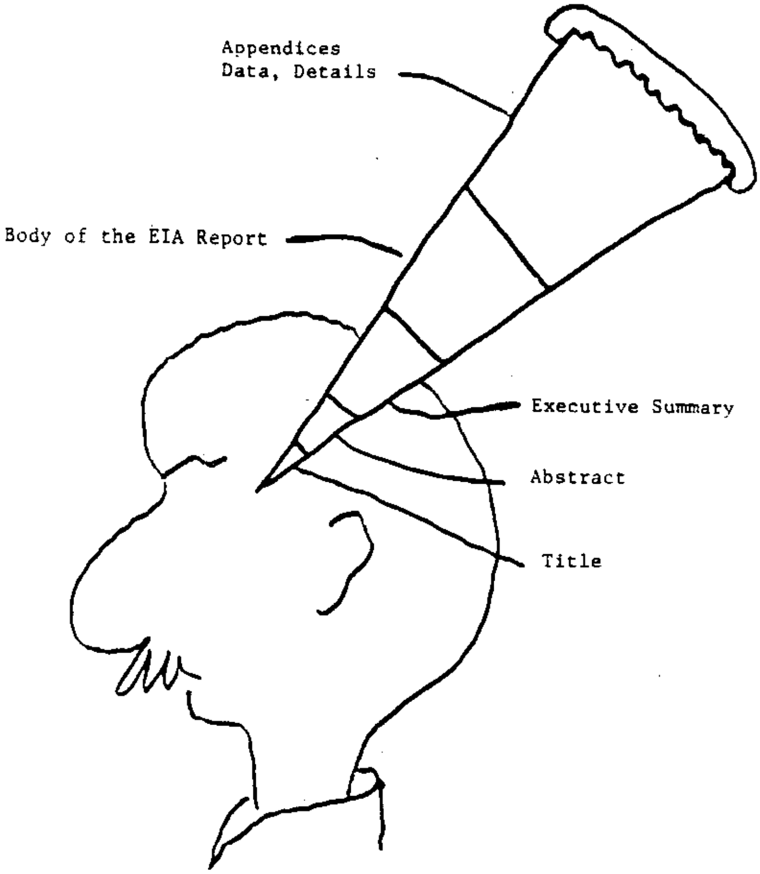

Figure II.14. Getting the message of the EIA into the minds of decision-makers.

statistical reliability. For example, "With the chance of being wrong one time out of ten, we believe that the increase in turbidity will result in a 25 to 50 percent lower catch of fish." Second, state what is not known and why; e.g., "Tests have been run only on species A and B so we cannot be sure of the response of other organisms." Third, explain what could be learned from further investigation if more time and money were available. Finally, indicate what should be known to proceed in a prudent manner (i.e., the risk of going ahead based on present knowledge vs. the risk of delaying the project). To summarize, the EIA predictions should state what we <u>do</u> know, <u>don't</u> know, <u>could</u> know, and <u>should</u> know.

The users of EIA findings and advice also should be urged to (1) understand the probabilistic nature of science and differences among sciences, (2) accept uncertainty in environmental science and learn to live with it, (3) manage adaptively and plan for surprise, (4) avoid unnecessarily tight timetables, (5) participate with scientists in the assessment process, and (6) find out the value and cost of better information and agree to pay and wait for it. Since policy and decision-makers have very little time to read, the title, abstract, and executive summary of the EIA should each repeat the key message for these individuals (Figure II.14).

II.K. TYPICAL CONTENTS OF EIA

Periodic written progress reports as the EIA process proceeds are useful to decision-makers and the public. When consequences are well developed, a draft report should be issued for comment from all interested and affected parties. Although this manual teaches the tailoring of each individual EIA to fit the circumstances of the project, it is useful to review the essential components and how they fit together to produce an advisory report helpful to the decision-maker. The following contents are typical:

1. Title, abstract, executive summary
2. Description of the purpose and scope of the proposed development activity
    - a. Purpose: What goals and objectives of society are served? Why is the project needed? (See "seven Ws," Section II.B.1.)
    - b. Direct benefits expected: products, services, jobs, return on investment
    - c. Location and extent of site boundaries and associated facilities at preferred site and other feasible sites
    - d. Technology to be used
    - e. Local infrastructure required: roads, utilities
    - f. Inputs of capital, labor, natural resources
    - g. Duration of construction period, operating life
3. Alternatives, including the proposed action, and mitigation measures for the proposed development activity
    - a. Reasonable alternatives that might reduce environmental degradation or use natural resources more efficiently and still provide the same or similar benefits
    - b. Mitigation, environmental protection, avoidance of adverse consequences associated with each alternative
    - c. Various site and design options
    - d. Postponing action or abandonment of the proposed project
    - e. Compensatory actions to overcome damages to natural systems and to people
    - f. Enhancement measures to improve present or future environment

   g. Comparison among alternatives (including economic, technical, and environmental aspects)

4. Existing condition and trends in the environment

   a. Activities in the same area that could lead to cumulative effects or interaction of effects

   b. Land use, zoning

   c. Population density and location

   d. Economic activities and conditions

   e. Sociocultural characteristics

   f. Baseline survey and inventory: geology and soils, climate and weather, land forms and water resources, energy supply and demand, vegetation, wildlife, and natural hazards

5. Prediction of <u>changes</u> in natural resources and environmental quality attributed to the project if implemented

   a. Sequence diagram linking development technology to changes in the environment and then to impacts on human health and welfare and ecosystems

   b. Ecosystem model, biogeochemical cycles, primary productivity, food web

   c. Results of other predictive techniques (e.g., extrapolation, interpolation, analogy)

6. Prediction of <u>direct</u> impacts on human health and welfare

   a. Unavoidable adverse effect

   b. Who cares and why?

   c. Models linking environmental change to impact (e.g., exposure pathways)

   d. Cumulative effects

7. Reasonably foreseeable <u>indirect</u> impacts or secondary effects

   a. Socioeconomic changes resulting from impacts on natural resources and the environment

   b. Linkages and multiplier effects

   c. Subsequent environmental consequences of socioeconomic changes

8. Sustainability
    a. Trade-offs between short-term impacts (both positive and adverse) and long-term condition of resource base
    b. Trade-offs between local and national or regional environmental consequences
    c. Options maintained and how
    d. Options foreclosed and why
    e. Irreversible and irretrievable commitments of natural resources
9. Benefit-cost analysis (summary)
    a. Present value of all benefits and all costs compared in benefit-cost ratio, internal rate of return on investment, and net present value
    b. Those effects that can be quantified only in nonmonetary terms are retained
    c. Effects unquantified (subjective values) are preserved and presented in the analysis
    d. Cost effectiveness of mitigating measures
10. Risk assessment
    a. Major uncertainties and their quantitative estimation--how likely are adverse impacts, and what is the range of magnitude of their consequences?
    b. Quantitative expression of net risk
    c. Distribution of risks among groups
    d. Identification of risk reduction opportunities
11. Public involvement
    a. Summary of scoping and public meetings, participation
    b. List of persons receiving this and previous draft reports
    c. Compliance with coordination and regulatory requirements
    d. Public hearings, press releases, notifications
12. Findings and recommendations
    a. What is known and with what certainty (statistical reliability)?

b. What is not yet known and why?

c. What could be known with more time and money?

d. What should be known in order to proceed?

e. Prudent course of action in the face of uncertainty

f. Monitoring necessary for adaptive management and compliance

g. Preferred alternative to implement the proposed development (including siting, design, timing)

h. Recommended mitigation associated with the proposed action (preferred alternative)

III. ANALYTICAL TECHNIQUES ASSOCIATED WITH EIA

FIGURES AND TABLES

Figures

Tables

III. ANALYTICAL TECHNIQUES
ASSOCIATED WITH EIA

III.A. QUALITATIVE EVALUATION PROCEDURES

Data collection is a critical and potentially costly aspect of environmental impact assessment. Collection of quantitative data requires careful planning and focused objectives to avoid needless expense. As a consequence, qualitative data collection, which is considerably less expensive, should precede execution of more detailed quantitative studies, whether for long-range regional planning or project-specific evaluations. It is essential that the scoping and preliminary assessment steps successfully define the specific resources and issues of concern which, in turn, define the specific scope, magnitude, and purposes of data collection. Relevant information means that the user understands what role the data will play in the impact assessment. If the relevance or use of the data cannot be established or tied to future impact analysis and decisions, it may not be needed. Specialists and consultants who make a living by collecting data or conducting research are often not in a neutral or unbiased position to identify relevant data requirements. The project sponsor or the technical staff must be in a position to evaluate independently the opinions of outsiders to ensure that information gathering will benefit the planning process and contribute positively to the impact assessment and decision-making process. The results of qualitative evaluation procedures can be incorporated into PEAs (see Section II.B).

1. Phasing of Studies

The phasing of studies is another way to cut down on unnecessary data collection during preliminary stages and defer collection to subsequent stages when decisions are made to proceed. Phasing should start with extensive reconnaissance-level evaluations at the beginning to help define the magnitude and type of possible impacts and the scope of future studies to assess them. Studies then proceed to the next echelon of detail and quantification after decisions are made and project planning progresses. On the other hand, if a project is dropped early during planning, down-scoped, or redirected, future expensive studies may be avoided. The importance of qualitative/reconnaissance-level investigation is to bring common sense and efficiency to the total data collection process. As the studies progress, they move from extensive to intensive, broad to focused, qualitative to quantitative perspectives. Examples follow:

a. Example 1. A resort development is proposed along a sandy beach. Consultation with the fisheries office and local residents indicate that endangered species of sea turtles may use the beach for nesting. The project sponsor is faced with two options. One is detailed tagging, recovery, egg translocation, and other measures to document nesting and specify measures to avoid or reduce impacts. The other is to confirm the use of the beach by turtles during several nights of night-time observations of nesting activity and day-time shoreline walks along the beach to count tracks and nest pits. He opts for the less expensive latter option, and the studies confirm heavy nesting use at the beach. Similar qualitative observations are collected at an alternative resort beach site at the same time, and no nesting activity or related evidence is found. The project sponsor elects to move the resort to the alternative site, thereby avoiding more expensive studies, delays to the project, and possible impacts to sea turtles. Data collection is integrated into the decision-making process. Qualitative and extensive approaches, including evaluation of alternative options early in the process, contribute positively to the decision.

b. Example 2. A combination hotel and townhouse project is proposed near the coast of a high island. Before site layout and design efforts, the sponsor fields a team of scientists to conduct qualitative reconnaissance-level environmental surveys of the project site and adjacent coastal sites. The archaeologist team member learns from interviews and a literature review that the coastal sand-dune site for the hotel may be an ancient burial ground. The archaeologist expands the scope of the survey to incorporate some test-pit examination over a broader area and confirms the presence of graves near the hotel site but an absence of graves and other cultural resources 300 m down the coast. The project is faced with two choices: (1) attempt to keep the site at the same place and sponsor expensive data recovery surveys to clear the hotel site of burials and other archaeological resources or (2) renegotiate a new site for the hotel and move it to the adjacent parcel. He opts for the latter because he took the step of accomplishing a more extensive survey that identified favorable options. The sponsor avoids expensive studies, impact to the burials, opposition to the project from resident islanders, and delays to the hotel project. Mission accomplished.

The preceding examples demonstrate the value of qualitative preliminary steps to data collection, which are integrated with decisions on a project. The following recommendations provide more specific advice on the direction and approach for data collecting that minimizes potential environmental and economic impacts:

1. Accomplish interviews, literature reviews, consultation with other experts and a site visit first as part of the scoping and preliminary environmental impact assessment process described in Section II.

2. Always conduct scientific reconnaissance-level surveys before designing and funding quantitative surveys and monitoring.

3. Always conduct qualitative reconnaissance-level surveys at the proposed site and at least one or two other feasible alternative project sites.

4. Avoid expensive data collection or monitoring until the sponsor decides that the project shall proceed to the step requiring the information.

5. Formulate data collection studies to be commensurate and coincident with the level of detail of other technical design and planning phases for the project. Detailed studies at one site may be wasted if the project design and location are changed to another site later.

6. Consult aerial photographs and maps, if available, to design sampling and survey strategies for both qualitative and quantitative investigations.

7. Begin data collection from a broad, extensive qualitative perspective and then narrow data collection efforts to address specific questions, issues, or concerns.

8. Consult with experts in other agencies and institutions for unpublished sources, new procedures, and free advice that may avoid or redirect survey effort.

9. Never rely on any one approach or analytical procedure. No one technique is the "best" or is the answer to all questions. Each technique has strong and weak points; some are better suited to answer some questions and others to answer other questions. The answer is not right or wrong, but which approach is appropriate for the specific needs. Comparing techniques is misguided unless comparisons address the specific purposes, needs, nature, and uses of the expected data.

Table III.1 offers a list of various techniques and their various attributes and advantages for collecting specific types of information.

III.B. SOCIAL SCIENCE TECHNIQUES

1. Overview (prepared by Lauren Wenzel)

Social science complements the knowledge of natural science necessary to prepare EIAs: the former explains the impacts of a project on people's lives and the latter on natural systems. At the broadest level, social science methods help to specify the goals of a development project so that progress toward them may be assessed. Is the intention to create employment, stimulate regional development, earn foreign exchange, or some mixture of these and other objectives? These needs and the alternative ways of meeting them must be determined by extensive analysis of social and economic conditions and trends. Once a development project has been proposed, social science techniques enable planners to identify potential, perhaps inadvertent, impacts on an area's social, cultural, and economic fabric. How will the physical impacts of the project affect the opportunities for work, cultural values, settlement patterns, and ways of life?

Table III.1. The relationship between methods to gather essential ecological information and phase of development planning

Type and Description of Technique	Study Objective and Purpose	Applicable Types of Development	Phase of Development	Applicable Ecosystem
Remote sensing surveys (satellite or aerial photo imagery)[*]	Map and describe major types of ecosystems and resources in order to base decision on future data collection and development alternatives	Comprehensive regionally planned development or all specific types of development	Earliest	All
Coastal resources inventories (field checks, interviews, literature reviews)[*]	Qualitative description of resources characteristics and uses in order to identify appropriate location for development	Same as above	Earliest	All
Quantitative ecological surveys (to compare and describe ecosystems to be affected by development)	Provide valid basis for comparing ecosystems and the impact of development at all alternative sites	Same as above	After identification of the feasible alternative development sites	All significant ecosystems within or adjacent to alternative sites
Exposure-level surveys (one-time ecological studies of comparable ecosystems elsewhere previously affected by comparable development)	Assess significance and zones of ecosystem impacts and rates of recovery in order to specify minimum buffer zones and other precautions	All types of development causing impact in study area that is comparable to proposed development.	Early, during identification of alternative project sites	All, provided that ecosystems subjected to impact in study area are comparable to those to be affected by proposed development
Annual/seasonal habitat surveys near proposed project development[*]	Identify seasonal periods of sensitive breeding, feeding and migratory activity of important species in order to specify time, distance, and other controls to limit development impacts	All development that will be sufficiently close to important coastal ecosystem	Middle planning phase: after most feasible project alternative identified	All that will likely be affected by projects
Ambient water current, circulation, and water quality studies	Assess circulation patterns and water quality of adjacent ecosystems to predict future water quality zones of influence and treatment/dilution required to control impacts	All development categories that directly affect or are located adjacent to aquatic ecosystems	Middle planning phase: after most feasible alternative sites and designs have been identified	All aquatic ecosystems adjacent to proposed development
Environmental quality monitoring studies (water quality and ecosystem monitoring of important pollutants and indicator species or habitats)	Document compliance with standards or criteria and establish a rapid feedback mechanism to contractors/operators to take corrective action and eliminate impacts, when warranted	All development that will generate pollutants that can impact ecosystems if not carefully monitored	Construction and/or operational phases	Sensitive or vulnerable ecosystems adjacent to development
Emergency action plans (for control or containment of accidental fires and spills during emergencies)	To prevent the spread of fire or pollutant spills that can cause catastrophic ecological damage	Development that runs the serious risk of fire, fuel spills, or other accidental hazards	During construction and/or operational phases	Ecosystems vulnerable to spills or fires
Post construction/operational environmental surveys (specific study methods are variable)	Refine the accuracy of future impact assessments conducted before development, identify unforeseen impacts, and assess magnitude of ecological damages for compensation/restoration	All major development likely to cause significant and uncertain ecological impacts	After construction and/or operational phase	Significant ecosystems affected by the development

[*] These studies are also valuable for comprehensive regional initiatives (coastal resource planning and management).

Table III.1. (Continued)

Type and Description of Technique	Study Objective and Purpose	Applicable Types of Development	Phase of Development	Applicable Ecosystem
Habitat restoration and enhancement analyses (a combination of scientific and engineering measures to facilitate reestablishment of valuable habitats)	Develop feasible and implementable programs to enhance ecosystem values or to compensate for the loss of ecological resources from development	Development projects that result in significant ecological losses	After construction and/or operational phase	Ecosystems affected by development and/or that can be enhanced or restored with human assistance
Time series surveys (quantitative ecological surveys before, during, and after proposed development at fixed stations both close to and removed from project site)	Quantitatively document the significant and geographic extent of development impacts in order to apply to future development of same type or to establish criteria for compensating for ecological losses	All types of major development that is likely to cause major ecological impacts or where there is uncertainty regarding the nature and significance of impacts	Beginning after project plan is selected and continuing beyond construction and operational phases	All ecosystems likely to suffer major impacts
Toxicity studies (bioassays, biaccumulation or tissue analyses, microcosm, controlled field impact/spill studies)	To assign effluent standards or criteria to control pollution or to prescribe treatment or dilution of pollutants to bring them into compliance with standards or criteria	All development that generates pollutants or effluents that can adversely affect ecosystems	After selection of project site and during advanced engineering and design phase	Ecosystems vulnerable to pollutants and effluents
Pollution abatement plans (a combination of engineering and scientific measures to control soil erosion, sedimentation, accidental spills, urban runoff, wastewater effluents, contamination and other pollutants)	Avoid, reduce, treat, dilute, or confine the generation of significant pollutants	All development that can lead to the generation of significant pollutants	Advanced engineering and initial construction state	Ecosystems vulnerable to the pollutants

Source: Maragos et al. (1983).

Like the physical impacts of a project, the social impacts are complex and intertwined. But, because human behavior is not governed by simple laws of cause and effect, social impacts are often more difficult to predict. For this reason, scoping--setting the limits of the information needed for an EIA--is particularly important when assessing social impacts. However, the difficulty in measuring social impacts makes them no less important. Fortunately, many disciplines can shed light on the social impacts of development processes.

The long-term economic viability of a project is one of the most essential contributions of social science to EIA and will be treated in Section III.E. Cultural acceptability and social equity are also essential components of project planning and hence of EIA. For instance, will the requirements of loan security for a land settlement scheme conflict with sharing? Will women carry out the sowing and harvesting of cash crops while their men collect the payments? Questions of this sort are subject to analysis by a variety of social science techniques.

Some social sciences, such as demography and sociology, depend on official records, censuses, and surveys for information. A census, a comprehensive collection of data about a country's population, obtains factual information from people about their ages, family relationships, residence, work, income, and land to assist policymakers in social and economic planning. This information could be used, for example, to help determine how many people would be displaced by a hydroelectric project, or whether the work force needed for a new factory is locally available. These data can also be manipulated, using the statistical and modeling techniques described here to predict the answers to more complicated questions.

In social science as in natural science, models seek to simplify complex realities so that relationships between different factors can be seen. The danger of models is that they will oversimplify human actions to conform with preconceived assumptions or patterns. If these pitfalls can be avoided, models can be extremely useful tools for understanding the social impacts of the changes brought on by development. Careful scoping can help identify the best indicators of social change. Factors such as crime, unemployment, or family dissolution might be analyzed using statistics on arrest rates, joblessness and underemployment, or the number of households headed by a single parent. Identifying trends is not an end in itself. Rather, they must be clearly linked to the development project, not to changes already occurring or caused by other factors.

Surveys or questionnaires may also be used to discover people's attitudes toward a particular project or kind of development. Not only does this technique enable policymakers to take these attitudes into account in their project planning, but it also gives people a sense of participation in the project. This combination is essential if the project is to be successfully integrated into the life of the community. People may choose to speak through their leaders or as individuals. Where large numbers of people are affected, necessity usually dictates obtaining information from a representative sample of the people reflecting the economic, social, and cultural diversity of the population.

Public participation may occur in other ways as well. Expert opinions from the community may be solicited. Often, as noted earlier, local people have detailed knowledge of their natural surroundings born from centuries of living within the limited resources of island environments. Outsiders with relevant expertise may also provide useful contributions. Many countries have instituted set periods for public comments during different phases of the project's evaluation. These comments can then be assessed and integrated into the next stage of project planning.

Often, surveys and similar techniques are inappropriate or inadequate for predicting the impact of a project on a community. Local people may lack the level of education or exposure to external influences to respond adequately or accurately to written or formal questions. Then, different approaches such as observation, reliance on written records, and informal personal interviews must be used.

Such a combination of techniques is often used in anthropology and sociology, the studies of human culture and society. These disciplines provide means of understanding a society's values--social integration, religion, relations of respect or familiarity, taboos--essential for minimizing undesirable social disruptions. A large luxury beach hotel, for example, could have unacceptable social impacts on an isolated, traditional community. An aquaculture scheme to culture tilapia for local consumption would be doomed to failure if the fish was not suited to local tastes.

A <u>historical perspective</u> provides a unique opportunity to circumvent one of the key constraints to EIAs--the difficulty of accurately predicting impacts. By studying the past uses of land and resources, policymakers can learn from experience to avoid making the same mistake twice. Historians may use written records (such as agricultural deeds or censuses, trading records, and agricultural or marine production data) or oral history, capturing knowledge of events and practices from preliterate times. In January 1989, for example, the Fiji Department of Fisheries banned exports of bêche-de-mer, fearing the species would become commercially extinct. Harvest levels were approaching those that caused the collapse of the fishery--Fiji's first commercial marine species--in the 1850s. Exports were temporarily halted to allow recovery of the species.

History reveals more than cases of mismanagement. It can also provide useful background on the past uses of an area, traditional management practices, and ways in which potential problems have been successfully circumvented in the past.

Once the predicted social and economic impacts of various alternatives have been identified, they must be analyzed and weighed, similar to physical impacts. Checklists of potential impacts are commonly used to compile these predictions for analysis. Once they have been compiled, drawing matrices of the impacts of various alternatives is one way of visual comparison. Interactions between different impacts may be illustrated through flow diagrams. Furthermore, the links between predicted physical and social impacts must be drawn.

Interpreting the mass of social and scientific data to select the best alternative requires a return to the broader social and economic context in which the project was conceived. The selected alternative must not merely be better than the others but must meet the objectives of the project, coming full circle back to the evaluation's initial stages.

2. Human Ecology in the Pre-Commercial Pacific: An Application of Social Science Methods

(prepared by William Clarke)

a. EIA in Retrospect. Two contrasting points need to be made in looking back at the relations between Pacific peoples and their environments during pre-European times or among pre-commercial people in the modern Pacific.

First, those Pacific peoples--living as they did (or in some cases as they still live) immediately dependent on land, forests, reefs, and seas around them--possessed intimate and exact knowledge of the uses, locations, and habits of an immense variety of plants and animals (terrestrial and marine) and of the potential of their lands for diverse kinds of agricultural production. Based on their knowledge, they worked out many effective forms of subsistence production that possessed the quality of sustainability, now so much sought after.

Second, those same people--like all people--were always in dynamic interaction with their environments. Some of their actions were destructive in ways that would today arouse great concern in an EIA. That is, they "impacted" their environments and then had to adjust to the environmental degradation or resource depletion that their own actions had initiated. No time can be found in the history of Pacific peoples before which people were perfect conservationists living in a steady-state of harmony with their environments. Early Pacific Islanders or present-day noncommercial Pacific peoples shared or share the universal human trait of altering environments, often destructively, and then seeking to redress the disadvantages brought by the change. Thus, though the modern world has much to learn from the traditional resource manager, we need not romanticize the past as a conservationist's Garden of Eden from which only the modern commercial-industrial world has strayed. Present-day technologies and population pressure do, of course, increase the magnitude of changes in the environment from development.

b. Ethnoscience and Traditional Resource Management. Much has been written on the knowledge that pre-commercial Pacific peoples had of their environment and resources and of their traditional techniques of utilization and management. Such accounts began in the writings of the first European explorers and scientists and continue to this day in the studies of anthropologists, geographers, biologists, and other scientists. All these records show how well the pre-modern inhabitants of the Pacific knew the plant and animal life with which they shared the islands (e.g., islanders used an immense diversity of tree species for scores of different purposes) (Thaman and Clarke 1987). Or, turning to marine life, Johannes's book (1981) illustrates the "encyclopedic reservoir of practical sea lore" possessed by traditional fishermen in the Pacific. As Johannes (1984:258) has written of traditional fishermen in a later paper:

> Studying their knowledge during the past few years has provided a host of valuable insights into the nature of shallow-water tropical marine resources. Information gained in this way is often superior in important respects to information gained by conventional resource surveys performed by imported consultants constrained by insufficient time and money.

Perhaps the best general summary of traditional resource management in the Pacific is the chapter on "Oceania" by Klee (1980). In that chapter, geographer Klee refers to many of the written sources on traditional resource management in the Pacific and describes many of the deliberate or inadvertent conservation practices carried out traditionally in the Pacific. For instance, he describes the unique pit-excavation cultivation of babai (Cyrtosperma chamissonis) that Pacific islanders developed in order to make use of the harsh agricultural environment on atoll islets, where surface fresh water and fertile soils are both absent (Figure III.1). Widely scattered in the Pacific, this system is not only an efficient use of limited water resources but also creates a soil capable of producing sustained yields of a staple crop by using only local and natural fertilizers.

Klee also notes the breakdown now occurring in traditional, time-honored ways of conservation management and urges that the reservoir of useful traditional knowledge be preserved.

c. Environmental Problems in the Traditional Pacific. In evolving the knowledge and techniques that made conservationist management possible, the Pacific islanders also took false steps that severely affected their environments, sometimes irretrievably, as in animal extinctions. Evidence for and descriptions of such problems are reviewed in papers by Clarke (1986, 1988) and can only be briefly sketched here.

There are now several islands in the Pacific where work by prehistorians and other scientists has revealed a pattern of profound landscape change, beginning shortly after the arrival of the first inhabitants and long before any modern attempts at commercial development. For instance, in the eastern South Pacific on remote Easter Island, severe deforestation over the past 1,000 years could have led to the decline of the Polynesian culture responsible for the sculpting and erection of the island's famous giant stone figures. For Samoa, there is evidence of extensive interference with mid-elevation forests (300 to 600 m) over a long period. On Tikopia in the Solomon Islands and on Aneityum (or Anatom) in Vanuatu, there is evidence that during early settlement (1000 to 3000 years B.P.), severe human-induced soil erosion and vegetation impoverishment occurred on the slopes, presumably because of forest clearing and burning for agriculture. In Micronesia, on Yap and Palau, large areas of native rainforest replaced by "devastated grasslands" is seen as the result of agricultural activities. In Fiji, written accounts from the nineteenth century describe the "brown, barren land" on the drier sides of Viti Levu and Vanua Levu. It is widely argued that this

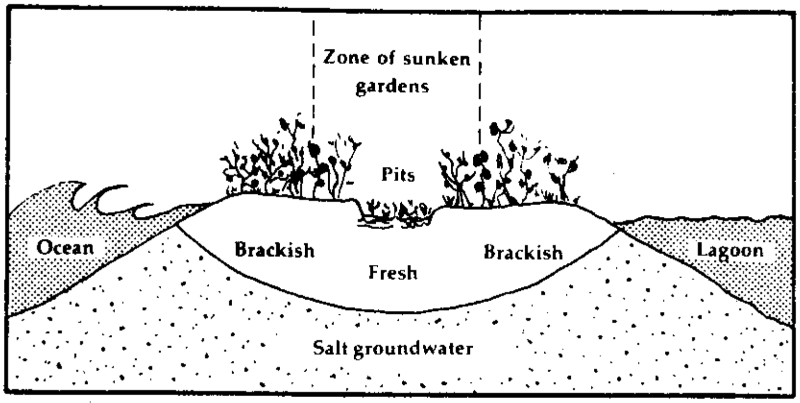

Figure III.1. Cross-section of an atoll islet with pit cultivation of babai. The pit allows the plants access to the freshwater lens near the center of the islet. The bottomless baskets placed around the plants are filled with miscellaneous organic matter, which acts as natural fertilizers and soil conditioners and sustains yields permanently. (Adapted from Klee 1980. Reprinted by permission of the publisher.)

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degraded vegetation complex (talasiga in Fijian) of fern, Casuarina, and Pandanus is the result of long human interference, particularly by burning, which has led to the destruction of natural woodland or forest and its replacement by talasiga, where the eroded soils are now so degraded that agriculture is scarcely possible. A similar story is described in one of the SPREP case studies for Wallis and Futuna, where the degraded areas are known as toafa (Dupon 1986).

Island faunas were affected too. Oceanic islands are noted for their endemic animal species. The extinction of the moa, a giant flightless bird, most probably at the hands of the first Polynesians to enter New Zealand, is the best known of the early extirpations. However, recent research indicates that much more is to be learned about prehistoric human impacts on biota. For instance, on Tikopia in the Solomon Islands, early settlers exterminated a megapode (another type of large flightless bird), greatly reduced the numbers of turtles, and diminished the size and quantity of shellfish (Kirch and Yen 1982).

Extinctions are forever; but degraded land can be rehabilitated or stable agricultural systems can be developed following a period of catastrophes. Following the severe slope erosion already described, stable farming systems, often based on irrigated taro, were developed by Pacific islanders on the lowland, alluvial soils created by the slope erosion. Even some of the degraded slope lands after the erosion were made productive by the heavy labor inputs required for terracing or by arboriculture--or in modern times by the plantations of exotic pines.

d. Learning from the Past. To return wholly to past ways of production is not a feasible solution to today's environmental problems, and as has been argued in this section, the past was not always a happy place for conservationists in any case. But it can be argued that certain traditional management approaches could be advantageously applied today, perhaps in combination with modern scientific knowledge. Klee (1980:276) stresses the value of the deep knowledge of marine life possessed by traditionally trained "master fishermen" and suggests that they could work together with Western-trained conservation officers: "ideally, both learning from each other." He also suggests (Klee 1980:274) with regard to agriculture that:

> Almost all traditional soil and water conservation techniques that have been identified (e.g., terracing, mulching, rotating fields, and so on) could be likely revived without much difficulty. The practice of using [natural] fertilizers to enrich the soil might be revived as well as modified slightly to make it more productive. For instance, after an analysis of the ingredients of a particular fertilizer, modern soil scientists along with tropical botanists might be able to improve on the original mixture by only slightly modifying its contents with other existing local vegetation. The whole idea would be to take an existing culturally acceptable practice and modify it only slightly to make it more productive or efficient, thus hopefully avoiding any disruptive side effects.

This sort of "progressing with the past" seems feasible in the Pacific where much traditional knowledge of resources remains (though it is disappearing fast), where rural peoples are not generally so pressed against the edge of survival that they cannot risk innovation, and where small islands as well as small-scale tenure systems encourage or make possible experimentation on a less than agroindustrial scale. At the very least, traditional patterns of management should be available for consideration for possible use in the mitigation/ameliorative measures brought forward in EIA.

3. Archaeological Surveys and Cultural Resource Management

(prepared by Philip J. Hughes)

a. Background. The Pacific region has a history of human settlement extending back at least 2,000 years in most areas and to more than 30,000 years in Melanesia. The physical traces left by these past inhabitants are known as archaeological sites. These may be prehistoric if they date to periods beyond the memory of local communities, or historic if knowledge of them is retained in the oral or written records of society. Prehistoric societies left no written records, and consequently it is through information obtained from archaeological sites that still survive that local and regional prehistories must be constructed.

Archaeological sites are the sole remaining physical manifestation of the diverse prehistory of the Pacific region, and as such constitute a regionally and often internationally important cultural resource. Such sites are, however, a non-renewable resource, and already large numbers of sites in the Pacific region have disappeared or have been damaged by natural causes or by human impacts, especially construction activities.

b. Types of Site

- Occupation Sites. These comprise mainly surface scatters of stone artifacts with or without pottery and food remains such as burnt bone and shell. Excavation may also reveal structures such as house support posts and postholes, stone or earth walls, and hearths. Some such sites may result from short periods of occupation by a very small number of people, such as a hunting camp, whereas others may result from long periods of occupation by large numbers of people, such as a village site. Some occupation sites contain stratified deposits of archaeological remains, either in the open or in rock shelters and caves.

- Rock Art Sites. Paintings and engravings occur widely throughout the Pacific region. Paintings are usually found on the walls of rock shelters and caves where they are protected from the weather. Engravings also occur in such locations, but they can also be found on exposed boulders and rock outcrops.

- Agricultural Sites. Agricultural systems involving drainage or irrigation commonly left archaeological traces in the form of terraces, stone and earth walls, and ditches (usually infilled with sediment).

- Burial Sites. Before the influence of Christianity, there were many different ways of disposing of the dead besides burial in the ground, and many of these have left distinct archaeological traces. Some of these traditional methods are still used today.

- Sites of Traditional Significance. Some archaeological sites of the types described here may have traditional as well as archaeological importance. There are also other sites, mainly natural features in the landscape, which are associated with origin stories, myths, or particular cultural practices. These sites need not necessarily have any archaeological manifestation.

c. Survey Techniques. The likelihood of archaeological sites being detected is dependent on factors such as:

- surface visibility, which is determined by the nature and extent of the ground cover of grasses and shrubs, and of organic litter such as leaves, bark, or twigs;
- burial of the original land surface on which the site occurred by, for example, slope wash material, flood alluvium, or windblown sand;
- exposure of the original land surface by erosion or by human activities; and
- site obtrusiveness--some sites, such as visually spectacular paintings on a rock shelter wall, are easier to detect than others, such as sparse surface scatters of stone artifacts and pottery, especially in well-vegetated terrain.

Archaeological sites are normally located by survey techniques that can range from a cursory inspection of the project area to an intensive, systematic survey of the area. Some types of visually prominent site (e.g., agricultural terraces) can be located using air photo interpretation techniques. Sites that are now buried can only be detected by excavation techniques. These can range from probing the deposit with a steel rod or soil augers, through the excavation of test pits (each normally about 1 m^2) into the deposit, to full-scale excavations covering large areas.

d. Assessment of Significance. In discussing the significance of individual archaeological sites and suites of sites, it is important to realize that there are several, often interrelated, ways of viewing significance.

Significance to the local community
Significance to the wider public
Educational significance
Scientific (or archaeological) significance

The various interest groups will normally have different views about how significant a particular site might be. Surface scatters of prehistoric stone artifacts and pottery containing examples of rare types of artifact may be of considerable scientific importance, but because they are not visually spectacular they are unlikely to be considered important by educators and the wider public, nor are they likely to have traditional significance for the community on whose land they occur. Some sites have sacred or religious importance (such as a cemetery or sacred reef) or depict the location of an important historical event, such as a major battleground or site of first colonization of an island by a group of settlers. On the other hand, a spectacular display of red ochre hand stencils in a rock shelter close to a tourist resort and community school may be of considerable interest to the wider public (especially tourists) and educators, as it can be used to illustrate aspects of the local culture. If the stencils were made recently by individuals known to the local community, the site is likely to be of significance to that community also. If they are prehistoric, the site is likely to be less significant to the local community. Hand stencils normally have little scientific value and are therefore likely to be of little scientific significance. Hence all of these different viewpoints need to be taken into account in devising a cultural resource management strategy.

Two kinds of framework are most suitable for assessing scientific significance (Bowdler 1983). The first of these involves assessing the research potential of a site or suite of sites, and the second involves assessing the representativeness of these sites. One aim of any heritage conservation program should be to conserve for future research representative samples from different environments of all classes of archaeological sites. Such a strategy would also ensure the conservation of a wide range of sites that have important values to other groups besides archaeologists.

e. Management Strategies. When archaeological sites are identified in an area of proposed development, and where they might be affected by development, several options are possible. These might be summarized as destruction, destruction with mitigation, or preservation. Preservation is often made possible by modifying the development slightly. If damage or destruction is inevitable and the site is deemed to be of value but not to be worthy of protection at any cost, some form of mitigation of its destruction may be warranted. This might take the form of a detailed recordation of the site, collection of artifacts exposed on the ground surface, or excavation of structures or stratified archaeological deposits. If the site is deemed "insignificant," it may simply be destroyed without further action.

Detailed archaeological surveys can be expensive, particularly if large areas, excavation, radio-isotope data, pollen analysis, midden analysis, osteological analysis, etc., are involved. If cost is a major concern, archaeological surveys can be phased over time beginning with relatively inexpensive reconnaissance level surveys with limited subsurface testing. Such surveys can identify areas both likely to include or exclude significant archaeological resources. After such a survey is accomplished, decisions can be made early during the planning process to move or redesign projects to avoid potential significant adverse effects. In the process more expensive archaeological surveys may no longer be needed in the same areas.

III.C. QUANTITATIVE EVALUATION PROCEDURES: STATISTICALLY RELIABLE MONITORING

This section is adapted from two 1987 East-West Environment and Policy Institute publications: Cost-Effective Data Acquisition by Brian W. Mar, Wayne S. Mitter, Richard N. Palmer, and Richard A. Carpenter; and Applying Ecology to Land Management in Southeast Asia by David E. Harper, Daniel B. Botkin, Richard A. Carpenter, and Brian W. Mar.

Two common types of information used in environmental management are (1) baseline information that estimates existing conditions or abundance of resources and (2) monitoring information that estimates that changes, if any, have occurred. In baseline information, a common measure of worth of that information is the probability that monitored (estimated) values of a parameter are within a given percentage of that parameter's true value. This is dependent on the number of observations and the variability of the observations.

In monitoring information that examines change, there are two measures for evaluating the worth of that information: Type I and Type II errors. A Type I error is to conclude that a change has occurred when nothing has changed, while a Type II error is to conclude that nothing has changed when change has in fact occurred. A Type I error results in considering, or taking, corrective action when none is needed; an error in favor of the environment, but costly. A Type II error leads to failure to act when corrective action may be needed. Type II errors may lead to serious environmental degradation or loss of a resource and its associated value. It is important to know the probabilities of making both types of errors.

TYPES OF ERRORS IN HYPOTHESES TESTING

TRUE STATE OF NATURE	MONITORING CONCLUSION	
	No change	Change
No change	CORRECT	TYPE I ERROR
Change	TYPE II ERROR	CORRECT

Most monitoring programs, however, exclude minimization of Type II errors as part of their design.

Any quantitative information used in environmental impact assessment should be evaluated in three steps. First, the error bounds (or goodness-of-fit criteria) should be established, indicating what tolerances are acceptable. Next, the probabilities that the measured values will meet these bounds or criteria need to be estimated. Finally, the risk to management associated with using information of this quality needs to be recognized. Managers typically are satisfied to avoid Type I errors 90 to 95 percent of the time (i.e., a 5 to 10 percent probability of error). They often ignore the probability of Type II errors.

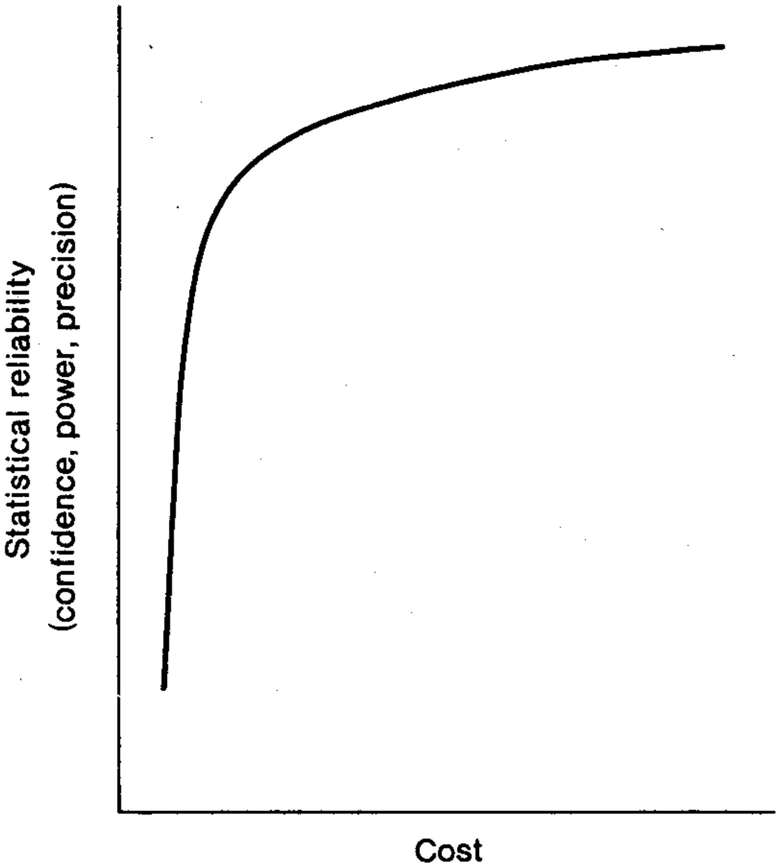

Figure III.2. Relationship of statistical reliability to cost (Source: Mar et al. 1987:5).

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1. How Much Will Better Information Cost?

Information is costly, and more data do not necessarily result in better information. Figure III.2 illustrates a typical relationship between the cost of more data and the probability that estimates from that data meet the stated reliability criteria. The relationship is far from linear and displays the characteristic "knee" or deflection point where an increase in statistical reliability becomes small compared to the added cost. As long as more data are obtained on the steep part of this curve, the improvement (in information or in the probability that the estimate is correct) is great relative to the cost. To the right of the "knee" or deflection point, the improvement in quality of information is much lower for each unit of cost. Since information is costly, a manager must be informed of these cost curves if trade-offs are to be made between the added investment in collecting more data and the reduction of risk associated with decisions based on these added data.

a. Cost Effectiveness. Cost-effective environmental baseline surveys and monitoring are characterized by the following elements:

- Cooperative definition (by the manager with the assessor-scientist-statistician) of the actual management problem, specific objectives, decisions to be made, magnitude of change considered significant, and required reliability. Information that may be needed for assessment includes (1) baseline conditions, (2) inventories, (3) discovery of cause/effect relationships, (4) detection of violation of standards, (5) evaluation of consequences of management action, or (6) monitoring during operations.

- Generation of alternative monitoring program designs for acquiring better information, including merely continuing the existing programs.
- Detailed examination of promising alternatives in an iterative interchange among the manager, monitor, and statistician. Each alternative design (for a program of data collection, analysis, and presentation) is screened and assessed as to feasibility, time and space constraints, understanding of biophysical relationships, and various associated costs. The most promising designs are optimized, using refined estimates of costs and quality of output information.

This procedure can quickly rank monitoring program design alternatives and, most important, can indicate when a design is far off the optimum "knee" of cost effectiveness.

Figure III.3 shows how monitoring is related to management objectives. In collaboration with the resource manager, the designer lists all reasonable alternatives for acquiring the data.

Objectives, indicators, parameters, and methods should be defined. Objectives here are those that have been discussed by the resource manager and the monitor-scientist. Specific indicators or groups of indicators are chosen that can best lead to conclusions as to whether objectives of a sampling or monitoring program are being met. The indicators may be independent or may be functionally related. The relationship between indicators should be described as fully as possible. Parameters must be quantifiable measures that efficiently describe their respective indicators. Relationships between parallel (interdependent) parameters must be established, and their degree of correlation calculated.

Criteria used to choose monitoring methods include probable economic feasibility, availability of equipment and trained personnel, credibility or public and political acceptance, and time constraints (see Mar et al. 1987).

There are separate goals for quantitative baseline surveys and monitoring. One goal for the first type of sampling program is to establish the mean value of a parameter with statistical reliability. Other goals include qualitative assessment leading to early decisions to relocate or redesign projects to avoid significant adverse effects. Such avoidance may eliminate the need for many quantitative data gathering and monitoring programs. When needed, the goal for a quantitative monitoring program is to detect, with statistical

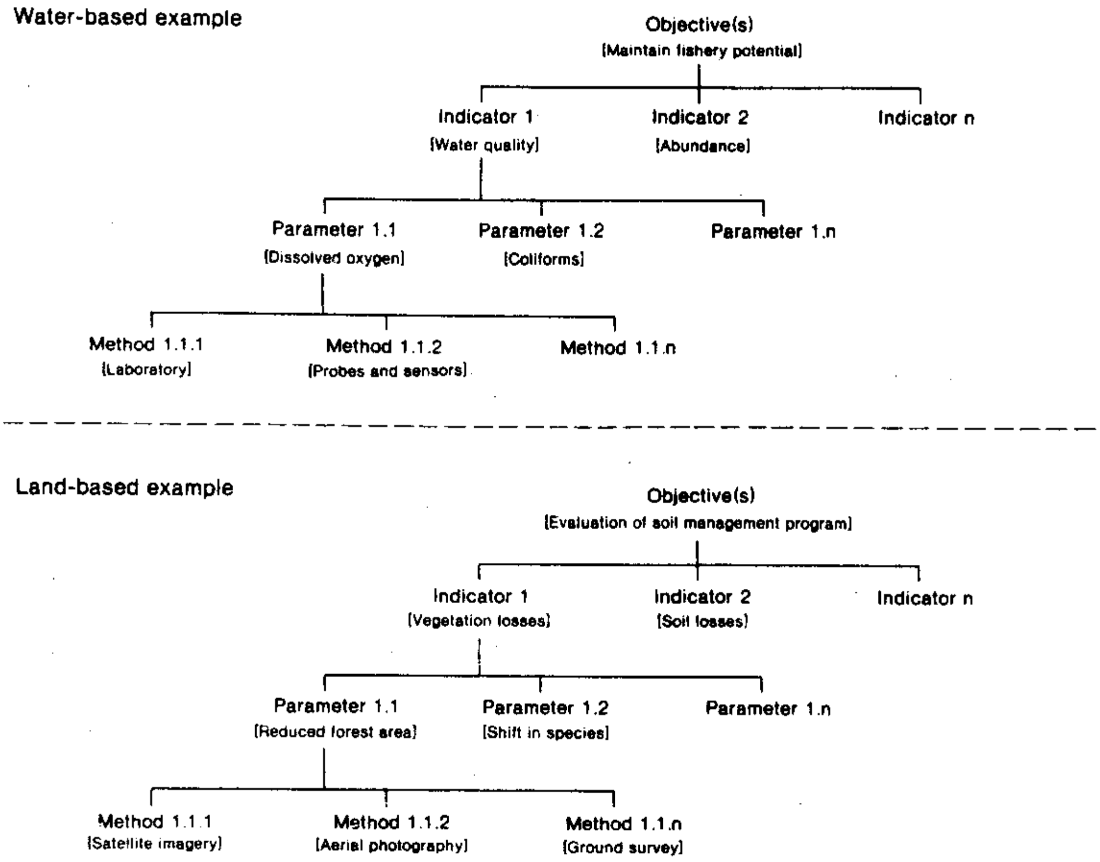

Figure III.3. Hierarchies of data acquisition concepts (design tree) (<u>Source</u>: Mar et al. 1987:11).

reliability, whether a significant environmental change has occurred before and after an act of intervention.

The separate goals for baseline surveys and monitoring can best be illustrated with an example: Low levels of dissolved oxygen (DO) in a reservoir are a suspected cause of fish kills, and it is felt that mechanical aeration in one sector of the reservoir can bring the DO up to satisfactory levels. In a proposed sampling program, DO concentrations will be the measured parameter.

The goal of a baseline survey is to determine, at minimum cost, a mean value of DO (i.e., a sample mean), which represents the mean reservoir DO with a specified degree of statistical reliability. The goal of a subsequent monitoring program, after mechanical aeration in a sector of the lake, is to determine, through sampling "before" and "after," at minimum cost and with a specified degree of statistical reliability, whether change has occurred in the reservoir with respect to DO and, if so, how much.

b. <u>Basic Statistical Concepts.</u> A simple statistical model can be used to relate the number of observations taken to the difference between the mean of the observed data set and the true mean of the population. To illustrate the use of this model, consider a baseline survey for estimating average monthly rainfall in a watershed. Usually, design of a sampling program proposes placing rain gauges throughout the watershed and observing the rainfall in each gauge monthly. An OBSERVATION is the observed rainfall in a gauge (e.g., inches of precipitation) and is represented by x_1. VARIATION is a general term characterizing the difference between each of the observations in a set of observations. If all observations are identical, there is no variation. If each observation is significantly different from the others, the variation is said to be great.

The SAMPLE MEAN ($\bar{x}$) is the average of n observations:

$$\bar{x} = \frac{x_1 + x_2 + x_3 \cdot \cdot \cdot x_n}{n}$$

The value of the real population mean (μ) is unknown unless all members of the population can be observed and correctly measured. In most cases it can only be estimated from means of sample sets.

SAMPLE VARIANCE (S^2) is defined by the expression:

$$S^2 = \frac{(x_1 - \bar{x})^2 \cdot \cdot \cdot + (x_n - \bar{x})^2}{n - 1}$$

STANDARD DEVIATION (S) for a sample set of observations is the square root of the variance for that set of observations. Standard deviation for an entire population is usually designated as Greek sigma (σ). The variance (σ^2) of a population cannot be determined unless all members of the population are known. The variance of a sample set may not approach the variance of the population unless very large numbers of observations are available.

The term TOLERANCE is introduced to indicate the difference between the real population mean and the mean computed from a set of n observations. TOLERANCE is defined as ($\mu - \bar{x}$). Sometimes tolerance is expressed in terms of a confidence interval (a bound about μ), e.g., ± 50 percent. Precision (P) of a set of observations is defined as the tolerance divided by the standard deviation of that set of observations:

$$P = \frac{\mu - \bar{x}}{S}$$

Precision is a measure of the signal-to-noise ratio for the populations being observed.

$$\frac{\text{Signal}}{\text{Noise}} = \frac{\text{delta}}{\text{sigma}} = \frac{\delta}{\sigma} = \frac{\mu_1 - \mu_2}{\sigma}$$

The number of samples required to obtain a "good" estimate of the mean and standard deviation of the variable of interest can be calculated. If the standard deviation is zero, only one sample is required to estimate the mean. As standard deviation increases, a greater number of samples are required to provide the same level of confidence for an estimated mean.

Few baseline surveys can afford as many observations as needed at a given station to obtain accurate estimates of means and standard deviations for use in designing sampling programs. Therefore, prior knowledge or experience must often be used to estimate the standard deviation of the population or variable of interest. Approximations of standard deviation provide adequate information for most sampling program designs. Furthermore, it is often (but not always) more cost effective to use literature values or expert judgment for estimating means and standard deviations than to measure these values in field predesign efforts. The money spent in predesign sampling can be better allocated to sample collection for the actual baseline survey or monitoring program.

Figure III.4 provides a basis for discussion of statistical concepts in a baseline survey. Here α represents the probability that $\bar{x}$ is within a specified bound of μ (e.g, within two standard deviations of μ). Also α represents significance level, and $1-\alpha$ represents confidence level.

If a sample of the population in Figure III.4 were taken, and if the sample mean $\bar{x}$ were observed, a question arises: What is the probability that $\bar{x}$ will be within a tolerance range of μ, when a sample of $\underline{n}$ observations is drawn from the population? If the tolerance is specified in terms of a bound about μ (the population mean), then for a normally distributed population, the probability that $\bar{x}$ falls within a specified bound (confidence interval) can be computed. For example, if the confidence interval is specified as approximately $\pm$ twice the standard deviation, the significance level can be stated as .05, and the confidence level as .95 or 95 percent.

A "t-distribution model" is used to define confidence interval for an estimate of the mean of a normal population. Given the assumption that a population of interest is normally distributed, and having calculated the mean and the standard deviation of this population of interest, the t-distribution model can be used in a trial-and-error solution to define the number of samples needed to estimate a mean at a desired significance level. Figure III.5 presents results of using this type of model to compute curves for 80, 90, and 95 percent confidence levels. The curves show the number of samples required as a function of precision. Figure III.5 is particularly useful for preliminary judgments as to the number of samples necessary to establish values of parameters of interest in a

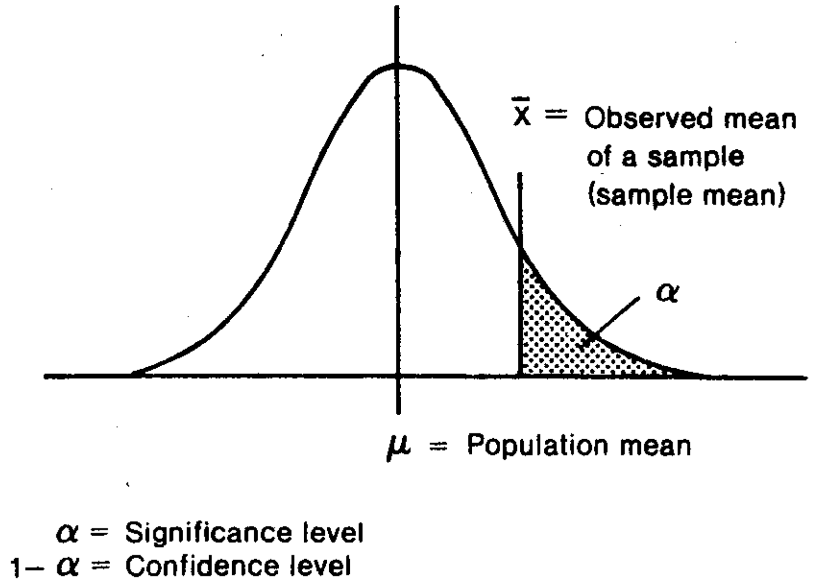

Figure III.4. Significance and confidence (Source: Mar et al. 1987:27).

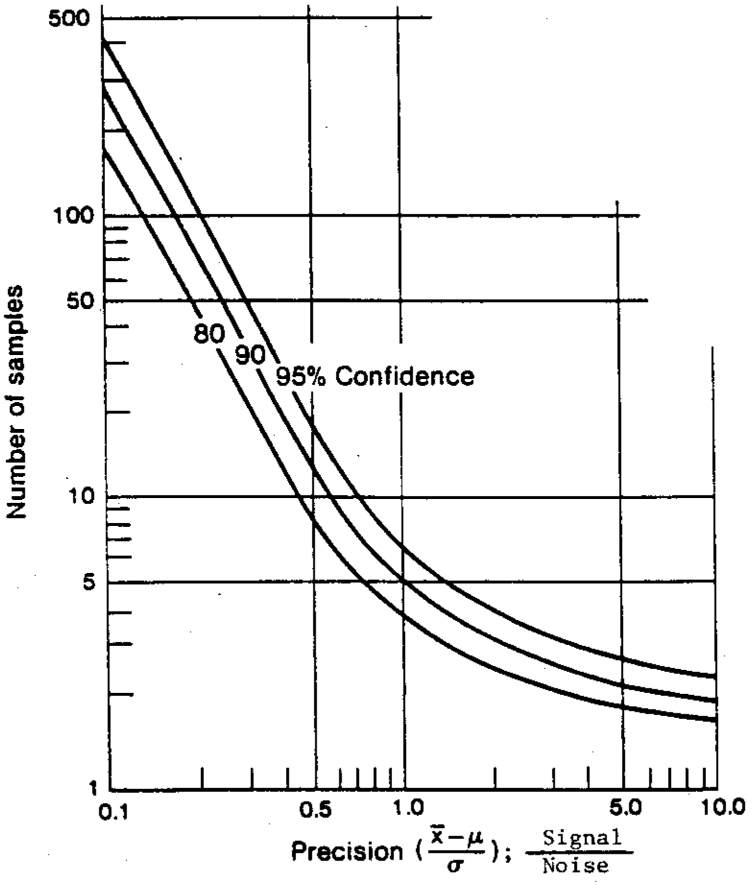

Figure III.5. Number of samples versus precision (signal-to-noise ratio) for three confidence levels (Source: Mar et al. 1987:29).

baseline survey. A value for precision appropriate for decision-making in a specific situation should be selected.

In both baseline surveys and monitoring programs, if observation costs are approximately equal for replicates taken at different times and places, the strategy for design of a sampling program should be to allocate more observations to periods or zones where the estimated natural variation and measurement errors are the largest. If there are differences in costs, then the observations with the lowest cost and highest variation should be the most frequently measured.

The precision of an estimate improves with the square root of the number of samples. Thus, increasing the number of samples does not give a linear increase in precision.

David (1985) reminds those designing monitoring programs that precision increases directly with reduction in standard deviation. Since the standard deviation of a population may be associated with the differences in characteristics between members of different subpopulations (e.g., different forest canopies, soil types, or reef zones), stratifying a large population into subpopulations that have some uniformity will yield a lower variation for each subpopulation.

Knowledge of natural variations in space and time for each parameter of interest is a key element in designing a sampling program. Qualitative surveys can often detect reasons or hypotheses for observed predictable patterns of variation. In the case of precipitation, there are usually wet periods and dry periods. With climate, there are warmer and cooler months. Most biological organisms have periods of rapid growth and periods of dormancy or slower growth. Within a watershed, specific types of soil and vegetation are not generally uniformly distributed. Within waterbodies, layering and patchiness can occur. The common practice of using monthly intervals between sample occasions should be seriously challenged. In most cases, the phenomenon of interest does not vary randomly during the year. All of the preceding situations argue against uniform sampling in space and time and for knowledge-based stratification of the population.

Another strategy used to reduce the variance of samples with time is to composite samples. An example is the measurement of storm runoff quality. If a flow-splitting device is constructed that allows the accumulation of a fixed fraction of the storm runoff, analysis of this composite sample will smooth out many of the short-term variations present in samples collected at discrete intervals in time (Clark and Mar 1980). Although less information is obtained, the information does have much less variation. Thus, the sampling program designer must consider a trade-off between a large number of samples with a large variance and a smaller number of samples with less variance.

Another source of variance is associated with experimental techniques, equipment problems, and analytical errors. Replicates of observations at the same place and time are often made to estimate this experimental error. Care must be taken that selection of replicates accounts for both analytical and collection errors. Dividing a sample into two aliquots for replication only checks analytical errors and does not reveal collection errors. Most sampling collection errors can only be observed by obtaining several samples at the same place and time. In practice, analytical errors can be reduced more easily than collection errors.

Examination of the literature describing the collection of watershed baseline or monitoring data suggests that typical measurement errors for physical and chemical parameters are within 25 percent of mean observed values, while measurement errors associated with observations of living organisms are 50 percent or more of mean observed values (Mar et al. 1985). Natural variations due to temporal or spatial factors appear to be much greater than collection or analytical errors. Typical values of natural variations range from 100 to 400 percent of observed mean values for both physical and biotic parameters.

2. Costs of Monitoring

A simple cost model for designing quantitative monitoring programs is:

$$C = C_O + (T \times C_T) + (S \times T \times C_S) + (N \times S \times T \times C_N)$$

Where

C = Total annual costs to sample a target variable

C_O = Annual overhead costs to sample

C_T = Cost to locate team on site on each occasion

C_S = Cost to move team to each station on any occasion

C_N = Cost to collect, analyze, and process data for a sample at any station

T = Number of sampling occasions each year

S = Number of stations sampled each occasion

N = Number of replicate samples taken at each station on each occasion

Under this model, costs are divided into overhead costs, trip or occasion costs, station costs, and sampling and analysis costs. The total number of samples collected during a year or any other design period is the product of the number of trips made to the watershed (T), the number of stations visited on each trip (S), and the number of replicates taken at each station (N). Increasing the number of trips will add NS more samples each trip. Increasing the number of stations adds TN samples per station, and increasing the number of replicates adds to the number of samples TS per replicate. Since NS does not have to equal TN, nor does NS or TN need to equal TS, and the cost of adding N, S, or T can be different, there will be trade-offs in deciding on the value of information gained by adding one station, one trip, or one replicate to the program design versus the added cost.

a. Definitions. The cost of a replicate is the easiest cost to define. It is the cost to collect and analyze one more sample, assuming that you are at the station. Even for this cost, there can be wide variation in the reported cost due to the various methods used to account for the cost of capital equipment used in the collection and analysis of a sample. For example, if the sample is an aerial photograph, the cost of the camera may or may not be included in the sampling costs. If the sample requires chemical analysis, is laboratory instrumentation included in the replicate cost? It is not possible to adjust reported replicate costs for the many different accounting schemes that are used to allocate capital costs, but the general guideline for replicate cost is that it should reflect the costs the collector faces, once on station, to perform the collection and analysis of the sample. A crude approximation of this cost, if real cost data are unavailable, would be the cost for an independent laboratory to perform these services.

Station costs are site-specific since they reflect the cost to move from station to station on a given occasion. Station costs are a function of the distance between stations, the time to travel this distance, the mode of transportation used, and the size of crew needed to perform the sampling. The cost for use of a vehicle, boat, or plane varies with accounting practices. In some cases there is no charge, and in others full cost recovery must be paid. Labor costs vary from country to country and may not be included in some estimates. If labor costs are included in station costs, they must also be included in the other cost terms. One of the major accounting issues is whether the cost of establishing a station is to be included as a station cost or an overhead cost.

The trip (occasion) cost is difficult to estimate since it represents the cost to assemble the sampling crew in the field but not to travel to the stations or to collect any samples. Occasion cost is incurred even if trips out to a sampling station are aborted. Accounting practices again will control reported values. However, costs such as travel from the office to the watershed, lodging costs, and labor costs associated with the base operations at the watershed are included in this term. Like station cost, this cost term is also site-specific.

The overhead cost term accounts for all other sampling program costs not allocated to the other terms. Capital costs can be allocated to this term rather than to others. Suggested practice is to allocate equipment capital costs to each of the other terms if the equipment either is purchased solely for this program or will not be used for other programs. When capital equipment is used for many projects, it may be rented to this project and these costs allocated to the other cost terms. Since the overhead cost term is a constant, allocating major cost items to the overhead term will make the trade-offs less sensitive to the variable cost terms.

b. Typical Parameters to Sample. Watershed management usually requires the collection of (1) data to classify land capability; (2) inventories of natural resources such as vegetation and wildlife; (3) census data on human populations and economic activities; (4) hydrologic data on rainfall, runoff, stream flow, and detention times in lakes and impoundments; (5) data on erosion and sediment transport rates; and (6) data on water quality, aquatic communities, and fish.

Before data acquisition cost estimates are presented for different sampling scenarios, a brief discussion of alternative methods for watershed survey and monitoring is presented here.

- Land Use and Related Data. Aerial and other remote sensing methods constitute a significant breakthrough in land-related observations. A single photograph or image can record land use, surface water, vegetation, slope, and soil characteristics of very large regions. The higher the resolution used in the observation, the greater can be the detail recorded for any area. Trade-offs in this type of data collection involve the size of area contained in each image, the number of spectral channels that are recorded, and the use of photographic film versus the use of electronic images. The larger the number of images needed for a given area, the higher the replicate costs (more images to collect and interpret) and the greater the number of passes that will be required to collect these images.

Aerial photography and other forms of remote sensing are used to define vegetation patterns, wildlife populations, erosion patterns, and even algal blooms in lakes and reservoirs. Costs for these observations are similar to the other land-related parameters and will be much lower per unit of land than on-site sampling.

Remote sensing tends to have high trip and station costs, and relatively low replicate costs. If the sensing is performed from an aircraft, the cost to fly to the site and to each station will be hundreds of dollars per hour. Occasion costs will be high since plane rental must be paid even if no pictures are obtained. Although the cost of the photo and photo interpretation is small (tens of dollars), if digital analysis of an image is required, analysis cost can approach station or occasion costs. High resolution sensors generate very large streams of data and consequent costs for interpretation.

- Hydrologic and Water Resource Data. Such data have very high station costs because weirs, gauges, and flumes must be constructed at each station. These costs are included in station costs rather than in overhead if the trade-offs are to reflect real costs and value of additional information. If extremes of flow and rainfall are of interest, recording rain and flow gauges must be installed to provide a continuous record of these events. If average values are acceptable, splitting weirs and rain buckets with much lower investment per station will suffice. Station cost for flow and rainfall measurements should include the cost to capture the sample (weirs, recording gauges, and automatic samplers). Investments of $10,000/station may be necessary to provide continuous data, while only a few dollars may be needed for rain buckets and gauges.

Assuming that a $10,000 hydrologic station may last for 5 years and that weekly observations are to be made, cost per station visit will be about $40. Station and occasion costs can be much higher than replicate costs for hydrologic data, since the cost to record precipitation/flow data is very low. With automatic samplers or large weirs, station costs can approach $100, while replicate costs are only a few dollars.

Rainfall and runoff estimates in a watershed based on observations at a single rainfall station are not precise. The trade-off between the variance of the runoff estimates and the number of rainfall stations is a common problem. If a single observation of runoff or stream flow is used to estimate weekly or monthly flows, the large variance in these types of observations leads to estimates with large error bounds that can be reduced only by the availability of more frequent observations.

- Water Quality Data. Spatial and temporal variability of water quality observations is compounded by chemical, physical, and biological reactions that magnify fluctuations in quality. The common practice of using grab samples of water from large waterbodies creates major errors in estimated concentrations of pollutants in lakes, rivers, and estuaries. One method of reducing this variation is to take many samples in either space or time and composite these into a single sample that represents an average of the overall waterbody. Compositing reduces replicate cost, since only one rather than many samples must be analyzed. An innovation to obtain a better composite sample is to use a power boat and collect samples by ramming a tube through a long transect of water. The cost to traverse a few miles of water is much less than the cost to analyze one sample of water. Moreover, major cost savings and more precise estimates of water quality result from use of such composite samples. This sampling concept can be applied to flowing waters by diverting a small fraction of flow for long periods into a collection container. This practice will reduce the number of samples to analyze, since it provides a time-integrated sample. The power boat ram provides a spatially average sample. However, information concerning spatial or temporal variation is lost when samples are composited; this variation often is of primary interest in watershed management.

As many as 30 water quality parameters may be analyzed in each sample. Typical analytical costs are:

Analyses requiring extensive digestion or wet chemistry such as BOD, COD, nutrients	$10-15/parameter
Trace metals (including preparation for analysis)	$50 for each metal

Suspended solids, volatile solids	$10-15/parameter
Coliforms	$10-15/sample
Oxygen, temperature, conductivity, pH, oxidation/reduction a probe	$1-5/sample or $100/day to rent for field use
Trace organic compounds (gas chromatography/mass spectrometer)	$2,000-3,000/sample
Suite of common analyses including most of the above except trace metals and organics	$100-150/sample

Since station costs depend on the size of the vessel needed to reach a station, these costs can vary from a few to hundreds of dollars per station. Occasion costs also include nonrefundable charter costs of a boat, vehicle, and test gear, when an occasion must be cancelled.

Water quality trade-offs depend upon the number of times each parameter must be analyzed. Although the cost to obtain a sample of water will be low, the cost to perform analyses on all possible parameters can reach several hundreds of dollars. The number of times each parameter needs to be analyzed is a critical sampling design question. Just because a sample is available, it need not be analyzed for all parameters.

c. Biological Data. Virtually all life forms are not evenly distributed in both space and time compared to water quality parameters. Fish can avoid detection devices and nets, and so present capture problems. Planktonic life forms are easy to capture and concentrate at certain depths and boundary layers but require much time and effort to identify. Benthic life forms are patchy and often show zonation patterns. Extensive sampling is required to obtain meaningful information.

Most life forms cannot be captured in a bottle like a water sample. Expensive nets, acoustical gear, poisons, and electroshock equipment all add to replicate costs. If a sampling method requires towing a large net over miles of water, replicate costs become much larger than station or occasion costs. If the samples must be collected or surveys conducted underwater by scuba diving, then data collection costs are higher. Replicate costs are also increased if large fractions of the population must be tagged, or when the captured animal must be examined for toxic chemicals or physiological defects. These same types of problems can also be encountered when estimating populations of terrestrial animals.

If the replicate sample is simply measured by number, mass, or volume, costs may be as low as $10 a sample. Station and occasion costs for ecological sampling are site-specific. Large waterbodies, remote watersheds, and natural forested areas require extensive effort to establish base camps and expensive transportation modes to reach the stations. Small rivers and local watersheds may be easily reached and present only minor costs. Archaeological sampling is often expensive since many cultural resources are embedded in subsurface soil layers, which complicate siting, density, and other sampling strategies.

d. Sampling Costs. When trade-offs are needed for sampling program design and cost estimates are not available, the approximations listed below are suggested. Local experts should be consulted to modify these estimates to reflect local conditions and costs. Absolute values of these cost factors are much less important than the ratio of these factors in the sampling design trade-off analysis.

	Occasion cost	**Station cost**	**Replicate cost**
Land use, remote sensing, aerial photos	$500	$200	$50-150
Soil identification, vegetation plots	$50	$20	$10-15
Rainfall, runoff, stream flow	$50	$50-100	$5-10
Water quality	$50	$20	$100-150 spectrum; $10-15/wet chemical; $1-5 temperature, pH, conductivity; $25 oxidation/reduction; $50/metal; $2,000 trace organics
Biological organisms	$50-500	$20-500	$10-20 biomass, weight, or volume; $50-100 identification of type and condition

3. Making Sense of Monitoring Data

Statistical analysis is now often performed by computers, using common software packages. These programs can produce a confusing array of test results and give the impression of great precision. The ease of calculation has not, however, reduced the need to understand the assumptions and limitations of statistical analysis and the proper application of results.

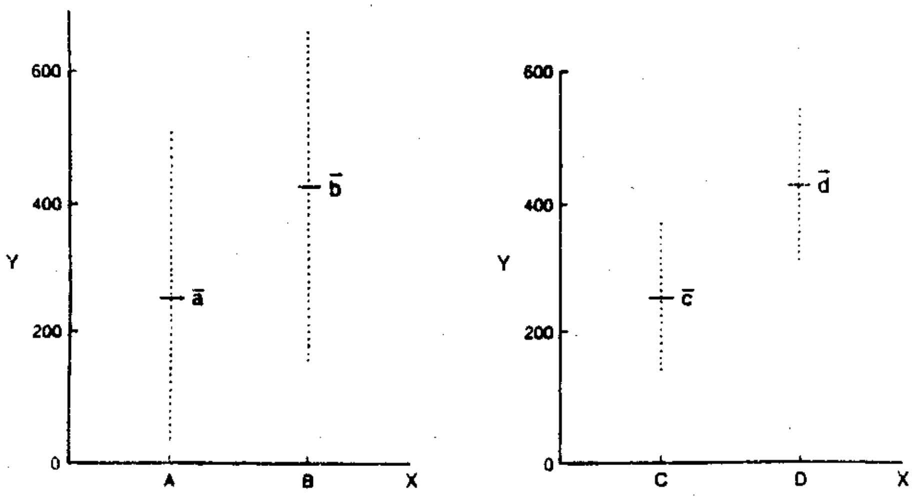

Figure III.6. Within-group and between-group variance. Assuming the same number of samples, the large variance in the populations of Groups A and B makes the difference between their means (a and b) not significant. The mean values of Groups C and D are identical to those of A and B, respectively, but the difference between c and d *is* significant because the within-group variance is small (*Source*: Harper et al. 1987:53).

This section provides a brief overview of some important data analysis techniques: analysis of variance (ANOVA), correlation, and regression.

a. *Analysis of Variance*. ANOVA compares between-group variance and within-group variance to determine if the two (or more) distributions are significantly different. Hence, ANOVA helps to distinguish whether experimental results are significant given the amount of variation in the populations and phenomena under study (Figure III.6).

The variance in monitored values can arise from natural variation or from experimental errors (including measurement and analysis errors). ANOVA aids assessors in discriminating between random and induced events. If the variance of more than two variables are to be compared simultaneously, then the researcher may use multiple analysis of variance (MANOVA). For the ANOVA or MANOVA results to be reliable, the samples must be randomly selected, the variables must be independent, and dependent variables must be normally distributed.

b. *Correlation*. A common measure of association between two variables is correlation analysis. The numerical index of the strength of correlation between two variables is the correlation coefficient or the standard deviation of measured values around the regression line. Correlation coefficients range from +1.00 to -1.00, both representing perfect correlation. A coefficient of 0 indicates a complete absence of association between variables. Figure III.7 shows these relationships graphically. Correlation analysis requires that

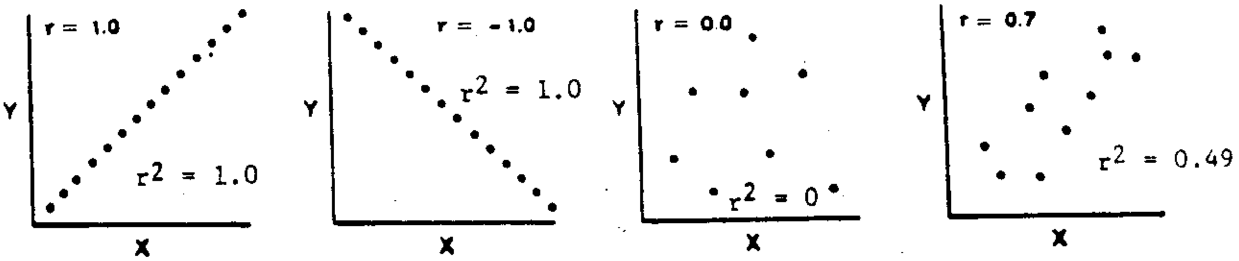

Figure III.7. Correlation coefficients (r) indicate the strength of relationship between two variables, X and Y. The square of the correlation coefficient (r^2) gives rough estimates of the proportion of total data explained by the interrelationship of the two variables and is called the coefficient of determination (see text) (Source: Harper et al. 1987:55).

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the variables under study be independent (i.e., the value of one variable has no effect on the value of the other).

c. Regression. Regression analysis attempts to describe or predict the behavior of one variable as a function of one or several other variables. Bivariate, linear, or simple regression considers two variables, and multiple regression correlates several independent variables with a dependent variable. In Figure III.8, the rainfall erosivity factor of the universal soil loss equation is the dependent variable (traditionally plotted on the Y-axis), and the average annual rainfall is the independent variable. From a plotted "scattergram" of measured data, a regression line (or line of "best fit") is fitted manually or mathematically. The regression line minimizes the squared deviations between the data points and the line. Once the relationship between X and Y has been plotted, the regression line permits estimation of unknown values of one variable from the known values of the other variable.

The regression equation describes the regression line and conveys information about the relationship between the variables under study. The equation is usually in the form of:

$$Y = aX + b + e$$

where Y = Value of the dependent variable
X = Value of the independent variable
a = Slope of the regression line
b = Intercept of the regression and the Y axis
e = The error term, or the unexplained variance

Simple regression analysis requires that the relationship between dependent and independent variables be linear. In most cases in nature, however, such relationships are not linear. The mathematical process of converting nonlinear plots to linear relationships is by data transformation. Although there are many methods of transforming data, most of them involve converting standard plots of data to logarithmic plots. The resulting log-transformed data can be subjected to regression analysis in the same way as linear data. The exponential curve of human population growth shown in Figure III.9 can be straightened by a log transformation.

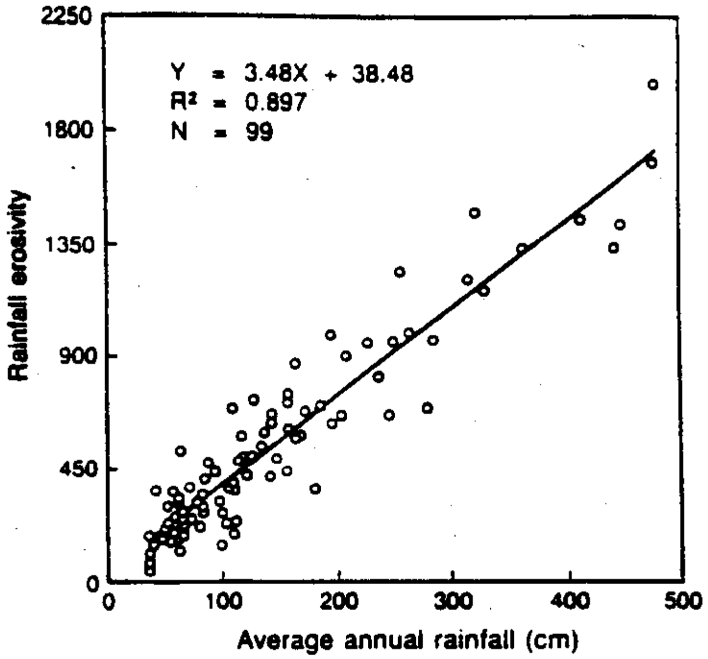

Figure III.8. Regression relationship between erosivity values and average rainfall. The regression line represents the "best fit" of the line to the data and is described by the equation Y = 3.48X + 38.48 (Source: Adapted from Lo et al. 1985:388. Reprinted with permission).

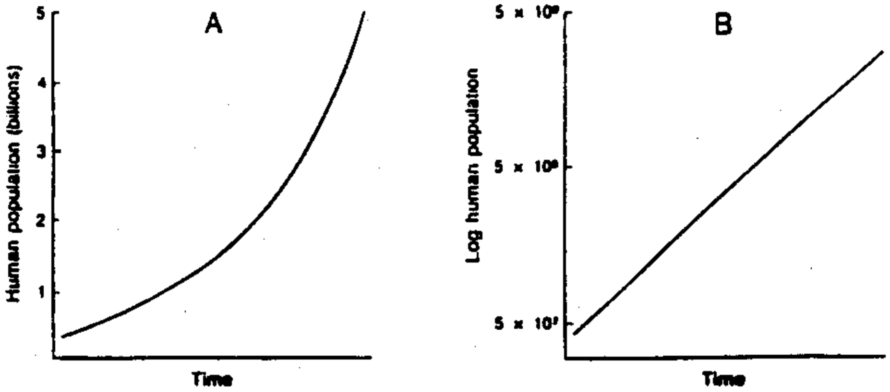

Figure III.9. Log transformation of the exponential growth curve in "A" creates a linear relationship in "B," capable of being analyzed using regression analysis (Source: Harper et al. 1987:59).

d. Spurious Correlation. Users and producers of statistical information such as regression and correlation should be wary of the so-called spurious correlation or the "post hoc fallacy." A statistical relationship established between two (or more) variables does not necessarily indicate a causal or real relationship. For example, the length of women's skirts has been correlated with stock market performance. Although the relationship may be statistically strong, skirt length is clearly an inappropriate variable to use for modeling the behavior of the stock market, and the study has no descriptive or predictive value. Good sense and a thorough understanding of the phenomena under study are necessary preconditions for using and interpreting correlation and regression. Suitability of variables is a basic criterion for evaluating statistical information.

e. Significant Figures. The accuracy of experimental results is reflected in the number of significant figures in data presentation. To report more significant figures than are justified by the accuracy of an experiment is misleading and should be scrupulously avoided. Variance is introduced into an experiment in three basic ways: natural variance (in the environment), collection variance (the difference between two samples collected at the same time and place), and analysis variance (the difference between laboratory analysis of identical samples). Controlling natural variance is the slowest and often most difficult task. The range of natural variance may be obtained by surveying the literature for relevant studies and variance estimates. Rough estimates of the variance introduced from these sources can be summarized as follows:

Source	Typical Variance %	Remedies
Natural	100-1000	More monitoring sites or occasions; stratified sampling
Collection	10-50	Repetition of sampling
Analysis	10-20	Improved lab techniques

The cumulative variance in a study should be reflected in published results. The following example indicates the effect of total experimental variance on warranted significant figures.

Total Variance (%)	Measured Value	Unit Variance	Warranted Number of Significant Figures	Proper Published Value
10	112.34	± 10	2	110
100	112.34	± 100	1	100
1000	112.34	± 1000	0	0

This example reveals that despite the comforting precision of the measured values, the amount of variance in an experiment justifies only a restricted number of significant figures for reporting the results in order not to mislead the audience.

4. Non-parametric Statistics (Distribution-Free Methods)

Use of analysis of variance and other parametric tests may be inappropriate in analyzing or comparing data sets due to non-conformance of the data to required assumptions including distributions around the mean. For example, data transformations to render a "normal" distribution of the data may not be possible, and ANOVA in this instance could not be used. As an alternative, distribution-free or non-parametric tests may be appropriate for use to analyze for significance between two or more sets of data. They are called non-parametric methods because their null hypothesis is not concerned with specific parameters (such as the mean in ANOVA) but only with the distribution of the variates (data). Non-parametric tests are popular because of the ease in computations and freedom from worry about more rigid assumptions associated with ANOVA and other parametric tests. However, ANOVA should be the preferred approach where the required assumptions hold true due to greater efficiency in detecting significant or non-significant departures from the null hypothesis.

Non-parametric tests are particularly useful in comparing the ranks or signs of two or more separate groups of data. In such instances, the data are simply assigned ranks (e.g., on a scale of 1 to 10) or signs (+, -) on the basis of their magnitude and associations. These assignments are then compared and analyzed to see if the populations sampled are actually different or not using any one or more of a number of available tests, such as the following:

Kruskal-Wallis test
Mann-Witney tests
Friedman's method for randomized blocks
Wilcoxon signed-rank test
Kendall's coefficient of rank correlation (see sample calculation, this section)
Spearman's rank correlation coefficient
Olmestead and Tukey's corner test for association

The details and computed examples of such tests can be found in many statistics books such as Sokal and Rohlf (1969) and others. The above tests have been successfully used in a number of applications over the years and require only simple computations. They offer an alternative in situations and locations where computers and local statisticians are not available for detailed assistance or guidance.

SAMPLE CALCULATION OF A NON-PARAMETRIC STATISTIC: THE KENDALL COEFFICIENT OF RANK CORRELATION (after Siegel 1956 and Kendall and Stuart 1961 in Sokal and Rohlf 1969)

I. Purpose. At ten stations surrounding an embayment subject to riverine sedimentation, data are collected on live coral coverage (percent cover) and water turbidity (nephelometric turbidity units). The Kendall coefficient of rank correlation is selected as the test to determine if there is statistically significant correlation between coral coverage and turbidity.

II. Raw Data and Rankings. The following data are collected at 10 stations (A thru J): Coral coverage (Υ_1) and turbidity (Υ_2). The values of each are then ranked as shown below from highest to lowest for coral coverage (R_1) and from lowest to highest for turbidity (R_2). The hypothesis is that turbidity negatively correlates with coral coverage.

Station	Coral Coverage (Υ_1)	Rank (R_1)	Turbidity Value (Υ_2)	Rank (R_2)
A	85	3	2.4	4
B	43	5	6.1	6
C	44	4	1.0	1
D	22	6	7.3	7
E	93	1	1.2	2
F	17	7	9.0	8
G	91	2	1.3	3
H	10	8	3.5	5
I	7	9	17	9
J	0.1	10	24	10

n = 10

III. Calculations: The first computation is to tally the sum of counts between the two sets of rankings (ΣC_i). The counts give an approximation of how well the two sets of rankings agree. There are several ways to obtain the ΣC_i value; one is simple counting as shown in the next paragraph. The computed value of ΣC_i is 39.

A. Conventional Counting Method

R_1	R_2	List subsequent ranks (of R_2) greater than pivotal rank	Counts (C_i)
1	2	3,4,6,7,8,5,9,10	8
2	3	4,6,7,8,5,9,10	7
3	4	6,7,8,5,9,10	6
4	1	6,7,8,5,9,10	6
5	6	7,8,9,10	4
6	7	8,9,10	3
7	8	9,10	2
8	5	9,10	2
9	9	10	1
10	10	-	0
		$\sum^{n} C_i = 39$	39

B. Calculation of the Quantity N, the Critical Value

$$N = 4 \sum^{n} C_i - n\,(n - 1)$$

$$N = 4(39) - 10(9)$$

$$N = 156 - 90$$

$$N = 66$$

C. Determination of Probability

To determine the probability (α) of a particular N value based on the number of samples (n), a table is consulted. One table is based on n with values of 10 or less. Another table and slightly modified procedures are used to determine probability for n greater than 10. Since, in our example, $n = 10$, the first table is consulted as shown:

n	$\alpha = 0.05$	$\alpha = 0.01$
5	20	-
6	26	30
7	30	38
8	36	44
9	40	52
10	46	58

The table shows the N values corresponding to probabilities of 5 and 1 percent (0.05 and 0.01) for specific n values. We consult the last line ($n = 10$) and determine that our N value of 66 exceeds both the $N\alpha$ values for 0.05 and 0.01. Hence, we can conclude that negative correlation between turbidity and live coral coverage is highly significant statistically, with a probability of occurrence of less than 1 percent (< 0.01).

IV. Variations. For more complex examples where $n > 10$, Kendall's coefficient τ of rank correlation is computed from the following formula:

$$\tau = \frac{N}{n(n - 1)}$$

In cases where the same data values lead to tied rankings, different equations are used to calculate τ and determine possibilities.

III.D. GEOGRAPHIC INFORMATION

Geographic data in the form of aerial photographs, other airborne imagery, and maps are among the most important information for both project-specific or long-range environmental planning. Such information collected at the same place but at different times gives a historic record of environmental change, or stability. Geographic data provide the basis to calculate the area of mappable resources and impacts; to help site settlements, roads, ports, and agricultural areas; to formulate land use and coastal zone plans; and to facilitate impact analysis using overlay techniques. Photographs and maps are easily read, interpreted, and transcend language or cultural barriers to communication and analysis. Aerial photographs can also be used to establish field surveys and sampling strategies to reduce cost, improve efficiency, and ensure adequate sampling of all relevant habitats and environments.

1. Aerial Photography

Most modern large-scale maps (those that show considerable detail within small areas) now rely in part on aerial photography. Photographic interpretation and ground-truthing (spot checks in the field to verify photo-interpretations) are also important components of mapping. Great strides in both map making and aerial photography were made during the World War II era as part of military intelligence gathering. The standard aerial cameras of the time (the Wild RC-10 and 11 with 9" x 9" negative format, for example) still provide among the best quality photographs available, and capabilities have been enhanced through decades of improvement in film quality and processing. Film is readily available in black and white, visible color, near infrared color, print negatives, and positive transparency types.

Vertical aerial photographs are needed for accurate map making and are more useful than oblique aerial photographs. Cameras are mounted in the floor of a plane or jet aircraft. The aircraft follows predetermined flight lines, velocities, and altitudes, usually along straight courses and constant altitude, and the camera takes a series of overlapping frames of the land or seascape. Although the camera faces straight down for vertical photographs, only the central part of each photograph is truly vertical and free of distortion. At increasing distances from the center (or vertical), distortion results from increasing side angle and distance between the camera and the subject (ground surface). This distortion is greater for wide-angle photographs. Most distortion is predictable and can be optically corrected to produce orthogonal aerial photographs. Other calibrations involve locating specific surveyed landmarks on the photo to establish distance scales and map coordinates (e.g., longitude and latitude). Standard geodesic survey techniques are used to make and calculate the exact locations of the ground control points. Although corrected aerial photographs are needed for map making, uncorrected photos can still provide many important types of environmental information and serve as the basis for rough maps.

2. Low-Altitude Aerial Photography

Low-altitude imagery offers the greatest resolution and detail but has limited field of view (or swath). Hence more photographs and flying time are needed per unit area. Common scales range from 1 inch = 20 ft to 1 inch = 1,000 ft (or 1:240 to 1:12,000, respectively). Common purposes for low-altitude photography include surveying proposed road alignments, settlements, ports, coastal zone resources, master planning, and facilities planning. Low-altitude photography is also important for flooding or inundation analysis, for the monitoring of beach or shoreline changes, the stability of stream courses, and changes in agricultural or forest cover or conditions. Low- and medium-altitude aerial photography is also important for accomplishing coastal resource inventories as described later in this section.

3. High-Altitude Aerial Photography

This type of imagery is often collected using jet aircraft or reconnaissance aircraft. Distant scales vary from 1:50,000 to 1:200,000 or more. Sophisticated military intelligence ("spy") aircraft, cameras, and special high resolution film are used to obtain multispectral imagery. Up to four different types of photographs are simultaneously taken by a bank of cameras to collect several types of imagery, each with unique properties or attributes (see Table III.2).

Special permission or arrangement with military or aerospace is often needed to take advantage of high altitude aerial imagery (e.g., the U.S. NASA U-2 aircraft missions). On a daily basis, the cost of the imagery is high but the coverage is so much greater (due to a wider swath and greater speed of the aircraft) that the unit cost of imagery can be low, especially when several users or clients join forces to sponsor a mission to a particular region (e.g., "daisy-chaining"). Entire island nations can be covered in a few hours to a few days.

Other advantages of high-altitude aerial photography include less distortion and good to excellent resolution for most spectral categories. Disadvantages include chromatic attenuation and fading at high altitude; interference from smoke, dust, haze, and cloud cover; and distortion from thermal anomalies in the atmosphere.

4. Satellite Imagery

Recent advances in the quality and resolution of satellite imagery have improved its value for geographic data collection. Although resolution (minimum resolution units or pixels) is not as good as high-altitude or low-altitude photographic imagery, discrimination has been lowered to 30 to 100 m for U.S. satellites (EROS, LANDSAT) and 10 m for the new French SPOT satellite. Satellite imagery can be commercially purchased as individual frames or imagery and in a variety of spectral signatures. It is particularly well suited for coverage of large areas, remote islands, and monitoring of global atmospheric trends, and for tracking of tropical storms and typhoons. Some disadvantages include resolution limitations;

Table III.2. Comparisons among major spectral categories of aerial photographic imagery

Type	Advantages	Disadvantages
Narrow band (black and white)	High resolution and good water depth details (up to 50 ft)	Discrimination between different hues of same shade is not possible
Near infrared (false color infrared)	Excellent discrimination among vegetation, crops, and other photosynthetic organisms	Poor depth penetration in lakes, ocean waters (maximum of 3 to 6 feet)
Thermal infrared	Detects temperature anomalies (especially in water bodies), such as cold water or warm water plumes and discharges	Poor resolution; normally requires use of a scanner (emitting device) to bounce the thermal IR waves off the land surface
Radar wavelength	Highest resolution due to short wavelength	Rapid atteruation; low subsurface penetration often requires use of scanner
Visible color	Great discrimination at depth in the ocean; good discrimination between most land-cover categories	Some color attenuation at high altitude; cloud and haze interference

atmospheric haze, distortion, and cloud cover; and some color attenuation in the visible range. As with other imagery, satellite imagery can be color-enhanced and digitized, and the many advances in the use of satellite imagery is described later in this section.

5. Cartography or Map Making

Table III.3 suggests a choice of scales for environmental maps.

Production of detailed accurate maps generally follow the steps listed below:

- establishing ground control points;
- planning and collecting aerial photography;
- correction and calibration of the photographs;
- transfer of imagery data to base maps;
- addition of coordinates and scales to maps;

Table III.3. Hierarchy of landscape units in relation to map scale

	Explanation	Suggested Unit Names	Approx. map-scale range
I.	Large size landscape units (approx. 10,000 ha or higher)	Bioclimatic region or zone, Biogeoclimatic zone, Life zone, Vegetation zone, Ecoregion, Biome, Ecological zone	National (small map scale) 1:1 million and smaller in map scale
II.	Intermediate size landscape units (approx. 500 to 10,000 ha)	Land system, Land form. Forest cover type, Plant formation, Forest land type, Forest ecosystem, type.	Regional-overview (medium map scale) 1:1 million to 1:100,000 (or occasionally up to 1:50,000)
III.	Small-sized landscape units (approx. 1 to 500 ha)	Forest site type, Forest habitat type, Land type	Sub-regional or Local-detailed (large map scale) 1:100,000 (or 1:50,000 up to 1:1,000)

Definitions relating to unit names given in Table

Bioclimatic region or zone: The data ranges and threshold values are originally adjusted to certain spatial changes in the biota. The biotic characteristics (aspects of vegetation physiognomy) reflect macroclimatic differences.

Biogeoclimatic zone: Refinement to include topography, geological substrate, land form, and soil as additional descriptors.

Life zone: See page 22.

Vegetation zone: A broad area with a certain macroclimate, which contains a mosaic of more narrowly defined vegetation types.

Biome: Broad area of landscape, such as desert, tundra, or coniferous forest, in which climate, animal communities, and vegetation physiognomy are the main criteria for identification.

Ecological zone: A broader area landscape unit defined through vegetation, climate, soil, and topography.

Ecoregion: An abbreviation of the term ecological region.

Land system: A unit of physiographically related habitats as often contained in a watershed.

Land form: A topographic-geological unit, such as a beach deposit, dune area, lava flow, alluvial flat, talus slope, etc.

Forest cover type: A vegetation unit distinguished usually by dominant species which cover mid-sized areas such as land forms or land systems.

Plant formation: A mid-sized vegetation unit distinguished by vegetation structure or architecture, such as closed forest vs. open forest, low-stature forest, etc.

Forest land type: A specific habitat or site identified in relation to its current or potential forest cover; for large-scale and intermediate scale.

Forest ecosystem type: Mid-sized unit in relation to a certain land system, such as a watershed, for example.

Forest site type: Small-area unit distinguished by a unique forest vegetation, soil-moisture regime, and habitat combination; e.g., alluvial bottomland, periodically flooded.

Forest habitat type: Definable physiographic segment of land, with all its particular environmental factors.

Source: Carpenter 1981.

- addition of thematic (subject matter) information, usually on separate film overlays;
- assembling all overlays to produce the composite print negatives; and
- printing and publication of maps.

Because of the number of steps and sophisticated procedures and equipment involved, map making is often slow and expensive following conventional procedures. Recent advances in computer graphics and digital cartography have served to accelerate some forms of map making. However, collection of the base information for the maps--the aerial photographs--is a significant benefit itself because of the many uses of the imagery and can serve as the important first step with preparation of maps deferred until funds and capability become available.

6. Mapping Application: Coastal Resource Inventories and Atlases

Since 1978 the U.S. Corps of Engineers has sponsored coral reef and coastal resource inventories specifically designed for tropical island and reef environments in Polynesia and Micronesia (Maragos and Elliot 1985). Since 1985 the University of Hawaii Sea Grant Program has also worked with the Corps on the Micronesian inventories. Each project involves the production of an atlas and companion report that map, describe, and evaluate the importance of resources along the coastal zones of islands and reef areas. These documents are designed and presented in a form useful for scientists, planners, and other officials with management responsibilities over coastal resources. An important component of the inventories includes the description and siting of important coastal resources based on their existing and potential uses, values, and functions. In order to improve comprehension and utility of the atlases, a series of symbols are used to depict the location of important resources (e.g., see Figure III.10).

Data gathering for the inventories rely on field surveys, interviews, interpretation of aerial photographs, and review of past reports and maps. Interviews with local experts in fisheries, cultural resources, land uses, and other subjects are particularly important in identifying important resources or their functions, since brief scientific surveys covering large geographical areas will likely not detect all resources that should be described. The inventories are qualitative and extensive in nature and can identify the area and scope of more important detailed studies. Available information and data are summarized in the companion narrative reports and cover topics such as marine biology (fishes, corals, algae), oceanography, geomorphology, water quality, fishing grounds, cultural resources, coastal transportation and settlements, and potential parks, sanctuary, and development sites.

Bottom Type and Land Cover Classification

OFFSHORE

Sediment
sc — Sand bottom in water depths less than 10 meters
sd — Sand bottom in water depths greater than 10 meters

Reef Complex
rc — Mixed bottom types consisting of reef rock (limestone) associated with shallow reef formations
rcl — Consolidated limestone, lacking sediment
rcp — Consolidated limestone with a smooth, pavement like surface
rcs — Mostly consolidated limestone with some (25-50%) sediment bottom
rct — Complex reef bottom type (**rc, rcs, or rs**) with loose materials formed into tracks by waves or currents
rcg — Consolidated reef with well defined groove-and-spur system
rs — Complex reef bottom type consisting mostly of sand, but with some limestone outcrops or boulders
co — Areas of greater than 50% live coral cover

SHORELINE

rr — Rip-rap shoreline
bc — Concrete/cement masonry seawall and shoreline
sb — White sand beach of predominately calcareous material
sbc — Calcareous rubble and/or shingle beach
br — Beach rock, usually exposed along the shoreline

VEGETATION COVER

Coconut Trees (circa 1946)
Woods or Scrub (circa 1946)

Other Symbols

⟷ Observed Range
Reef Edge
· · · Submerged Reef
Historic/Cultural Site
Shipwreck
Navigational Marker
H Helicopter Pad

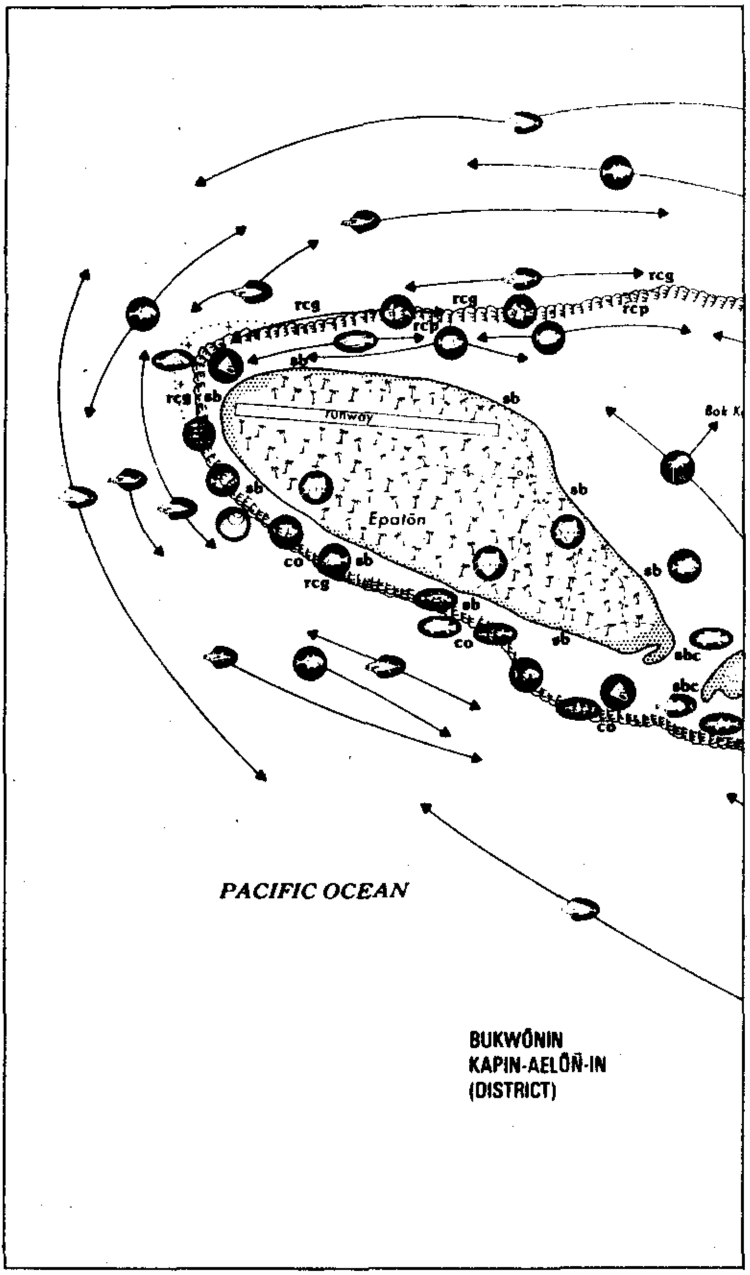

Figure III.10. Location of important resources (<u>Source</u>: U.S. Army Corps of engineers, forthcoming).

Coastal Resources

PELAGIC FISH

● **Barracuda** — *Jure, Jujukōp, Ñiitwa*

● **Billfish, Marlin, Swordfish, Sailfish** — *Ļōjkaan, Wūjinleep*

● **Dogtooth Tuna** — *Ļooj*

● **Dolphinfish** — *Koko*

● **Flying Fish** — *Jojo*

● **Tuna** — *Bwebwe, Ļōjabwil*

● **Wahoo** — *Al*

INVERTEBRATES

● **Conch, Turban, Helmet** — *Aorak, Jidduul, Bukbuk*

● **Giant Clam** — *Mejānwōd, Tōtwōd, Dimuuj, Kapwor*

● **Lobster** — *Wōr*

● **Octopus** — *Kweet*

● **Squid** — *Nōt*

● **Topshell (Trochus)** — *Likōppejdat*

● **Sea Turtle Capture Area** — *Wōn*

LAND BIOTA

● **Coconut Crab** — *Barulep*

● **Land Crab** — *Baru, Atūñ, Baru Waan*

● **Seabird Site (rookery)** — *Ļārooj*

REEF FISH

● **Bigeyed Scad** — *Ļwōl*

● **Emperor** — *Dijiñ, Nōt, Weo, Mejmej, Ṃōjam*

● **Flagtail** — *Jerwōt*

● **Goatfish** — *Jo, Jome*

● **Grouper** — *Kūro, Ļōjepjep, Ojalọ, Jawe, Pooklịṃ*

● **Jack** — *Ļāne, Deltokrōk, Ikbwij, Dedep*

● **Mackeral Scad** — *Pati*

● **Mullet** — *Iōōl*

● **Parrotfish** — *Merā, Ekmouj*

● **Rabbitfish** — *Ṃọle*

● **Rainbow Runner, Fusilier** — *Ikāidik, Bōbed, Paļoj*

● **Rudderfish** — *Pājrōk*

● **Snapper** — *Jato, Jepļọ, Jāj*

● **Squirrelfish** — *Jera, Ṃōn, Mālij*

● **Surgeonfish** — *Bwilak, Ṃọṇe, Kwi, Ael, Kupañ*

● **Triggerfish** — *Iṃiṃ, Būb, Liele*

● **Wrasse** — *Lappo, Likōb, Dāpijdekā*

OTHER SYMBOLS

● **Harbor, Boat Ramp, Pier, Wharf, Channel**

● **Marine Park/Tourism Site**

Figure III.10. (continued)

The goals of the inventory program include several requirements for effective coastal resource management.

- Accurate information on the abundance and distribution of important resources;

- Accurate information on uses, functions, values, and demands on the resources;

- Establishment of a planning and decision-making process that integrates the preceding two factors into a full evaluation of alternatives, including siting, to achieve future development and conservation objectives; and

- Placement of priority attention on those areas, especially population centers, where the resources are in greater jeopardy or exposed to conflicting demands.

Integrating both scientific and socioeconomic information into the texts and atlases of the inventories offers officials greater functional and geographic perspective and help to identify specific follow-up studies or analyses.

7. Map Analysis Technique

(prepared by Daniel van R. Claasen)

Maps may be used to spatially analyze different components to derive new parameters or select "least impact" alternatives. The method is commonly referred to as "overlay" or "sieve" mapping and is described in detail in Design With Nature (McHarg 1969).

A general base map is prepared at an appropriate scale. Transparent overlay maps are prepared of each of the primary and derived environmental factors and attributes. In the simple foregoing example, maps of the terrain, slope, and soil would be overlaid in order to identify areas suitable for traffic under various constraints: easily trafficable, some constraints, difficult, not trafficable (see Figure III.11). This overlay map in turn would be combined with a soil erosion susceptibility map (soil type, thickness). This procedure would potentially rule out more areas where traffic should be prohibited.

One can add more constraints/attributes as required (e.g., critical habitat, endangered or rare plant communities, buildings on the national heritage list) until satisfied that all essential aspects have been covered and an optimum, least impact road alignment or a number of alternative alignments have been identified. In the latter case the differences would be listed, qualified, and presented for final decision.

The result is a graphic representation of the type, area, and location of impact. It permits a better than educated guess about the intensity and risk of impact that may occur. It does not make the final decision but provides additional information in a readily understood medium so that the decision can be made with a greater degree of confidence.

The interpretation of the data is based on logical analysis of the attributes and a definition of the threshold above or below which an impact is known to occur. The known threshold of an environmental attribute or factor to a specific activity or combination of activities allows prediction of the prevalence of the impact. It also allows qualitative and sometimes quantitative assessment of degree and probability of direct impact.

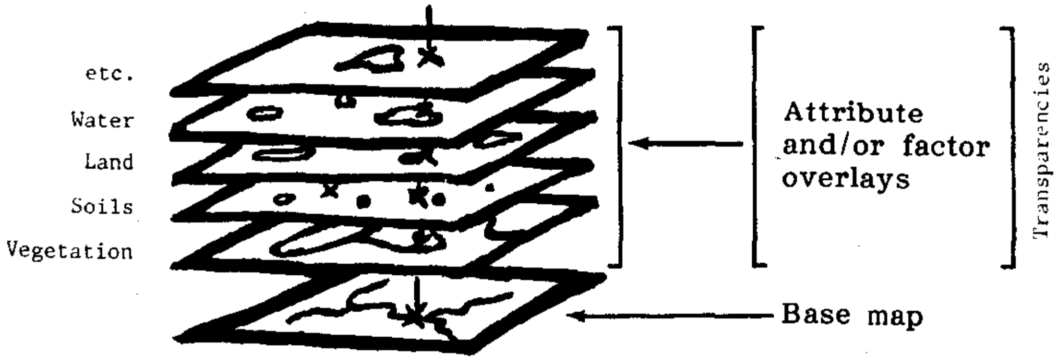

Figure III.11. Overlay mapping.

Indirect and distributed impacts can also be assessed. It is difficult to determine the full impact of waste discharge into a stream, for instance, if the spatial aspect is not explicit. The downstream occurrence of recreational areas, fishing grounds, or water intakes may not be fully evident if not mapped in relation to the project activity.

The spatial and temporal aspect which maps give to environmental impact assessment merges with integrated land use and regional planning. Many projects affect present land use and may preclude future uses of land. Permission for a project to proceed with waste discharge, for instance, may not affect any current downstream uses but may prevent the future use of a highly scenic area for future recreational use.

8. Computerized Geographic Information Systems

(prepared by Daniel van R. Claasen)

It is often suggested that maps are manual geographic information systems. The term "geographic information system" (GIS), however, commonly refers to computerized geographic (mappable) data retrieval and manipulation systems.

Environmental data can be analyzed in several ways. Each aspect can be analyzed using only one characteristic (i.e., single-factor analysis by progressively adding factors or characteristics according to potential or increasing limitations; added-factor analysis by adding characteristics according to increasing limitations, risk, potential); or sorted-factor analysis by using a stepped, decision-tree approach similar to those used in taxonomic or identification keys, to sort or classify groups of significant characteristics) along the lines suggested; and/or weighted-factor analysis by combining and weighting characteristics to reflect relative importance.

Single-factor, added-factor, and sorted-factor analyses can be readily accomplished using manual overlay techniques. As can be appreciated, however, the overlay mapping system can quickly become cumbersome as the number of attributes, factors, and characteristics increases. Where detailed field work has been completed on which criteria for selecting and weighting can be developed, a weighted-factor approach becomes feasible. Where large sets of data exist, the number of maps can become unmanageable and computer assistance to handle the data may be required.

It must be noted, however, that a GIS does not reduce the need to gather information or to develop the maps for in-put into the digital computer base. The use of the computer will not reduce the amount of mapping work required in the first instance. It may also, unless the computer hardware and software systems are well developed and running without "bugs," delay the completion of the assessment.

It is also essential, a fact which can be time-consuming in itself, that the factor analysis and weighting decision rules or algorithms are very carefully defined and developed.

In general the use of a GIS in environmental impact assessment is not recommended unless all of the logical relationships, attributes, and map bases have been previously developed and are working, and data entry is a routine matter.

Computerized GISs are warranted where long-term monitoring of the effects of a project on the environment of a region is contemplated, where data will add to the ongoing maintenance and use of an existing regional data base, or where it will be used as an ongoing resource management or regional planning tool.

The latter situation may apply in regional surveys for development, corridor planning and selection, and/or development of regional or national land-use data bases for departmental (e.g., agriculture, forestry) program management.

9. Example of GIS Application
(adapted from Fingleton et al. 1989)

A computerized geographic information system was used to select suitable areas in which to site an industrial waste landfill near Bangkok, Thailand. Maps at the 1:50,000 scale showing topography, land use, and highways were digitized. Criteria for acceptance were defined to minimize the risk to nearby persons. The major hazard was contamination of surface water or groundwater used for drinking, irrigation of vegetable crops, or aquaculture. Table III.4 gives the screening criteria. With these instructions the computer quickly generates a map of potentially suitable areas as shown for two subdistricts in Figure III.12.

Table III.4. Screening criteria for industrial waste landfill

Criteria	Acceptable Conditions
Population	No resident population, at least 100 m from urban and built-up land
Surface water features	At least 500 m from surface water
Land use	Paddy fields, orchards, horticulture, animal farm houses, forests, forest plantation areas, wetlands, and operating mines are not acceptable
Roadway	Within at least 1 km of a major roadway
Topography	Slope less than or equal to 5%; at least 100 m from foothills

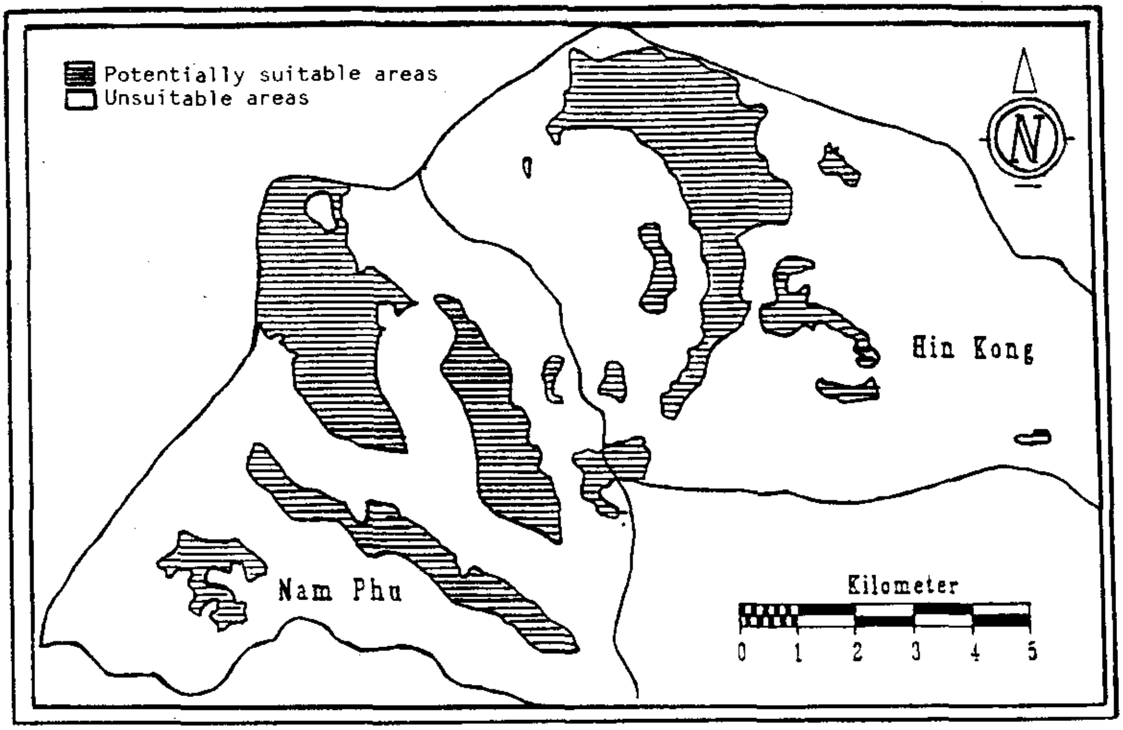

Figure III.12. Results of stage II screening for Nam Phu and Hin Kong subdistricts of Ratchaburi Province. (Created by P. Hastings and C. Boonraksa of the Thailand Development Research Institute, Bangkok.)

III.E. ECONOMIC ANALYSIS

Planning and implementing sustainable development require trade-offs because money, personnel, and natural resources are always in short supply compared to the opportunities. The efficient allocation of limited resources is aided by economic analysis, recognizing that the final decision involves many other factors as well. EIA should culminate in an extended analysis of the costs and benefits of different development alternatives. Although some environmental factors are difficult to express in monetary terms, benefit-cost analysis is a valuable framework for interpreting the biophysical findings of EIA in economic welfare terms. Most important, it presents results in the economic language familiar to decision-makers.

The environmental officer should work with economists in the government planning department to incorporate the techniques described here. When contracting for EIAs, the terms-of-reference should request the use of appropriate economic analysis techniques and the summarization of findings in an extended benefit-cost framework.

1. Financial and Economic Analyses

Financial analysis is concerned narrowly with profits and losses of private individual projects. Typically, it relies on market prices to guide investment decisions. It will normally be available for the EIA from conventional project appraisal and is valuable data. Economic analysis, in contrast, is concerned with the total effect on society and evaluates development alternatives based on change in social welfare, or the sum of individuals' welfare.

Project analyses usually focus on easily measured direct costs and benefits and often ignore environmental "externalities," many of which are damage costs such as respiratory illness from air pollution or loss of fisheries because mangroves were cut (see Figure III.13).

A benefit foregone is a cost, and a cost avoided is a benefit. For example, the net value of improved wastewater treatment should be analyzed to include not only direct costs of equipment, operation, and maintenance but also the benefits, or damage costs avoided, in further downstream uses of the water. The broader economic analysis seeks to capture these externalities through the EIA and establish monetary values for them so they may be included in benefit-cost analysis.

Only the additional benefits and costs actually due to the project are considered, however. Sunk costs--money already spent related to the project--are not included. For example, a project analysis of a beach hotel would not include costs of roads and infrastructure already in place.

2. Net Present Value

In the course of a project, both costs and benefits occur at various times (see Figure III.14). Since money (either spent or

		Location of Goods and Services	
		On-site	Off-site
Valuation of Goods and Services	Marketed	**1** Usually included in an economic analysis (e.g., poles, charcoal, woodchips, mangrove crabs)	**2** May be included (e.g., fish or shellfish caught in adjacent waters)
	Nonmarketed	**3** Seldom included (e.g., medicinal uses of mangrove, domestic fuelwood, food in times of famine, nursery area for juvenile fish, feeding ground for estuarine fish and shrimp, viewing and studying wildlife)	**4** Usually ignored (e.g., nutrient flows to estuaries, buffer to storm damage)

Figure III.13. Benefits and costs in a mangrove ecosystem (Source: Hamilton and Snedaker 1984:110).

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acquired) is always valued higher at the present than in the future, a discount rate must be applied in order to compare costs and benefits correctly over the life of the project. The most widely used formula in project analysis is net present value, which involves discounting the time streams of benefits and costs back to the beginning.

$$NPV = \sum_{t=1}^{n} \frac{B_d}{(1+r)^t} + \frac{B_e}{(1+r)^t} - \frac{C_d}{(1+r)^t} - \frac{C_e}{(1+r)^t} \quad \text{or} \quad \sum_{t=1}^{n} \frac{B_d+B_e-C_d-C_e}{(1+r)^t}$$

Where NPV = net present value

B_d = direct project benefits

B_e = external and/or environmental benefits

C_d = direct project costs

C_e = external and/or environmental costs, including environmental protection costs

r = discount rate

t = year in which costs or benefits occurred

n = number of years in economic time horizon or project lifetime

Σ = summation sign

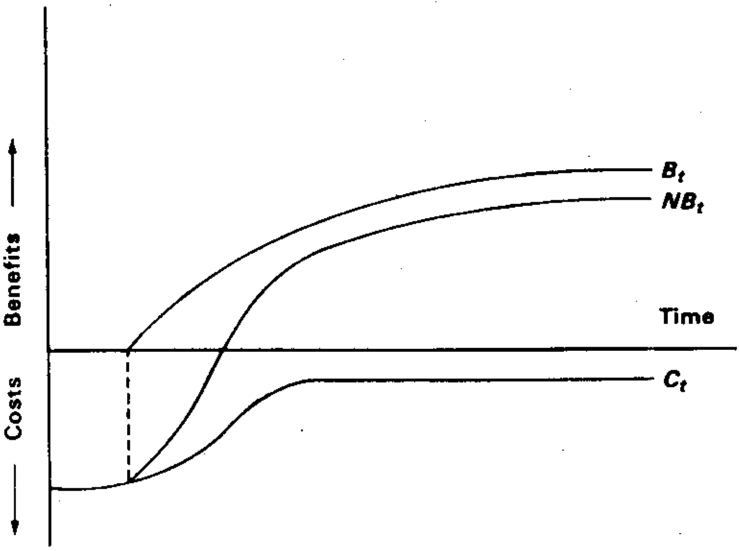


Figure III.14. Project costs and benefits over time (<u>Source</u>: Hufschmidt et al. 1983:37).

Other uses of the same present value information are the internal rate of return (IRR) and the benefit-cost ratio (BCR). These are related to NPV as follows:

$$\text{NPV} = \text{Present value of benefits} - \text{Present value of costs}$$

IRR = Discount rate that results in the present value of benefits becoming equal to the present value of costs

$$\text{BCR} = \frac{\text{Present value of benefits}}{\text{Present value of costs}}$$

These measures are related in the following way:

NPV		BCR		IRR
If > 0	then	> 1	and	> r
If < 0	then	< 1	and	< r
If = 0	then	1	and	= r

Table III.5 shows how measures were used for selecting or ranking projects.

Table III.5. Comparison of the three measures of present value

	NPV	IRR	BCR
Selection or ranking rule for:			
Independent projects:			
No constraint on costs	Select all projects with NPV > 0; project ranking not required	Select all projects with IRR greater than cut-off rate of return; project ranking not required	Select all projects with B/C > 1; project ranking not required
Constraint on costs	Not suitable for ranking projects	Ranking all projects by IRR may give incorrect ranking	Ranking all projects by B/C where C is defined as constrained cost will always give correct ranking
Mutually exclusive projects:			
No constraint on costs	Select alternative with largest NPV	Selection of alternative with highest IRR may give incorrect result	Selection of alternative with highest B/C may give incorrect result
Discount rate	Appropriate discount rate must be adopted	No discount rate required, but cut-off rate of return must be adopted	Appropriate discount rate must be adopted

3. Discount Rate

At least three factors enter into the choice of a discount rate. The opportunity cost of capital is related to the theory of capital productivity. A dollar's worth of investment in manufacturing equipment should yield net benefits of goods produced to pay off the costs. The discount rate reflects this rate of return on investment. The cost of borrowing money is set in the market place by financial institutions.

Governments, another source for the discount rate, usually have a different (lower) cost of borrowing money because of the security of such loans. A third approach is the social rate of time preference indicating society's willingness to sacrifice present consumption for the future. This rate will normally be lower than that of the money market.

Example of Net Present Value Calculation

A project involves the following flows of money at the end of each year. The discount rate is 10 percent. What is the net present value of this 4-year economic development project?

	Year				
	0	1	2	3	4
Costs	$ 1000	100	100	100	100
Benefits	none	600	700	800	700
Net benefits	-1000	500	600	700	600
Discount $(1+r)^t$	1	1.1	1.21	1.331	1.464
Present value	-1000	455	496	526	410

NPV = -1000 + 455 + 496 + 526 + 410 = 887

In a single economic analysis, the discount rate must remain constant. Since no one actual numerical value is "correct," however, the analysis should be repeated for two or three different rates to test the sensitivity of the results. One of the rates used should be approximately the cost of borrowing money for private projects in the country of concern. Ignoring the discount rate (or not performing the discounting calculation) is, in effect, choosing a rate of zero. This may be an erroneous interpretation of society's preferences or trade-offs between present and future consumption.

4. Time Horizon

Some cutoff point in the future must be chosen for an economic analysis. One factor is the expected useful life of the project in providing the benefits for which it was designed. Predicting benefits and costs in the distant future may be so uncertain that they are better ignored (e.g., obsolescence of equipment or changes in market demand). A second reason for limiting the time horizon is the decreasing present value of future costs and benefits depending on the discount rate. The typical opportunity cost of capital today is between 10 and 15 percent so that benefits and costs occurring beyond 20 years in the future are insignificant (see Table III.6).

5. Valuation Techniques

Some environmental effects are relatively easy to value in monetary terms (e.g., changes in fish catch or expenditures for pollution control equipment). When market prices do not exist, a substitute may be used (e.g., clean air is unpriced but air pollution may affect the market value of a house near a coal-burning electric power plant). More difficult, and less useful, are valuations based on surveys or interviews of peoples' preferences, willingness to pay, or compensation demanded. The analyst should start simply with the

Table III.6. Present value of $100 in future years at various discount rates

Time (yr)	Discount rates (%)				
	2	5	8	10	15
0	$100.00	$100.00	$100.00	$100.00	$100.00
10	82.03	61.39	46.32	38.55	24.71
20	67.30	37.69	21.45	14.86	7.56
25	60.95	29.53	14.60	9.23	7.05
40	45.29	14.20	4.60	2.21	0.57
60	30.48	5.35	0.99	0.33	0.04
100	13.80	0.76	0.05	0.01	--

most obvious, easily valued environmental effects. Table III.7 presents some typical impacts and the means for their monetary valuation.

Finally, some economic values of intact ecosystems are real but extremely difficult to quantify (Ehrenfeld 1978:210). They are:

- recreation, conservation, and esthetic values,
- ecosystem stabilization values,
- value as examples of survival,
- environmental baseline and monitoring values,
- habitat reconstruction values, and
- scientific research and teaching values.

6. Cost-Effectiveness Analysis

This technique is used to find the least costly way to achieve a given environmental goal (e.g., water quality standard) or to get the most benefits for a given amount of money.

Figure III.15 illustrates the case of air pollution abatement technology. With no control, the damage costs (e.g., lost work days from respiratory illness could be used for valuation) are high. Different pollution control equipment may be installed to reduce emissions; but the greater the control, the higher the cost. Summing the two cost curves reveals a minimum cost point (not necessarily where the curves cross). The technology to control emissions as near that point as possible will have the greatest net benefits.

Table III.7. Examples of development projects, possible environmental impacts, and measurement and valuation techniques

Type of project	Environmental impacts	Measurement and valuation techniques (comments)
Agriculture, forestry, and fisheries development		
Fertilizer factory	Project designed for solid, liquid, and gaseous waste treatment	Cost effectiveness of alternative treatment designs
Hill forest development	Project will increase fuelwood and fodder production, and protect critical watershed	Change in productivity of forests and agricultural land Opportunity cost of dung as fertilizer to value benefit of alternative fuel Opportunity cost of preserving critical watershed
Fisheries development	Project contributes to overexploitation of shrimp resources Project vessels competing with artisanal fishermen--project catch not fully incremental Evidence of overfishing inshore	Change in productivity of fishery due to overfishing Loss of earnings of artisanal fishermen must be subtracted from project-catch projections
Brackish-water shrimp culture	Removal of mangroves for construction of shrimp ponds	Change in productivity of fishery due to mangrove removal
Livestock development	Effects on forests and rangeland of overgrazing	Change in productivity of forests and rangeland Opportunity cost of dung as fertilizer
Irrigation		
Low lift pump maintenance	Shallow flooded areas overdrained resulting in lack of water for surface water irrigation in dry season	Change in productivity due to moisture deficit in dry season
Irrigation and settlement	Project located in watershed in good condition; there should therefore be low sedimentation rate	(Watershed management covenant in loan agreement to assure that increased development resulting in increased sedimentation would not affect project's future operation)
Outfall drain	Project should have positive environmental impacts by correcting waterlogging and soil salinization problems	Change in productivity from better growing conditions Cost effectiveness of alternative rehabilitation designs

Table III.7. (continued)

Type of project	Environmental impacts	Measurement and valuation techniques (comments)
Infrastructure		
Road development in hilly area	New cuts in embankments not stabilized with vegetation, causing potential for soil erosion and landslides	Change in productivity due to soil erosion and sedimentation Loss of property due to landslides
Urban water supply	Project contributed to increased wastewater volume without providing adequate sewerage facilities	Loss of earnings directly due to flooding or indirectly from increased incidence of waterborne disease Loss of property due to flooding
Provincial cities water supply	Watershed denudation in the upper recharge area of the project affects project performance	(The broader issue of management of watershed on which the project depends should have been given consideration.)
Water supply	Water diverted from downstream users by artificial well recharge in river bed	Change in productivity of downstream water users
Low-income urban housing	Increased air pollution due to use of underfloor heating systems burning soft-coal briquettes	Cost effectiveness of alternative heating designs Loss of earnings from increased respiratory diseases
Industry and power		
Gas turbine generation	Designed as peak-load facility to run on gas; no air quality control included in design; was used as base-load facility run on oil; air quality adversely affected by emissions	Cost effectiveness of alternative designs to decrease emissions
Palm oil processing plant	Untreated effluent with BOD of 20,000 mg/1 discharged into river	Change in productivity of inland fishery due to water pollution Cost effectiveness of alternative water-treatment designs Loss of earnings from increased health problems due to use of polluted water
Tin mining	Environmental aspects given due consideration with respect to waste tailing disposal, water storage pond dike burst prevention, and prevention of malaria-mosquito breeding	(Project accounted for major potential environmental problems. Negative environmental impact should be minimal.)
Hydropower development project	Service roads gave access which promoted deforestation resulting in changes in hydrological patterns, soil erosion, siltation, and flooding	Change in productivity of forests, agricultural land, and downstream fishery; reduction in useful life of downstream hydropower facility Loss of earnings as a direct result of flooding or indirectly from increased incidence of disease
Hydropower development project	Run-of-river power facility located in catchment with heavy development pressure resulting in increased extreme river flow rates and heavy siltation loads	(Project design and estimates of project's useful life should account for surrounding environmental conditions which will affect project operation even though not a direct consequence of project. Preventive expenditures made to reduce downstream consequences of deforestation.)

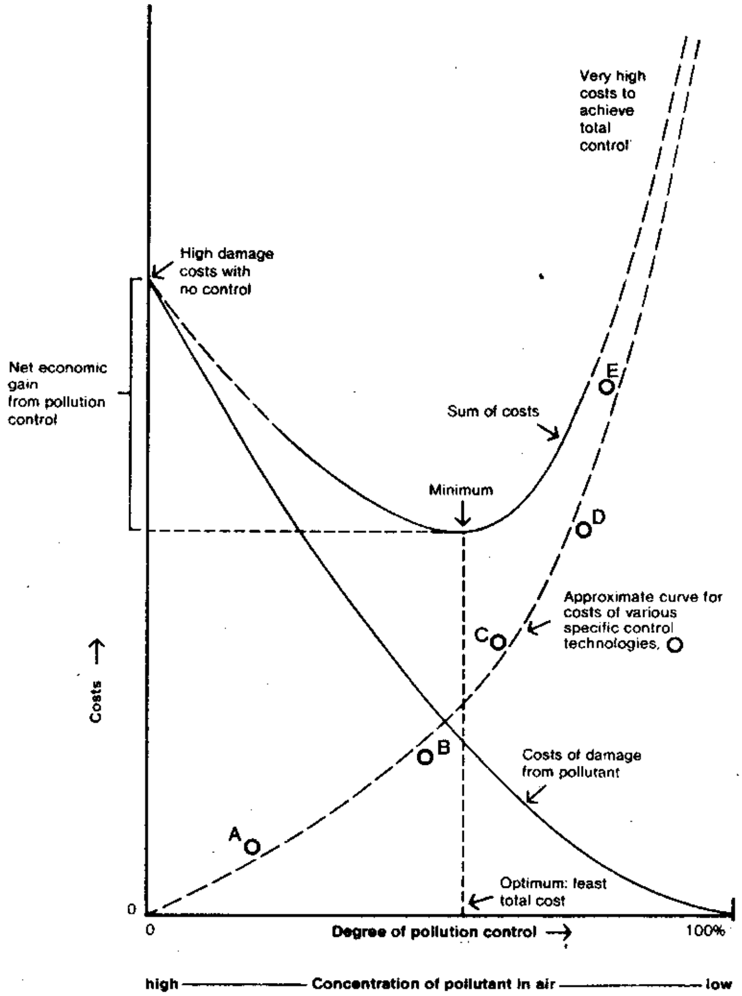


Figure III.15. Benefits (damage avoided) and cost (Source: Carpenter and Sani 1983:372).

The cost effectiveness of different technologies is compared based on the amount of pollutant removed per dollar. As the degree of control increases, the cost effectiveness usually decreases. Technology B in the figure would be most cost effective. Other considerations, such as the ability of some technologies to remove more than one pollutant, may affect the choice, however.

The proportion of capital (start-up) costs to operational and maintenance costs may also be important. Citing a common example, the capital cost to construct a secondary sewage treatment plant with a short outfall may be less than the cost of constructing an advanced primary plant with a long or deep ocean outfall. However, the operating costs for the secondary plant are so much higher because of high energy consumption and higher levels of technology and training required to run the plant compared to the advanced primary plant. Within a matter of years, the total cost of the latter may be less than the former. Note that the same net environmental benefit may be achieved because the longer, deeper outfall allows the sewage subjected to less treatment to be disposed in an area where it will do less harm.

III.F. RISK ASSESSMENT

All data pertaining to EIA possess some degree of uncertainty and many involve random, stochastic processes such as rainfall events. Thus, a cause for concern is that most EIAs present results without reference to underlying uncertainties. For example, an EIA may warn that an oil spill from a tank farm could damage nearby habitat and aquatic birds. Often, no information is given about the likelihood of the spill or the magnitude of the impact on the bird population. Or only a single number is given: "once a year" and "up to 25 percent of the birds harmed." For significant impacts, the assessor should attempt to provide a quantitative probabilistic risk assessment as a complement to the EIA. This is particularly important when different development options are being compared (see Figure III.16).

Some definitions of risk terminology are:

- A hazard is a danger, peril, or a source of harm.
- Risk is the chance, possibility, or probability of adverse consequence, loss, or injury.
- Uncertainty is lack of knowledge about an outcome or result.
- Assessment is appraisal or evaluation in order to judge.
- Analysis is detailed examination or thorough study in order to understand.

Risk assessment need not and should not be viewed as a new and different component of project planning. It can usually be built based on the EIA and thus take advantage of the 20 years of growing experience in both developed and developing countries. Risk assessment addresses three questions:

- What can happen; what can go wrong?
- How likely is it that the event will actually occur?
- If it does happen, what is the range of consequences?

EIA and accompanying engineering and economic analyses will generate most of the scenarios for the first question and also will predict the nature of the consequences in question 3. What remains is to answer questions about the likelihood of hazardous events and to express the severity of impacts as a distribution of magnitudes. Risks are measured in terms of both frequency and severity. Nuclear power plants, for example, may present the risk of a catastrophic but rare failure. Pollution discharges may present the risk of frequent events but with minor damage. Highly sophisticated techniques have been developed for quantifying risks of cancer from exposure to toxic chemicals. It is possible, however, to estimate risks in a practical way by using technical judgment and experience and thus to give decision-makers more information about impacts.

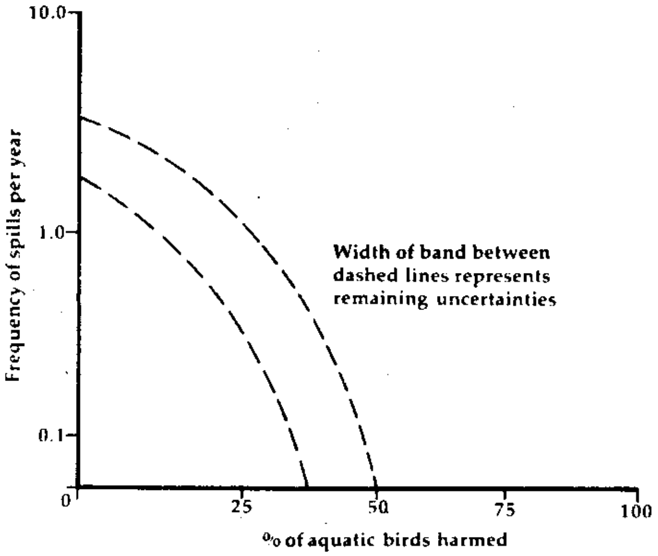


Figure III.16. Frequency of oil spills vs. degree of damage to aquatic birds. This presentation of risk suggests that about every 10 years a spill will harm between 35 and 50% of the bird population, or about once a year a spill will harm 10 to 25% of the birds. If it is decided that this risk is too high, then measures can be taken to reduce the number and size of spills or to improve emergency response cleanup methods.

Figure III.17 diagrams a risk assessment of exposure to toxic chemicals in an ecosystem. The assessment traces the likelihood of exposure for each receptor (fish, birds, mammals) and considers the magnitude of the toxic effect (i.e., dose and response). The uncertainties are noted in the questions asked, such as "How does length of exposure affect toxicity?" Even a qualitative examination may reveal which part(s) of this system present the largest risk (e.g., juvenile fish might be affected by low concentrations of the toxic agent).

Another example is given in Section III.D.9 where a geographic information system was used to help pick the site for a hazardous waste landfill. The systematic examination of the movement of electroplating wastes from the point of generation, through transport, storage, treatment, and disposal, revealed that the biggest risk was in contamination of surface water or groundwater. The risk could be reduced by siting the landfill well away from any surface water, irrigated fields, fishponds, or wetlands.

Figure III.18 shows a rapid risk assessment method that employs four levels each for frequency or probability of occurrence and severity or magnitude of the impact. The severity is defined for each level according to the specific hazard being studied. Some sample definitions are shown for an industrial hazard, but the assessor should construct a scale to fit the problem at hand. A group of experts and officials familiar with the hazard can then judge where a

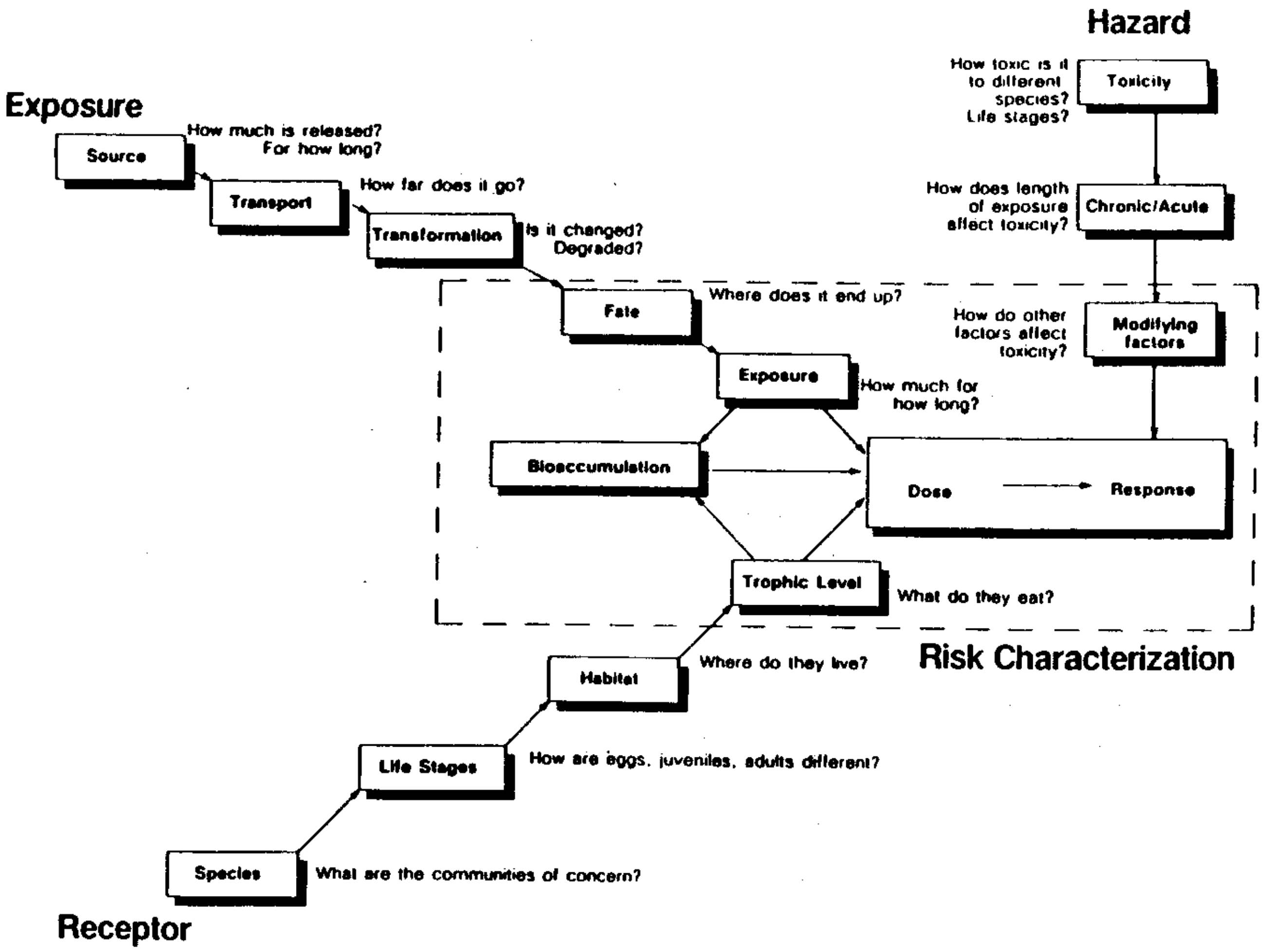
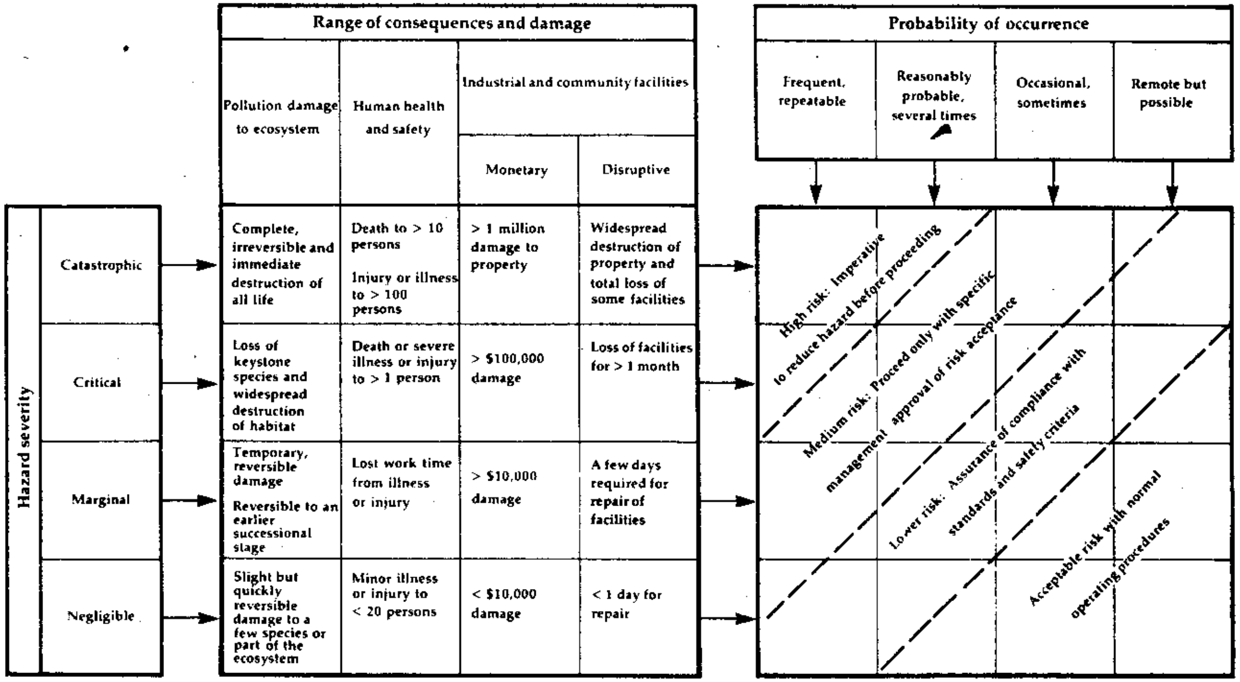


Figure III.17. An integrated model for ecological risk assessment.



Hazard severity	Range of consequences and damage			
	Pollution damage to ecosystem	Human health and safety	Industrial and community facilities	
			Monetary	Disruptive
Catastrophic	Complete, irreversible and immediate destruction of all life	Death to > 10 persons Injury or illness to > 100 persons	> 1 million damage to property	Widespread destruction of property and total loss of some facilities
Critical	Loss of keystone species and widespread destruction of habitat	Death or severe illness or injury to > 1 person	> $100,000 damage	Loss of facilities for > 1 month
Marginal	Temporary, reversible damage Reversible to an earlier successional stage	Lost work time from illness or injury	> $10,000 damage	A few days required for repair of facilities
Negligible	Slight but quickly reversible damage to a few species or part of the ecosystem	Minor illness or injury to < 20 persons	< $10,000 damage	< 1 day for repair

Figure III.18. Risks may be ranked based on their probability (frequency) of occurrence and severity of the hazard. Categories may be established in a semiquantitative way based on consequence to life or safety, time of interrupted operations, and monetary loss. The result is a useful, necessarily flexible, separation of risks into categories ranging from high to acceptable levels.

specific development situation would be placed in the risk matrix. Any risk that combines catastrophic or critical severity with frequent or reasonably probable occurrence is rated high and must be reduced before the development proceeds.

Just as in qualitative EIA, it is not necessary to have complete probability distribution data in order to perform a useful risk assessment. It is often helpful to the decision-maker to have some idea of the frequency and relative severity of adverse consequences.

IV. ASSESSMENT DESIGN FOR MAJOR DEVELOPMENT SECTORS

FIGURES AND TABLES

Figures

Tables

IV. ASSESSMENT DESIGN FOR MAJOR DEVELOPMENT SECTORS

IV.A. INCREASED AGRICULTURAL PRODUCTION, FORESTRY, AND AGROFORESTRY

(prepared by William Clarke)

1. Initial Scoping Considerations

It is an area's existing plant cover, or vegetation, that is most immediately affected by development projects in agriculture, forestry, and agroforestry. The extent to which the existing vegetation is removed and what replaces it strongly influence the intensity and character of environmental change and the impacts consequent upon development. In the high islands of the Pacific, inland from mangroves and beach strand forest, the most common natural vegetation was tropical moist forest (TMF) with some lighter forest or woodland in the drier areas. Alteration of these forests brings generic environmental impacts, which will be considered briefly here, followed by more specific considerations of increasing agricultural production, forestry, and agroforestry as development activities.

a. Soil Erosion/Soil Compaction/Mass Wasting (see also Section V.B). Soil erosion under a cover of mature TMF or drier zone natural forest is minimal. However, accelerated erosion may increase by several orders of magnitude, from a level well below the tolerance limit to disastrous soil losses. Factors contributing to such erosion depend on the kind and intensity of disturbance of TMF from activities such as cautious selective logging, limited shifting cultivation, road building, clear-cutting, and conversion to agriculture, together with the degree of slope, rainfall, and soil type. The physical structure of soil is also usually degraded by forest removal, which exposes the soil to compaction by hammering raindrops and to loss of soil-lightening humus. The result of these processes is an increase in soil bulk density.

Landslips and slumping--although they may occur naturally under forest following some occasions of exceptionally high rainfall--are increased by forest removal because tree roots counteract shearing stress and maintain slope stability on steep slopes prone to mass wasting (O'Loughlin 1974).

b. Runoff/Watershed Health. Similarly--acting together with soil type, landform, and (in some cases) bedrock--runoff is controlled by the vegetation cover. TMF intercepts a large proportion of the rainfall, slowing or preventing its arrival on the ground (through evaporation from leaf and stem surfaces). Of the water that reaches the soil, TMF transpires a further large proportion. The net effect of TMF compared with, say, grasslands or cultivated fields is to diminish the quantity of water delivered from a watershed but not necessarily to give significant protection against flooding (Hamilton 1985). The great benefit of forest in watersheds is that its mere presence protects the soil from compaction, which would increase flooding, and also from badly managed cultivation and grazing, which would increase erosion and downstream sedimentation.

c. Soil Fertility/Ecosystem Nutrients. TMF also holds essential plant nutrients in the local ecosystem, preventing or greatly slowing their leaching from the soil. Removal of TMF biomass through timber harvests, burning, or decay after felling means loss of nutrients from the ecosystem, which is in effect a decline in soil fertility.

d. Loss of Biodiversity and Minor Products. As the most heterogeneous ecosystem on Earth, TMF possesses great scientific value and potential economic worth because of the immense diversity of plant and animal species found in undisturbed forest habitats. Because the forests of many of the larger, high islands of the Pacific are rich in endemic species (hundreds, if not more, still unknown scientifically), the inevitable loss of biodiversity (decline in number of species--a kind of genetic "erosion") that goes with removal of Pacific island forest ecosystems is particularly to be lamented.

On a smaller scale, the loss of forest products gained by a sustainable hunting and gathering of local inhabitants can be seen as a cost of forest removal, although these products steadily diminish in significance except within the context of agroforestry (Thaman 1988).

e. The Forest As Model for Sustainable Development. Important though biodiversity and environmental maintenance may be, great areas of once-forested land have already been deforested or degraded, and rapid conversion of forestland to other uses is in progress, for land remains the basic resource of most Pacific islands (and other tropical areas). Development imperatives press strongly against large-scale preservation of natural forest which is economically unproductive. So, despite various recent international calls to halt tropical deforestation, forest depletion continues implacably: "obviously an indicator of the common opinion that the TMF is less useful for farmers, industrialists and governments than alternative land uses" (Maydell 1989:14). It follows that saving forests, in the sense of preserving all remaining forests from depletion, is a fruitless effort almost anywhere in today's world--although strenuous efforts to maintain forests in the "preservation" and "protection" categories should continue, as discussed here under "Forestry." On the other hand, the ecosystem conditions created by forests can be usefully seen as a guide or ideal model in planning developmental alterations to land under natural forest or in devising mitigating measures against the impacts that inevitably result from forest removal. In other words, efforts should be made to maintain the benefits conveyed by forests even in the absence of forest.

2. Increasing Agricultural Production

Two development modes are open to a country wishing to increase its agricultural production: spatial expansion and intensification. The first is simply an extension of agriculture onto previously unused lands. Intensification, which tends to occur when there is no further frontier of available unused land, implies increased inputs of labor or of fossil fuels, machinery, and chemicals into a fixed unit of land in an attempt to increase the output of crop. "Green Revolution" is the shorthand for the modern method of intensification. Both processes may bring significant environmental impacts.

a. Spatial Expansion of Agriculture. Spatial expansion of agriculture has been marked in some Pacific island countries in recent years. For instance, in Fiji's main island of Viti Levu, Ward (1985) calculates that the land in use or committed to use increased by 233 percent between 1958 and 1978, while rural population increased by only about 30 percent. Much of the expanding agricultural frontier in Fiji can be accounted for by an increase in cattle raising, but the spatial expansion of sugarcane (a growth of about 60 percent between 1972 and 1985) was economically the most important. Because much of Fiji's limited supply of flat, alluvial land was already in use, movement of the agricultural frontier was of necessity mostly upslope where the danger of soil erosion always increases.

The largest development project in the expansion of sugarcane in Fiji was the expensively funded (US$26 million) World Bank project at Seaqaqa. The project was initiated in the mid-1970s on some 5000 ha (eventually 18,000 ha) of little used, largely forested, rolling to hilly land underlain by red latosols. At the inception of the project, the soils were recognized as erodible, infertile, and of poor water-retention capacity. Although careful soil management and appropriate land uses were incorporated into the plans for the Seaqaqa project, the realities of uneven topography, variable soils, careless bulldozing of the forest by contractors, inadequate training of newly settled farmers, and lack of attention to the particular requirements of each farmer and each holding have led to a variety of problems. These problems included underutilization of holdings, inefficiency in fertilizer use, serious soil erosion (e.g., 34 t/ha/yr over a 5-year period), increasing soil bulk density, and a significant decline in soil fertility that requires ever greater applications of fertilizer to maintain production (Bayliss-Smith and Haynes 1988; Clarke and Morrison 1987). See Table IV.1 for an overview of the impacts of a spatial expansion of agriculture.

b. Agricultural Intensification. The case example of Seaqaqa has been presented at some length to illustrate the nature of possible impacts from spatial expansion of agriculture. The example also suggests the alternative of agricultural intensification, which has its own potential impacts but does lead to greater crop production without more forest clearance or expansion of farming onto marginal lands. Modern industrial "Green Revolution" style of agricultural intensification is not as strongly developed in the Pacific as in some other parts of the world. Traditional Asian, labor-intensive methods (typified by traditional wet-rice production) are now less common in the Pacific than in pre-European times when taro and the larger aroid Cyrtosperma chamissonis (via kana in Fiji, babai in Kiribati) required large labor inputs compared with tapioca (manioc, cassava), a post-European introduction now widely grown.

Table IV.1. Impacts of spatial expansion of agriculture

Economic/ development goals	Increase crop production. Utilize undeveloped land. Spread development more evenly on a regional basis within a country. Increase employment, economic opportunities. Increase export crops. Import substitution (e.g., local beef production).
Project technical activity	Spatial expansion of agriculture activity (land-development projects, resettlement schemes).
Changes in the environment	Clearing of natural vegetation. Road building and other construction work. Movement of people. Introduction of crops, livestock. Cultivation, usually of marginal land (steep, infertile soils, remote).
Environmental impacts	Soil erosion/compaction, off-site sedimentation, decline in water quality. Loss of accumulated biomass and plant nutrients. Decline in natural biodiversity. Hydrological changes.
Impacts on human welfare	Settlers must adjust to new environment (physical, social, economic). Farming and transport costs may be high (fertilizer, remoteness). Inadequate services. Off-site health and economic impacts from sedimentation and degraded water quality. Increased downstream flooding possible.
Mitigation measures	Agricultural intensification (with its own set of problems). Firmer land-use planning. Improved erosion control. Better services, infrastructure, and more extension agents. Corridors or blocks of natural landscape left intact.

Many of the impacts of modern agricultural intensification result from the misuse of the inputs intended to increase production--specifically fertilizer, herbicides, and pesticides. Even if the agrochemicals are applied using safe equipment and in recommended amounts, their outflow from the agroecosystem can cause downstream pollution. Another impact associated with the Green Revolution is the loss of a range of varieties within each crop species, a process that occurs as plant breeders and development promoters press for the use of a variety that responds maximally to the inputs. See Table IV.2 for an overview of agricultural intensification.

Table IV.2. Impacts of agricultural intensification

Economic/ development goals	Increase crop yield to improve nutrition, increase exports, increase national and individual incomes, limit expansion onto marginal lands.
Technical activity	Intensification of agriculture.
Changes in the environment	In TRADITIONAL SYSTEMS: Increased manual labor. In AGROINDUSTRY (Green Revolution) SYSTEMS: Inputs of agrochemicals, extra-somatic energy, machinery, genetically standardized seeds. Increased production costs.
Environmental impacts	LOCAL: Toxic outflow of agrochemicals from agroecosystem, loss of organic matter in soil, increased vulnerability of yield to climatic variation, monocultural vulnerabilities to pests and disease, antipathetic to polyculture, soil erosion/compaction if no mulch, continuous cultivation, and heavy machinery. GLOBAL: Genetic "erosion" of seed variability, contribution to increased atmospheric carbon dioxide.
Impacts on human health and welfare	Immediate health menace from improper use of agrochemicals, water contamination from outflow, possible deterioration in local diet, possible loss of equity among farmers (rich favored), increased dependence, narrowed range of exports. Labor involution if traditional intensification.
Mitigation measures	Two GENERAL PRINCIPLES of increased self-sufficiency and diversity could include the following measures: Education for use of agrochemicals, integrated pest control, incorporation of nontillage and mulching to maintain humus level, erosion control practices, stress on cycling (not throughput), agroforestry, polyculture, increased biomass (agroforestry, alley cropping).

3. Forestry

So great is awareness of the rapidity and of the serious consequences of the loss of tropical forest from the Earth that little more needs to be said about it. In the Pacific, all SPREP country reports from high-island countries list deforestation or forest loss as a major concern. As the forests go, biodiversity diminishes greatly, endemic species become extinct, and the health of the whole landscape from mountain peak to reef deteriorates as the ecological services provided by forests disappear. It can even be argued that deforestation brings an aesthetic impact as the integrity of island landscapes is diminished by the loss of their crown of trees.

However, as noted near the beginning of this section, continued forest loss or forest degradation is inevitable. Both the timber and the land it stands on can be seen as assets that must be used for a nation's development. High-quality tropical woods represent accumulated biological "capital" that cannot be kept in a reserve bank of natural forest, although selective logging of high-value trees can be carried out in such a way that the TMF is not destroyed. Furthermore, the devaluation of a forest brought by the withdrawal of the best trees can be to some extent counterbalanced by enrichment planting, as exemplified by Fiji's planting of mahogany.

In other words, TMF management (in its infancy compared with temperate-latitude forest management) is in theory able to provide sustainable production within a context of fairly limited degradation and loss of natural diversity. The problem for tropical forestry has less to do with how to develop techniques to manage TMF (or plantation forests) on a sustainable basis than with how to prevent the conversion of all forestland to nonforest uses--a process whereby the one-time exploitation of accumulated biological "capital" of trees and forest topsoil all too frequently is followed by degenerative forms of agricultural land use.

Data on the rates of conversion in forested Pacific islands are scarce. Careless logging and clear-cutting play a role, but much forest conversion is the work of small-scale cultivators, who may gain access to previously remote areas along logging roads. Forest clearing is carried out in part under the simple demands of increasing population densities but also arises in part from development pressures such as the growth of the ginger-export market in Fiji or the expansion of livestock, which may take over lowland garden areas and push cultivation farther upslope.

It follows that the mitigation of environmental impacts caused by bad logging practices and conversion of forestlands rests less on technical ameliorative measures of the processes than on total land-use planning or zoning that divides remaining forestlands into classes that optimize their functions for society. Various terms are used, but the classes generally include the following four functions:

- Preservation Forests (parks, reserves): Forests that should be preserved because they are unique ecosystems containing rare and endangered species; they are part of a nation's or of the global "natural heritage." Biological inventories are required as a basis for their establishment.

- Protection Forests: These occupy lands where permanent forest cover is necessary to provide ecological services of soil protection and watershed maintenance and to retain aesthetic quality. Any lands steeper than, say, 30 degrees would certainly fall into this category as would hill lands on highly erodible soils.

- Production Forests: Native or semi-native forests managed for sustained production of one product or for multiple use.

- Conversion Forests: Native forests that are exploited prior to their transformation to other land uses, which could include plantation forests of exotic trees or secondary forest used for subsistence agriculture and serving as buffer zones around Preservation and Protection forests.

Establishing these categories of forests on a firm basis requires legislation, forest inventories, monitoring, and control mechanisms, none of which is adequate in the Pacific. Until they are, forestry development projects involving extensive logging should be minimized, and small-scale conversion of forestlands should be limited to the extent that is technically and politically possible.

The following is excerpted and adapted from Hamilton (1988):

> The complex, primary, humid tropical forest has been called a nonrenewable resource, since human disturbances result in a forest that differs from the original in species and structure. Humid tropical forests regenerate, but the altered or secondary forest that results is not the same kind of forest. The primary humid tropical forest is "fragile" in this sense.
>
> Because of the great diversity of species characterizing most of these forests, the number of individuals of each species in any one area tends to be small. This suggests that a disturbance such as tree harvesting can result in loss of species in the area. If the area happens to be one of endemism (an only occurrence of a species), then extinction of one or more species is possible.
>
> Harvesting of primary humid tropical forests must be done in ways that assure the continuance of as much biological diversity as possible, and with minimal species loss.
>
> Yet the primary humid tropical forest is not disturbance free. Natural windthrow and gaps created by death of large upper canopy trees are a continuous feature of forest dynamics. Moreover, many of these forests have experienced, and periodically will continue to feel, the impact of more severe disturbances such as cyclones, volcanic ash or lava deposits, landslips, or unusual drought (perhaps coinciding with fire as in the Great Fire in Indonesia in 1983).

In most parts of the world, the humid tropical forests are not uninhabited or unaffected by humans. Even in those areas that we think of as pristine rainforest, there has often been a continuous but relatively low level of disturbance by primitive forest dwellers, or dwellers adjacent to the forest, who hunt, gather, and cut small amounts. In some cases, a low-disturbance forest gardening has been practiced wherein useful plants (e.g., yams) have been planted in the forest. In other cases, a sustainable, long, fallow shifting cultivation has produced a secondary humid tropical forest. Forest farmers may have occupied an area and then left so that the forest now appears pristine.

Although many humid tropical forests have experienced continuous or periodic disturbance, additional human impact almost invariably will reduce the biological diversity and result in loss of species from the area. The obvious answer to this concern is to set aside preserves--substantial representative samples of the various kinds of the world's humid tropical forests and protect them as much as possible from major human intervention. This should be done as part of a global network of parks and preserves with humid tropical forests.

Aside from these preserves and parks, the need for forest products in development and subsistence areas makes it operative that forests be exploited. The subject of this section is <u>how sustainable forest-products harvesting can proceed</u> in those forests allocated to production. These forests will be allowed to remain as forest only if they are useful. While some will be valued sufficiently for their soil and water or wildlife protection functions to merit continuance as forest, most will be required to do more--to produce directly useful products that can be valued in the marketplace or in the daily lives of people. In this context (realizing that these will be altered forests), a strategic development of sustainable use would involve keeping the area in forest through repeated harvests, with little or no decline in site productivity and with little or no adverse impacts off-site.

To maintain forest productivity and minimize adverse off-site impacts in the humid tropics, the way in which the wood products are removed is of greater importance than the amount cut and the system of cutting. Of particular significance is extraction with minimum erosion and minimum channeling of water off-site. This "minimum," of course, has economic limits. Prevailing logging practices in humid tropical forests, however, pay little attention to measures for control of water and erosion. Many useful practices can be implemented at little additional cost to the logger; others will involve major modifications of the logging and will incur costs. In view of the societal benefits of sustainability and of reducing downstream costs, governments may either enforce better logging practices (thereby reducing the profit to the concessionaire) or offer financial inducements for following conservation logging guidelines.

Within a narrow financial analysis, the increased costs incurred under such a scenario of sustainable harvesting may suggest that there is no economic future in managing humid tropical forests. Such analysis has sometimes led to clear-cutting and conversion to planted forests of exotics. However, extended economic evaluation that accounts for as many of the indirect and nonmarket values as possible, and which internalizes the off-site externalities, may well show favorable benefit-cost ratios from managing the natural forests along such sustainable constraints.

One cannot adopt short-term and narrow accounting when dealing with this many-valued forest biome, and until more is known about the many potential and indirect benefits, harvesting should conform to a conservative policy (definition: within safe bounds; adhering to sound principles; involving little risk).

4. Agroforestry

Agroforestry is a new word for what is in the Pacific a very old practice. Pacific island agriculture has traditionally incorporated trees into gardens of annuals or quasi-annual crops. What appear to be spontaneous forests on atoll islets or the inhabited village and garden areas of the high islands are often human-created forests. They contain a great variety of trees that supply many useful products and foods as well as provide ecological services such as stabilizing soil and producing organic matter to enhance soil fertility and the soil's physical condition.

Thus, when agroforestry is recommended as part of a formal development project (as it is very widely now), an EIA in the usual sense is not required for the purposes of agroforestry projects are generally those found in the "mitigation" section of an EIS, and the environmental impact of agroforestry is generally ameliorative, not deleterious. Further, as noted, the "development" is already widely known and practiced in a variety of forms, using a wide range of tree species in both traditional subsistence systems and commercial production of, for example, coconuts, cacao, and coffee. Nonetheless, formal agroforestry projects should not be dismissed, for the monocultural emphasis of much commercial agriculture acts to eliminate trees from modern agricultural landscapes, a process described as "agrodeforestation" by Thaman (1988:145).

Agroforestry, now an "in" topic in international development circles, has become the subject of an explosive growth in research (e.g., at ICRAF [International Council for Research in Agroforestry] in Kenya; IITA [International Institute of Tropical Agriculture] in Nigeria; CATIE [Centro Agronomico Tropical de Investigacion y Ensenanza] at Turrialba in Costa Rica). Because the growth of literature on the suject has been equally great, it is impossible in this section to discuss the many functions of agroforestry and the almost limitless mix of trees, crops, and livestock in time and space that can make up agroforestry systems. Instead, in this section with its stress on soil erosion, the focus will be placed on a single agroforestry approach: alley cropping (e.g., see Kang et al. 1984; Pacardo 1985).

Alley cropping is an agroforestry system in which food crops are grown in alleys formed by rows of trees or shrubs, which are cut back when the crops are planted and kept pruned to reduce competition with crops. When no crops are growing, the trees and shrubs are allowed to grow freely and cover the land. The system is designed to stabilize on one piece of land the traditional shifting cultivation system, which does not require extra-system inputs. Leguminous trees or shrubs are often used in the system because of their nitrogen-fixing characteristics (e.g., Leucaena leucocephala, which is a common, small leguminous tree in the Pacific). The benefits offered by trees in alley cropping include:

- Green manure from tree prunings for the food crops, thus adding plant nutrients from deeper soil layers.
- Mulch and shade suppress weeds during fallow.
- Browse for livestock, staking material, and firewood.
- Addition of biologically fixed nitrogen to the soil.
- Barriers to control soil erosion when planted along the contours of sloping land.

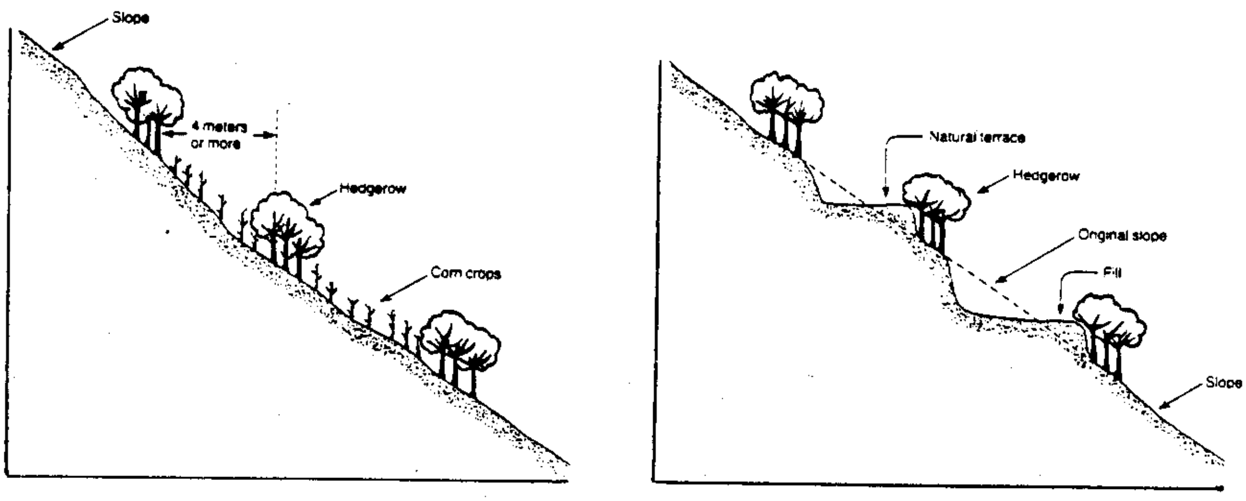
Figure IV.1 illustrates the effectiveness of this last function, as described by Vergara (1982) for the Philippines, where the Leucaena are pruned about every 60 days and the cuttings chopped into smaller pieces and returned to the soil to decompose. The space between the double rows of Leucaena is plowed to prepare the land for corn. Because of the trees, the plowing must be along the contour lines, rather than up and down slope, which is the usual practice. Continual plowing along the contour lines results in forming natural terraces (Figure IV.1B). An unforeseen disadvantage of Leucaena was the outbreak of psyllid insects that killed many trees and defoliated others. This illustrates the risk of introducing a foreign species in development projects.

IV.B. COMMERCIAL FISHERIES

(prepared by Paul Holthus)
(see also ADB Guidelines for Fisheries and Aquaculture in the Appendix)

1. Development Objectives

Commercial fisheries development in Pacific island countries has a high priority in government development planning and among regional



A. Arrangement of corn and <u>Leucaena</u> (in a double row) running along the contours of a slope.

B. Formation of natural terraces on the slope after 3 years of continuous cultivation.

Figure IV.1. <u>Leucaena</u> corn alley cropping in the Philippines (<u>Source</u>: Vergara 1982:7).

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and international development aid and technical assistance organizations. This section covers the following types of fisheries development:

- small-scale, in-country commercial fisheries;
- large-scale, export-oriented commercial fisheries;
- acquaculture and mariculture; and
- specialized fisheries (bêche-de-mer, aquarium fish, precious corals, stony corals).

The objectives of fishery development generally include:

- development of fisheries toward optimum sustained production;
- improved animal protein availability and diet;
- increased employment, especially in remote rural areas where alternatives are limited;
- improved trade and foreign exchange;
- increased economic independence; and

- a more equitable lifestyle (improved well-being for rural producer groups).

The rest of this section will deal only with the environmental aspects of fisheries development which are particular to the commercial fisheries sector, as summarized in Table IV.3. Impacts and mitigation of many other fisheries development-related activities are dealt with more directly in the following sections of the manual:

PORTS AND HARBORS (includes fishing fleet state facilities)
ENERGY (includes oil storage and transfer)
COASTAL CONSTRUCTION (includes shore structures and facilities)
ADB GUIDELINES: FISHERIES AND AQUACULTURE in the Appendix

2. Development Activity (Technological Change) and Environmental Consequences

a. Small-Scale, In-Country Commercial Fisheries. Small-scale fisheries development objectives are often achieved by introducing or expanding supplies of boats, motors, fuel, or gear technology and techniques. To process the increased harvests obtained from these infusion of materials and technology, various types of physical facilities and infrastructure may also be required. These include (1) the addition or expansion of fish-processing facilities to clean, fillet, freeze, chill, salt, dry/smoke, pack or store the harvest, and (2) the creation or expansion of port areas, shore facilities, and infrastructure (roads, power, water supplies). The development of facilities and infrastructure entails activities with potential impacts during both the construction phase (e.g., land clearing, land filling, habitat removal, dredging) and during operations (e.g., effluent discharge, power and water demands, solid waste disposal, and boating activities).

The environmental consequences of small-scale fisheries development include a general growth in fishing pressure in areas which may be already heavily fished or an expansion of fishing activities to areas previously not fished commercially. This can result in overexploitation of sought-after species and an increase in incidental damage to habitat (e.g., anchor and diver damage to reef corals). The availability of a sure cash return for consistent local fish supplies may lead to, or add to, use of destructive fishing practices, such as fishing with dynamite or poison, which cause direct, long-term destruction of coral reef habitats. Increased amounts of fuel and oil will be stored, transported, and used, heightening the risk of pollution from major spill accidents or chronic long-term pollution from numerous minor spills.

Introduced or subsidized gear includes metal fish traps and monofilament gill nets which, when lost or abandoned, will not deteriorate for many years. These "ghost nets" and "ghost traps" can continue to catch fish or marine turtle and dugongs, uselessly depleting these resources, and can create a navigation hazard for boats. Gill nets with too small a mesh size will catch juvenile fish

Table IV.3. Environmental consequences of fisheries development

Activity	Consequence to environment	Environmental impacts	Human health and welfare impacts	Mitigation
Increased shipping activity in ports and nearshore waters	Chronic or major accidental discharge of fuel oil	Destruction/degradation of valuable coastal habitats, tourist amenities	Reduction in fish available	Adequate regulations
			Health risk due to contamination of fishes	
			Lost income from tourism	Contingency plans and response equipment
				Reduce navigation hazards
Introduction of alien species	Predation on, replacement of, desired species	Reduction of preferred species populations	Reduction in food supplies	Develop and adhere to strict guidelines for consideration and quarantine of proposed introductions
	Introduction of disease, parasites	Creation of pest populations		
Creation of wage labor force	Increased urban development			
Introduction of cash economy dependence in rural areas			Degradation of traditional lifestyle and subsistence economy	Involvement of local people in fisheries development planning
Destructive fishing practices, improper aquarium fish harvesting, reef coral harvesting	Destruction and degradation of coral reef community	Reduction in fish populations	Less fish available for consumption	Adequate regulations and enforcement
		Reduced aesthetic quality of reef environment	Loss of tourism revenue	Education and training program for fishermen

Table IV.3. (continued)

Activity	Consequence to environment	Environmental impacts	Human health and welfare impacts	Mitigation
Increased availability of boats, motors, fuel, or gear to fishermen	Increased exploitation of preferred species	Overfishing	Reduction in fish available to local population	Fisheries management for sustained yield
	Increased damage by divers, anchors, fuel spills	Degradation of valuable coastal habitat		Education program
Construction of port and shore facilities, fish-processing plants, infrastructure, aquaculture facilities		See "Coastal Construction, Ports and Harbors"		
Effluent discharge from fish-processing plants, aquaculture ponds		See "Waste Management"		
Freshwater requirements of fish-processing facilities	High demand on limited freshwater resources	Overuse of freshwater sources	Lack of adequate supplies for population	Require development of freshwater supplies and infrastructure as part of facilities development

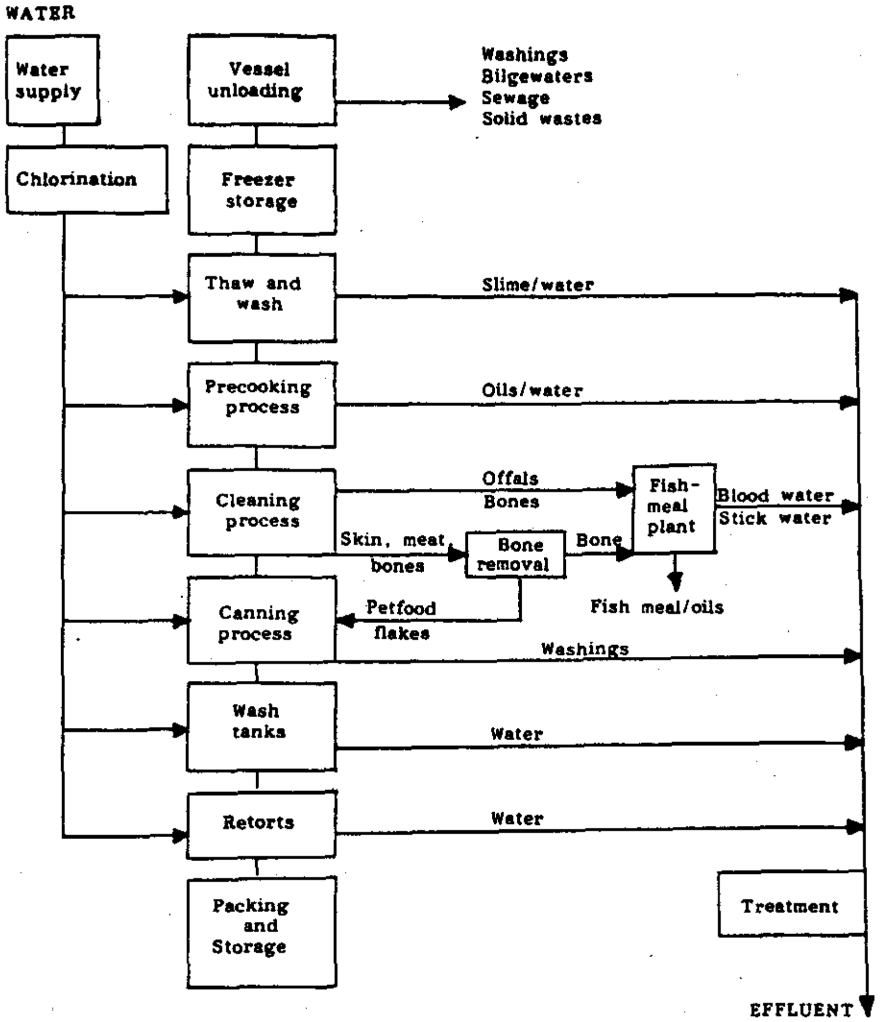

Figure IV.2. Basic tuna canning process: Water supply and waste disposal. (Source: Hundloe and Miller n.d. Reprinted with verbal permission from Hundloe.)

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before they have grown to adult size of value for consumption, adding to the problem of overexploitation.

b. Large-Scale, Export-Oriented Commercial Fisheries. This development involves most of the preceding activities, but particularly may include the construction and operation of large, centralized, industrial fish-processing plants (usually canneries/fish-meal plants). These plants require large supplies of fresh water (600,000 to 2 million liters/day) for fish cooking and cleaning, plant and equipment washing, steam generation, cooling, retorting, thawing, and transport of waste materials (Figure IV.2). The wastewater is subsequently discharged as effluent containing organic matter (offal and blood), oils, grease, bacteria, nitrogen, and suspended solids. The consequences of these inputs depend on the dilution and dispersion of the effluent and the quality of receiving waters. If not sufficiently diluted and dispersed, fish-processing effluent and solid wastes affect receiving waters and their organisms through (1) increased biological oxygen demand from organic matter decomposition or eutrophication, which can result in anaerobic conditions and fish kills; (2) turbidity, which reduces light available for photosynthesis by algae, corals, seagrasses, and other organisms; (3) settling out of solids, which can smother bottom-dwelling organisms; (4) oil and grease slicks, which create aesthetic problems; and (5) contaminated shellfish, which are a health hazard to human consumers of the shellfish.

Foreign companies are often licensed to harvest marine resources for export. These may involve purse seining, long-lining, pole and line fishing, or bottom trawling. Trawling is of special concern due to the physical alteration of the benthic environment from the dragging of trawl nets across the bottom which results in long-term changes to fish community composition. Foreign licensing may lead to significant increases in shipping activity and port operations (e.g., fuel storage and handling, bilge washing) with attendant problems (see "Ports and Harbors"). In addition, development of pelagic fisheries will usually require bait from inshore bait fisheries.

Development of both small-scale and large-scale fisheries activities creates job opportunities during the construction of ports, plant facilities, and infrastructure. Large-scale fish processing plants require an available work force for wage labor, often drawing in labor from rural areas, adding to unplanned urban development and its consequences.

c. Aquaculture and Mariculture. Aquaculture development involves construction of ponds and other shore facilities and effluent discharge during operations. Some aquaculture and mariculture involve the introduction of exotic species. Other schemes result in abnormal concentrations of fish or shellfish either (1) in artificial habitats (aquaculture ponds); (2) through modifications of natural areas (addition of larval recruitment surfaces, enclosing natural embayments); or (3) by addition of organisms to natural habitats (seaweed farms, reef seeding, clam grow-out areas).

The direct environmental consequences of aquaculture development are linked to the construction of facilities, including the loss of coastal habitat such as mangroves, seagrass beds, fringing reef flats, and salt marshes (see "Coastal Construction") and in nutrient-rich effluent discharge (see "Waste Management"). The accidental or planned introduction of alien marine species for aquaculture or mariculture can have disastrous, unforeseen impacts on marine ecosystems. These include predation on, or replacement of, desired species and introduction of disease, parasites, or associated pest species. The concentration of large numbers of naturally occurring exotic species through mariculture projects, reef-seeding operations, or aquaculture grow-out areas can facilitate the spread of disease in the aquaculture populations and subsequently into natural stocks. Concentrated aquaculture operations can also result in other ecosystems imbalances (e.g., increase in organisms that prey on the cultured species).

d. Specialized Fisheries. A number of specialized fishery activities may be part of Pacific island development plans, including bêche-de-mer harvesting and processing; aquarium fish collecting and export; harvesting of stony corals for tourist curio sale (either in-country or overseas); export of specimens for medical uses; or deep-water precious coral harvest for jewelry making.

Bêche-de-mer and other fish-smoking operations require a supply of fuelwood which may not be available in large quantities on small islands. The overexploitation of limited hardwood or mangrove stands to supply fuel can deplete these habitats, especially in the case of mangroves, which provide shelter and nursery for useful organisms. The water remaining from bêche-de-mer processing can be harmful to marine organisms if dumped in shallow, near-shore waters, resulting in fish kills due to the concentration of toxic substances.

The collection of aquarium fish can result in direct, long-term destruction of the coral habitat of the fish if improper collection techniques (e.g., use of sodium cyanide or other poisons that break apart coral heads) are employed. The collection of stony corals directly destroys coral reef habitat by removing coral colonies which are the building blocks of the reef structure and a major component of the reef community. Precious corals are extremely slow growing and relatively aggregated in their distribution and are thus highly susceptible to overexploitation.

3. Impacts on Human Health and Welfare

The effects of fisheries development on human health and welfare are not often obvious or acute. However, commercial fisheries development projects do have long-term social and economic implications which should be considered.

Human welfare is most directly affected by the environmental consequences of commercial fisheries development activities which reduce the quality or quantity of fish available for local consumption. Serious consequences include overfishing by commercial fisheries activities and destruction or degradation of fish habitat (including water quality). In some instances (e.g., effluent pollution from canneries), human health may be endangered by contamination or spoilage of seafood.

Traditional lifestyles and subsistence economies may be disrupted or subverted by the introduction of cash economies from rural fisheries development schemes or from the employment available in industrial scale fish-processing plants or canneries.

Fisheries development projects often require substantial capital input to acquire equipment, build facilities, or install infrastructure. However, many fisheries development projects fail or do not live up to expectations for a variety of environmental, social/cultural, or economic reasons. The capital is usually irretrievably invested and is thus unavailable for other forms of sustainable development in the fisheries sector or elsewhere.

4. Mitigation of Environmental Consequences of Commercial Fisheries Development

a. Small-Scale, In-Country Commercial Fisheries. Overexploitation of fisheries stock and long-term depletion of the resource base can be mitigated through fisheries management for optimum sustained yield. This can only briefly be mentioned here and includes restricted harvest (minimum size limits, catch quotas, seasonal closures), gear restrictions (trawl bans, minimum gill net mesh size), closed areas (permanent reserves, periodic closures), limited entry systems (annual or permanent licensing, exclusive access), and prohibited practices (use of explosives, drift netting). It is critical that the role of traditional fishery management practices be considered and incorporated as much as possible in modern fisheries development as aspects of many of these practices can assist to reduce the adverse environmental and social/cultural impacts of fisheries development activities.

Destructive fishing practices must be strongly discouraged through active education on the impacts of dynamiting, poisoning, and drift netting. Strong application and enforcement of legislation at both central and local government levels that prohibit such practices are also required. Incidental anchor and diver damage from increased fishing activities can be mitigated through programs to inform fishermen of the effects of the damage and by the installation of mooring buoys and designation of mooring areas in heavily used areas.

The problem of "ghost fishing" for fish, sea turtles, and dugongs after nets or traps have been lost or abandoned can only be countered by a program to educate fishermen against purposefully abandoning gear.

b. Large-Scale, Export-Oriented Commercial Fisheries. Mitigating impacts from the construction or expansion of ports and harbors for in-country or foreign fishing fleets and measures to reduce and avoid impacts from the transport, storage, and handling of fuel oil are addressed elsewhere in this manual (see "Ports and Harbors"). Reducing or avoiding adverse effects from the actual construction of shore facilities for fisheries-related development, including fish processing and aquaculture facilities, is also covered (see "Coastal Construction").

Mitigating the effects from the operation of fish processing facilities depends on the size and location of the activity. Most small, remote fish-processing operations discharge limited amounts of wastewater into receiving waters with adequate assimilative capabilities. For existing facilities, a program of (1) water quality monitoring (for suspended solids, oil and grease, dissolved oxygen, nitrogen ammonia/total nitrogen and coliform); (2) marine ecological surveys (especially of benthic organisms); and (3) analysis of edible shellfish (if present) should be conducted to confirm that adverse impacts are at acceptable levels. For proposed facilities, water circulation studies should be carried out to determine if receiving waters are able to disperse and dilute the projected quantity and type of effluent.

If receiving waters for existing or proposed large-scale fish-processing facilities cannot assimilate the quantities of wastewater generated, a number of mitigation measures can be employed. Primary among these are (1) waste reduction by recycling offal into usable products (e.g., fish meal); (2) water use reduction (i.e., minimizing water transport of fish and wastes); and (3) physical separation of fish from sources of wastewater (e.g., keep fish separate from ice, thaw frozen fish with air).

If effluent is unavoidable in fish-processing facilities, the simplest treatment method is grinding of solids. Grinding aids in waste assimilation by facilitating the dispersel of solids and accelerating decomposition. Further treatment methods include (1) screening, (2) biologial systems, and (3) air flotation. All of these methods create solid and sludge residues which are very difficult to dispose of in landfills and must be barged to sea for dumping because of their high water content. Screening involves passing wastewater through static, vibrating, or rotating screens of various mesh sizes. Biological treatment methods include (1) aerobic treatment by settling pond, (2) activated sludge, (3) biological filter or disk, or (4) trickling filter. Dissolved air flotation is a complex, expensive process with high waste recovery rates, if the system is properly maintained and operated. It is used in industrial scale tuna-processing plants, such as those in American Samoa.

c. Aquaculture and Mariculture. Nutrient-rich effluent from intensive aquaculture operations in the Pacific generally should be able to be disposed of in receiving waters with adequate assimilative capacities. If monitoring or preconstruction studies show that adequate dilution and dispersion are not, or will not be possible, aquaculture effluent can be treated by the biological treatment methods described for fish-processing plants.

Mitigating the often unforeseen consequences of the introduction of alien species for mariculture or aquaculture requires that (1) the biology and life history of the introduced species is known; (2) the introduced species be assessed for overall ecological impacts, cultural acceptance, edibility, catchability, and marketability; (3) introduced specimens be regularly monitored for disease, parasites, or associated organisms; (4) sterile hybrid organisms be considered; (5) quarantine procedures and escape-proof facilities be developed for initial introductions and experiments; and (6) the public be fully informed before introductions take place.

The impacts associated with concentrating large numbers of organisms in mariculture operations, grow-out areas, or through reef-seeding requires monitoring of the health of the introduced organisms and the surrounding natural stocks. If disease or parasites spread, reducing the artificial populations may be the only mitigation measure possible.

d. Specialized Fisheries. Damage from aquarium fish collecting can be minimized by licensing and catch monitoring programs, with associated training in acceptable harvesting techniques. Harvesting of stony corals requires strict licensing with quotas, area restrictions, and monitoring to ensure that removal of these important components of the reef community occurs only at acceptable levels.

Adverse effects of bêche-de-mer processing can be avoided by determining if an adequate, sustainable source of fuelwood for smoking/drying is available before operations commence. Wastewater from sea-cucumber processing should be dumped away from lagoons, lakes, rivers, or shallow groundwater sources.

5. Summary

The foregoing environmental mitigation measures will reduce the depletion of fish stocks which may result from commercial fisheries development activities, lessening the impacts associated with reduction of fish stocks available for subsistence or artisanal harvesting.

The social/cultural impacts of fisheries development activities can best be anticipated and mitigated through public input into development planning. Thorough analysis is also needed to ensure the economic viability of commercial fisheries projects to avoid the depletion of limited financial resources.

Finally, it must be recognized that fisheries development is dependent on the quality of the marine environment which supports the fish. Thus, all development activities with effects on nearshore waters and habitats need to be considered in the context of their impacts on fisheries resources and activities.

IV.C. TOURISM

(prepared in part by John Harrison and Rory Frampton)

1. General Considerations

a. Development Objectives. Resorts are primarily developed for their financial return. Economic benefits to local communities through enhanced employment opportunities are cited most often as the principal advantage of such projects. In fact, weighing costs and benefits in resort assessments usually comes down to balancing jobs against other impacts.

Tourism is the development sector where financial success and environmental quality are most clearly aligned. The very features that attract customers are those threatened by careless development. The justification for expenditures to protect the environment should be obvious. In fact, it may be necessary and profitable to do considerable cleanup work in order to produce an attractive tourist destination from a currently degraded site.

b. Components. The central components of a resort are the actual structures that house and support guests. Adjacent to rooms or cabanas may be various service and recreational amenities such as restaurants, golf courses, swimming pools, and tennis courts. The resort will require the provision of basic utility and service infrastructure such as water, waste disposal (sewage and solid), power, and roads. Another vital component of a resort complex is relatively efficient access to and from major tourist markets by major airports, roads, or ports.

As noted earlier, the success or failure of a resort project usually hinges on the natural amenities in the surrounding environment, especially in tropical environments such as found throughout the Pacific islands. Parks and natural resource areas, scenic vistas, archaeological and historic sites, beaches, and coral reefs are all potential attractions. Given the competitiveness of tourism in the Pacific islands, successful resort development demands that these natural amenities are maintained in a clean, pollution free, and safe environment. Recent marketing strategies for tropical tourism promote the location of resorts at or near white sand beaches. Placement of buildings and permanent structures near beaches often aggravate beach erosion, construction of shore protection structures, and property damage. Hence, resorts situated near beaches require proper siting and setbacks to protect beaches and resort property.

c. Environmental Factors Influencing, and Influenced by, Design and Site Location. Because of the nature of tourism, sociocultural factors influence resort development more than port and harbor or energy development. Certainly, aspects of the natural environment are important; but because the primary activity involves human interaction, the need for a good understanding of existing sociocultural characteristics takes on greater significance. Some important influencing factors are as follows:

- The quality of natural amenities in the area. As previously mentioned, these are the attractions upon which much of the success of tourism depends. The capacity of these amenities to withstand the intrusion of large numbers of tourists should be closely examined. The placement of permanent structures close to sandy beaches should also be controlled.

- Public works and utilities infrastructure. Resorts are dependent on infrastructure and services that closely resemble those available in the visitors' home country. Potable water, electrical power, and modern plumbing are virtual necessities. Thus, information is needed on the availability and capacity of existing infrastructure in and near the project area.

- Labor supply. Because it is service based, resort development is dependent on an adequate supply of labor. If local labor pools are insufficient, where will immigrant workers come from and where will they live? If labor is to be supplied locally, in what ways will this new type of work and associated living patterns affect traditional customs and social patterns? What training opportunities for local residents will be provided to allow them to assume higher pay and higher skilled jobs?

- Existing uses of the surrounding area, especially those to which tourists will be attracted. For example, coral reefs, which serve as traditional fishing grounds or natural scenic areas and are of cultural or religious importance, may be subjected to heavy tourist use, disrupting traditional or artisanal activities. Additional activities or entertainment that tourists might pursue include traditional, religious, sacred, or culturally important sites, local crafts, art, music, and drama.

d. Impacts

Construction/short-term impacts. Activities include overall construction and residuals or waste disposal from these activities (e.g., bulldozer operations, cranes, supply trucks, workers, which generate minor oil spills, dust, sludge, and sewage). Oil spills and other wastes may contaminate soils and water supply when rains come. Runoff has the potential to contaminate ground, surface, and nearshore marine waters. Sewage from workers also poses a substantial threat to these waters. Contamination of water supplies could lead to human health problems, especially bacterially related ones from sewage spills. Contamination of water supplies could be very serious if a shortage of potable water occurs in the area. Therefore, there should be strict controls on disposition and monitoring of oil and sludge. Temporary lavatory facilities should be maintained for workers. During construction, a large amount of labor will be necessary; if this resource is not available locally, then workers must be brought in and housed. However, an influx of immigrant labor has the potential to introduce new diseases and different, conflicting morals and lifestyles. The increase in population will also place an additional demand on infrastructure and services. Temporary housing structures and roads could lead to erosion problems. If supplied locally, labor resources will likely be drawn away from primary productive activities of either economic or subsistence significance such as agriculture or fishing. Training and use of local residents as laborers should be maximized.

Operations and associated long-term impacts. Overall activities of day-to-day operations of a resort complex will require a certain level of infrastructure and public services. Demand will increase on existing sewer, water, waste disposal, and power facilities. If these facilities are not capable of handling this increase, sewer and waste disposal facilities could overflow or water and power could be diverted from existing uses. Serious deterioration could occur in either the physical or social environment. If local government is faced with the costs for providing new services, given the almost universal limited supply of government funds, the monies will have to come from other programs or from the private/development sector. Developers could contribute to or provide for their own services or pay the incremental costs to upgrade existing municipal facilities. However, caution must be taken to assure that private facilities are not substandard. Effective land-use planning could guide infrastructure development compatibility with other large-scale developments both sequentially and spatially.

Tourist activities will increase access to traditional recreation, subsistence, or economic areas of importance. For example, activities on coral reefs for souvenir collection or for reef walks can significantly alter or destroy existing habitats unless controlled. Litter could also become a substantial problem unless there are regularly scheduled cleanups. Loss of available habitats could significantly reduce the local fish population, which might translate to a loss of an important economic or subsistance resource. Increased access for local fishermen could also lead to overfishing in an area. These negative impacts can be lessened through educational and public awareness programs on the fragile nature of these systems and of the potential damage that could be caused by certain activities. Resource inventories could also be accomplished to identify potential tourism attractions situated away from known important subsistence sites, thereby avoiding any conflicts.

A resort complex will also generate an increase in service-based employment, including a shift of resources, labor, and capital from primary production to agriculture; around the clock work shifts commonly filled with female workers; and an increasing reliance on cash income and new opportunities for social mobility. Depending on existing culture, the new employment and increase in cash income might also result in less reliance and obligation on traditional kinship ties. New work shifts will alter existing lifestyle patterns and family relationships. A widening of social gaps is possible if outsiders are given higher level jobs and locals are hired only for wage labor.

Table IV.4 summarizes the consequences to the environment of tourism development.

2. Case Studies

a. Large-Scale Tourism Development on a River Delta Island, West Viti Levu Island, Fiji

Background. The southwestern "Gold Coast" of Viti Levu has emerged as the major tourism region of Fiji. The gateway for visitors to the region is the Nadi International Airport near the northern end of the Gold Coast. Although the region offers a number of visitor amenities and attractions (shopping, condominiums, beaches, dunes, rivers, rainforests, offshore islands, and resorts), there were no luxury beach resorts in Nadi until recently. The town of Nadi is situated near the mouth of the Nadi River, which terminates into a large mangrove forest and delta system. White sand beaches are rare, and one of the nearest beach systems is located off the ocean side of Denarau Island, a large delta island off the northern fork of the Nadi River (see Figure IV.3). It was here that Nadi's first two luxury-class beach resorts were opened during the past 2 to 3 years. The island is low lying and the delta serves as a broad natural

Table IV.4. Environmental consequences of tourism

Activity	Consequences to environment	Ecosystem impacts	Human impacts	Mitigation
<u>Tourism: Long-term concerns</u>				
Solid waste disposal	See Ports & Harbors			
Sewage disposal	See Ports & Harbors	Increased groundwater contamination	Increased local infrastructure costs	User/impact fees
Land-use changes	See Ports & Harbors; enhanced access/high density usage			
Tourist activities ● sightseeing ● reef walks ● souvenir collection	● enhanced access ● increased contact with different cultures and lifestyles	● resource depletion ● change in ecosystem structure ● degradation of important cultural/historic or recreational areas	Welfare losses ● commercialization of cultural or religious practices ● quality of life ● subsistence ● economic (fisheries)	● education and information ● ensure compatibility with community through participation ● compensation in money or land
Employment of local residents	● shift of labor resources from production to service ● round-the-clock work shifts	● loss of productive capacity in other work ● change in lifestyle ● dependence on imported goods	● disruption of traditional family values ● cultural conflicts ● social differentiation ● reliance on cash income ● new mobility	● employee training and upward mobility
Employment of immigrant labor	● increased population		● housing shortages ● overburdening of infrastructure ● social gaps (outsiders fill high-level jobs)	● housing impact fees ● employee training ● employee interpretation
Landscaping	Fertilizer/pesticides	● toxicity/habitat loss ● eutrophication	● public health risk ● welfare losses 1. subsistence 2. recreation 3. economic (fisheries)	Chemical product management; intercept and treat runoff water

Tourism: Construction/short-term concerns

Site clearance/ grading	See Ports & Harbors • altered drainage characteristics	• degraded and coastal surface • instream and coastal habitats/species loss	• welfare losses 1. subsistence 2. recreation 3. economic (fisheries) • catastrophic risk 1. flood 2. loss of landform stability	• avoid stockpiling in natural swales • revegetation • grading controls 1. drainage berms 2. settling basins
Construction activities	See Ports & Harbors			
Labor importation	See Ports & Harbors			
Landscaping	• introduction of exotic species • fertilizer/pesticides	• displacement of indigenous, rare endemic species • toxicity: species/habitat loss • downstream eutrophication	• natural/cultural resource loss • welfare losses 1. subsistence 2. recreation 3. economic (fisheries, tourism)	• use of native plants • management of chemical products

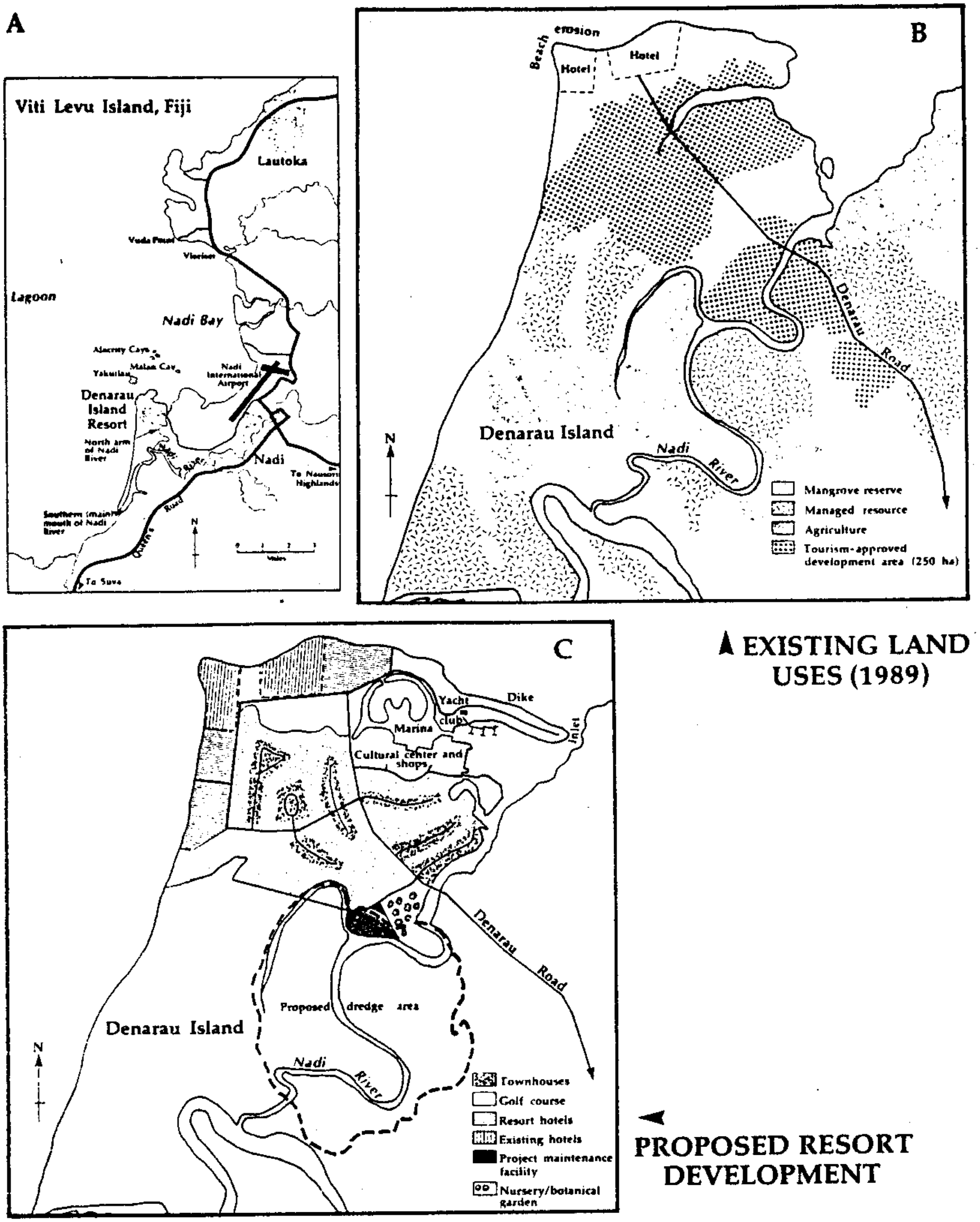

Figure IV.3. Proposed large-scale resort development on Denarau, a river delta island west of Viti Levu Island, Fiji. Map A is a vicinity map of the region where the proposed resort would be located. Map B shows the existing land-use designations and major resource categories including mangroves, lagoons, river, beaches, agricultural lands, and the existing resorts. Map C shows how the proposed resort features would modify the existing environment. The proposal includes three additional hotels, a protective dike, marina, townhouses, shopping center, cultural center, and a golf course. The proponents' preferred dredging area within the mangrove reserve is also shown.

floodplain during intense rainstorms. The delta islands and offshore coral islands in the lagoon are protected by a barrier reef system about 10 to 20 km offshore to the west. Nevertheless, the delta islands are vulnerable to typhoons approaching from the northwest and riverine flood inundation from the river. The interior of Denarau consists of floodplains, bottom lands, salt marshes, mangrove associations, and low lying dune systems closer to the beach. The Fiji Government has zoned most of Denarau Island for tourism and has approved additional proposed resort development for the island. To the southeast of the island closer to the river mouth are several hundred acres of prime mangrove forest designed as protected reserves (see Figure IV.3). Several small Fijian villages are situated in the delta, and many villagers claim fishery and foraging rights to the mangroves. The villagers own the delta island and mangroves, and resort development requires compensation for lease of lands and loss of fishery rights and other resources. A few of the villagers work at the existing resorts that include tennis courts, a beach boat landing to shuttle passengers to and from the offshore island resorts, and two 200-room hotels.

Proposed resort expansion. A major expansion of resort development encompassing the remainder of Denarau Island is now being proposed (as of June 1989), including three new 300-room hotels, a cultural center, a golf course, a shopping center, townhouses, a boat marina, utilities, drainage improvements, roadways, and shore protection structures such as a large dike to protect proposed resort improvements from storm surge and wave damage. The first phase of construction involves dredging and filling to raise the entire island (except for the existing resorts) by an average of 1 m. The proponents propose dredging 130 ha of the mangrove forest reserve to obtain most of the fill material to raise the island. The proposal would convert the mangroves into a large lake with a water depth of about 3 m. The proponents advocate the massive dredge-and-fill operation to protect the new resort from inundation from storms and possible sea-level rise from global warming. Alternative sites to obtain the fill material were only superficially examined. Large sand deposits are known to exist in offshore lagoon waters, but dredging operations would be less convenient and more expensive. The protective dike would be built on reclaimed lands to the east of the northern facing beach. The marina would be located to the south, behind the dike, and much of the dredged material to excavate the marina channel and boat basin would be used in the dike structure. No improvements are proposed for the existing hotels, which eventually would lie in depressions surrounded by higher elevated resort lands.

Recent observations and trends. As part of a June 1989 EIA training course, the class and instructors visited the existing and proposed resort complex at Denarau. The field trip revealed that the two existing hotels were built too close to the beach shoreline and on very low lying land. The beach system is not stable, and shortly after construction of the second resort at the corner of the sand bight, the beach retreated, causing shoreline erosion and threatening resort structures. In response, the resort management constructed a seawall along the west face of the beach and a massive groin off the corner of the sand bight. However, the seawall itself was built too close to the ocean and is beginning to be undermined and damaged. The groin, although arresting further erosion along the west facing beach, has actually caused serious beach erosion along the north facing beach. A 2-m high erosional scarp is now present, and palm trees are now falling into the sea. During the day of the field trip, several truckloads of sand were being placed along the eroding beach to replace the sand constantly being lost to the sea.

In addition, new road grading and land raising at the proposed hotel site along the west facing beach have deflected drainage and floodwaters toward the existing resort during moderate rainstorms. These waters approach from the landward (eastern) side and inundate low lying resort areas, including underground parking and utilities. Neither of the two existing hotels has been around long enough to experience a heavy rainstorm or typhoon. It appears likely that both would experience damage from floodwaters, storm surge, and large waves. The existing resorts apparently are operating separately from the development of the proposed resorts, and no measures to protect or prevent damages to the existing resorts are being contemplated. Even without the new resorts, the existing resorts are clearly vulnerable to major damage from natural hazards.

Expected effects of the proposed resort. An environmental impact assessment (EIA) is being prepared for the proposed resort expansion by consultants for the developer. The EIA is not yet completed and many impacts have not been addressed in the draft, nor have alternative sites, designs, and mitigative measures yet been fully treated. The proposed resort concept plan has already been given tentative government approval. At issue is the ecological impact of the proposed dredging of the mangrove forests and the approvals required to dredge in a mangrove reserve, obtain leases, and calculate compensation to the villagers who own or use the mangrove and other island resources.

The proposed resort development provides a classic example of the value of treating the entire resort complex, both the existing and proposed resorts, as a system. There are clear interrelationships between the existing and proposed facilities and some major environmental effects on one component could be either reduced or aggravated by actions involving the other component, and vice versa. The training class and instructors raised the following questions which might be considered as part of the EIA process for the proposed resort expansion:

1. Why dredge the valuable mangrove areas rather than some other less valuable alternative sites? What other land reclamation options are available that involve less fill and the need for much less dredging?

2. How would the loss of mangroves affect the way of life of the Fijian village residents? What uses in terms of medicine, firewood, fish, shellfish, lifestyle, and culture would be lost?

3. What are the characteristics of riverine and coastal flooding for the delta region, and what are the contingency plans to protect occupants and property?

4. What effects on the lagoon ecosystem would result from the resort construction and operation, including possible use of an offshore dredging site in lieu of the mangrove site?

5. What effects would the proposed hotel development have on adjacent existing low lying resort properties and occupants, particularly during flooding or storm surge inundation?

6. To what extent and in what ways will the predicted sea-level rise affect the viability of Denarau as a tourism area--with and without the proposed resort expansion?

7. What net benefits of the proposal will accrue to Fijian society? How will local residents participate in decisions and obtain training and employment?

8. Will a small-scale model of the existing and proposed resort be constructed to better communicate to local residents the extent of the anticipated changes?

9. What are the plans for public access to the beach including parking and movement along the shoreline?

10. What are the construction stage impacts of the proposal, and how will they be mitigated?

11. How have the economic analyses for the proposed resort incorporated possible losses and damages from natural hazards, including maintenance and repair?

12. What alternative designs will be considered to reduce avoidable economic and environmental losses such as setting back resort structures farther from the shoreline, structurally raising the hotel's first-floor elevations, and reducing the elevation of reclaimed land for nonstructural amenities (e.g., golf courses)?

Although these questions reflect only some of the major issues raised during class discussions, they clearly point out the complexity of planning, designing, constructing, operating, and maintaining a large-scale resort in a river delta coastal area. Resort developers often overlook other options and designs for proposals and advocate a preferred plan. The preceding example points out the need to use a systems approach for large-scale development that incorporates alternatives, cumulative effects, indirect effects, and measures to reduce or avoid adverse environmental and socioeconomic effects.

b. Palau Resort Hotel. An environmental assessment was prepared in 1981 for constructing a 100-room international resort on 17 acres of a 63-acre parcel of privately owned land in Ngerakabesang Hamlet, Arakabesan Island, Koror State, Republic of Palau. The principal developer was a Japanese businessman who has built numerous resorts throughout the world. A "Palauian motif" was used in the design, with the resort catering to international guests.

The project would include constructing two-story structures for guest rooms, tennis courts, a swimming pool, a coral sand beach and swimming area, jetties, and a seawall and pier to replace an eroding shoreline and enhance recreational opportunities at the site. Since public facilities are lacking in the area, the developer would provide electrical, water, telephone, and sewage/sewage treatment systems.

The resort site is located on the western side of the island at the head of a small embayment, referred to as Ngerdis Bay. The original shoreline of the bay--rocky and bordered by a low, narrow terrace--is characteristic of the island. The bay area has undergone considerable disturbances by construction workers, mostly during the war years between 1936 and 1943. Alterations included land filling and construction of a seawall, a seaplane ramp, causeway, and other related facilities at the head of the bay.

Dredging for the swimming area would involve removing about 11,700 m^2 of ". . . refuse-littered, rock and rubble intertidal and subtidal zone which is of only marginal use for any activity in its present state." Adjacent to the intertidal zone is a rich reef and marine environment in an expansive lagoon. As described in the EIA, the loss of the intertidal zone and subtidal zone would appear to be offset by the newly created swimming area. The creation of the sand beach is also described as beneficial because of ongoing wave erosion of the shoreline, which was filled land and causing high levels of suspended silt and sediment throughout the bay.

The dredging process itself was seen as potentially damaging the surrounding areas; however, it was stated that mitigation controls, such as silt curtains, would be used during the activity. Acquisition of sand for the beach could have had impacts similar to those of dredging processes; but it was stipulated that sand removal would take place at an expansive sand bar in the lagoon, where continual movements and shifting of large quantities of sand were normal.

Land clearing activities for the project site had the potential for coastal erosion problems and excess loss of vegetation. As part of the local government's permit process, a number of conditions were tied to an earth-moving permit in order to reduce the possibility for adverse effects. These included revegetating exposed slopes as soon as possible, no stockpiling in natural drainage areas, maintenance of storm-water controls, requiring that waste oil and sludge be properly disposed of, maintenance of natural vegetation downslope of all earth moving, and maintenance of on-site drainage systems with silt and sedimentation traps.

Construction workers, most of whom would be brought in to the island, needed temporary housing. The construction of these temporary houses and roads if not mitigated properly could have led to erosion problems. Health measures would also have to be taken to prevent introduction of infectious diseases by these workers. Depending on their origin, contact with construction workers might also introduce the island residents to different or conflicting morals.

As mentioned earlier, a "Palauian motif" was used in designing the resort. A conscious effort was made to have the resort's structures blend in with the surrounding environment. This could be seen in the actual design of the structures themselves, as well as in the layout and landscaping of the site.

To ensure that the jobs provided by the resort would go to Palau residents, the developers stipulated that 109 of the 114 jobs created would be reserved for qualified local residents. Although this would ensure increased job opportunities for local residents, these opportunities could also come at some cost. The qualified applicants for the more skilled jobs might be drawn away from jobs that provided government services and operations. The lure of cash income could also attract people away from more traditional activities.

Traffic increases from the resort would overburden the few roads leading to the resort and would increase traffic congestion in Koror, a major town between the resort and airport. To help alleviate this traffic problem, a ferry system was proposed that would bypass the town. The ferry would be coordinated with airline arrivals and would also provide guests with a ". . . breathtaking introduction to the scenic wonders of Palau" (pp. 1-15).

c. Saipan Marina Hotel Resort, Garapan, Guam. An assessment for the Saipan Marina was completed in 1987. The project was a large-scale resort that would be built in conjunction with a marina. The hotel was considered dependent on the marina and other nearby ocean recreational opportunities that would serve as its drawing attractions.

Existing at the site was a fishing base used by local fishermen for unloading and shipping. The fishing industry was local and supplied fish for local consumption. Construction would displace this complex, which the developers planned to relocate.

Marine water quality in the area had been degraded in preceding years due to discharges of untreated sewage into ocean waters and cesspool overflow. Plans for disposal of the hotel's wastewater involved tapping into an existing system in the area. Concern was expressed about whether or not the worn-out system could handle the increase. An overloading of the system could increase sewage contamination in nearby waters and degrade the very attraction upon which the success of the hotel was dependent on.

Since the hotel would replace the existing ground cover with impermeable materials, such as concrete or asphalt, it would alter existing percolation and drainage patterns and dramatically increase surface runoff. Runoff from areas such as parking lots might contain contaminants and present a threat to water quality. It could also lead to sedimentation or siltation problems. The developers proposed a drainage system to divert runoff into green areas, which would serve as natural filtering mechanisms.

A number of recommendations resulted from the assessment, including the following:

- Establish water quality monitoring programs before construction.
- Minimize pesticide and fertilizer use.
- Coordinate work shifts to avoid periods of high local use.
- Pump sewer-holding tank during low use.
- Allow local use of recreational facilities.
- Conduct educational programs for tourists on the history of the site.

IV.D. ENERGY DEVELOPMENT

(Based on Guidelines for Environmental Assessment of Energy Development Projects in Small Island Countries, prepared by Graham Baines for the United Nations Pacific Energy Development Programme [UNPEDP]. PEDP Report Reg 89-2, January 1989. Excerpted by permission of G. Baines and UNPEDP.)

1. Introduction

Energy development projects are a critical component of national economic development goals and plans. Power is required for growing urban populations, industry, agriculture, and tourist resorts. In the Pacific, electric power generation and fuel importation are the most common answer to energy needs.

Electric power is usually generated by thermal power plants (either diesel or oil-fired) or hydropower projects (either large or small scale). In addition, solar energy systems (photovoltaic) are increasingly used at a small scale and ocean thermal energy conversion (OTEC) may have some future potential in the Pacific. The use of biomass fuels (e.g., fuelwood, charcoal) for energy production in the Pacific will also be reviewed.

Energy to run diesel and oil-fired power plants and energy in the form of gas for motor vehicles and aviation fuel for airplanes is an imported commodity to the Pacific islands. The transport, storage, and handling of diesel, oil, gas, aviation fuel, and other petroleum products have serious potential environmental impacts which must be assessed and planned for.

Most energy development activities involve construction of facilities and infrastructure. The impacts associated with the construction phase of energy development projects is covered in Section IV.F, "Coastal Construction." The remainder of this section will focus on those impacts specific to the energy development sector including petroleum products, importation, and operations.

2. Electric Power

a. Thermal Power Plants. Thermal power plants in the Pacific islands are often diesel fuel operated, with more-or-less closed cycle (recirculating) cooling systems. Although there may be some problems with noise from these plants (especially as they are often sited in urban areas), the major problem concerns the diesel fuel transport and storage, which will be considered in more detail later in this section.

There are some oil-fired thermal plants in the Pacific, with plans for more. These usually have open (non-recirculating) cooling systems which require the construction of ocean intake and discharge systems. The intake of large volumes of ocean waters for cooling usually "entraps" and kills fish and other marine organisms which get sucked into the system and caught on screens, which must be periodically cleared. Smaller organisms, primarily plankton (usually including fish larvae), are "entrained" in the system and killed as part of the cooling process or by chemicals added to the water to prevent fouling organisms from settling on the inside of pipes and clogging the system.

After use, cooling water is hot and contaminated. Its dispersal into the environment is the potential cause of serious problems by:

- altering the salinity (saltiness) of seawater if freshwater sources of cooling water are used;

- increasing the temperature of the stream or coastal water into which thermal effluent is disposed; and

- introducing into those waters chemicals which can be poisonous for animals, plants, and humans.

Nearshore corals of the Pacific islands are widespread and hardy marine species capable of withstanding some dilution of seawater from freshwater sources. However, substantial dilution of seawater such as from rainstorms and flooding can only be tolerated for short periods. Where they are exposed to fresh water for extended periods, corals will die.

Corals are particularly vulnerable to the effects of heated water. A rise of 2° C (Celsius) above ambient seawater temperature is as much as they can tolerate for long periods. Summer water temperatures in many areas of the Pacific island region are close to the upper lethal limits of many corals and other bottom reef life already. Thus, only a small amount of heated waste cooling water is required to increase the water temperature to a level which will kill corals or decrease their ability to tolerate other environmental stresses. In addition, coral recruitment, reproduction, and recolonization are affected by the thermal effluent, limiting the potential for reef recovery.

Chemicals must be added to cooling water to inhibit corrosion and to prevent contaminating growths of algae. A proportion of these chemicals will be discharged into the receiving waters adjacent to a thermal power plant, and these could include potentially dangerous metals such as copper and chromium. In one of its chemical forms (hexavalent), chromium is very toxic to animals, fish, and people.

b. Large-Scale Hydropower Projects (more than about 1 megawatt) (see also ADB Guidelines, Appendix). Hydropower projects require a natural and renewable resource, water, and need an assured supply of that resource. Hence, facilities are often built as combined power and water supply projects, which require protection of the water catchment. Although hydropower projects do not have the pollution problems associated with other forms of power generation, they can bring a distinctive set of environmental problems--especially those requiring water impoundments. These problems arise because dams and reservoirs can cause extensive manipulation of the natural drainage pattern with consequences for the natural environment and for those who may depend on that environment in its natural form (Figure IV.4). The environmental cost of a poorly planned hydro project can be extremely severe.

Since run-of-the-river type hydropower schemes remove water from a streambed, a portion of that streambed between the inlet and the tailrace below the turbine will function with reduced or no water flows unless designs incorporate low (conservation) flows and accept surplus flows during high rainfall periods. Elimination of stream flow will result in loss of stream habitat and conversion to terrestrial habitat. Nevertheless, this is an environmental cost which is usually accepted. Where an attractive waterfall of recreational or tourism value may be affected, however, the operational procedures may be defined to provide for a minimal continuous flow.

In most run-of-the-river hydropower schemes, the water will be returned to the same stream farther downstream. Total flow downstream of the turbine remains much the same as upstream of the intake. For impoundment hydro schemes in which water is stored behind a dam to facilitate steady release of flow and power generation, however, the natural flow pattern inevitably changes, since the primary determinant of downstream flow will be the demand for water for power generation and the corresponding rates and patterns of reservoir releases. This overriding priority for power, unless curbed by other considerations, can in some cases cause serious direct and indirect environmental costs which must be borne by downstream users. For instance, a coastal settlement that depends on groundwater for potable water supplies may suffer from saltwater contamination of these supplies if dry season stream flows are substantially reduced, groundwater

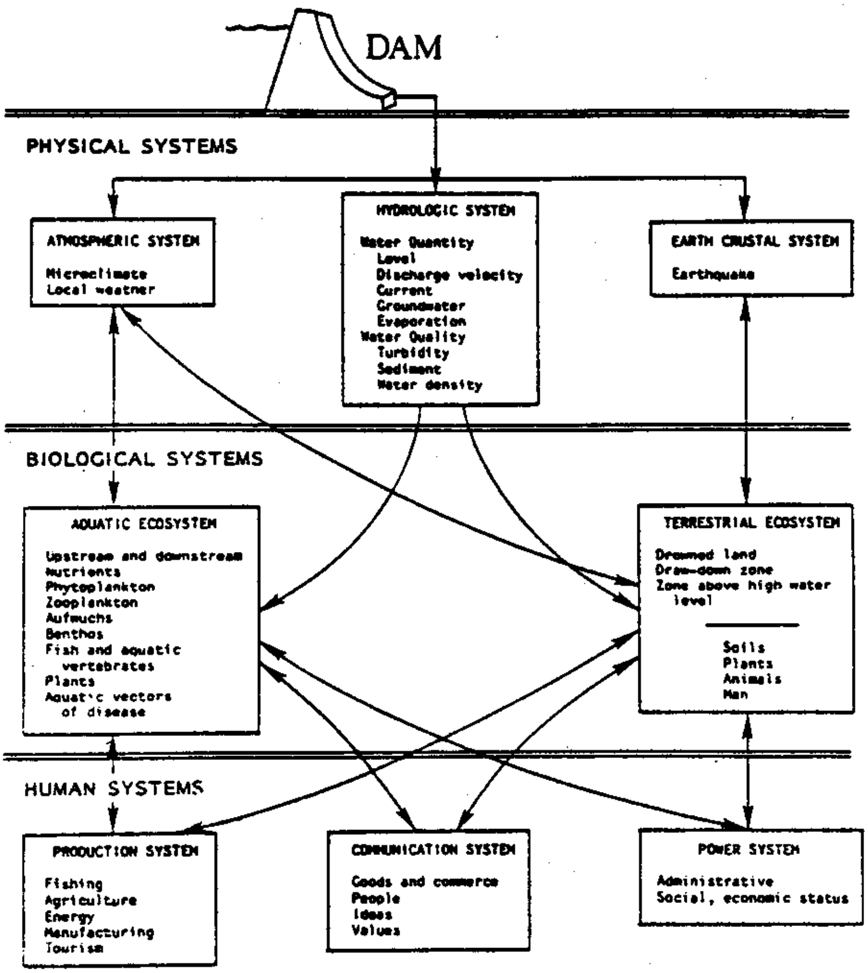

Figure IV.4. The relationship of physical, biological and human systems to dams (Source: Snedaker and Getter 1985).

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recharge is slowed, or seawater infiltrates farther upstream and into that groundwater.

Dry stretches of riverbed may isolate populations of fish and shellfish in hot pools, where they die. Seawater advances into estuaries may seriously disrupt the complex ecology of these areas and associated mangroves and seagrasses. The close relationship of mangroves with adjacent lagoons and reefs, which are important habitats for seafood species, may also be affected.

A hydropower dam will block the movement of almost all sediment from the water catchment upstream of it. The waters of its reservoir do not normally flow rapidly. Therefore, not only the heavy but also the lighter sediment components fall from the incoming water to the reservoir bottom, gradually making it shallower.

The effect of reduced sediment supply from streams and rivers to beaches can be quite serious, particularly if these beaches are frontage for an area in which there has been a great deal of investment in infrastructure. A case in point is the Lungga River of

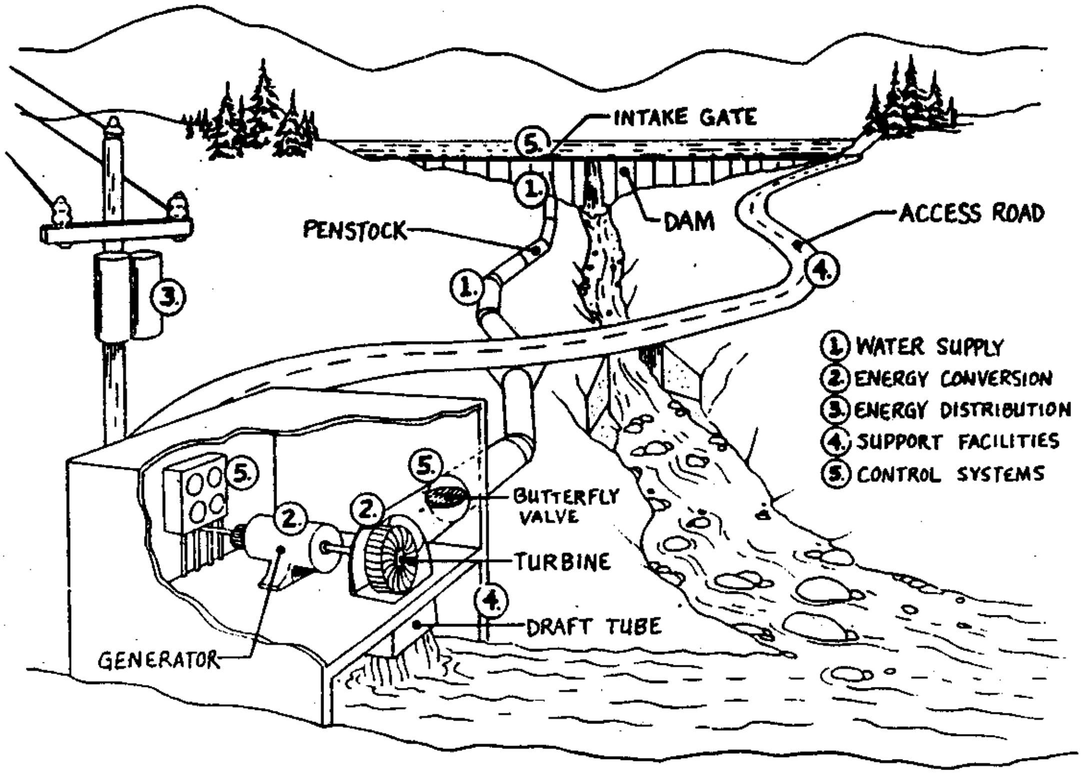

Figure IV.5. Basic elements in a hydroplant (Source: Rochester et al. 1984).

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the Solomon Islands from which sediment provides sand for the maintenance of a beach fronting Honiara's industrial estate at Ranandi. Some years ago proposals were afoot for a large hydropower dam across the gorge of the lower Lungga. This would have substantially reduced the supply of sediment to the Lungga estuary and might well have resulted in erosion of Ranandi Beach and the loss of industrial capacity.

c. Small-Scale Hydropower Projects. Small-scale hydro (usually not more than about 100 kw) implies a smaller alteration of the environment. The environmental consequences of altered stream flow and sedimentation, however, must still be addressed (Figure IV.5).

More often than not, a small-scale hydropower scheme is intended for a local community rather than a national grid. This is likely to make that community more favorably disposed toward the project than toward a large-scale scheme. Even so, the customary and other established rights to the water source and the water course must be recognized, and any adverse environmental alterations minimized.

Schemes that involve only a small weir and which return flow after a short diversion to the same stream are not likely to give rise to environmental difficulties. Local effects need to be borne in mind, however, such as scour in the stream at the outlet, and the effect that this might have on stream ecology through stirring up of muddy sediments.

Where water is diverted into another water catchment or is used for irrigation before being returned to its source stream, significant downstream effects are possible (as explained in the preceding section on large-scale projects).

d. Small-Scale Solar Energy (Photovoltaic) Systems. Major recent technological advances in photovoltaic research have led to the commercial production of self-contained units for freezers, block ice plants, refrigerated storage of milk and chilled fish, and other applications such as for outer island communications facilities and small-scale tourism (e.g., refrigeration and ice for food, restaurants). Photovoltaic systems require only simple installation and maintenance, are cost competitive, result in negligible environmental effects, and have few if any moving parts (which simplifies maintenance). They seem particularly suited to remote outer islands where energy demand is low and needed primarily for small-scale fisheries, tourism, and residential use (ice, refrigeration, freezing, autoclaving).

e. Ocean Thermal Energy Conversion (OTEC) (prepared by John Harrison). OTEC is not a commercial off-the-shelf option for consideration and requires additional research, development, testing, and feasibility analyses for applicability to the practical needs of many island communities. The following aspects of OTEC need to be considered:

- Quality of warm and cold water sources: Which sites have the necessary temperature gradient nearby?

- Platform effects: Different types of containment structures have been proposed for OTEC systems, including land-based plants, tower-mounted facilities, and moored or mobile plantships. Land-based shoreline applications are most likely candidates for Pacific islands, for which major environmental impact considerations include biota attraction, both to the structure and to night lighting; facility, pipeline, and cable emplacement; and effects of the structure on nearshore currents.

- Deep and surface water withdrawal: The OTEC process requires huge volumes of water, and both swimming and drifting biota may be drawn into the plant. Thus, plants must be sited carefully to avoid spawning or nursery grounds of important fishery species.

- Water discharge: Effluent from an OTEC plant will differ in water quality from receiving waters. It will be colder, and its nutrient content may be significantly higher. Thus, biotic communities in the vicinity of the discharge must be evaluated carefully to anticipate their response to the effluent. Innovative applications of the OTEC discharge have been suggested, including lagoon fertilization for atolls and various aquaculture applications. In addition, industrial accidents involving OTEC technology (e.g., release of working fluid or biocide) should be considered.

- Exposure to the elements: Maintaining operation and power generation from OTEC plants during and after typhoons, tsunamis, large storm waves, etc., have yet to be assessed in the field for a full-scale plant.

3. Biomass Resource Development

The idea of power generation from biomass (fuelwood or charcoal) is very attractive because the fuel is locally produced, with all the potential benefits of foreign exchange savings and employment of people in the rural sector. Expressed in simple terms, it seems environmentally harmless and dependent on raw materials (sun, soil, and water) readily available in several South Pacific islands.

a. Fuelwood. Biomass production reduces nutrient recycling between plants and soils in harvested areas. In natural forests, aged trees die, fall, and decay, and their contained nutrients are returned to the soil for the growth of younger trees. In fuelwood plantations, however, the wood is removed. Ultimately the soil becomes deficient in nutrients and plant (and wood) growth slows. Soil fertility must then be restored by applying fertilizers or allowing the lands to remain unharvested during a longer period.

Furthermore, the nature and quality of the soil on which a fuelwood crop is grown will change. Where the area is grassland resulting from destruction of the original forest (e.g., parts of western Viti Levu in Fiji and Rarotonga in the Cook Islands), the soil change may largely be favorable. Where natural forest is being displaced for fuelwood production, the change usually is not good. It tends to become more compacted, for instance, reducing the soil's ability to absorb water and support crop growth. Also soil erosion and sedimentation in streams and coastal waters tend to increase.

A biomass tree plantation or woodlot is not a forest. It is not adapted to the local soil and climatic conditions and does not provide the wide variety of building and food materials that the natural forest provides. It supports relatively little wildlife and may encourage populations of aggressive pest plants and animals.

Another consequence of the reduced rainfall absorption in tree plantation soils is that less groundwater will be held in the soil for slow release during drier periods to natural and cultivated plants in the area. The water table can be expected to drop and streams in the area are likely to experience marked changes in flow.

Therefore, a biomass plantation cannot be used as a supporting environmental feature in a biomass energy proposal. Its net environmental effect could constrain other development options through soil erosion, water-table changes, and fertilizer pollution. Further, since tree plantations take up sizable areas of land, a fuelwood plantation may seriously restrict other land-use options which are perhaps economically and environmentally more attractive in land-short countries.

A 3-Mw wood-fired steam power station requires up to 2,000 hectares of fuelwood plantation. Operation on this scale in Pacific island countries thus ties up a great deal of land and potentially threatens a vast area of natural forest.

b. Charcoal. The extraction and processing of wood from natural or from plantation forests for use in the form of charcoal are often promoted at the level of rural household or "cottage" industry. Charcoal production often makes good sense because local resources and labor are used. and reduced transport costs are incurred with greater energy value per kilogram of fuel for the user.

Nevertheless, it is important to think carefully about all possible consequences of even small-scale projects. In the Solomon Islands, a community was encouraged to use charcoal as a more efficient fuel source and proceeded to use coconut plantation waste for charcoal manufacture. Life in the kitchens was improved, but workers in the copra plantations lost their fuel source. They then used the nearby stands of mangrove, which produces a superior fuelwood. The area is a fishing community, however, and a crucial element in fisheries production in the area is the mangrove ecosystem. The air in the kitchens may be cleaner, but it was attained at the cost of possible declines in fisheries production, requiring more effort to catch fish for home consumption and a reduced surplus for sale.

4. Petroleum Transport, Storage, and Handling

An environmental assessment of the importation of petroleum products must take account not only of the storage area itself, but also of the offshore environment where problems may arise while petroleum products are in transit (shipping accidents are one concern; cleaning-out of tankers after fuel delivery is another) and at the point of transfer from ship to shore.

The main environmental problems specific to energy development at petroleum storage sites are (1) environmental features of the site; (2) fuel oil transfer and storage leaks; (3) fuel oil tanker wastes; and (4) wastes from fuel tank farms.

Oil will spill! The first important point is that spillages will happen! Chronic, operational small spills from shipping and handling of oil account for more than 70 percent of oil in the marine environment, while dramatic, large accidental spills contribute less than 10 percent. The best possible choices of location and of engineering design can do much to minimize the chances of spillages from storage facilities and the extent of the harm which they do, but environmental assessment must realistically be based on minimization of spillages and control of environmental damage--not on complete prevention. In other words, a decision to locate a storage facility at the shore, and to effect ship-to-shore transfers, implies that a "trade-off" has been made--that some other actual or potential use of the area (perhaps fisheries, public recreation) has been "traded off" and fuel storage given priority. Petroleum companies should be required to employ the latest spill prevention technology (e.g., automatic shut-off devices) and have spill-response equipment available: Even so when spills do occur, the agency concerned will need to be well prepared to deal with them.

To ensure that this preparation is thorough, each country should have an Oil Spill Contingency Plan that is frequently tested and updated. The plan should contain a complete list of oil-response equipment (owned by private companies and government), trained personnel, and a 24-hour pollution emergency alerting and response network with designated authorities and their contact telephone numbers. In addition, the plan should contain oil-sensitivity maps that indicate important and sensitive resources at risk (e.g., coral reefs, mangroves, beaches, port facilities) and preferred response options under a variety of spill scenarios. Pacific island governments should also participate in the SPREP Regional Oil Spill Contingency Plan, which provides an assistance network in the event of a major accident, and participate in oil-spill response training offered by SPREP.

a. Effects of Oil in the Marine Environment. The impacts of spilled oil on the marine and coastal plants and animals of Pacific Islands vary with the natural system involved (see Gilbert 1983). All petroleum products biodegrade naturally. Thus, if a spill is being carried out to sea and is not threatening important resources, it is best to allow the oil to be broken down and dispersed naturally. When oil does reach coastal areas, its effects depend on the coastal ecosystem present. For example, oil floating on the water surface will not have a major impact on subtidal corals. Mangroves, however, are particularly susceptible because of their intertidal location and air breathing roots (Figure IV.6). Most shorelines can be ranked according to a sensitivity and clean-up index (e.g., exposed rocky headlands and hard-packed mud flats are less sensitive and easier to clean; medium-grained sand beaches and cobble beaches are moderately sensitive; and estuaries, mangroves, and coral reefs are most sensitive and practically impossible to clean when oiled).

The persistence of oil in the marine environment depends on the amount and type of oil spilled and the wind, wave, current, and weather conditions. Aviation fuel and gasoline (petrol) are "lighter" and vaporize quickly into the atmosphere, creating less of a pollution and clean-up problem. However, because they are more toxic and highly flammable, special care must be taken if a large amount is spilled in shallow areas or is trapped under shore structures (e.g., piers, wharf areas). Diesel, distillate, and refined oils are more of a problem. Heavy crude oils and ship (bunker) fuel are especially persistent.

When oil is spilled, the response plan decision-making process should be rapidly put into action to prevent the worst damage,

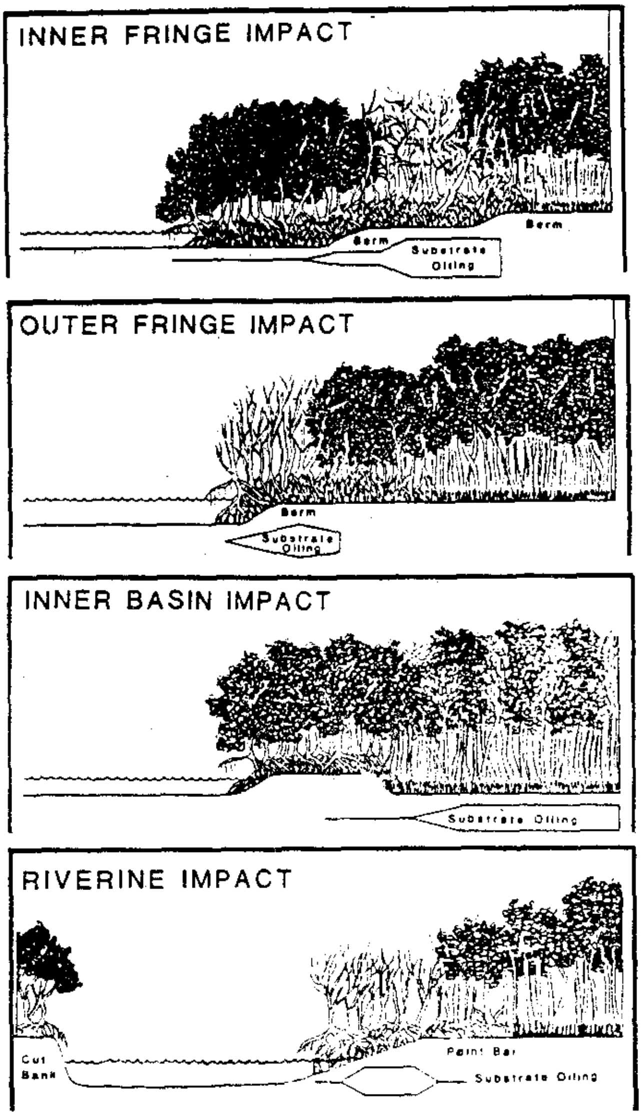

Figure IV.6. Oil damage to mangroves depends on forest types (Source: Snedaker and Getter 1985).

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facilitate clean-up, and to minimize environmental degradation and financial losses. Two decision areas are particularly important. The first is whether to use chemical dispersants or to try and physically contain and remove the oil from the water or shoreline. Some modern dispersants can be used where fish, coral, seagrass, and other benthic organisms are present without doing too much damage to these. However, a trade-off is required between allowing oil to come ashore where its impact depends on shoreline type, and dispersing oil offshore where its impact depends on bottom communities, depth, and water movement.

A second important decision in oil spill response involves disposal of collected oil and oily debris. After oil is physically contained, usually by floating booms on other barriers, it is collected for re-refining or disposal. This collection process and the shoreline clean-up of spilled oil are very messy operations. In the end a decision must be made as to how and where to dispose of the oil and oily debris. The relatively clean oil should be stored in barrels for reshipment to refineries. The oily debris must be stored and shipped, buried, or burned. Burial is not always a good solution, as oil can seep into groundwater or streams, and it may be difficult to find available land on small Pacific islands with customary land ownership. Burning can cause local air pollution problems, and there will usually be leftover material that cannot be burned. Thus, some oily debris may also need to be shipped for proper disposal.

b. Pipelines. The laying of buried pipelines on the seabed can cause sediment disturbance during trench excavation. Some inshore sediments are particularly fine (very small particle size) and are easily resuspended. Once disturbance stirs them up, sediments can remain suspended in the water column for periods of days to months. In well-mixed waters, where current and wave action quickly flushes away sediment, environmental effects are minor or temporary. However, the disruptive effect of such fine sediment on corals, seagrass, fish, crabs, and shellfish in a sheltered body of water can be very marked.

The location and nature of all buried pipelines should be carefully planned and mapped. Some years ago a chronic leak of petroleum products into Walu Bay, Suva, polluted coastal waters for a long period. Despite the existence of legislation to deal with the problem and a willingness of the health authorities to take action, the offender could not be identified. There was such a complicated, unplanned network of pipelines to and from several oil companies and users that it was not possible to determine the responsible party for the faulty pipeline.

c. Bilge and Tanker Washout. The bilges of most ships and tanks of petroleum tankers need to be cleaned periodically. Emptied oil compartments are also filled to adjust trim and ballast. Subsequent discharge of oil-contaminated ballast is therefore a source of oil pollution. These were once a major source of marine oil pollution as tanker masters took the easy option and cleaned out tanks while underway and out of sight of land--whether in national or international waters. Strict regulations under the International Maritime Organization have curbed much of this abuse of the seas. It still can be done, however, where surveillance of shipping is weak, as in the South Pacific.

d. Tank Farm Wastes. Tanks used for storage of petroleum products need to be cleaned occasionally. The sludges removed from the bottoms of these tanks are always potential problems for the environment. Careful arrangements for their disposal must be decided and included in the waste management procedures which should be part of the outcome of the environmental assessment. The environmental hazard posed by these wastes is worsened where the sludge contains residues from leaded petrol. Close cooperation with health authorities is necessary to ensure that lead does not become an environmental contaminant. In the tropics, metal tanks (both above ground and underground) undergo rapid weathering and deterioriation. A constant program of maintenance, repair, and replacement is needed to avoid accidental leaks.

5. Environmental Assessment of Energy Development at the Pre-Feasibility Stage

a. Thermal Power Projects

- Engineering and environmental consultants should work together on environmental aspects of their preliminary design for thermal power projects.

- Prepare a preliminary map of water circulation and sediment transport in the area of beach and coastal waters considered by the consultant to be potentially subject to disturbance by operations at the proposed power station.

- Ensure an oil-spill contingency plan, including an oil-spill sensitivity map for the development site area, is in place.

- Broadly characterize the coastal dynamics of the area under different wind and tide conditions, particularly with respect to hurricane/cyclone/typhoon events, tsunamis, and the expected sea-level increase for the duration of the project.

- Describe the existing environmental circumstances at the site and in the area subject to the proposed project's influence, including coastal water quality, seagrass beds, coral reefs, and mangroves, and water circulation.

- Investigate the possibility that sites of special cultural, historical, and/or ecological significance may occur in the area, which will be affected by the proposed project, and indicate their nature and locations.

- For fuel-fired power plants requiring use of once-through cooling water systems (such as seawater), thermal effluents and outfalls should be designed to minimize thermal plume impingement on the bottom environment near coral reefs and other sensitive areas.

b. Hydropower Projects

- Engineering and environmental consultants should work together on environmental aspects of their preliminary design for a hydropower project.

- Broadly characterize the environment and component ecosystems of the area to be affected by the proposed project, with particular reference to current and projected land use in the hydro water catchment and downstream of the dam site.

- Under a range of seasonal/rainfall conditions, report on stream flow, water quality, and suspended sediment in at least three locations--upstream of the proposed dam, downstream of the tailrace, and between these two sites.
- Examine the options for road access and for power transmission line routes, and report on their relative suitability for minimizing soil erosion and avoiding areas of cultural, historical, and ecological significance.

c. Petroleum Product Storage Projects

- Engineering and environmental consultants should work together on environmental aspects of their preliminary design for a fuel storage depot with all ancillary equipment and services.
- Prepare a preliminary map of water circulation and sediment transport in the area of beach and coastal waters to be potentially subject to disturbance by operations at the proposed depot (including ship-to-shore transfer of fuel).
- Ensure an oil-spill contingency plan, including an oil-sensitivity map for the development area, is in place.
- Broadly characterize the coastal dynamics of the area under different wind conditions, particularly with respect to hurricane/cyclone/typhoon events, tsunamis and the expected sea-level increase for the duration of the project.
- Give a preliminary estimate of the costs for installation, maintenance, and operation of pollution prevention and control equipment and indicate the nature and level of economic, social, and environmental costs in the absence of such provisions.
- Examine and comment on provisions for clearance distances around fuel storage tanks in respect of fire and explosion hazards.
- Describe the existing environmental circumstances at the site and in the area subject to the proposed project's influence, including coastal water quality, seagrass beds, coral reefs, and mangroves, and water circulation.

6. Case Studies

(prepared by John Harrison and Rory Frampton)

a. Nanpil River Hydropower Project, Island of Pohnpei, Federated States of Micronesia. Based on a U.S. Army Corps of Engineers report (1985), "Nanpil River Hydropower Project, Island of Pohnpei, Federated States of Micronesia" by James Pennaz. The very high costs of oil-fired electrical energy production led the government of Pohnpei to seek alternative energy sources. Previous hydropower efforts in Pohnpei during the Japanese era had been generally successful, and high rainfall and topographic conditions appeared favorable. Studies performed by the Army Corps indicated that the Nanpil River provided the best overall conditions for such a project because of its closeness to the main urban and commercial center of Pohnpei, good access to the proposed facility site, and an existing water diversion structure that could be utilized.

The completed project is a run-of-the-river 1600-kw hydropower facility consisting of an intake at the existing water supply dam, a 4600-foot penstock (pipe) buried under the access roadway, a powerhouse, a switchyard, and a 2-mile power transmission line. Decreased water flow due to the project's diversion occurred along a 1.2-mile stretch of river between the upstream intake and the downstream outlet at the powerhouse. Downstream at the outlet, river water flows return to normal for the remaining several kilometers to the sea.

Pohnpei island is surrounded by a barrier reef and lagoon that support a coastal fishery. The island's mountainous regions are covered by rich tropical rainforests with mangrove forests and swamps in abundance along the shorelines. The rugged terrain of the mountains makes access to rivers extremely difficult. Nanpil River contains an assemblage of aquatic life that supports subsistence fisheries.

The 1.2-mile section of river that would experience a decrease in water flow supports small-scale agricultural activities for some local residents and has a scenic waterfall, which is a tourist attraction.

Construction activities posed significant threats of erosion from land clearing and grading for the powerhouse, penstock, and access road. In an effort to minimize disturbance, the access road was designed to be built over the penstock.

The creation of an intake structure could adversely affect stream life, inhibiting migratory routes and diverting the minimal amount of stream flow necessary for habitat maintenance. In this case, the existing diversion dam was noted to have had an effect on migratory routes of stream biota. As part of the project's design, a notch was created in the existing dam to maintain a minimal flow for the waterfall and in-stream biota, and to allow for migratory passage. Additionally, the policy for water use from the river designated hydropower as the lowest priority, below both water supply and conservation flow. As such, the creation of the notch in the diversion structure and the policy of maintaining a minimum conservation flow constituted an environmental improvement. The intact structure design incorporated boxes and wire mesh screens to reduce entrainment of stream biota.

Another mitigative measure to offset impacts to downstream uses along the affected 1.2-mile segment was the extension of a continuous water supply to the affected homes.

Two other factors were considered in designing the project. The first was the recognition of the cultural significance of land to the local people. The importance of ancestral homelands and the values attached to these lands are common attributes of Pacific island communities. The reluctance of the local population to give up their lands was cited as an important factor in the decision to place the access road over the penstock (to minimize land acquisition) and in other land-use decisions. Archaeological surveys were also performed to record cultural sites and document the historic significance of the ruins of the earlier Japanese-built plant at the site.

The second consideration was maximizing overall operational lifetime of the facility while minimizing the risk of adverse impacts of a long-term power outage due to breakdown. To this end, local integration with the project was given high priority. However, the local public works department faced a shortage of individuals with technical expertise. As such, the project was designed for simplicity of operation and minimal maintenance. Additionally, the Army Corps required the contractor to include a number of spare parts in the bid package and also to operate and maintain the facility for 1 year while training local operators. The training program has been extended to ensure the plant is operated and maintained properly.

b. Assessing Energy Facility Expansion on Guam. In November 1978, the government of Guam completed an initial assessment of potential impacts for expanding of energy facilities. Conventional oil-fired plants were the only type considered, due in part to the presence of large oil refineries nearby on the island. The goal of the assessment was to examine the various sites and alternatives for energy expansion so that project development would come close to reaching the often conflicting goals of enhancing economic growth and preserving the environment. A major focus of the assessment was examining the impacts of two existing plants, Tanguisson and Cabras, which had, since their construction, altered many aspects of the environment.

The Cabras plant is located along the Piti Channel of Apra Harbor. The intake pipes are situated across a peninsula outside Apra Harbor while the discharge pipes for the cooling system are located inside the enclosed waterbody of the harbor. Since the intake structure is located in a sandy area, it continuously had to be redredged to prevent clogging. The same problem was also encountered at the Tanguisson plant. The dredging activity not only increased turbidity and sedimentation problems but also was a significant drain on capital.

Impacts from the thermal plume of the output in Piti channel were not considered extreme because of normal ambient conditions. Since the shallow and enclosed nature of the waterbody resulted in natural warming from insolation, the temperature increase from the discharge did not represent a large change from ambient conditions.

Perhaps the most damaging impact of the whole project came from construction activities. Most notable of these was the careless operation of a bulldozer that destroyed reef areas during construction of the intake pipe on the viable coral reefs immediately outside and north of the harbor.

Impacts from the Tanguisson power plant have been observed since operations commenced in 1971. The plant site is adjacent to a narrow fringing reef and is in a beach strand environment. Because of the location of the thermal discharge, it was concluded that the effluent was responsible for destroying the flora and fauna of two hectares of the fringing reef. Biofouling control additives had played a role, but most of the damage was attributed to the thermal effluent. Reef-building corals along the reef margin were killed, and fishes, crustaceans, and echinoderms characteristic of the reef flat abandoned the plume area. Studies had indicated that the upper thermal tolerance level of reef species was generally between 30 and 33°C. With a 4°C rise above the ambient (28.5°C), 48 species died within 6 to 14 days; and with a 6°C rise, most species died within 6 days or less.

Air emissions were assessed, particularly with regard to sulfur dioxide contamination. Normal tradewinds in the area blow emissions out to sea; but when wind patterns change, nearby towns are affected by air pollution. The mitigation measure proposed for these days was to burn low sulfur fuel, but this fuel is costly and hard to find.

IV.E. MINING AND MINERALS PROCESSING

(prepared by Philip J. Hughes)

1. Development Objectives

Mining and minerals processing has or is likely to become an increasingly important component of the development strategies of many South Pacific nations. Of particular importance is the gold-bearing "rim of fire" that encompasses a zone extending from PNG (Figure IV.7) through the Solomon Islands, Vanuatu, and Fiji to New Zealand. Other important minerals are copper in PNG and nickel in New Caledonia.

Mines are primarily developed to exploit nonrenewable resources (i.e., minerals) for their financial returns. The major benefits of mining will accrue to the shareholders (in the form of dividends) and to governments from company, income, and other taxes, royalties and profits from equity holdings. Local communities will benefit from their share of the royalties, compensation payments for loss of or damage to land and other resources, and from wages. However, these

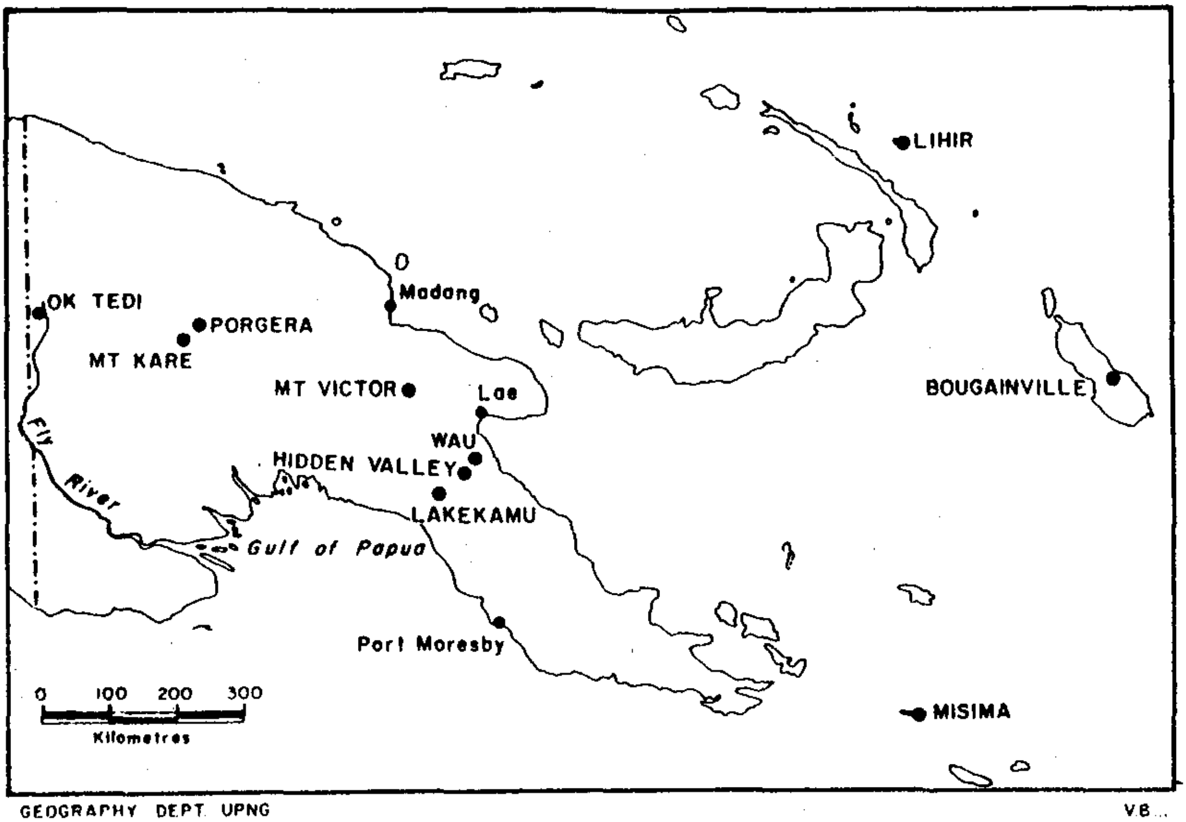

Figure IV.7. Mines in PNG in operation or at advanced planning stage.

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communities will also bear the brunt of the negative effects mining inevitably brings into existence.

2. Project Components

Although mines vary greatly in size, output of ore, and mine life (Table IV.5), their project components are essentially similar (Figure IV.8). Most mines in the region are or will be open-cut rather than underground operations. There are two phases--construction and operation--to any mine, and the infrastructure requirements and impacts will differ in many ways. The main elements of the operations phase are as follows:

The open-cut pit, from which the mineral-bearing ore is extracted. In addition to ore, there is usually an equal, if not greater, amount of waste rock to be removed. The rock is drilled and blasted, dug out with heavy machinery, and transported to the ore-processing plant or the waste rock dumps.

The ore-processing plant, where the ore is crushed, then milled to a fine powder before being chemically and/or physically treated and processed to extract the valuable minerals. In the case of gold and silver, the end-product is normally impure metal produced by smelting; whereas with copper, a concentrate of the ore is produced, which is

Table IV.5. Scale of mines in PNG

Mine	Tailing (tonnes/day)	Mine life	Workforce (no.)
Bougainville	135,000	30	4,000
Ok Tedi	60,000	30	2,500
Misima	15,000	10	350
Hidden Valley	10,000	10	300
Porgera	9,000	18	900
Wau	1,400	9	280
Mt Kare	3,000	3	100
Mt Victor	400	2	100

NOTE: Hidden Valley and Mt Kare are still at the planning stage, and Misima is being constructed. The others are all operating mines.

usually refined overseas. The nickel mined on New Caledonia is smelted on the island.

Cyanide is often used to extract gold and other metals. The transportation and handling of this extremely toxic chemical are potentially hazardous to human health and other animals. Cyanide complexes are also present in waste streams from ore processing.

In all cases, the tailing (or sludge) left after the minerals have been extracted will consist of a mixture of water, mud, and chemicals used in the extraction process.

The waste disposal system consists of two components: waste rock from the open pit and tailing from the ore treatment plant. Normally the waste rock is stored in stable dumps close to the open pit or is used partially to backfill the pit. Sometimes some of the waste rock is too soft to be stored safely in this way and must be disposed of in the same way as the tailing.

There are a variety of options for disposing of the tailing, including impounding it behind a dam wall (a tailing dam), discharging it into an adjacent river system (whereby most or all of it eventually reaches the ocean), or dumping it directly into the ocean.

Infrastructure includes, for example, roads, water and electrical power supply, office accommodations, workshops, storage facilities, and workforce accommodations and services.

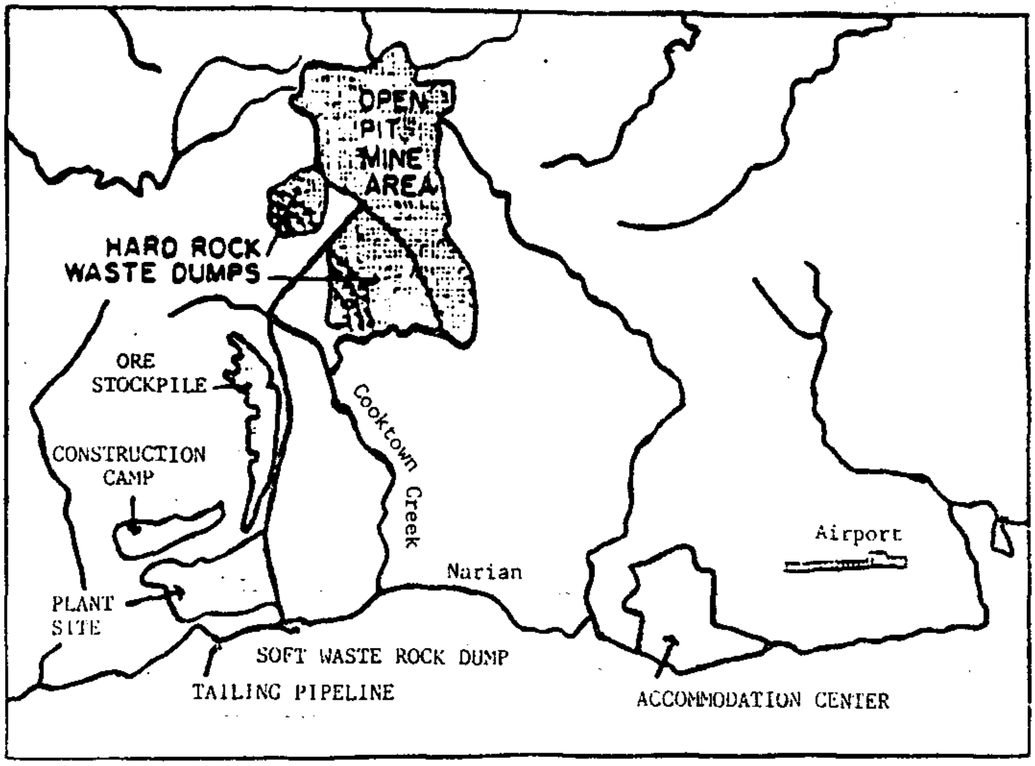

Figure IV.8. Misima gold mine: Project components.

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3. Environmental Factors Influencing, and Influenced by, Design and Site Location

The location of any mining project is largely determined by the location of the ore body, which is absolutely fixed. Because major project components such as rock waste dumps, ore-processing plant (and hence tailing disposal), and industrial infrastructure must be located close to the mine pit, there are normally fewer locational options than are available to other types of development project. Furthermore, the nature and size of the ore body determine within a narrow range of options the mining and ore-processing methods that will be used.

In such circumstances, a thorough prior understanding of the biophysical and social environment of the project area and its surroundings is essential if optimal use is to be made of the limited locations likely to be available for the project components and to result in acceptable impacts. Such baseline biophysical and social environmental data are not only vital to the initial assessment but also for monitoring effects once construction and operations have begun.

Take, for example, the normally contentious issue of waste disposal. In determining a suitable waste disposal strategy, especially for tailing, the following sorts of questions need to be addressed: Are there suitable sites for building a tailings dam? Is the nearby river capable of transporting the increased load that would result from the discharge of tailings? What would be the impact of such discharge on downstream users, especially villagers who may take their drinking water from, or wash in, the river, or fish in the sea? What would be the ecological impacts of tailings discharge? In particular, would important species or communities be adversely impacted?

In the case of the proposed Porgera gold mine in PNG (Natural Systems Research 1988), for example, the answers to these questions were, simply put: "No, there are no safe tailing dam sites; yes, the nearby river can physically cope with the increased load; no, there are virtually no downstream users who would be noticeably affected; and, no, there are no major ecological impacts." Consequently the project operators have been given permission to discharge their tailings into the river system, after appropriate detoxification treatment.

In contrast, the answers to the same questions when asked of the proposed Hidden Valley gold mine (Hidden Valley Gold 1989), which is very similar in its operation and environmental setting, were: "Yes, building a tailing dam is technically and economically feasible; and yes, there are numerous downstream users of the river system who would be very adversely affected by the discharge of tailing, even if it was detoxified." In this case the option of river discharge of untreated tailing (the cheapest option) was discarded, and the project proponent proposes to build a dam to store the tailings.

4. Impacts

The major environmental impact issues raised by the development of open-cut mines in the region can be considered in four related categories (e.g., see Natural Systems Research 1987).

- The capacity of the project area and its surroundings to accommodate the project physically.
- The capacity of the environment to assimilate wastes from the project.
- The effects of the project's land requirements and discharges on natural ecological values, and the subsistence and commercial resources used by local people.
- The socioeconomic effects.

In most South Pacific nations the population is largely rural, land is communally owned, and communities and individuals have a strong attachment to their land. Thus, in almost all resource development projects, including mines, there are actual or potential land-use conflicts to be resolved in the planning process. Concerns about possible negative socioeconomic effects, alienation of land, and impacts on resource used by local people invariably outweigh concerns about possible adverse effects on natural ecological values.

In PNG the basis for environmental management of the project is as follows (e.g., see Mt. Kare Mining 1988):

- Prediction of the project's potential impacts.
- Implementation of a hierachy of management measures, which are determined by technical feasibility, costs, and benefits: (1) pre-emption of the impact, (2) containment of the impact, and (3) compensation for the impact that is unavoidable, where appropriate.
- Monitoring of the management measures and of the validity of the impact predictions on which the validity of the management measures in turn depends.
- The undertaking of remedial actions, if necessary, to counteract adverse environmental effects detected by the monitoring program.

5. Case Studies

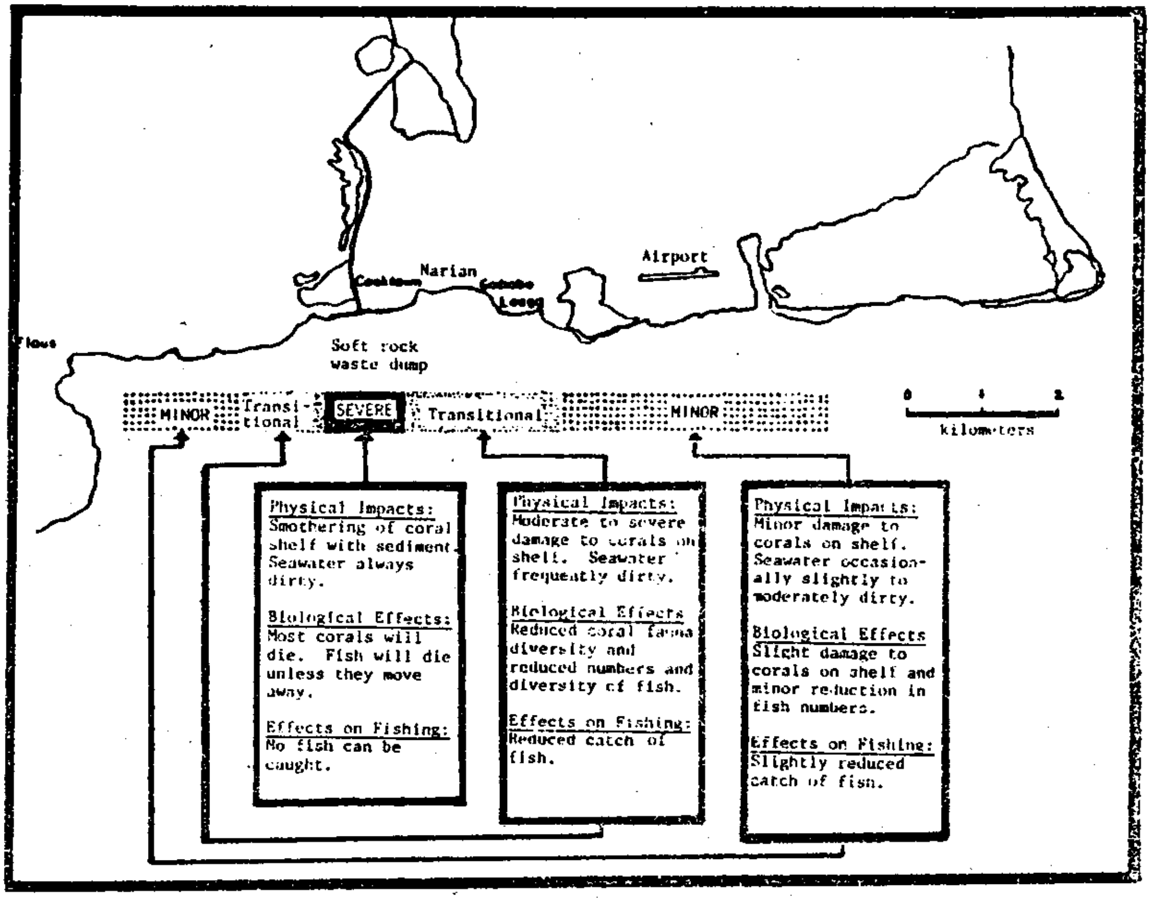
a. The Misima Island Gold Mine. A major feature of this medium-sized mine (Figure IV.9), which was scheduled for production in July 1989, is that it will be the first in PNG to use marine disposal of soft rock waste and of tailing. This form of disposal has already been proposed for two other high island gold mines in PNG and may be widely implemented on high islands throughout the Pacific region if experience shows that environmental impacts are acceptable.

The following summary is based on the project's Environmental Plan, prepared under the requirements of the PNG Environmental Planning Act 1978 (Natural Systems Research 1987; see also Hughes, in press).

- Operation. The total ore to be extracted is 56 million tonnes (Mt) at a stripping ration of 1.3 tonnes of waste for each tonne of ore. This will allow the mine to operate for 10 years at 5.475 Mt/yr. Three categories of material will be removed from the pit: ore (56 Mt), hard rock waste (35 Mt), and soft rock waste (35 Mt).

The ore will be delivered by trucks to the processing plant on the coast. The hard rock waste will be delivered to dumps close to the open pit. The soft waste, which cannot be stored safely in stable dumps, will be hauled by trucks to the south coast and be dumped directly into the ocean adjacent to the plant site.

The ore treatment will be a gold cyanidation plant with gold recovery by the carbo-in-pulp process. The tailing left after the gold and silver have been extracted will consist of a mixture of water, mud, and chemical such as cyanide used in the extraction process. This tailing will flow to a mixing tank where it will be diluted with seawater to reduce the residual cyanide concentration to a level acceptable for deep ocean discharge down a pipeline.



Physical Impacts:
Smothering of coral shelf with sediment. Seawater always dirty.

Biological Effects:
Most corals will die. Fish will die unless they move away.

Effects on Fishing:
No fish can be caught.

Physical Impacts:
Moderate to severe damage to corals on shelf. Seawater frequently dirty.

Biological Effects
Reduced coral fauna diversity and reduced numbers and diversity of fish.

Effects on Fishing:
Reduced catch of fish.

Physical Impacts:
Minor damage to corals on shelf. Seawater occasionally slightly to moderately dirty.

Biological Effects
Slight damage to corals on shelf and minor reduction in fish numbers.

Effects on Fishing:
Slightly reduced catch of fish.

Figure IV.9. Misima: Impacts of soft rock waste disposal.

- <u>Land and land resource use impacts and migration</u>. Land alienation and the associated depletion of traditional resources were major issues. Local population densities are high. Although there is no shortage of gardening land, the population is increasing rapidly, raising concern that alienation of land for the mining project might lead to land shortages. It was accepted from the outset that wherever possible, project infrastructure should be placed on land of low productivity for gardening use or for exploitation of bushland resources.

The mine pit site and the hard rock waste dumps will be in hilly terrain on previously disturbed and largely unproductive land away from populated and gardened land. The processing plant and accommodation facilities are being located on freehold land currently used (unproductively) as coconut plantations. Only the haul road and the low-grade ore stockpile will be situated on productive village-owned land. Much of this land will be rehabilitated when the mine ceases production.

- <u>Stream impacts and migration</u>. During the 15-month construction phase, about 200,000 m^3 of sediment will find its way into Cooktown Creek. A further 170,000 will reach the Creek during the 10-year life of the mine. Although most of this sediment will eventually be washed out to sea, there will be localized accumulation of sediment in the valley that will affect a locally important sago swamp. In addition, the Creek will be continuously muddy and undrinkable.

This loss of sago resources will be small (and temporary), and compensation will be made for these losses. The company has already installed piped water supply systems for all affected villages adjacent to the Creek. (Compensation--how much and in what form--is a difficult concept to implement and is often critical to acceptance of a project.)

- Waste disposal and mitigation. Waste disposal was the other main issue. Both land and ocean disposal were considered for the soft rock waste and tailing. Since the island is subject to seismic activity and to periodic severe cyclones, land disposal of soft waste and tailing behind one or more dams was rejected because of a high risk of their failure due to such events.

- Hard rock waste. Most of this will be stored in stable dumps in the largely unproductive hilly interior of the island, and the rest will be used to back-fill one end of the open pit. Since the rocks are nonacidic, the leachate from these dumps is not expected to be acidic or to contain high concentrations of dissolved metals.

- Soft waste. Two alternatives were considered. The first, and environmentally preferable, option would have been to mill the soft waste and dispose of it, along with the tailing, down the submarine pipeline. This option was rejected because of its excessive costs; had this method been implemented, the mine would not have been profitable.

The ocean surface disposal method was chosen because it was cheap. The waste will be transported to the shoreline and dumped into the sea. The material will cascade down the steep slope as a density current, but there will be localized increased turbidity at and around the dump site. Soft waste will peak at 20,000 tonnes a day or 183 truckloads a day.

This aspect of the overall waste disposal strategy caused the greatest concern. Thus, considerable effort was given to predicting its physical and biological effects. In a zone 0.5 km either side of the dump site, the effects were predicted to be severe (Figure IV.9). The effects would be progressively less severe either side of this central zone and would cease about 3 km to the west and 6 km to the east of the dump site. The company will compensate the villagers for losses of marine resources and amenities as a direct result of discoloration of nearshore waters from soft waste disposal.

Recovery of the coral reef may occur once mining stops, as was the case following an earlier phase of mining that ceased in 1942. (Recovery of corals to a previous condition and productivity is unusual, however.)

- Tailing. The ocean is very deep immediately offshore from the island, and submarine disposal of the tailing was the agreed-to option. The tailing/seawater-mixed slurry will be discharged through an outfall pipe to the ocean at a depth of between 75 and 100 m. The slurry will be denser than the surrounding ocean water at the discharge point and will flow down the steep submarine slope as a density current and will not mix with, or pollute, the surface seawater.

The tailings will smother the surrounding deep ocean floor habitants, either forcing away or killing those animals incapable of adjusting to the new conditions. The Misima people do not fish at such great depths, and there is little potential for commercial deep-water fishing.

b. Hidden Valley Gold Mine. This mine, which is similar in size and mode and length of operation to the Misima mine, is at an advanced stage of planning. The following discussion is based on information in the project's Environmental Plan (Hidden Valley Gold 1989). A number of important differences between the two projects warrant emphasis as they have resulted in substantially different strategies to manage predicted environmental impacts.

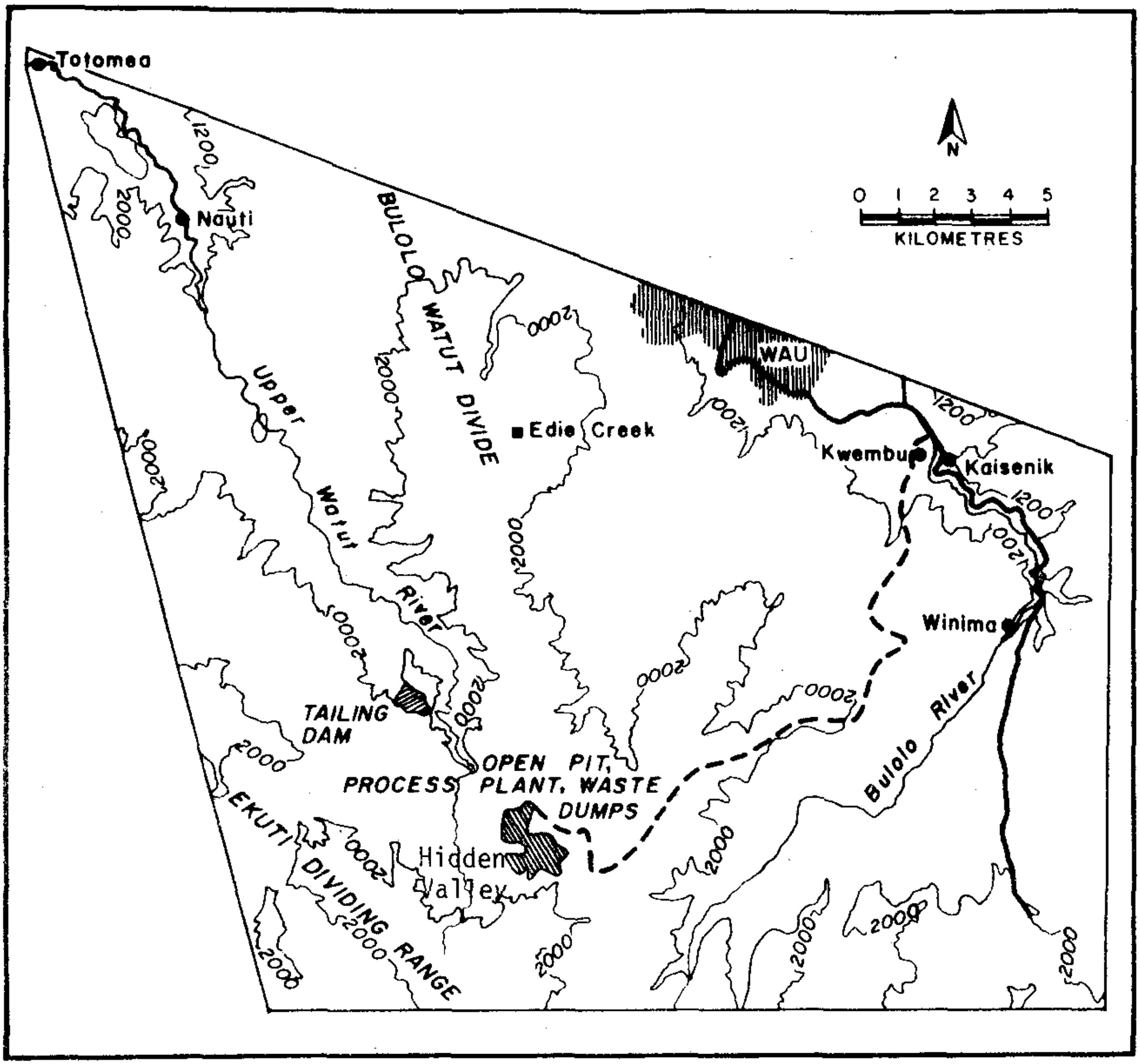
- Land and land resource use impacts. Hidden Valley differs from Misima, where minimizing potential land-use conflict was an important component of the project planning processing (including environmental planning). But by careful siting of the project components on unproductive or alienated land, the impact on productive, village-owned land was eventually reduced to very low levels.

The Hidden Valley mine site, in contrast, is located at high altitude (2600 m above sea level) in rugged, forested, and unpopulated land well away from the heavily populated grassland valleys to the east and north (Figure IV.10). The ore-processing plant, industrial plant, and waste disposal facilities will all be located in this unpopulated terrain close to the mine site. The workforce will be accommodated on already alienated land in nearby Wau, and a road will be built connecting the mine site with Wau. Because of this, very little agriculturally productive village-owned land will be affected.

Hence, because Hidden Valley is in a remote location, potential land-use conflict was never the major issue it has been with other mining projects in PNG.

- Waste disposal. Unlike at Misima, where damage from ocean disposal of soft rock waste proved to be the major environmental issue, at Hidden Valley almost all the rock waste will be hard, which can be safely stored in stable dumps adjacent to the pit.

However, whereas at Misima leachate from the nonacidic dumps was not expected to cause environmental problems, at Hidden Valley about 38 percent of the waste (the metasediment component) is either acid-forming or potentially acid-forming. Furthermore, acidic leachate containing dissolved metals entering the stream system has the potential to be environmentally damaging.



GEOGRAPHY DEPT UPNG. V.B.

Figure IV.10. Hidden Valley gold mine project components.

A major environmental objective for designing the waste rock dumps, therefore, is to minimize generation of acidic leachate (Figure IV.11). The following action must be taken to reach this objective:

- Locate the acid-forming dumps in the heads of valleys where runoff from the catchment will be minimal.
- Restrict the amount of time that each dump will remain active.
- Divert surface runoff away from the dumped material.

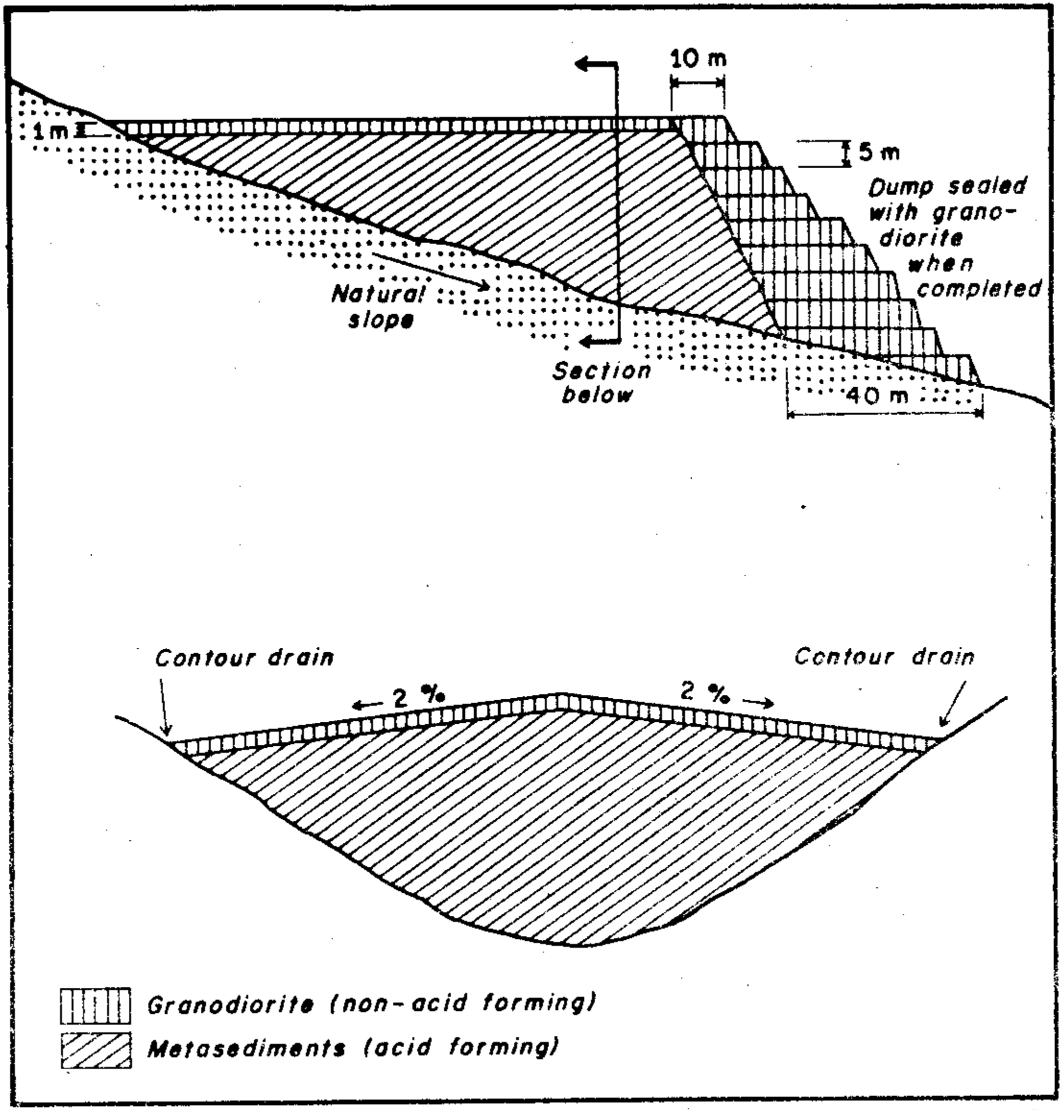


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Figure IV.11. Hidden Valley rock waste dump design.

- Progressively seal the surface of the dump to restrict oxidation and to minimize percolation of rainfall and surface runoff.

- Rehabilitate the dump as soon as possible by sealing the surface and facing it with nonacid-forming (granodiorite) rock waste material.

The two main tailing disposal options considered were:

- Discharge of either untreated or detoxified tailing to the Upper Watut River.

- Tailing impoundment behind a dam in a tributary valley of the Upper Watut River.

Several hundred people live in at least nine villages along the Upper Watut River. These people regularly use the river for drinking and cooking, washing utensils and clothes, bathing, swimming, fishing, and gold sluicing. The dumping of untreated, cyanide-rich waste would be by far the cheapest option (about US$0.5 million in total over 10 years); but at times of low water flow, cyanide would be at levels toxic to humans for some distance downstream. This would clearly be unacceptable.

The tailing could be detoxified at about US$50 million to make it chemically safe. However, the water would still be highly turbid due to the very heavy sediment load, making the river water virtually unusable for most domestic purposes.

An alternative would be to store the tailing in a permanent dam. A suitable site in a stable valley with unproductive land has been identified, with a preliminary cost estimate of US$15 million to construct and operate. Thus, for both environmental and economic reasons, impoundment of the tailing in this permanent dam is the preferred option.

IV.F. COASTAL CONSTRUCTION ACTIVITY

1. Development Objectives

Transportation projects have accounted for most of the coastal construction in Oceania. Obviously, navigation projects (docks, ports) must be located at the shoreline, but many road, bridge, and airfield projects are also near the coast where most of the people live and desirable construction materials are found. Roads in Oceania are, by necessity, mostly unpaved and capped with coral aggregate which has the best available maintenance and drainage properties. Because of the ready access and "free" sources of construction aggregate on coral reef flats, most material for road construction and maintenance is obtained from shallow lagoons, coral reefs, seagrass beds, and mangrove flats overlying carbonate substrates.

Traditionally, many nearshore water areas were owned or policed through native customs and tenure. However, centuries of colonial dominance by foreign powers and decimation of island populations from warfare and disease brought by the foreigners have destroyed, weakened, or undermined these controls in most of Oceania. Consequently, more and more reef, lagoon, seagrass, and mangrove flats are being exploited for construction materials for roads and other projects. The government official faced with the choice of buying aggregate from upland private landowners or dredging it "free" from accessible coastal areas will most often opt for the latter in the absence of land use and other environmental controls.

For similar reasons, many airfields and roadways in Oceania are located in what was previously marine habitat, and substantial landfills and causeways have been constructed, particularly near urban centers.

Harbors and the side slopes of coastal fill land require structural reinforcement to protect the land and facilities from the destructive effects of large waves and strong currents. A common practice is to quarry large rocks (armor stones) from offshore reef flats and use them in shore protection structures.

Many other government, community, and private landholdings (especially resorts, schools, churches, and meeting halls) are situated on fill land. Decision-makers faced with purchasing limited or expensive land from private owners will instead create new land on "free" reef and mangrove tracts. This is particularly evident in crowded urban centers and capitals with access to heavy equipment.

The clearing and filling of mangroves in many areas of Southeast Asia for mariculture is worthy of mention. Many thousands of hectares are actively being converted to pond culture for milkfish and marine shrimp (termed <u>tambak</u> extensification) in Indonesia, the Philippines, Malaysia, and elsewhere.

2. <u>Construction Practices Potentially Damaging to Marine Ecosystems</u>

a. <u>Excavation and Dredging</u>. The most common excavation techniques include use of a crane for clamshell dragline (or bucket) dredging, pipeline cutterhead or suction dredging from a floating barge, and hopper dredging from a ship. Augering is a less common technique with limited application due to the extreme hardness of coral materials and the complex nature of the operations. Dragged chains or cables to knock down or loosen coral heads have also been used. Besides explosives for excavation, drilling and shooting (quarrying) are often used with mechanical excavation and dredging to facilitate removal of particularly hard materials.

b. <u>Landfilling and Shore Protection Measures</u>. Landfilling is the placement of fill to convert aquatic habitat to dry land. Dredging and filling sites are often located next to each other (such as for harbor projects; see Section IV.G) so that dredging operations can conveniently generate material required for landfilling.

Sides of landfills facing the ocean or exposed to other elements require structural protection to minimize slumping and erosion of fill from currents and wave action (U.S. Army Corps of Engineers 1979a, 1979b). Revetments are protective structures usually consisting of sloping rocky walls. The outer basal extension of the rubblemound revetment (the toe) takes the brunt of wave action striking the slope, and the irregular surfaces and interstices between the stones are effective in dissipating wave energy and minimizing reflected waves. Reflected waves can carry sand and other bottom material seaward of the shoreline and can undermine shore protection structures unless they are properly designed or placed on a solid rock foundation.

Seawalls, bulkheads, and sheet piling are functionally all the same and consist of solid vertical walls (either metal, concrete, or masonry) to protect shorelines or fill land. The main advantage of vertical walls is that they require less material and take up less space; also ships can conveniently berth next to docks with vertical walls. However, reflected wave energy is maximized with a vertical facing wall; hence, these are only normally constructed along calmer shorelines such as within harbors, protected lagoons, or embayments.

Groins and breakwaters are rocky protective structures that project or occur seaward of the shoreline. Groins function by trapping sand on the updrift side, causing the shoreline to prograde. However, the downdrift sides of groins can cause shoreline erosion because longshore transport is interrupted. Unless groins are properly designed and located, they can cause, more than solve, shoreline erosion problems (Clark 1985). Other structures such as harbors or landfills projecting offshore can inadvertently act as groins, causing shoreline accretion and erosion on updrift and downdrift sides of the structure, respectively.

Offshore breakwaters are aligned parallel to the shoreline but are separated from the shoreline. The outer (seaward) face of the breakwater absorbs wave energy and causes currents and wave action shoreward of the structure to be diminished. As a consequence, shorelines opposite properly located offshore breakwaters are less prone to erosion but still allow longshore transport to occur, thus reducing the likelihood of erosion along adjacent shorelines to either side of the breakwaters. Both groins and breakwaters are often incorporated into harbor designs to minimize surge, wave action, and sediment accumulation within harbor basins where ships are berthed.

c. Other Coastal Construction Activities. Clearing involves removal of groundcover and vegetation, usually at the start of construction, to facilitate compaction or other preparation of ground surface for erecting buildings and foundations and to facilitate excavation and filling.

Other activities include disposal of mine tailings, metallic waste, and other construction debris into estuaries, shorelines, and rivers. Disposal of solid waste including garbage is a common practice in urban centers of Micronesia.

3. Physical Consequences of Coastal Construction

a. Excavation. Mechanical excavation and dredging physically disturb or remove the bottom substrate including habitat for benthos (bottom-dwelling organisms), deposit sediment on the substrate, suspend sediment in the water column, reduce light penetration, increase turbidity, change circulation patterns, and can reduce dissolved oxygen and increase nutrient levels in the water column. Ecologically, substrate removal can have the most significant ecological impact, although eventually at least some recolonization by marine life is possible on the dredged surfaces after dredging is completed. The accumulation of sediment on the bottom in adjacent areas can also have a significant adverse effect on benthos. The most widespread and visible consequence of dredging and excavation, however, is the generation of suspended sediments and turbidity.

b. Explosives. Underwater explosions can cause considerable physical disturbance to both water column and benthic habitats. Impacts are proportionately greater closer to the detonation sites, particularly for open-water explosions. Organisms shallower or to the side of explosions are more likely to be injured or killed compared to organisms deeper than the explosions; hence, deeper water explosions tend to generate higher mortality and casualties. However, explosions in water that is too shallow are ineffective as an excavation method and can generate large quantities of flyrock. Explosives packed into holes or crevices, or covered by sandbags, for example, will cause less damage from shock and concussion.

4. Ecological Consequences of Coastal Construction: Documented Examples

a. Dredging. An unavoidable impact of any dredging operation is the direct elimination of benthic habitat in the dredged area and reduction in associated demersal species.

Although ecological recolonization is possible on dredged surfaces, harbor bottom environments tend to accumulate fine sediments and are most often colonized by soft-bottom or sand-dwelling communities. Dredged surfaces that are not deep (greater than 10-m depth) and exposed to waves and currents (such as quarry holes on outer reef flats) can be extensively recolonized by reef life within a decade or more following dredging. Also hard, elevated surfaces such as revetments and seawalls can attract greater numbers and types of recolonizers, especially fish and corals, based on evidence collected in Hawaii, Kosrae, and American Samoa.

Some of the most significant impacts of sedimentation associated with dredging have occurred during open-water disposal of slurry from pipeline dredging. Slurry from cutterhead dredging at Kwajalein spilled out over a large reef tract, burying coral communities and inhibiting recovery. At Okat Reef, Kosrae, the rate of slurry discharged into a retention basin exceeded the basin's capacity, causing slurry to overflow the walls and spill out over 10 ha of seagrass and coral habitat (see Figure IV.12) and completely buried it under 0.25 to 0.5 m of fine slurry muds (Maragos 1984). In this last case, the impact could have been prevented by a reduced rate of slurry discharges, but the construction contractor had a schedule to meet and was unwilling to slow down operations.

Physical barriers such as silt screens and earthen berms can be effective in reducing areas affected by dredging and filling operations. Silt screens are curtains of plastic, fiberglass, or other fabric that suspend from the surface using a system of floats and anchors; normally, silt screens are effective where wave action is low and water currents are 50 cm/sec or less.

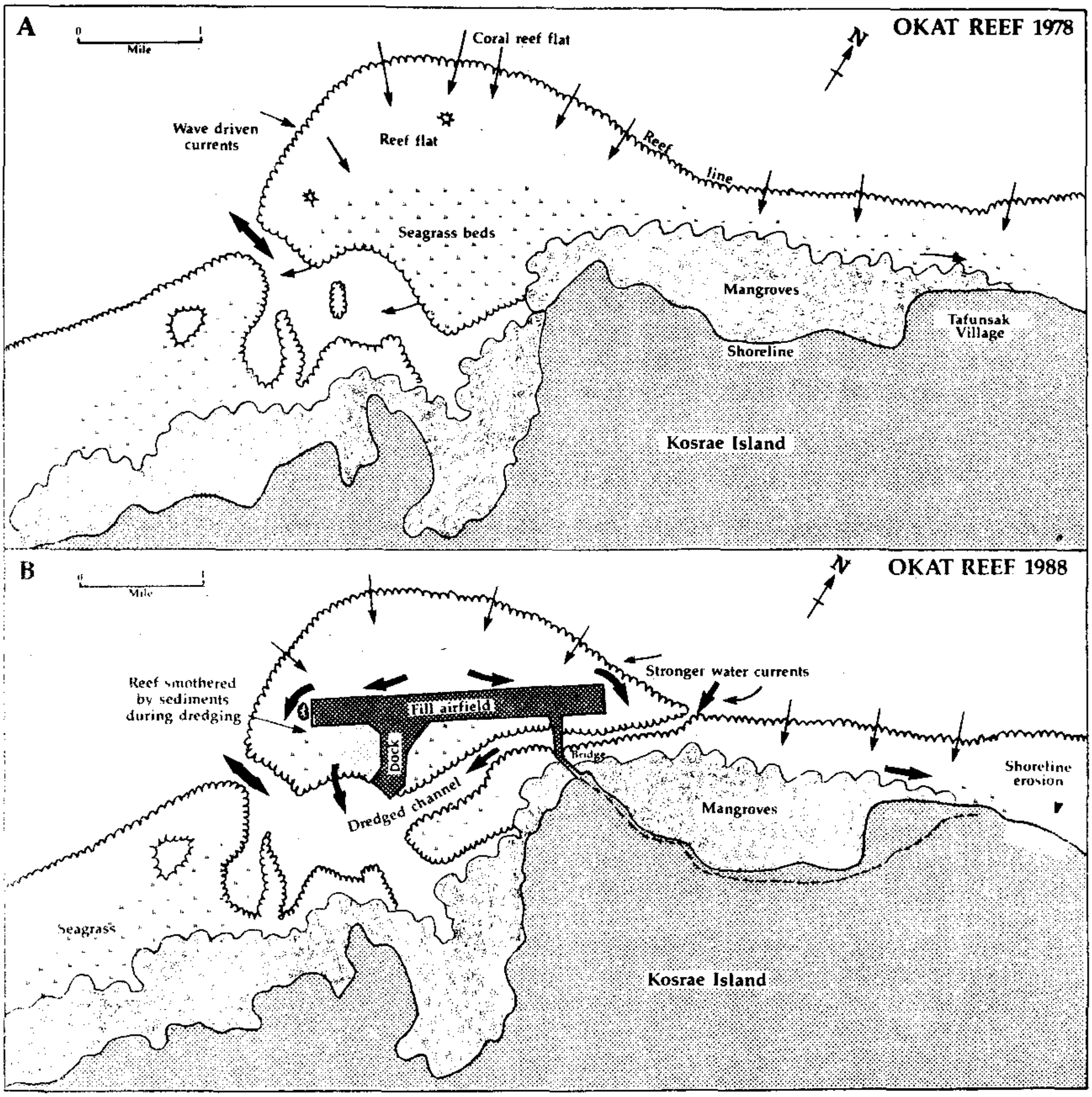

Figure IV.12. Adverse effects of dredge and fill for reef flat runway and dock construction at Okat Harbor, Kosrae Island, Federated States of Micronesia. Construction buried most of the seagrass beds and much of the reef under fill land. Dredging further destroyed reef and seagrass beds and greatly altered circulation in the harbor. The stronger water currents have been implicated as causing shoreline erosion near the airfield and Tafunsak Village, once Kosrae's most important fishing ground. Okat reef yields have declined to half of preconstruction levels (Adapted from Manoa Mapworks 1987; U.S. Army Corps of Engineers 1989).

Indirect impacts of dredging include anchoring operations for barges, ships, and pipelines. Placement and dragging of anchors over sensitive ecosystems damaged fingercoral communities at Keauhou, Hawaii. Conversely, careful anchoring at sand-mining sites in Pohnpei Lagoon avoided damage to reef corals.

The potential synergistic effects of water pollution such as sewage discharges can also inhibit coral recolonization on dredged surfaces based on studies in Pala Lagoon (Helfrich 1975) (see Figure IV.13) and Kaneohe Bay (Maragos 1972; Maragos et al. 1985) (see Figure IV.14). In the Kaneohe Bay example, recolonization of corals on dredged surfaces was accelerated after removal of sewage outfalls in nearby lagoon environments.

On the other hand, quarrying operations on outer shallow reef flats for shore protection, harbor, and airfield projects in the Marshalls and Carolines have improved the value of habitat for reef fishes and reef corals. Quarry holes located too close to shoreline or sandy environments tend to get filled with sediments or be less favorable for coral recovery. Nevertheless corals, fish, and associated reef invertebrates are capable of rapid recovery in holes created from dredging and quarrying, particularly in clear waters subject to flushing from wave action or currents, such as in Pala Lagoon (Figure IV.13), Johnston Atoll, Kwajalein Atoll, Majuro Atoll, and Honokohau Harbor in Hawaii. Reef flat filling and channel dredging through the reefs at relatively closed atolls can lower sea level in the lagoon, killing the reef tops such as may have occurred at Canton Atoll and which may occur at other closed atolls (see Figure IV.15 for Taongi Atoll) if proposed channel widening is implemented.

Less information is available on the impacts of dredging on other important coastal tropical ecosystems in Oceania. Mangroves tend to recolonize the shallower upper slopes of dredged holes near a previous mangrove habitat but will not reestablish on surfaces of holes deeper than 1 m.

b. Use of Explosives. Although information is limited in Oceania on the impacts of explosives used directly for construction projects, there is documentation on the destructive effects of explosives used as a fishing technique, especially from Western Samoa, Truk, and Sulawesi (Indonesia). Corals can be destroyed, shattered, fractured, sheared, or dislodged at progressively greater distances up to 100 m away. Furthermore, fish populations can suffer massive mortality or injury. Observations at Barbers Point indicate most fish killed or stunned by explosives were not preferred edible species and most did not float to the surface (Maragos and Moncrief 1982a, 1982b). Thus, aside from the devastating effect on coral habitat, the use of explosives for fishing is extremely wasteful. Also many corals dislodged, sheared, or otherwise resting on the bottom undamaged were later carried away by waves and surges from a typhoon, thereby amplifying the impact of the explosives. Fish and small marine reptiles or mammals with air cavities (e.g., bladders, lungs) may also be more prone to injury. Explosives stolen or otherwise obtained from construction companies and military sources are used extensively for fishing.

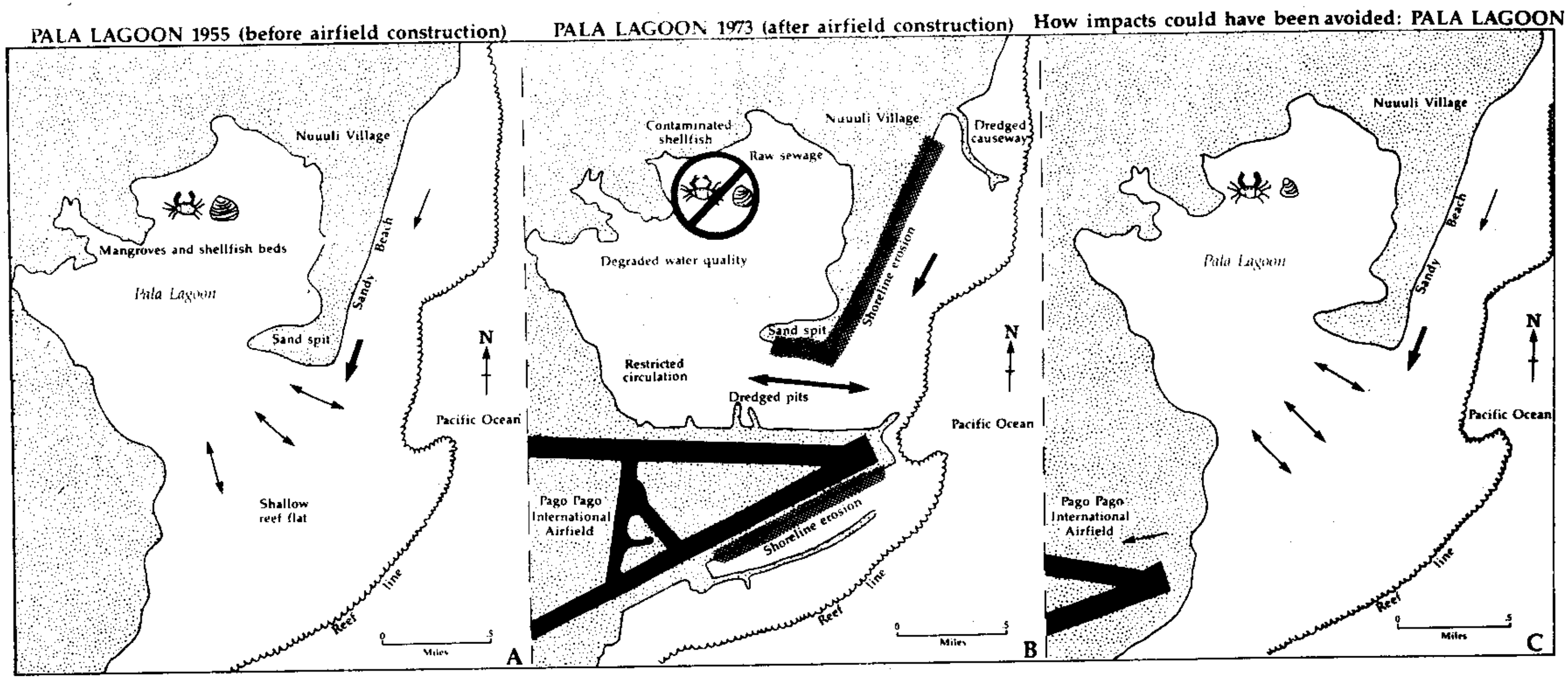

Figure IV.13. Adverse effects of coastal airfield construction, dredging, and filling at Pala Lagoon, American Samoa. Before airfield construction (about 1960), Pala Lagoon was home to American Samoa's most important shellfish grounds. Dredging and filling along the coast disrupted longshore drift, prevented sand replenishment along the coast, and caused shoreline erosion. The airfield partially blocked the entrance to the lagoon, restricting water exchange between the ocean and lagoon and degrading shellfish and water quality in the lagoon. To avoid the impacts, the airfield should have been relocated away from the coast.

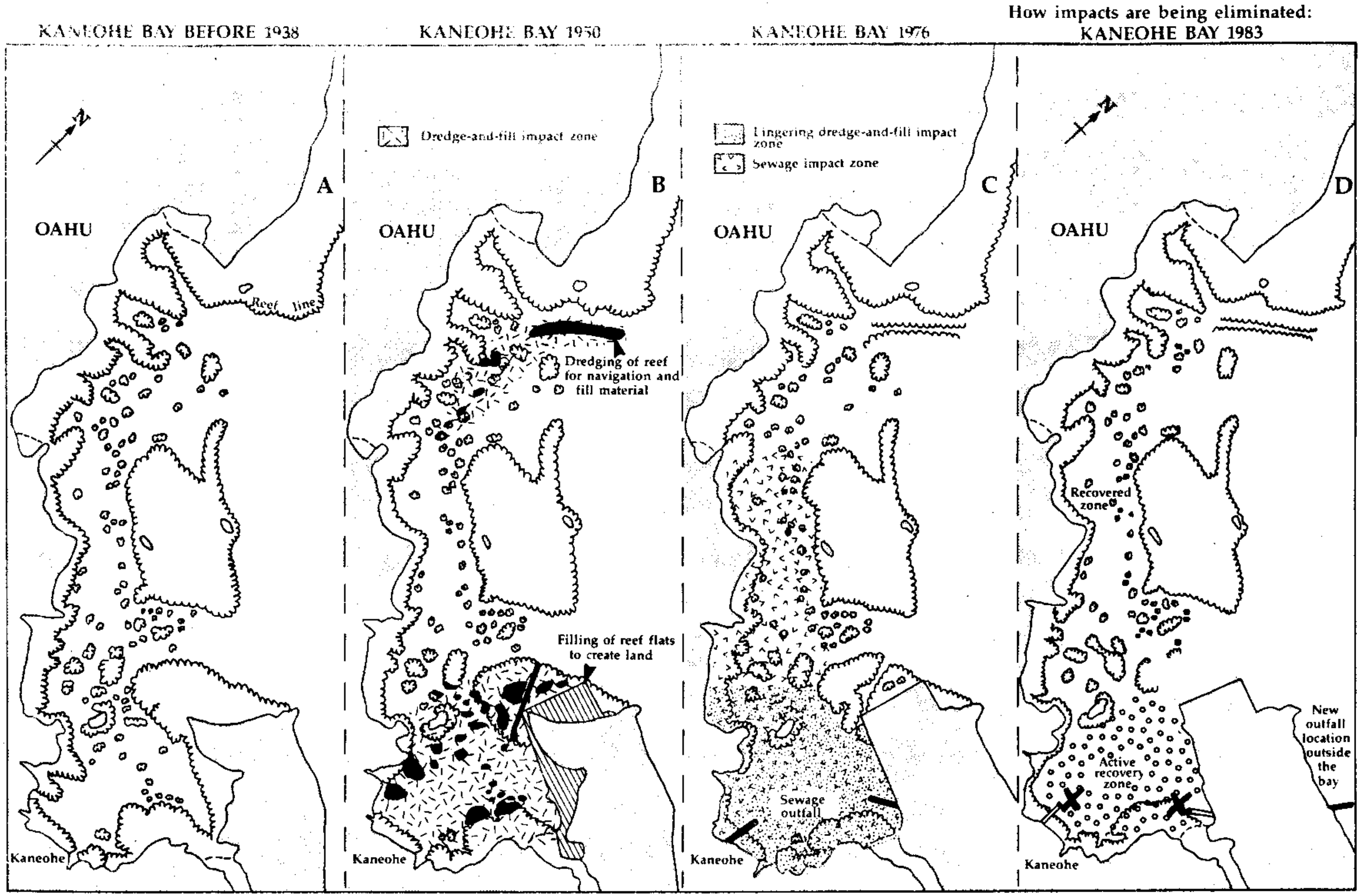

Figure IV.14. Adverse effects of dredging, filling, and sewage discharge in Kaneohe Bay, Oahu, Hawaii. Military dredge and fill between 1938 and 1950 increased circulation in the north bay but reduced circulation in the south bay. By 1970, only northern bay reefs were recovering while central and south bay reefs declined further because of sewage pollution introduced into the south bay from 1950 to 1977. The sewer outfalls were removed from the bay during the years 1977-78, allowing near-complete coral recovery in the central bay and beginning active long-term coral recovery in the south bay. Outfall at new site has not resulted in adverse effects to reefs because of its 35-m depth and the excellent mixing and flushing at the site (After Maragos 1972; Maragos et al. 1985; Evans et al., 1986).

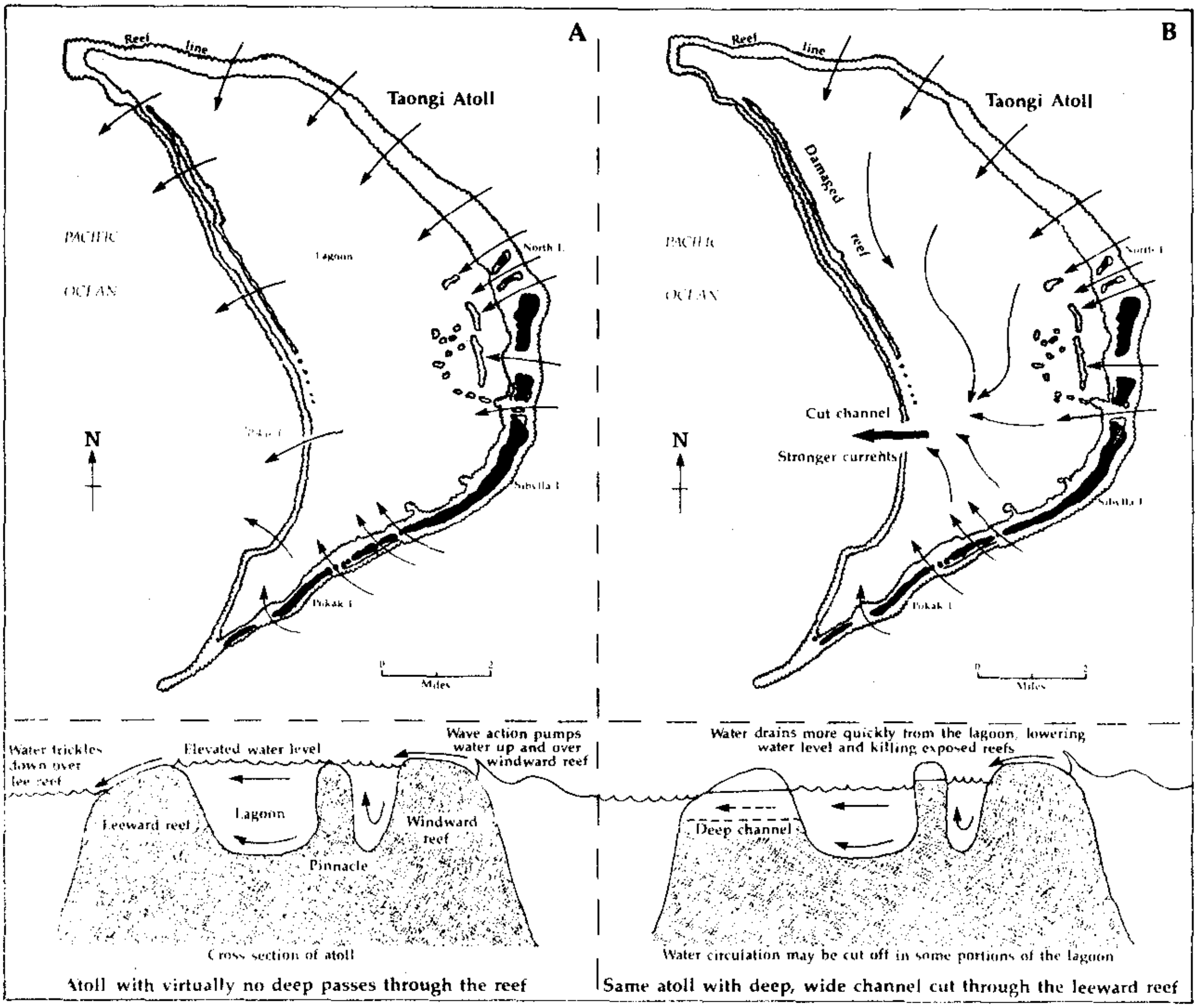

Figure IV.15. Adverse effects of cutting channels through semi-enclosed lagoons. Many atolls (including Taongi above) have elevated lagoon water levels because of wave action pumping water over windward reefs and the lack of large, deep channels to drain the excess water. The reefs grow above normal ocean sea level because of constant water flow and in response to higher lagoon water level. Cutting a deep channel through such an atoll reef would cause waters to drain more quickly, lowering lagoon water level and killing emergent reefs (After Maragos 1989).

On the other hand, drilling and shooting operations have caused little noticeable or documented impact on reef environments, due to the smaller charges and the buffering from shock and concussion afforded by their loading and tamping in predrilled holes. Also, evidence suggests that operations involving staggered detonation times or explosives with slower detonation speeds cause less impact. Chemicals and turbidity generated during explosions appear to cause negligible ecological consequences.

c. Landfilling, Shore Protection, and Other Construction. Landfills, particularly large fill projects such as airfields or other landfills that block circulation and longshore transport, permanently convert aquatic habitat to land and can destroy many hectares of valuable ecological habitat. For example, reef runways at Keehi (Hawaii), Moen (Truk), and Okat (Kosrae) (Figure IV.12) covered hundreds of hectares of reef and seagrass habitat. In Okat, fish catches in the region dropped to one-half of their previous level due to habitat reduction, based on interviews with village fishermen.

The edges of landfills are often the site of colonization by mangroves and seagrasses in soft sediments and by corals on elevated or rocky surfaces such as the revetments for airfields and harbors and the temporary dikes or causeways for dragline dredging in Pohnpei. Reef fishes are often attracted to the interstitial crevices and holes between the armor stone and riprap for the shelter they provide; thus, these sites serve as popular recreational fishing grounds.

Indirect effects of landfills, particularly road causeways, can be substantial if they block water circulation to valuable aquatic habitats or degrade water quality. At Palmyra Atoll (see Figure IV.16), road causeways completely blocked exchange of lagoon waters to the open ocean, causing the catastrophic collapse of lagoon ecosystems; 20 to 30 years later, some recovery was reported in the lagoon after waves and currents breached several sections of the causeways. Ecological impacts included reduction of water exchange, aggravated water pollution from sewage discharges, and blockage of migratory pathways used by reef fishes. Additional causeways are now being planned on Kwajalein Atoll to facilitate communication and population redistribution, but measures such as adequate sideslope protection, bridge openings, and culverts are being included to ensure water quality and reduce ecological impacts (see Figure IV.17). Such projects are extremely expensive and require considerable maintenance and repair, however.

Road projects around the high islands of the Carolines and Samoa have also caused considerable concern (Figure IV.18). A large roadway constructed across a reef flat at Moen, Truk, blocked off circulation to Pou Bay (Figure IV.19), the most important estuary and subsistence fishery habitat on the island. Raw sewage discharges from villages at the shoreline of the bay aggravated water pollution, potentially contaminating shellfish and generating public health hazards. Improvements to the causeway in 1977 included much larger culverts through the causeway, significantly improving water exchange and bay water quality, but it took considerable effort to convince reluctant engineers and government officials of the value of installing the expensive culverts. Circumferential roadway construction around the islands of Pohnpei and Kosrae required a number of "borrow" sites on nearby reef flats to obtain fill and aggregate, and mangroves, seagrasses, and coral reefs were diked and dredged. In an effort to reduce the length of roadways and their costs, "shortcuts" were constructed across the mouths of small embayments, blocking circulation on the landward side within mangroves and estuaries. Also, road alignments were often located on the shoreline to avoid

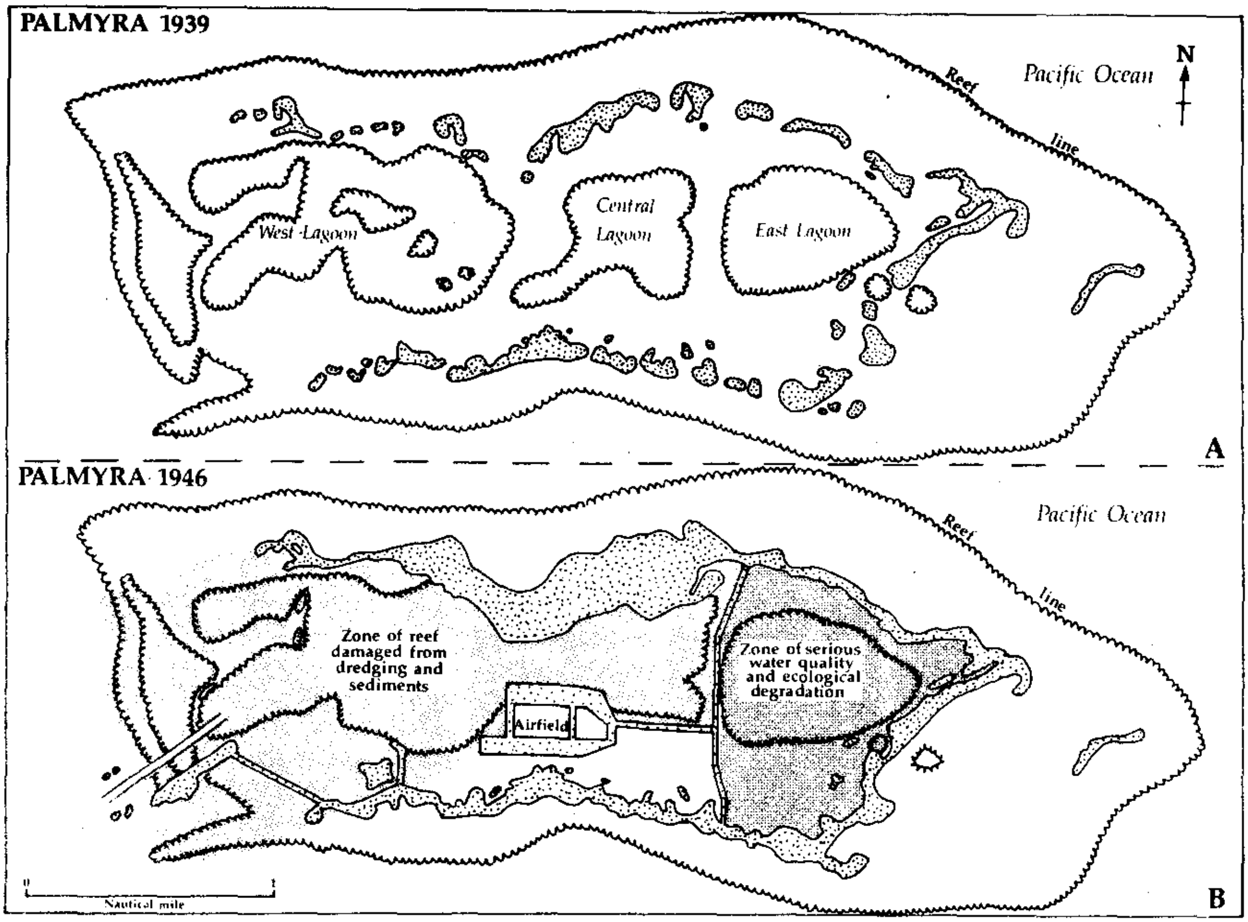

Figure IV.16. Adverse effects of dredge-and-fill operations at Palmyra Atoll, U.S. Line Islands. Construction of road causeways around East Lagoon by the U.S. Navy completely blocked circulation, causing collapse of coral reef communities. Dredging of a channel through the western reef and between the Central and East Lagoons destroyed reefs and altered water circulation. Sediments drifting west from the dredge-and-fill areas damaged reef communities off the western end of the atoll. By 1979, some of the northern causeways had breached restoring some exchange between the East Lagoon and the ocean. Observations in 1987 reveal only partial recovery of the reefs from military construction (After Dawson 1959; Maragos 1979b, 1987).

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costly construction and roadcuts into steep erodible volcanic rock and soils. The large causeway to connect the port and airfield to the town of Kolonia, Pohnpei, has blocked circulation to much of Kolonia Bay and has aggravated water quality and sedimentation and also choked off a mangrove area. A similar causeway across Lelu Harbor to connect Lelu and Kosrae islands reduced circulation water quality, fish migrations, seagrass beds, and fishery catch rates (see Figure IV.20).

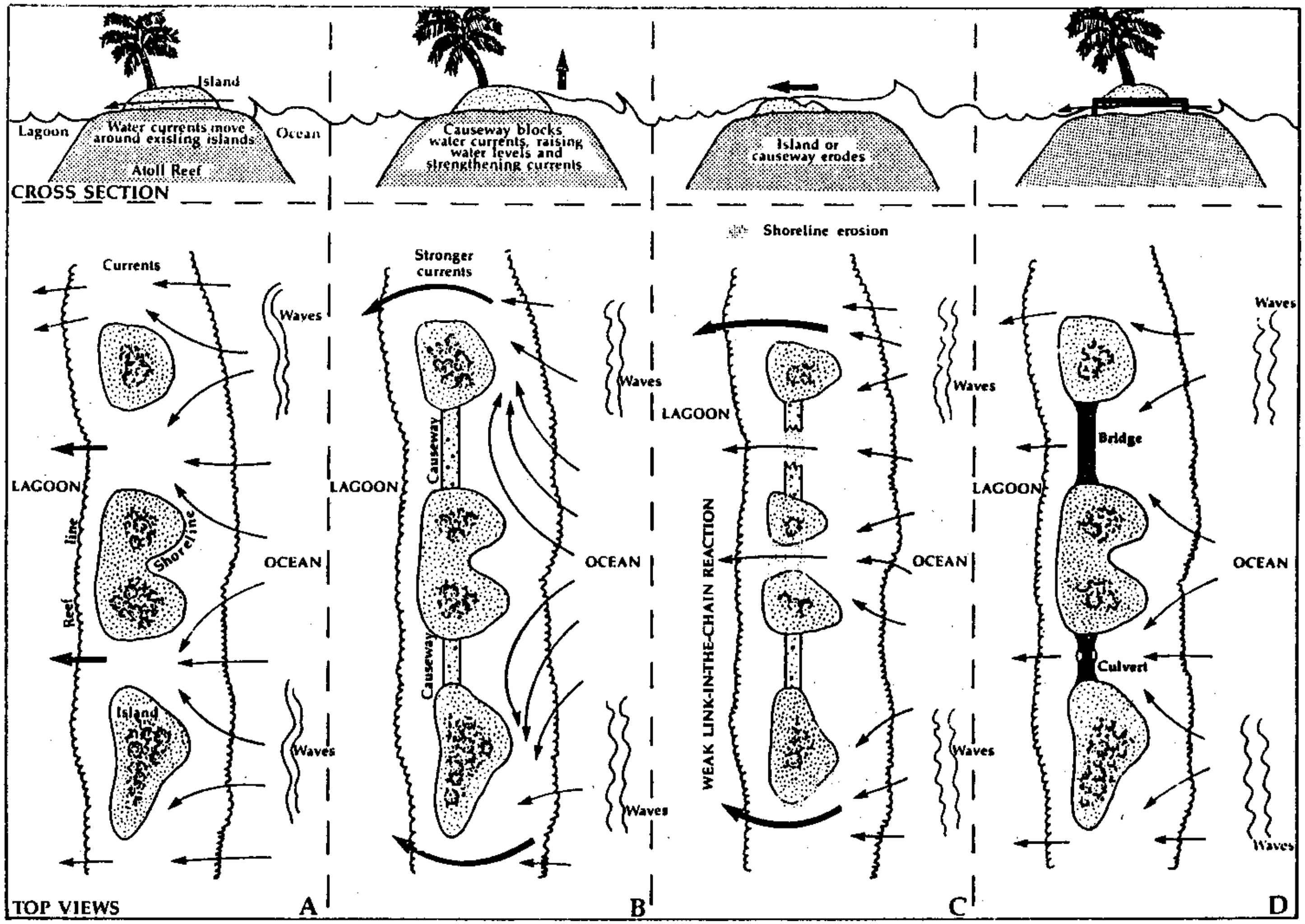


Figure IV.17. Response of water currents and island configurations to causeway road fills to connect islands along a windward atoll reef.

A. Natural configuration before causeway construction. Waves push water currents over the reef into the lagoon.

B. After construction, causeways cause currents to deflect and strengthen. Water levels are pushed higher against islands and causeways by waves.

C. Eventually currents and waves break through lowest causeway or island links, causing erosion.

D. Impacts can be eliminated by placing culverts or bridges continuously through the causeway section to maintain diffuse current flow between islands and reduce sea level rise from wave setup.

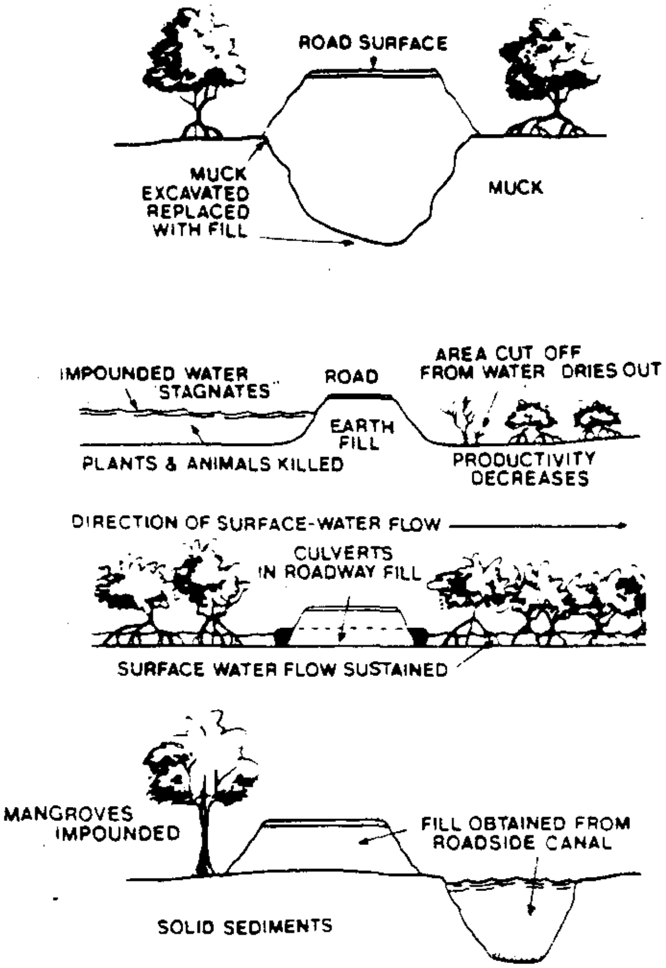


Figure IV.18. Four different road construction techniques, each with different environmental effects (Source: Snedaker and Getter 1985:150).

Landfills that project offshore and lie upon or are adjacent to sandy beaches often function as large groins, causing beach and shoreline erosion on the downdrift sides of the fill structures. At Kualoa, Hawaii, groins constructed to protect waterfront houses disrupted longshore transport of sand and caused many hectares of public beach park erosion 1 to 2 km down the coast. A more dramatic example occurs at Kuta beach on Bali, Indonesia, where the 1967 construction of a large airfield at right angles to the beach and projecting one-half km offshore created a giant groin and caused more than 300 m of beach erosion up to 2 km downdrift from the airfield (Figure IV.21). Not only has the beach berm and dune habitat been lost, but millions of dollars of damage and destruction to restaurants, hotels, and residences has occurred. Erosion continues to this day and has prompted considerable investment in shore protection structures, further degrading the remaining beach. On the updrift side of the airfield, land is accreting and new resorts are being established. Setting back the runway and damaging properties

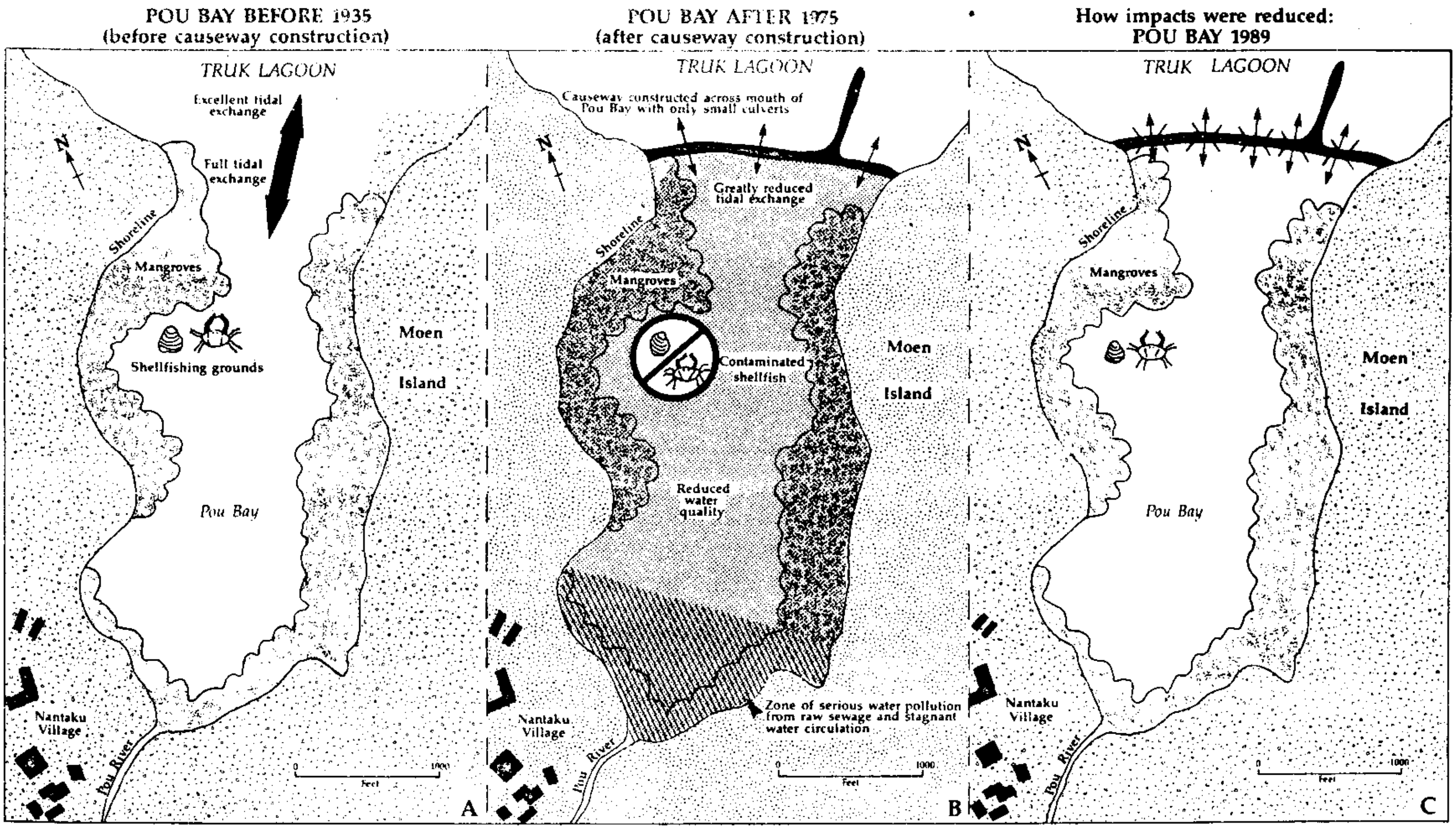
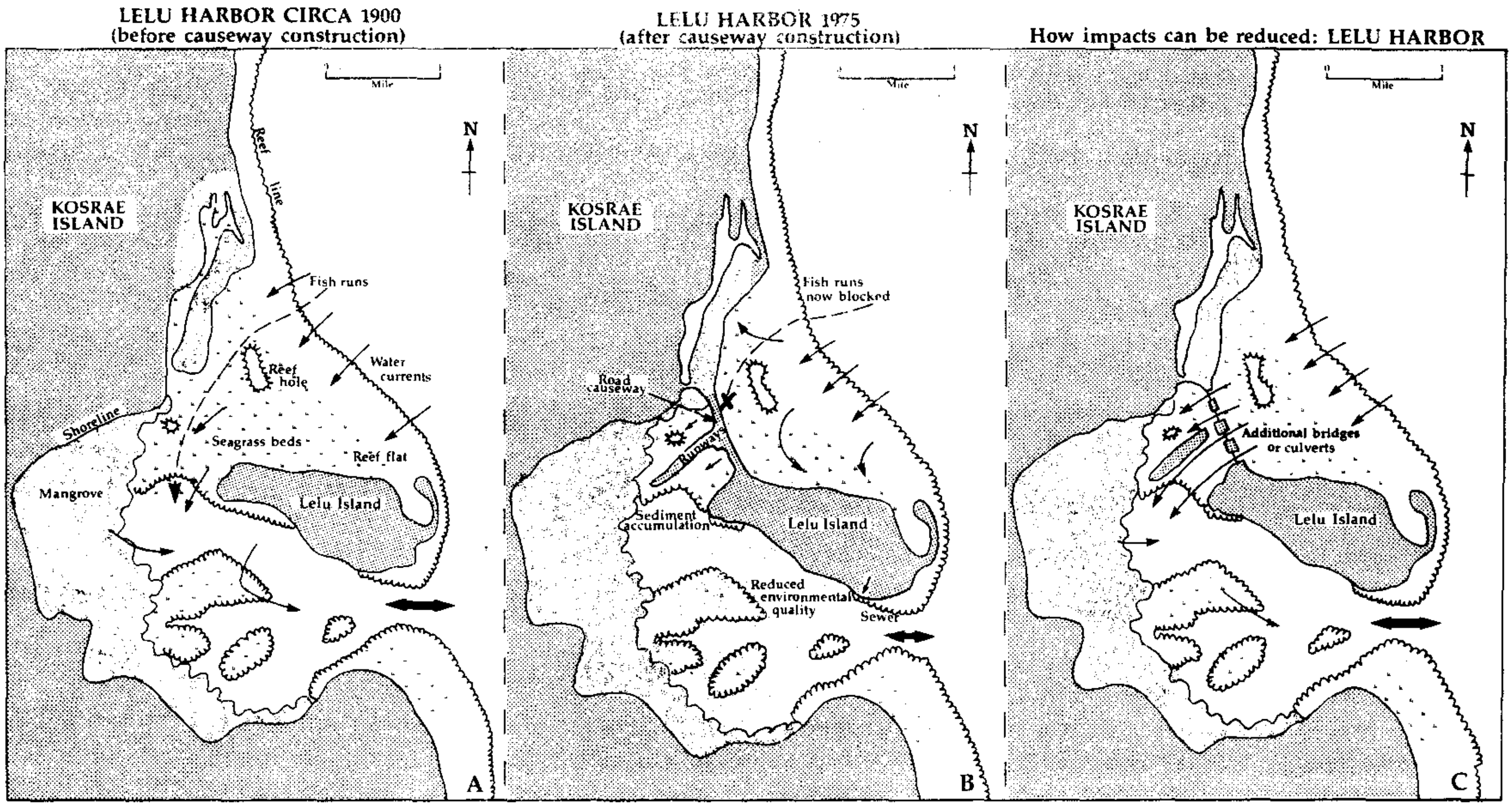


Figure IV.19. Adverse effects of road causeway construction across Pou Bay, Moen Island (Truk Lagoon, Federated States of Micronesia). Original causeway construction blocked circulation into Pou Bay, degrading water quality and contaminating Moen Island's most important shellfish resources. Causeway construction after 1975 required installation of larger culverts to increase circulation and reduce pollution. Additional culverts would result in greater improvement and water quality (Adapted from Environmental Consultants 1979; Cheney et al. 1982).



LELU HARBOR CIRCA 1900 (before causeway construction)

LELU HARBOR 1975 (after causeway construction)

How impacts can be reduced: LELU HARBOR

Figure IV.20. Adverse effects of causeway construction between Lelu and Kosrae islands, Federated States of Micronesia. Original causeway blocked most circulation and fish runs into inner Lelu Harbor, leading to a decline in seagrasses and fish catches. The main culvert in causeway was later blocked for runway fill expansion, further reducing circulation, fish yields, water quality, seagrasses, and coral reefs in Lelu Harbor--once Kosrae's most valuable fishery. Impacts could have been reduced or avoided by adding a continuous line of culverts through the causeway, replacing a section of the causeway with a bridge, and unblocking the main culvert (Adapted from Manoa Mapworks 1987; U.S. Army Corps of Engineers 1989).

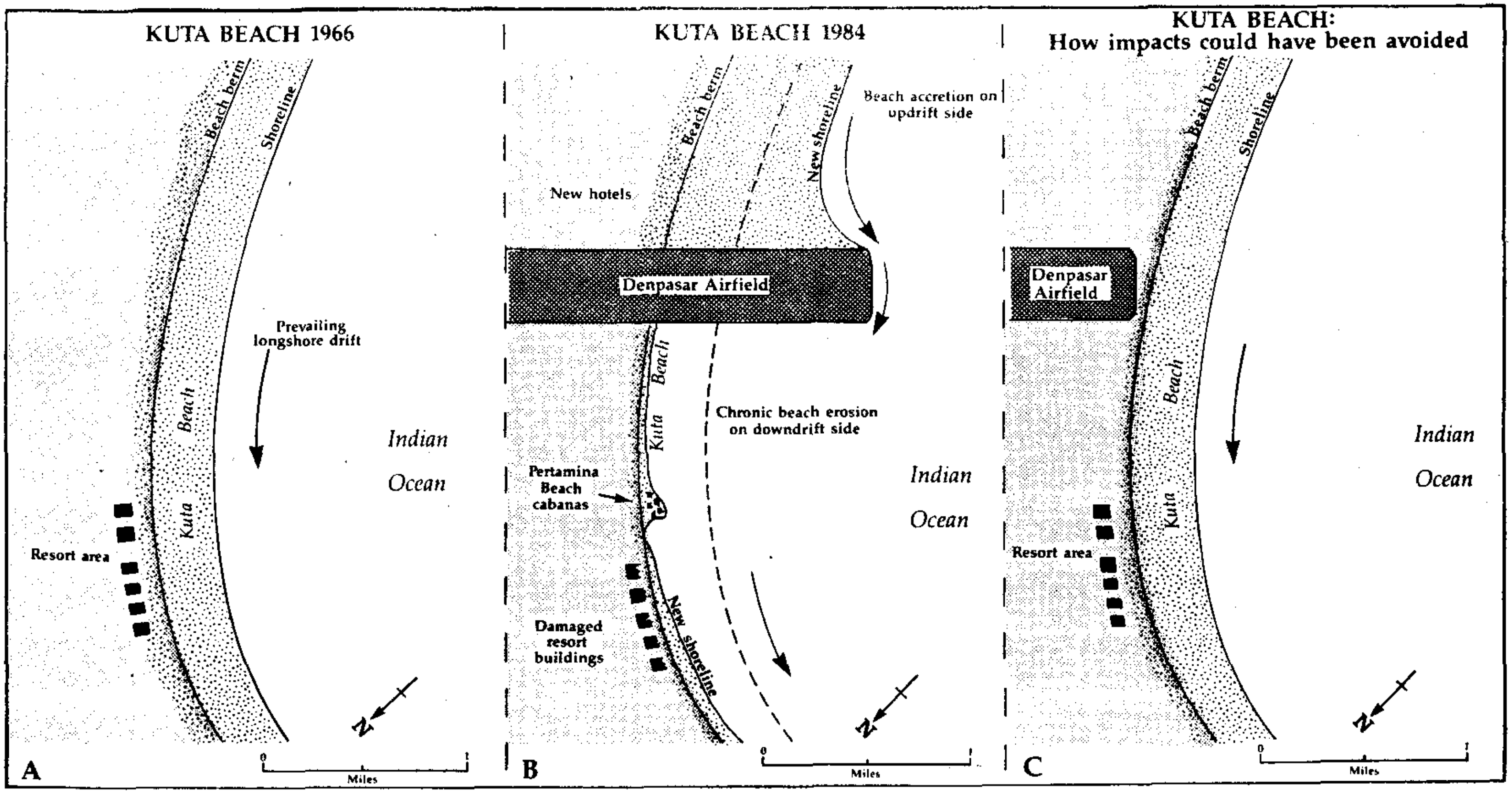


Figure IV.21. Adverse effects of coastal airfield construction near Kuta Beach, Bali Island, Indonesia. Before 1967, Kuta was Bali's largest resort and beach area. In 1967, the new Denpasar airfield was constructed, projecting 3,000 ft offshore beyond the beach. Since that time the beach has eroded more than 1,000 ft on the downstream-side of the airfield. Uninformed officials blamed the erosion on traditional coral mining activities but, in fact, the airfield acted as a huge groin blocking beach replenishment and causing the erosion. While restaurants and hotels fall into the water on the eroding side of the airfield, entrepreneurs construct new resorts on the accreting side. The airfield should have been moved landward of the beach dunes and berm to avoid beach erosion caused by the airfield projecting offshore. In turn, damage to the beach and structures and the need for shore protection could have been avoided (After Burbridge and Maragos 1985).

away from the shoreline could have avoided these economic and environmental impacts (Burbridge and Maragos 1985). Road causeway and airfield construction at Majuro Atoll in the Marshall Islands may have been responsible for shoreline and beach erosion more than 20 miles down the coast.

5. Ciguatera

Dredging, filling, and other physical changes to habitats in the tropics have been implicated as causes for the increased incidence and outbreaks of ciguatera fish poisoning. The poisoning is caused by a toxic dinoflagellate Gambierdiscus toxicus growing on macroscopic algae, which are eventually consumed by fish. The herbivores are eaten by carnivorous fish with the toxin passed up the food chain. Although mildly toxic to fish, ciguatera is much more toxic to mammals, including humans. There is considerable circumstantial evidence for a relationship between ciguatera and construction. Ciguatera was absent on some atolls before construction; however, heavy outbreaks occurred on Palmyra (see Figure IV.16), Johnston, and Bikini atolls during and after construction.

IV.G. PORTS AND HARBORS

(prepared in part by John Harrison and Rory Frampton)

1. Development Objectives

Ports and harbors can range from small facilities such as ramps to accommodate trailer boats for local subsistence fishing to deep draft ports capable of handling freighters, large passenger ships, and supertankers. "Ports" refer to developments for larger deep draft ships requiring basin and channel depths of 30 to 50 ft (9 to 15 m). "Harbors" refer to facilities designed for medium and light draft vessels needing basin and channel depths less than 30 ft (9 m). Light draft harbors (less than 5-m depth) are designed for small boats such as skifts, sailcrafts, and small fishing vessels. Most often medium draft harbors (5- to 8-m depth) are used for field ships, tug and barge operations, and larger fishing vessels. The basis of port or harbor development is access to the ocean for economic, subsistence, emergency, military, and recreational activities. Objectives are to provide safe and efficient facilities for fishing, shipping, trade, or transportation. Harbors or ports usually attract a variety of dependent activities such as dive charters, commercial services, and light industry. As a result, they are frequently envisioned as a catalyst for further development.

2. Project Components

Whatever its size or configuration, a port or harbor will have some common attributes. The most essential purpose is the provision of a safe passage to a sheltered area for boating or shipping-related activities. Thus, it must be free of strong surge or the potential for wave damage. Necessary components to provide this shelter may include the following: (1) an access channel deep enough for desired vessel size and designed to prevent waves from cresting, standing, and breaking; (2) structures to protect the harbor area from waves and surge, usually rock jetties, breakwaters, or moles; (3) a turning basin, deep and wide enough to accommodate maneuvering of desired vessel size; (4) a berthing or docking area; (5) shoreside facilities for unloading, loading, storage, and refueling operations; (6) a small-boat launching ramp; (7) aids to navigation such as channel buoys, range markers, and mooring dolphins; and (8) various related infrastructure to accommodate activities such as access to water, power, waste disposal facilities (especially for vessels), and land access (e.g., roads). Most harbors also require periodic maintenance to repair protective structures, service aids to navigation, and to restore navigation depths (via maintenance dredging) within the channel and basin.

3. Environmental Factors Influencing, and Influenced By, Design and Site Location

The following are examples of important areas of concern for consideration when assessing potential designs for ports or sites of harbor developments:

a. Direction of waves at various times of the year and frequency and direction of storm waves. Without this information, one would not be able to predict if the harbor or port would provide a safe and protected area for vessel operations. Harbors improperly designed and unsafe will not be used by experienced navigators and encourage accidents among inexperienced boaters.

b. Characteristics of the marine environment in the surrounding area. What important fish, coral, estuarine, mangrove, seagrass, and other marine populations occur in the immediate vicinity, and are there any offshore fisheries that depend on nearshore habitats during some stage in their lifecycle? Unique characteristics such as endangered species or rare habitats should also be closely examined.

c. Nearshore currents and other physical oceanographic characteristics and processes. This information will be vital in assessing dispersal of inputs to the water from construction and operations. Knowledge of currents will also assist in understanding how physical structures will affect processes such as shoaling and shoreline erosion along coastal areas near the proposed port. Information on the composition and stability of the nearest adjacent sandy beaches and related coastal berm and dune formations is vital to assess possible shoreline erosion or accretion impacts.

d. Terrestrial inputs, such as rivers, streams, and storm drains. Ports are often placed near the mouths of streams and in estuaries. Maintenance dredging is frequently required in harbors that receive large amounts of erosional deposition from rivers and streams. In addition, terrestrial runoff is responsible for most harbor pollution.

e. Land tenure in the local community. Land transfer and ownership are significant within Pacific island communities. Acquisition and use of shoreline and submerged lands should be examined for legal as well as cultural ramifications. For example, how will leasing or selling submerged land for building private docks or marinas affect public use and right of way?

f. Existing uses in the surrounding area, both on and offshore. The manner in which the location is currently used will influence community reactions about the project, potential loss of use, and nature of activities to be supported by the project.

Other concerns that influence design and site choice are land access to site and ocean access to other islands, population centers, or fishing grounds.

4. Impacts

The nature and extent of project impacts depend directly on the environmental characteristics of the project site. Therefore, it is impractical to attempt to develop a broadly applicable specific checklist of potential impacts. There inevitably will be different sets of environmental circumstances for every project that is assessed. For illustration, we will consider here a general framework with which to understand and assess potential problems. A more complete list of impacts commonly associated with ports and harbors can be found in Tables IV.6 and IV.7 or in the ADB Guidelines (Appendix). The most common environmental impacts in tropical island areas associated with harbor and port development include (1) degradation of water quality in the basin and berthing areas; (2) erosion of adjacent beaches and lands due to changed current and wave regimes attributed to the harbor structures; (3) inadequate safety due to channels too narrow, too shallow, or inadequately marked; (4) the unforeseen need for costly maintenance such as dredging and repair of protective structures; and (5) ecological impacts from dredging, blasting, and filling.

The headings in the tables provide a framework for environmental impact assessment. It is helpful to consider separately (1) the activity causing the impact, (2) the effect or immediate change in the surrounding environment, (3) the effects of this change on human or nonhuman receptors, and (4) possible ways to avoid or mitigate the impact. By recognizing sequential or causal links between specific parts of an activity and its effects, environmental managers may enhance opportunities for meaningful assessment and mitigation.

Harbor construction usually entails blasting (explosive excavation), dredging, filling, emplacement of revetments, and installation of shoreside facilities for berthing and cargo handling. In some cases harbors may be carved out of solid rock (see case study on Barber's Point, Hawaii). Others, such as Pago Pago in American Samoa, have naturally deep basins and channel features which require little modification other than construction of docks and shoreside facilities. Proper site selection is a crucial first requirement for

Table IV.6. Ports and harbors: Construction/short-term concerns

Activity	Consequence to environment	Environmental impacts	Human health and welfare impacts	Mitigation
Dredging/disposal of dredge spoils	• Turbidity • Sedimentation • Benthic destruction • Dredge spoil	• Water quality degradation • Habitat destruction and species loss • Toxicity 1. Ocean disposal - species loss 2. Land disposal - leachate damage	• Public health risk 1. Ciguatera correlation • Welfare losses 1. Subsistence 2. Recreation 3. Economic (fisheries, tourism) • Loss of potentially productive land • Aesthetics	• Design and siting -avoid high-quality areas • Siltation controls 1. Silt curtains 2. Settling ponds 3. Appropriate technology • Productive use of dredge spoil • Compensatory habitat enhancement
Blasting	• Concussion • Noise • Seismic shock	• Destruction of corals • Fish kills • Disturbance of endangered species	• Property damage • Welfare losses 1. Subsistence 2. Recreation 3. Economic (fisheries, tourism)	• Timing to avoid migratory or spawning seasons • Minimize charge size • Placement/ configuration of charges
Site clearance/ grading	• Denuded landscape • Altered soil profile • Altered topography	• Soil erosion • Water quality degradation • Habitat destruction and species loss • Increased runoff • Increased risk of land slippage	• Destruction of cultural resources 1. Archaeological sites • Welfare losses 1. Subsistence 2. Recreation 3. Economic (fisheries, tourism) • Loss of potentially productive land • Cultural displacement • Aesthetics	• Design and siting -avoid sensitive areas • Archaeological survey/ excavation • Grading controls 1. Drainage berms 2. Settling basins • Relocation of displaced population
Construction activities	• Noise • Fugitive dust • Machinery emissions • Congestion/traffic • Structural addition to coast and landscape • Fertilizer/pesticides	• Disturbance of endangered species • Toxicity: species/ habitat loss • Water quality degradation • Eutrophication	• Worker safety • Public health risk 1. Respiratory irritation • Welfare losses 1. Quality of life 2. Subsistence 3. Recreation • Aesthetics	• Noise and emission control ordinances • Toxic substance controls • Timing to avoid migratory or spawning season • Compensatory enhancement
Labor importation	• Immigrant worker population • Sewage • Temporary housing	• Water quality degradation	• Public health risk 1. Disease introduction 2. Sanitation problems • Overburdening of infrastructure • Overburdening of public facilities • Cultural conflicts • Loss of labor from productive sectors	• Minimize contact between temporary workers and local people • Construction of housing adequate for post-construction period • Infrastructure enhancement integrated with project design

Table IV.7. Ports and harbors: Operations/long-term concerns

Activity	Consequence to environment	Environmental impacts	Human health and welfare impacts	Mitigation
Maritime wastes and effluents	• Organic petroleum residues • Heavy metals • Sewage effluent • Anti-fouling compounds	• Water quality degradation • Toxicity: species/ habitat loss • Eutrophication • Change in ecosystem structure	• Public health risk • Welfare losses 1. Subsistence 2. Recreation 3. Economic (fisheries, tourism) • Aesthetics • Clean-up costs	• Discharge regulations • Shoreside collection facilities • Education • Enforcement
Oil spills • Chronic	• Oil and oily wastes POL	• Acute toxicity: species/habitat loss	• Public health risk (long term)	• Emergency response plan--cleanup and removal
• Catastrophic	• Decomposition products • Floating, suspended, and dissolved pollutants • Detergents from clean-up action	• Water quality degradation • Intertidal habitat degradation • Change in ecosystem structure • Coating of birds and animals	• Welfare losses 1. Subsistence 2. Recreation 3. Economic (fisheries, tourism) • Catastrophic risk (cost of clean-up) • Aesthetics of water and beach	• Design-specific safeguards 1. Containment structures 2. Overflow controls
Coastline modification • Harbor configuration • Coastal topography	• Altered physical oceanography • High residence times	• Beach erosion/ accretion • Sand transport • Change in ecosystem structure • Eutrophication • Accumulation of wastes	• Public health risk • Welfare losses 1. Property 2. Recreation 3. Economic (e.g., nearshore fishery) • Aesthetics	• Comprehensive, predesign phase environmental survey • Appropriate site-specific design • Compensatory preserves
Runoff • from shore • delivery by stream	• Sediments/organics • Toxics • Inorganic nutrients	• Water quality degradation • Toxicity: species/ habitat loss • Eutrophication • Change in ecosystem structure	• Public health risk • Welfare losses 1. Subsistence 2. Recreation 3. Economic (fisheries, tourism) • Aesthetics	• Drainage control system 1. Ponding basins 2. Storm drain maintenance
Land-use changes	• Secondary development • Enhanced access	• Urbanization • Overfishing/resources depletion • Change in ecosystem structure	• Public health risk 1. Air pollution 2. Water pollution • Welfare losses 1. Quality of life 2. Loss of agricultural land 3. Overburdening of infrastructure • Aesthetics	• Land-use planning and control • Resource management 1. Catch limits 2. Education • Appropriate site selection avoiding sensitive areas

Solid waste disposal	• Waste from human activities pollutes water and soil • Leaching from landfills or dumps • Smoke and fumes from burning	• Water and air quality degradation • Toxicity: species/ habitat loss • Marine life entanglement	• Public health risk • Welfare loss 1. Economic (tourism) • Aesthetics • Clean-up costs	• Plentiful supply of litter receptacles • Routine clean-up • Adequate treatment and disposal technology
Land-based sewage effluent	• Suspended solids • BOD • Pathogenic organisms • Chlorine • Freshwater demand • Toxic industrial waste	• Water quality degradation • Eutrophication • Toxicity: species/ habitat loss	• Public health risk 1. Pathogenic exposure/ transmission 2. Food web toxic accumulation • Welfare loss 1. Subsistence 2. Recreation 3. Economic (fisheries, tourism) • Aesthetics • Clean-up costs	• Waste management program
Harbor operations (terrestrial and marine)	• Noise • Congestion/traffic • Hazardous material concentration	• Disturbance of endangered species • Toxicity: species/ habitat loss	• Welfare loss 1. Quality of life 2. Economic (time costs) • Public safety risk	• Vessel operations management • Noise ordinances • Toxic substance controls

the mitigation of significant environmental effects of harbor construction. Design and siting are equally important to minimize costly maintenance operations such as periodic dredging of channels and basins and repair of protective structures.

The example illustrates sequential and causal relationships between activities and their impacts as presented in Tables IV.6 and IV.7.

Modification of the shoreline and nearshore submerged lands by dredging and filling activities results in the destruction by removal or smothering of benthic habitats and lifeforms such as coral reefs and their associated fauna (see previous Section IV.F, "Coastal Construction Activity"). The degree of destruction obviously depends on the quantity and quality of the benthic community at the site and the extent of the construction activity. Additional direct effects of dredge-and-fill operations include generation of turbidity plumes and crushing of shallow reef communities by heavy equipment. The disposal of dredged material can occur either on land or at an offshore site. The collection, transportation, and disposal of this material also can cause significant turbidity and sedimentation.

Coral reefs of Pacific islands are adapted to clear waters and thus are particularly susceptible to turbidity caused by dredge-and-fill processes. Advance knowledge of currents in the area of construction allows prediction of direction and persistence of turbidity plumes, thereby facilitating assessment of potential impacts of dredging surrounding marine communities.

Local currents also play a role in recruitment and survival patterns related to the distribution and zonation of corals and other marine life. Thus, dredging and the resultant physical alternation of topographic features that may alter current regimes also can have profound effects on reef community structure in a surrounding area. (See numerous examples cited in Section IV.F, "Coastal Construction Activity.")

The potential ramifications of the loss of a coral community are extensive. Coral reefs can serve a variety of functions, some that are not readily apparent: (1) they provide protection of the shoreline from the effects of large wave action; (2) they can provide fish for economic stability and way of life; (3) they are an important resource for education and culture; and (4) they provide aesthetic values by playing a significant role in tourism and the "sun, sand, and sea" appeal of a Pacific island.

As noted in Table IV.6, recommendations for alleviating impacts of dredging usually fall into three categories: (1) site selection (look for natural conditions that would alleviate impacts and avoid valuable or sensitive areas); (2) selection of appropriate technology (to minimize turbidity and sedimentation--dredge spoils can often be collected in settling areas and used for alternative purposes such as revetment fill or other construction-related purposes); and (3) restoration of sites.

Revetments or harbor structures may interact with local wind, tide, and wave forces to alter offshore currents, sand distribution, and shoaling processes. In addition, a variety of factors including depth and orientation, and groundwater flow into the harbor will influence seawater residence time and circulation within the harbor.

Alteration of nearshore currents could result in erosion of nearby beaches or shorelines, while high water residence times could lead to deterioration of water quality within the harbor basin. In the absence of adequate flushing, accumulated wastes from harbor-related activities (e.g., minor oil spills, land runoff, and sewage from boats) would diminish the attractiveness of the harbor and could threaten the quality of nearby fisheries and beaches.

As outlined in Table IV.6, nearshore currents, wind patterns, wave conditions (regular and storm), and groundwater influx must be well described to determine the harbor configuration for maximizing both harbor flushing and safety.

Harbors can be classified as inland or coastal. For inland harbors the turning basin and berthing areas are excavated or quarried inland from the natural shoreline with only the entrance channel and some protective structures constructed seaward of the shoreline. Coastal harbors have all basin and channel areas seaward of the natural shoreline. Inland harbors take up more existing land and involve more excavation but are usually safer. Coastal harbors involve more offshore dredging and protective structures.

The siting of harbors on atolls also pose unique constraints. Few ocean-facing reefs on atolls are suitable and safe sites for harbors; therefore, most facilities are located on the lagoon side of the reefs. However, lagoon harbors often require lengthy and sometimes treacherous passage of vessels through reef channels, and near reef shoals and other navigation hazards. Thus, atoll harbors must be carefully planned and sited.

5. Illustrative Case Studies

a. Barbers Point Deep Draft Harbor

Project and site description. In the late 1970s, the U.S. Army Corps of Engineers and the State of Hawaii Department of Transportation prepared environmental impact statements (EISs) for developing Barbers Point Deep Draft Harbor--the former for dredging and excavation activities and the latter for construction of shoreside facilities. The harbor is sited on the south-western corner of the island of Oahu, 15 miles west of Honolulu Harbor. The purpose of this port development was to provide a second major facility for shipping on Oahu to meet projected increases in waterborne commerce. The facility was intended to complement an adjacent industrial park and to attract development in the area by reducing shipping and land transportation costs. These plans coincided with the local government's intent to shift growth toward this area of the island and away from overcrowded Honolulu.

The Corps proposed an inland harbor configuration to create a 96-acre basin with a depth of 38 feet. An entrance channel 450 feet wide, 4200 feet long, and 42 feet deep was dredged, and 4800 feet of wave absorbers were emplaced (see Figure IV.22). State plans included construction of shoreside facilities on 200 to 300 acres of surrounding lands.

Existing at the site was a 9-acre privately owned barge harbor built in 1961. At the time of the EIS preparation, water exchange within the harbor was considered efficient, in part due to seepage from groundwater sources. Nearshore marine environmental quality was considered good, with a practically flat bottom in the proposed access channel consisting of hard coral rock or rubble and a low coral cover. One kilometer to the north of the site, coral heads up to 30 feet in diameter and height were common. The landform from which the harbor was to be excavated was an emerged coral-algae calcareous reef with a flat, hard, and extremely porous surface.

Impacts-dredging, disposal of spoils, water quality, land use. Excavation of the 96-acre basin and access channel was estimated to produce 10.6 million cubic yards of material. Thus, it was felt that dredging would potentially cause significant sedimentation and turbidity problems. Because of the inland configuration of the design, however, most of the excavation for the harbor basin could be isolated from the coastal waters by maintaining a land barrier between the ocean and the inland dredging operations until most of the excavation had been completed. This mitigating proposal substantially reduced the sedimentation problem associated with the land-based dredging.

As mitigation against effects of ocean-based dredging, a number of measures were proposed: suspension of dredging during heavy seas; use of silt barriers or containment facilities for nearshore operations; piping of materials to shore and providing settling basins to remove sediment before water was returned to the harbor or the ocean; and minimal blasting. The EIS concluded that, along with the longshore current and wave action in the area, these controls would prevent significant sedimentation or turbidity impacts. However, a problem arose when the actual operations took place. The company contracted to perform the job determined the need to conduct extensive blasting operations because the hardness of the rock was greater than estimated by Corps engineers. As a result, offshore blasting produced shock waves that local biologists feel destroyed corals within at least 100 meters of the blast sites in the proposed entrance channel alignment. Green sea turtles, which were commonly sighted before blasting, did not reestablish themselves in the area for at least 3 years. Also, nearby residents complained that blasting in the inner harbor excavation caused concussions that cracked their house foundations. A number of lengthy lawsuits resulted from these claims.

A second major issue was the disposal of the roughly 10.6 million cubic yards of material that would be generated. If dumped on land, the stockpile for this material was estimated to be 30 to 35 feet high, covering 370 acres. This amounted to a large commitment of land

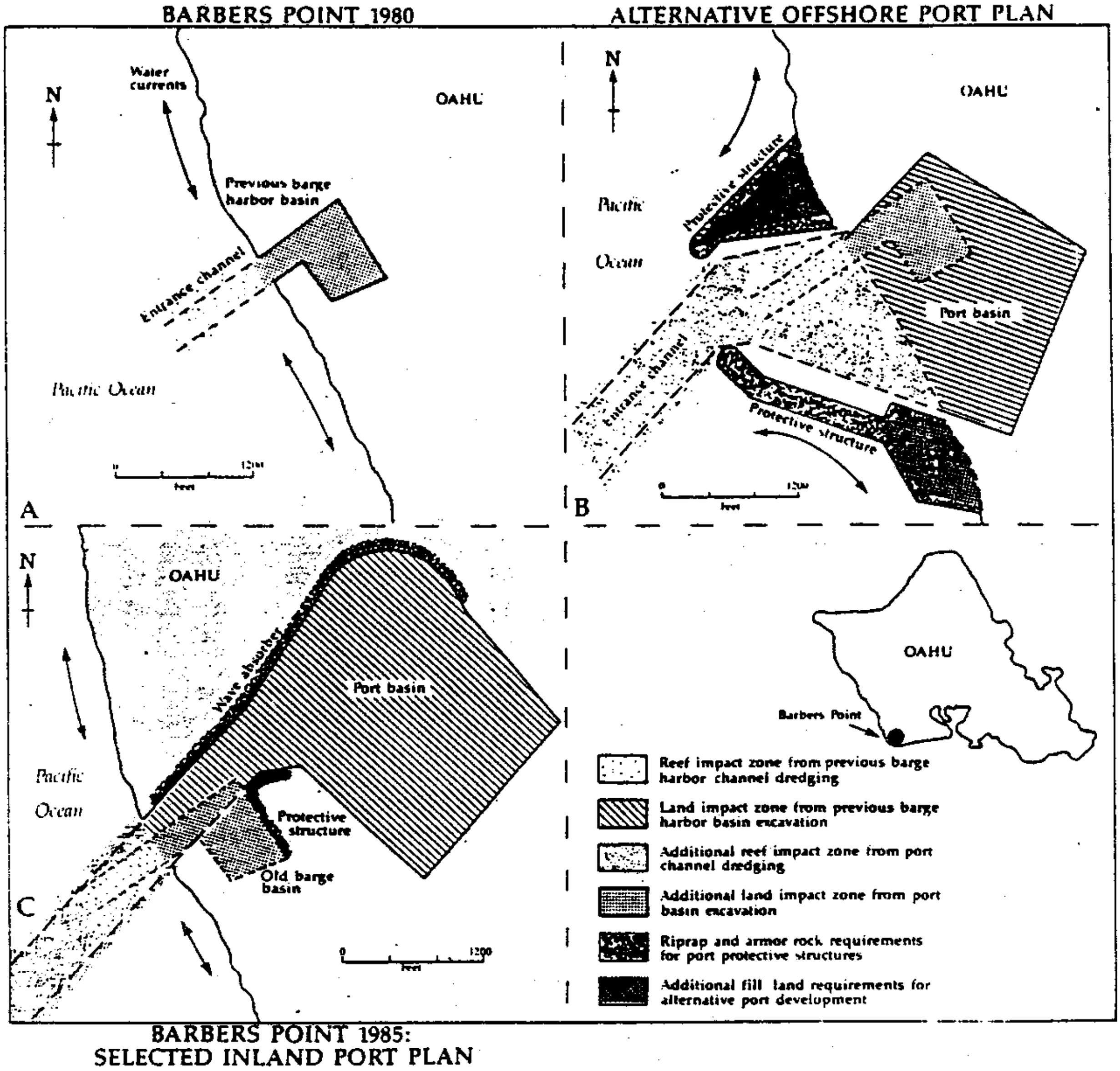


Figure IV.22. Port Development at Barbers Point, Oahu Island, Hawaii. Deep draft port development invariably results in significant environmental and economic impacts. An existing medium draft barge harbor off the SW corner of the island of Oahu (A) was too shallow and small for commercial ships. A conventional offshore port plan (B) would have caused greater marine impacts from dredging and filling and moderate loss of land to port basin excavation. An inland port concept (C) was selected for development. This port design resulted in substantially less marine impacts but greater loss of land to basin development. No permanent loss of marine habitat to fill land resulted. Material dredged from the basin was stockpiled on adjacent land and is being sold for construction purposes to offset the cost of the harbor. Excavation of the inland basin was isolated from the sea by an earthen barrier, further limiting adverse environmental effects to coastal reefs from turbidity and sedimentation during construction. Overall development of the inland port plan resulted in less economic cost and environmental impacts.

and also to a visual impact in the relatively flat surrounding area. However, conserving the excavated limestone was important, because the material was useful both in agriculture (because of its high calcium content) and for construction purposes. In fact, amortization of a major portion of the payment for the project site was derived from the sale of this material. Thus, the visual impact and the commitment of land would be temporary. Based on processing plant limitations and marketability, the depletion period was estimated at 17.5 years. It was suggested that the visual impact of the stockpile could be mitigated by planting vegetation on it. Furthermore, to compensate for the loss of land use, the expanse of flat land on top of the pile could be used as a storage site. Land disposal of the dredged materials eliminated significant impacts to marine ecosystems had the materials been disposed in the ocean. Land disposal clearly resulted in less impact compared to ocean disposal.

Another area of concern was the water residence time and circulation patterns within the proposed harbor. If residence time was high and circulation poor, eutrophication and/or accumulation of sediments and concentration of toxic substances would occur. Model studies predicted that impacts would not be significant as verified by post-constructing ecological surveys. A drainage system was designed for collection and disposal of site runoff to minimize water pollution. Additionally, a regional treatment plant at the nearby industrial park would be used for disposal of wastewater from vessels and shoreside facilities.

b. Leone Harbor (This discussion is based primarily on information contained in an environmental assessment (EA) for Leone Harbor by Noda and Associates.) In August 1987 an environmental assessment was prepared on a proposal by the American Samoa Government to develop a harbor facility at Leone Village, on the island of Tutuila. The government's objectives in building the harbor are "to enhance the local fisheries infrastructure, improve commerce and transportation between Western Samoa and Tutuila, encourage decentralization of commercial and retail development from the Pago Pago bay area towards the Western District, and reestablish Leone as a traditional landing port." The proposed plan consists of facilities for small boats as well as an inter-island ferry, the Queen Salamasina, which transports people and cargo between Western Samoa and Tutuila.

The actual structures would consist of a small-boat launching ramp; a 140-foot wide entrance channel, 16 feet below msl; a 78,000-square foot turning basin, 12 feet below msl; a 30,000-square foot berthing area, 6 feet below msl; a 300-foot long breakwater; a 300-foot long revetted mole; and 2.6 acres of revetted fill area.

Leone is the largest village in the Western District of Tutuila, about 13 road miles from Fagatogo and 6 road miles from Pago Pago International Airport. There is no system of land-use controls or planning, and public works infrastructure (water, power, solid waste, and transportation) is considered to be at or very near capacity. There are no sewer facilities in the area.

Leone Bay contains a variety of physical and biological features including a mangrove swamp at the outlet of Leafu Stream, archaeological sites, shallow reef flats, and a dense climax stage coral reef community. As a result of the devastating effects of an Acanthaster planci (crown-of-thorns starfish) infestation in the late 1970s, which for unknown reasons bypassed a portion of Leone Bay, the dense reef reportedly is the last remaining major climax community of table corals (Acropora) on Tutuila. Therefore, it may be extremely important for the recovery of Tutuila's coral reefs through the planktonic dispersal of sexually produced larvae.

Much of the discussion concerning EA has centered around the potential damage to the coral reef and on the impacts that the harbor and harbor-related activities will have on infrastructure and land use in Leone.

Dredging proposed in the EA directly eliminates about 0.5 acres of the roughly 2-acre Acropora community. The extent to which the construction activities will adversely impact the rest of this community is unclear, but the potential damage due to sedimentation and blasting could be severe. Destruction of the reef would result in loss of habitat for fish and other marine organisms, as well as diminishing a natural resource that attracts diving and other tourism-related activities. Although the draft EA did describe the reef's primary characteristics for species distribution, it failed to mention the ecological importance of this last remaining climax stage reef in terms of island-wide reef systems. The public review process was instrumental in focusing attention on the importance of this reef in the surrounding environment.

Operations in the harbor could have a variety of impacts. Chronic minor oil spills, bilge pumping, sewage discharge (especially from the ferry), and litter could pose health and pollution threats. These impacts also would have an adverse effect on aesthetics in the area and could lower its appeal to residents and tourists alike.

The Leone area is projected to grow in population in the coming years. The harbor development will undoubtedly hasten the growth rate by attracting commercial, tourism, and fishing-related activities. Without land-use controls, an overall decrease in the quality of life might emerge from lack of attention to problems of incompatible uses, housing, health (pollution/sewage), and infrastructure needs.

Expansion of infrastructure and public services to meet the needs of the new harbor facilities and related community growth will place additional burdens on the local government and should be considered part of the project costs. Given the limited supply of government funds, it is highly likely that money for construction and maintenance of the harbor and other infrastructure facilities will have to be diverted from other sectors or programs.

c. Marshall Islands Dock Project. A major component of the prior Trust Territory of the Pacific Islands (TTPI) Capital Improvement Program in the late 1970s was construction of new piers on

14 atolls to improve shipping and to stimulate economic self-sufficiency of the out islands, especially with respect to fisheries development. The docks would also promote tourism and more efficient movement of copra, the only other economic potential to the out atoll islands. During project planning, much emphasis was placed on getting information from local residents to identify existing uses of the environment and their cultural and historical significance, probable users of the facilities, local environmental conditions, and participate in design and siting decisions. Due to funding constraints, only one of the proposed docks has actually been constructed at Jaluit Atoll but preliminary EIAs have been performed for all 14 sites.

The basic design of most of the projects consisted of small, pile-supported docks with a cement bulkhead that required no dredging or fill to minimize construction impacts on marine habitats. Theoretically, bulkhead construction could alter the existing topography of the beach and could affect current velocities and direction. As a result, altered sand distribution patterns eventually could lead to erosion problems at adjacent beaches. However, the design and siting of the docks were evaluated at each atoll by a team consisting of a geologist, ocean engineer, and marine biologist to avoid these very effects.

Although pile emplacement and bulkhead fill would disrupt the substratum in the working area during construction, long-term disruption of the benthic community would be minimal. The open piles themselves do not displace a large area, would create additional hard substratum for colonization, and would minimize disruption of longshore transport of sand. Environmental damage also would be mitigated through careful on-site selection to avoid high-quality benthic communities such as reefs, which were evaluated by field survey and during interviews of knowledgeable residents.

Vessel operations at the dock could affect water quality in the area through sewage, chemical, or solid waste contamination. Chronic sewage discharge would increase algal production, which could have adverse effects on reef organisms. Proposed measures to minimize these potential problems were site selection and prohibiting bilge or septic tank discharge at the dock. In this case, the assessment occurred very early in the planning process, and proper site selection was emphasized. However, the remoteness of the various sites raised the problem of enforcing discharge regulations.

Construction of an access road would result in devegetation and disruption of soils over the site area. This could expose soils to water erosion; however, effects here were considered minor due to high permeability of rocky soils and low rainfall. Mitigation steps identified were to leave whatever thin topsoil there was undisturbed or to stockpile it for further redistribution, and second, to grade in conformance with normal contours of the site as surveyed prior to construction.

There was also concern regarding the potential for introducing exotic biota (e.g., rats and insect pests) through increased vessel contacts. Vessel operators were instructed to use rat guards and other measures to prevent introduction of additional exotic biota to the island.

Although suitable dock sites were identified along lagoon island shorelines for most of the 14 atolls, not all of the atolls had naturally safe passages through the reef to permit lagoon dock siting without extensive blasting and dredging. Also some lagoon reef flats and shoals were too extensive to place docking facilities near some inhabited islands without extensive dredging. Consequently, some alternative designs for docks were developed including detached lagoon platform docks and ocean-facing docks. The detached platforms allow large ships to moor safely in the lagoon where cargoes can be offloaded or onloaded. Smaller vessels would then be needed to transfer cargoes between the dock platform and the inhabited islets at the atoll. The ocean-facing docks would not be usable during heavy winds and seas. Complete EIAs at these and remaining undeveloped atolls could identify other designs and sites to facilitate safe, usable, and environmentally compatible dock facilities on the outer inhabited atolls of the Republic of the Marshall Islands.

IV.H. WASTE MANAGEMENT AND POLLUTION CONTROL

1. Strategic Planning for Wastewater Management

Water pollution control and abatement were the focus of U.S. pioneering efforts in developing environmental laws and regulations during the past three decades with little precedent and experience. The evolution of U.S. programs for restoring and maintaining the integrity of the nation's waters was a trial-and-error process with both successes and failures. Developing countries in the tropics, especially island nations, can learn much from the U.S. record to promote approaches in restoring or maintaining clean water that maximize efficiency and minimize cost and complexity in maintenance and operation.

Primary sewage treatment consists of removing floating and settleable solid materials and allowing biological decomposition of organic matter to proceed to the extent that storage (residence time) is available. Perhaps 25 to 50 percent of the biological oxidation demand (BOD) is removed. A pond may be used to hold the liquid waste. It is then filtered through a screen and discharged to a stream or into the ocean, sometimes with chlorination to kill pathogenic organisms. Secondary treatment involves essentially completing the digestion of organic matter by aeration in tanks so that 90 percent of the BOD is removed. A large investment in equipment and tankage is required to assure sufficient time for the reaction to occur. Tertiary treatment means addition of coagulating agents and other chemicals to the secondary effluent in order to precipitate and remove phosphates, heavy metals, and other dissolved materials. The product of this sophisticated treatment can be water of fairly high quality if the operation is carried out as designed. Surges in the amount of sewage to be treated can overwhelm any of these treatments and result in raw sewage spilling out into the environment.

Early U.S. emphasis on clean water was on treatment of sewage to meet established levels of water quality necessary for beneficial uses. Secondary treatment was to apply to all municipal (human sanitary) sewage. In some cases, tertiary treatment, a process essentially eliminating all impurities from sewage, was also espoused by many engineers to maximize use or even permit recycling of treated water. However, two decades of experience have shown that secondary treatment is complex, expensive, and requires high energy consumption. Furthermore, tertiary treatment has never achieved full expectations. Actual levels of treatment often fail to meet even secondary levels. Insufficient attention to siting and ecological factors was a major flaw in early clean-water policies. Over the years, however, engineers realized that some ecosystems can assimilate low to moderate levels of sewage with few obvious effects (e.g., mangrove swamps) while other ecosystems (coral reefs) appear less adaptive to sewage. For example, coral reefs do not benefit from the increased nutrient levels in sewage because they have evolved functional processes in recycling nutrients within the system. Importing nutrients to the coral reef opens up the possibility of growth of other benthic organisms (particularly macroscopic algae), which would otherwise compete unsuccessfully with corals and other reef life.

Greater emphasis on commercial fishing, aquaculture/mariculture, beach going, resort development, and subsistence fishing mandates adequate sewage treatment to protect public health and ecological health, especially in small island nations surrounded by coral reefs.

The U.S. experience has demonstrated that standard, inflexible, across-the-board treatments for all sewage effluents are inappropriate. Secondary treatment, for example, may make inorganic (instead of organic) nutrients more available for plant growth. Primary or advanced primary treatment with chlorination may be acceptable if outfall locations are not situated near population or food supplies. The high energy requirements of advanced treatment processes may be a luxury that the U.S. can afford, but that developing energy-poor nations cannot. During power outages at sewage treatment plants, raw sewage is often shunted directly to the outfall without treatment. If the pumps are not working, the raw sewage overflows or backs up and contaminates storm drains and urban land areas. The following Kaneohe Bay case history exemplifies the problems and solutions directly relevant to Pacific islands and other tropical nations.

a. Lessons Learned: Kaneohe Bay. Kaneohe Bay is the largest embayment on the island of Oahu, Hawaii, measuring 7 miles long, 2 miles wide, and fringed by numerous coral reefs. The northern third of the bay is more open to exchange and wave action from the offshore ocean, and the surrounding lands are mostly conservation and rural. The middle third of the bay is a lagoon protected by a broad barrier reef 1 to 2 miles offshore. Surrounding lands are mostly agriculture, rural, and some residential. The southern third of the bay is a nearly enclosed basin surrounded on three sides by land and with restricted connection to the rest of the bay due to broad, shallow reefs and islands. Outside the bay the open reefs are constantly exposed to heavy wave action from the tradewinds and efficient flushing and mixing with open ocean waters (see Figure IV.14, p. 193). The coral reefs were the most flourishing and developed of any comparable area in Hawaii at the turn of the century.

Beginning in the late 1930s, the bay was exposed to several new pollution and related stresses. In preparation for World War II, the U.S. Navy established a major air base off the southern peninsula and dredged and filled most southern bay reefs to expand military landholdings, to clear channels, and to create seaplane runways. Dredged materials not directly used for landfilling were dumped into lagoon waters, covering corals and deeper reefs and much of the filled land that covered previously existing reefs.

Then beginning in the 1940s, the small town of Kaneohe at the southern end of the bay grew rapidly as a suburban community. By the early 1960s, the need for improved sewage disposal for the urban communities in Kaneohe and military communities led to the decision to construct a new sewage treatment plant and outfalls discharging into the southern lagoon. By 1964, the military and civilian outfalls were discharging more than 2 million gallons per day.

By the end of the decade, marine biologists at Coconut Island's Hawaii Institute of Marine Biology learned of continued poor development of reefs in the south bay and the rapid decline of reefs in the middle bay. The southern bay, due to restricted circulation and a water resident time measured in weeks, became eutrophic (rich in plant nutrients). The dissolved nutrients in the discharged sewage were stimulating massive phytoplankton (algal) growths that led to proliferation of filter and suspension feeders (e.g., clams) on the bottom of the bay. Corals and other normal reef life were all but wiped out, probably through increased sedimentation, lack of recovery from previous dredge and fill, competition from sponges, tunicates, and other suspension feeders, and perhaps from lack of oxygen and associated sulfide toxicity in the sediments.

The middle bay's coral reefs in contrast were rapidly being overgrown by prolific mat-like growths of a green algae. Marine scientists believed the algae was stimulated by higher nutrient levels of sewage moving up from the south bay. The continued decline of the bay's reefs, recreational use, and other values generated considerable public outcry, convincing decision-makers to move the sewage outfalls from the restricted south bay to the well-flushed, open-sea conditions outside the bay in 1977-78.

Within 6 years of sewage removal from the south bay, middle bay reefs showed remarkable recovery while south bay reefs are also recovering. Sewage discharges outside the bay since 1978 have not caused problems because of rapid dilution and mixing of sewage with open waters. The outfall is also placed at more than 100-ft depth to promote dilution and reduce sewage effects at the surface. The prognosis appears good for complete recovery of south bay coral reefs.

In retrospect, public expenditures for sewage disposal were higher than necessary because of heavy reliance on treatment and lack of adequate analysis of outfall siting. The discharge of even secondary treated sewage into the confined south bay basin was analogous to dumping sewage into a swimming pool. The confined nature and slow turnover of south bay waters were major factors for favoring an outside bay location for sewage. Careful evaluation of ecological, recreational, commercial, and other values of proposed receiving waters for sewage should enter the equations along with standard engineering, sanitation, chemical, and mixing parameters.

The following list of suggestions and guidelines reflects the lessons learned from the Kaneohe Bay and other similar experiences. Developing countries in the tropics, particularly island nations, need not make the same mistakes.

Wastewater management guidelines

- More emphasis should be placed on siting of outfalls to take advantage of areas with greater flushing (potential to dilute sewage rapidly) and containing less sensitive ecosystems. Natural dilution and transport of sewage plumes by currents, tides, and wave action can lead to outfall placement and design to reduce sewage impacts.

- More emphasis should be placed on reducing treatment levels to primary or advanced primary that need less capital investment and fuel.

- Secondary sewage treatment, although removing most solids, results in high levels of dissolved nutrients in a form more usable to marine plants and may stimulate "blooms" and other desirable effects.

- Disinfection, which relies heavily on chlorine, can result in adverse effects on organisms near the outfall.

- Proper maintenance of secondary sewage treatment plants is complex and is often faulty due to inadequate training of personnel or inadequate supplies, repair, and maintenance programs.

- Achieving and maintaining tertiary levels at treatment has been unsuccessful in most cases. Some plants in Hawaii, designed for tertiary levels (pure water as the effluents), consistently fail to achieve even secondary treatment goals.

- India and other developing countries have designed low energy-consuming treatment processes that rely more on human labor, removal of pollutants by aquatic plants and animals, and recycling of treated effluent to agricultural and irrigation lands. Fish and aquatic plants can be regularly harvested from the treatment ponds for composting or consumption.

- Recycling of treated effluent to water golf courses has met with some success in Hawaii while reducing discharges to coastal water.
- Mangroves and coastal marshes may be suitable sites for limited disposal of treated sewage provided the wetlands are maintained through regular harvesting or removal of biomass.
- A better funding strategy may be higher costs to extend outfalls and diffusers to deep, open ocean waters far from land. With consequent less costly treatment for sewage required, maintenance and operating costs and complexity can be reduced to help offset the initial investment.
- Water quality standards established for ambient (receiving) waters can be an important control in establishing treatment levels and monitoring programs. Such standards, based on the beneficial uses desired, can result in accurate classification of coastal waters and appropriate levels of water quality for such class.
- On many low lying coral islands, contamination of groundwater from sanitary waste is a serious health problem that can be prevented or controlled through installation of a sewage collection system.
- Use of saltwater systems on atolls to flush toilets and carry municipal waste may be an important option where water conservation is important.

2. Industries Likely to Produce Undesirable Effluents

(prepared by S.D. Naidu and R.J. Morrison)

The following industrial operations are common to developing countries. The typical waste stream compositions may be used in EIAs to estimate pollution loads from proposed new installations (see also the WHO rapid assessment method, Section II.F.2, p. 45; WHO 1989).

a. Brewing and Distillation. The brewing process involves production of a fermented beverage of low alcohol content from various types of grain. A product of higher alcohol content is usually obtained by distillation.

Outline of the process. Barley is commonly used in the brewing process because it contains about 60 percent starch. Before fermentation, the starch present in barley is converted into sugar by a process called "malting." This involves the moistening of barley grains with water under appropriate conditions to initiate germination. During germination an enzyme, diastase, is formed which

Table IV.8. Characteristics of typical waste streams

Parameter	Typical concentration	
	Brewery waste	Sugar mill waste
BOD_5 (mg/L)	1200 - 3000	500 - 3000
SS (mg/L)	100 - 800	100 - 2000
COD (mg/L)	3500 - 4000	2000 - 5000
pH	4.3 - 11.0	6 - 9

converts starch to maltose. Germination and subsequent growth is then stopped by heating the sprouted grain. Following washing, the ground barley is extracted with hot water to give a liquid called "wort." Beer manufacture continues by boiling wort with hops in a brew kettle to give beer the desired flavor. The wort is then passed to a fermenter where yeast is added to convert sugar in the wort into alcohol and carbon dioxide. Filtration or carbonation, for example, can also be carried out to make beer of the desired type. The type of liquor produced from distillation will depend on the alcoholic liquid used as a base (e.g., the base for brandy is wine, whisky is distilled from a fermented wort derived from corn, rum is distilled from a product obtained by a fermentation of molasses).

Sources of pollution. The process of malting produces both liquid and solid wastes. The liquid waste is basically a product of the barley steeping, while solids consist of the sprouts and rootlets screened out during the malt preparation. Wastes from fermentation and subsequent operations include spent grain, hops and yeast, liquors from spent grain, yeast washing and pressing of yeast wastes, and wash waters (e.g., from the washing of equipment, casks, barrels). The liquid wastes have a high suspended solid (SS) content, a high biological oxygen demand (BOD) and a high chemical oxygen demand (COD). Typical effluent compositions are shown in Table IV.8.

b. Cane Sugar Manufacture

Outline of the process. At the mill, whole cane stalks are crushed between rollers to extract juice which is screened and treated with lime to prevent sucrose inversion. The extract is heated, insoluble compounds removed by filtration, and the liquor concentrated until a mixture of sugar crystals (raw sugar) and syrup (molasses) is formed. Sugar is separated from molasses by centrifugation.

Sources of pollution. Cane crushing water contains a substantial amount of soil and impurities, especially where harvesting is done manually. The cane wash water also contains sugar and may appear colored. Other waste waters that cause pollution problems include those from washing floors and equipment. Effluents from sugarcane processing plants are characterized by high BOD and high SS (see Table IV.8). The solid trash remaining contains nutrients including nitrate and phosphate, and its disposal near the seashore or estuaries may lead to eutrophication problems. The return of mill mud and mill ash to the canefields is highly recommended.

c. Metal Finishing. A wide range of specialized metal finishing processes are used for protecting metals, particularly against corrosion, improving their properties, or enhancing their appearance.

Outline of the process. Before coating, pretreatments are usually necessary to remove natural oxide coatings, corrosion products, and even protective oils and greases. The oxide films and corrosion products can be removed by either mechanical methods (such as brushing, descaling, polishing, shot blasting) or by chemical processes (such as acid pickling, sodium hydroxide descaling). Oil and grease may be removed by using suitable organic solvents. The methods used for metal finishing may be grouped as:

- electroplating
- stripping
- chemical conversion (anodizing, phosphating)
- chromating
- metal coating (e.g., galvanizing, rust proofing)
- machining
- final polishing
- case hardening

Sources of pollution. Because metal finishing involves many processes, the types of effluents produced will vary with the processes involved. Thus pretreatment by means of acid pickling prior to galvanizing will produce used acid pickling liquors containing high concentrations of iron salts which, if neutralized, will produce insoluble hydroxides, while liquors from pickling of copper and its alloys will contain salts of copper with smaller amounts of zinc. The electroplating acid wastes will generally contain dissolved copper, nickel, zinc, chromium, cyanide, and sometimes cadmium or lead. Anodizing gives rise to a range of wastes, including both alkaline and acidic solutions, nitric acid and nitrates, phosphoric acid, chromium-bearing acidic solutions, bright anodizing solutions (nitric/phosphoric/acetic acids), and nickel-bearing sealing solutions. Typical effluent composition is shown in Table IV.9.

d. Tanning

Outline of the process. The first stage in the tanning process is the hide preparation to remove hair, protein, grease, and oil. After the unwanted material has been removed, the hides and skins are treated with appropriate tanning agents to produce leather. The leather then undergoes various finishing operations to achieve the desired surface finish and mechanical properties.

Sources of pollution. Both the preparation of the hide and the subsequent tanning contribute to pollution and these are discussed separately.

- Hide preparation. The hides are prepared for tanning in the beam-house process in a number of stages. The first stage is the washing and soaking in large amounts of salt to remove dirt, blood,

Table IV.9. Characteristics of electroplating plant waste

Parameter	Typical composition
pH	3 - 8.5
Cu (mg/L)	0.1 - 0.3
Zn (mg/L)	0.1 - 8
Cr (mg/L)	0.1 - 5
Ni (mg/L)	0.01 - 60
Cd (mg/L)	0.01 - 0.1
CN (mg/L)	5

manure, and nonfibrous proteins as well as to preserve the hides for long periods. This stage is followed by liming and unhairing in which the soaked hides are treated with a mixture of lime slurry and a solution of sodium sulphate. During this process, the hair is destroyed and the hides swell so that tanning agents can penetrate easily.

Liming and unhairing are followed by fleshing, at which time any remaining muscle and fatty tissues are removed. Finally, the hides are delimed with weak acids (and/or acid salts) and bated with a proteolytic enzyme (pancreatin, trypsin) which peptizes the protein fibers and removes unwanted protein (elastin). The process of washing, soaking, liming, and unhairing produces substantial amounts of wastewater heavily contaminated with organic matter resulting in high BOD and SS.

- Tanning. Depending on the type of leather to be produced, different tanning chemicals are used. The common ones used are vegetable tanning, chrome tanning, or a combination of chrome/vegetable tanning (also known as "semi-chrome tanning"). The process of tanning produces wastewater heavily contaminated with used tanning solutions. Since tannery operations are basically a series of washings to remove all unwanted materials in the hide, the wash liquors are heavily contaminated with used tanning solutions. Wastewater may be alkaline or acidic, is highly colored, have high oil and grease (O/G) levels, and high salt content. Such wastes will generally have high BOD, COD, SS, and odor. Also of concern would be chromium ions, particularly the hexavalent state, Cr(VI), which is the form most toxic to humans and also to aquatic invertebrates and fish. Typical effluent composition is shown in Table IV.10.

e. Food Manufacturing and Processing. The following industries have been grouped under this heading: (1) abattoirs and meat canning/packing; (2) manufacture of dairy products; (3) refining of edible oils and fats; (4) canning and preserving of fruits and vegetables; and (5) canning and preserving of marine food (e.g., fish, crustacea, shellfish, clams).

Table IV.10. Characteristics of tannery waste

Parameter	Typical composition
BOD_5 (mg/L)	500 - 1500
COD (mg/L)	3000 - 6000
SS (mg/L)	400 - 1000
O/G (mg/L)	120 - 500
Total Cr (mg/L)	12 - 100
pH	6 - 11

- <u>Abattoirs and meat canning/packing</u>. At abattoirs the slaughtering of animals, dressing and packing of cattle, sheep, lamb, and poultry products occur.

  - <u>Sources of pollution</u>. Water from the washing of stock trucks and stock before slaughtering will contain substantial amounts of dirt and fecal coliforms. The washwater also contains blood, washings of hides, skin, hair, and all edible portions. The effluents will thus be highly contaminated with organic matter which results in high BOD and SS. Typical effluent composition is shown in Table IV.11.

- <u>Manufacture of dairy products</u>. Industries include factories specializing in the manufacture of creamy and processed butter; natural and processed cheese; condensed, powdered, and evaporated milk; fresh and preserved cream; ice cream and other dairy products (e.g., yogurts, dairy desserts, and sterilized/pasteurized milk).

  - <u>Sources of pollution</u>. Because the manufacture of dairy products involves many processes, the chemical composition of effluents will vary with the processes involved. The effluents, however, will be high in organic materials and have high pH and detergent content mainly from washing of tanks and bottles. Typical effluent composition is shown in Table IV.11.

- <u>Refining of edible oils and fats</u>

  - <u>Outline of the process</u>. Crude vegetable oil is mixed with an alkali such as caustic soda and fed into a high-speed centrifuge that separates impurities. The supernatant is then washed and spun through other centrifuges with water to remove all traces of the alkali. At this stage the oil is only partly refined because it still contains color which is removed by bleaching. This is done by heating the oil under vacuum, following agitation of the mixture with natural bleaching earth and vegetable carbon. The used bleaching earth and carbon are removed from the oil by filtration. Oil at this stage is called "refined and bleached" but needs further processing before it is considered edible.

Table IV.11. Characteristics of waste streams

Parameter	Typical effluent composition				
	Abbatoir	Dairy	Edible Oil	Fruits/Veg.	Fish
BOD_5 (mg/L)	1200-3800	1600-2500	100-500	1000-3000	3000-3500
SS (mg/L)	450-2400	900-1400	130-600	100-400	1200-1600
COD (mg/L)	5600-6900	3000-4200	150-800	2000-4000	4000-5000
O/G (mg/L)	20-100	200-400	-	-	40-60
pH	7-7.2	4.5-10	2-6	4-12	6-8

The next stage in oil refining is called hydrogenation. This process leads to an increase in the degree of saturation and, depending on this factor, the liquid oils or semi-liquid oils may be converted to solids. The process involves heating refined bleached oils in closed vessels with a catalyst to assist reaction and introduction of gaseous hydrogen. After the reaction is complete, the hydrogenated oils are filtered to remove the catalyst. The refined and bleached oil obtained contains minor traces of volatile impurities which can give an unpleasant taste and must be removed by deodorizing. This treatment involves heating the oils with steam in closed vessels, cooling, and finally filtering to remove any suspended particles. Oil at this stage may be classed as refined and deodorized.

- Sources of pollution. The principal waste from this industry is the earth used for bleaching the oil. This solid residue can be disposed of at the municipal rubbish dump or used for landfilling. The liquid waste from the factories contains soap, free vegetable oil, and sodium hydroxide which is used for cleaning of tanks. Typical effluent composition is shown in Table IV.11.

• Canning and preserving of fruits and vegetables. These industries include those involved in canning and packing of fruits and vegetables in air-tight containers, canning and bottling of fruit and vegetable juices, and manufacture of jam, jellies, sauces, and canned soups.

- Sources of pollution. The wastewater from these factories will contain substantial amounts of suspended solids and organic materials which are highly putrescent and thus carry high bacterial population. Typical effluent composition is shown in Table IV.11.

• Canning, preserving, and processing of marine organisms (e.g., fish, crustacea, shellfish). The industries included in this group are those canning fish, shrimps, oysters, clams, crabs, and other sea foods.

- Sources of pollution. Wastes from these factories are chemically similar to domestic waste and meat-processing factories. These are characteristically wholly organic, consisting of dissolved colloidal and suspended material. These also contain considerable amounts of grease. The organic wastes are extremely putrescent and carry high bacterial population. Typical effluent composition is given in Table IV.11.

f. Cement. Cement is a complex calcium aluminosilicate material produced by the combination of limestone with material containing alumina and silica (usually clay). When mixed with water, cement forms a binding material for aggregates in concrete.

- Outline of the process. After the raw materials have been extracted and brought to the factory, they are reduced in size by crushing and grinding. The ground limestone and clay are then blended to give a feed of the correct composition for the kiln in which they are heated to form the product known as "clinker" in the rotary kilns. The rotary kiln feed in the form of a wet slurry is introduced into the upper end of the kiln, while fuel (coal) for heating enters and is burned at the lower end. In this way the feed is successively heated, dried, calcined, and finally heated to incipient fusion when chemical reaction occurs and clinker is formed. This is cooled with air, ground to a fine powder, and passed to packing and storage.

- Sources of pollution. The rotary kiln is the main source of dust emissions in cement manufacture. The hot gases produced by the combustion of the fuel are pulled by forced draft up through the kiln counter-current to the raw material flowing down the kiln. The gases, therefore, carry entrained dust with them from the upper end of the kiln. Dust emissions are also produced in crushing, grinding, blending, clinker cooling, finish grinding, and in moving finely divided material to silos and in packing. Wastewaters are produced in cement manufacture during the blending process and from the use of wet scrubbers for removing dust from the kiln exit gases. These waters contain significant quantities of suspended (inorganic) solids and have a relatively high pH.

g. Receiving Water Standards. Quality control of coastal and riverine waters is facilitated by standards for the waters receiving discharges or effluents which will ensure that the water remains suitable for current and planned uses. In this way the quality of the actual waters after receiving the discharges is measured directly, rather than indirectly from, for example, calculation of dilution after measurement of effluent concentrations.

To be effective, such a procedure requires a regular monitoring program to ensure that established water quality standards are not exceeded. A mechanism for remedial action in the case where standards are exceeded also needs to be established before the use of receiving water standards is introduced.

Receiving waters include all coastal waters offshore from the mean high-tide level including estuarine waters, lagoons, bays, brackish and inland waters like rivers, creeks, streams, and standing waters in lakes, marshes, swamps, and reservoirs. Receiving water quality criteria will differ for different categories of water, the categories depending on the primary use of the water.

Three major categories of water are widely used:

Category 1	Waters in this category are primarily for aesthetic enjoyment and recreation apart from protection of natural aquatic life. These waters should be kept free from pollution attributed to domestic, commercial, and industrial discharges, shipping and intensive boating, construction, and other activities which may impair their intended use.
Category 2	Waters in this category are primarily for marine biological activity. Thus, standards must ensure protection for marine organisms, particularly shellfish and coral reefs. Other important uses are mariculture activities, aesthetic enjoyment, and recreational activities inclusive of whole body contact.
Category 3	Waters in this category are primarily for general use including commercial/industrial uses such as shipping, but should be of sufficient quality to protect aquatic life and permit limited body contact. Aesthetic enjoyment and recreational use should also be maintained.

In setting limits for receiving waters, it is important to recognize that these limits are aimed at avoiding:

- algal blooms (due to excessive nutrients) and subsequent water quality problems,
- direct toxicity to marine organisms (due to metals, hydrocarbons, or pesticides),
- significant bio-accumulation in food chains leading to indirect toxicity problems for fish and other life forms,
- health problems to water users (e.g., bacteria, viruses),
- significant changes in the redox conditions of the waters (BOD, COD, dissolved oxygen level changes),
- serious damage to marine/coastal ecosystems (due to the influence of sedimentation), and
- damage to engineering facilities (e.g., pipelines, piers, dams) caused by changes in pH, redox conditions.

3. Air Pollution (see also Section V.C.2)

In tropical islands and coastal areas, air pollution may become a problem when industrialization occurs in regions with low wind speeds and terrain that trap air masses for long periods of time. Along coasts, the day-to-night variation in wind direction often wafts air out to sea at night but returns the same air over land the next day, preventing dispersal of pollutants.

Understanding air pollution involves (1) the sources of pollutants; (2) the behavior of weather, climate, wind, and air movement; and (3) the effects of pollutants on human health, animals, plants, and materials. Figure IV.23 shows the development activities that produce the major air pollutants and their effects. An air quality system is shown in Figure IV.24.

An emissions inventory comprises data on type, quantity, and location of major pollutant sources. If monitoring or detailed industrial information is not available, emissions may be estimated based on the rated capacity or use of raw materials (e.g., sulfur dioxide from a coal-burning power plant could be estimated from knowledge of the electricity produced, the thermal efficiency, the heating value of the coal and its sulfur content; see WHO 1982 and WHO 1989).

The four broad categories of sources are:

- Stationary combustion: fossil-fueled electric power plants, space heating, industrial processes.
- Mobile combustion: automobiles and trucks; in special cases, ships and airplanes.
- Refuse combustion: open burning of dumps, trash piles, and agricultural wastes, municipal and industrial incinerators.
- Industrial and commercial processes: fertilizer manufacture, petrochemical plants, dry-cleaning shops.

Typical performance standards for new U.S. industrial installations are shown in Table IV.12. Such data may be combined to form an estimate of total emissions of each pollutant in a given geographical area.

The emissions and sources may be tabulated on a map that becomes the basis for an Air Quality Management Region (AQMR). Once emitted, the fate of pollutants depends on atmospheric processes (see Table IV.13).

In summary, the EIA should identify pollution sources, trace their movement through the AQMR, and predict their impacts on human health and welfare using meteorology and related atmospheric sciences.

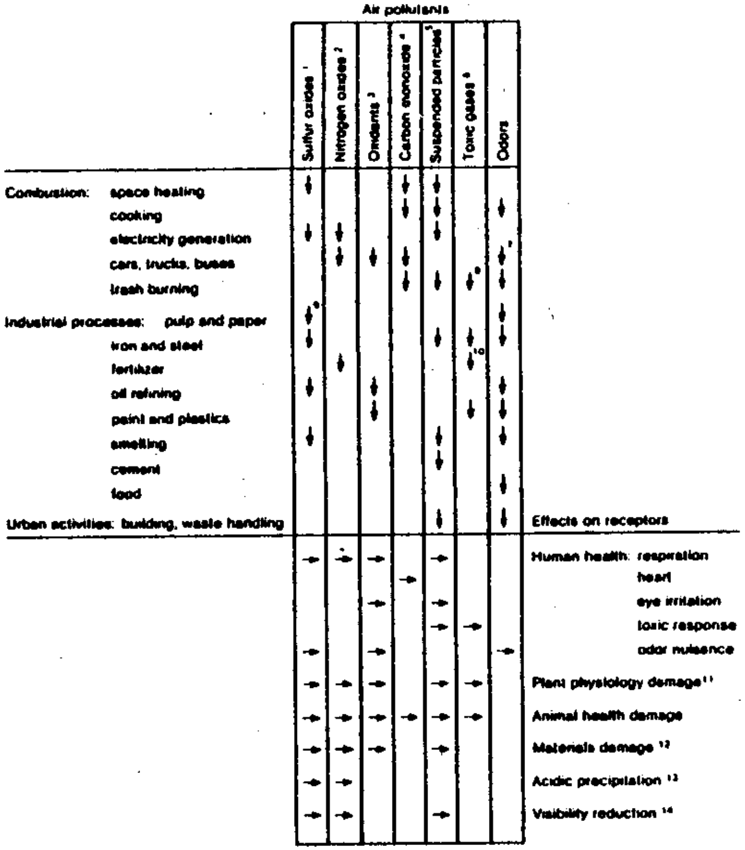


Figure IV.23. Sources, pollutants, effects (<u>Source</u>: Carpenter 1983:338-339).

Notes for Figure IV.23

1. Sulfur oxides are usually emitted as sulfur dioxide, which automatically oxidizes to sulfur trioxide, which in turn may be converted to sulfuric acid mist or to particulate sulfate salts.
2. Nitrogen oxides are usually emitted as nitric oxide, which automatically oxidizes to nitrogen dioxide, which in turn may form nitric acid or nitrate salt particles.
3. Oxidants are formed through complex chemical reactions of nitrogen oxides and hydrocarbons in the presence of sunlight (photochemical smog). Ozone and peroxide compounds are in this category.
4. Carbon monoxide is formed in the incomplete combustion of fuels. When inhaled, it interferes with the ability of blood to carry oxygen throughout the body In the open it can be incapacitating; in a closed area, deadly. In the concentrations found in urban air the effects are fully reversible.
5. Suspended particles include soot and smoke, industrial dusts, and street dirt Very small particles are termed respirable in that they are not filtered out by the nose and are breathed into the lungs.
6. Toxic gases are usually carefully controlled because of hazard to workers but may escape into the ambient air environment.
7. Diesel engines produce noxious odors.
8. Some plastics produce phosgene or other hazardous materials if their burning is improperly controlled.
9. The sulfur compound hydrogen sulfide has an offensive odor and is also oxidized to sulfur oxides.
10. Phosphate rock contains fluorides, which may be emitted as hydrogen fluoride upon processing.
11. Plant damage includes interference with growth (photosynthesis) and consequent lowered crop yields, damage to ornamental flowers, and even death of some species.
12. Damage to materials includes soiling, corrosion of metals, and accelerated deterioration of building stone, paper, paint, textiles, and rubber.
13. Acid rain. Precipitation of water vapor as rain or snow is usually neutral—neither acidic nor basic (caustic). In some instances associated with polluted air, rain has been found to be significantly acidic, probably due to nitrogen oxides and sulfur oxides that react to form nitric and sulfuric acids. A direct connection between sources of acidic gases (smelters and power plants) and acid rain has been established in Canada, the northeastern United States, and in Scandinavia. The increased burning of coal in Asian countries may lead to evidence of this phenomenon. Acid rain can increase the acidity of lakes, and these acid waters are in turn toxic to indigenous fish and prevent fish eggs from hatching. Acid rain can also mobilize aluminum compounds from soils that are toxic to aquatic life.

    Some lakes may be treated with lime to counter the increased acidity. Lakes that are flushed regularly may recover from acidifying episodes. Acid rain on some alkaline soils may actually improve their desirability for agriculture by mobilizing nutrients and trace elements.
14. Aesthetics and Visibility. Particles and fine droplets in the air can reduce visibility and impart a dull gray or brown color to the sky. In scenic areas this effect prevents enjoyment of natural beauty and damages tourism values. In any area poor visibility is displeasing, and dirty air can have an adverse psychological effect on people. Around airports or on highways a significant reduction in visibility is hazardous and disruptive to traffic.

Table IV.12. Selected examples of emission standards for new industrial installations (U.S. Federal Regulations)

Source of Emission and Substance Emitted	Standards
Electric utility steam generating units	
particulate matter	0.03 lb/million BTU < 20% opacity
sulfur dioxide	1.2 lb/million BTU
nitrogen oxides	0.5 lb/million BTU
Incinerators	
particulate matter	0.18 g/scm*
Portland cement plants	
particulate matter	0.3 lb/ton of feed < 20% opacity
Nitric acid plants	
nitrogen oxides	3 lb/ton produced
Sulfuric acid plants	
sulfur dioxide	4 lb/ton produced
acid mist	0.15 lb/ton
Asphalt concrete plants	
particulate matter	90 mg/scm*
Petroleum refineries	
carbon monoxide	0.05% by volume
Iron and steel plants	
particulate matter	< 10% opacity
Primary copper smelters	
sulfur dioxide	0.065% by volume
Primary aluminum reduction plants	
fluorides	2 lb/ton produced
Super phosphoric acid plants	
fluorides	0.01 lb/ton P_2O_5 feed
Kraft pulp mills	
total reduced sulfur	5 ppm by volume
Lime manufacturing plants	
particulate matter	0.316/ton of feed

*scm = standard cubic meter.

Source: Carpenter 1983:368.

Table IV.13. Some factors influencing the ambient concentration of an air pollutant following emission from a stack

Influencing Factor	Processes Particularly Affected	Influencing Factor	Processes Particularly Affected
Meteorological Conditions		*Atmospheric Chemistry*	
Wind speed	Transport, dilution	Concentrations of other gaseous pollutants Rate of chemical interaction with other pollutants	Rate of chemical transformation
Wind direction	Plume direction and shape		
Precipitation	Scavenging of pollutants		
Duration of calm conditions	Dry deposition, diffusion		
Temperature changes with atmospheric elevation	Plume rise and shape; diffusion	Solar radiation	Catalysis of photochemical reactions
Humidity and dew	Transport and solution of gaseous pollutants	Concentration of particulates	Adsorption of gaseous pollutants
Cloud cover	Thermal convection at ground level	*Terrain*	
Atmospheric pressure	Plume rise	Water bodies	Absorption of pollutants; surface heating
Technological Design Factors		Vegetation and soil	Absorption or adsorption of pollutants; surface heating
Stack height	Long-distance transport, dispersion		
Exit temperature	Plume buoyancy		
Exit velocity Stack internal diameter Rate of gas emission	Height of plume rise Concentration of gases	Mountains, valleys	Trapping, channeling of pollutants; effects on wind speed and direction

Source: Ecology, Impact Assessment, and Environmental Planning, by Walter E. Westman. Copyright © 1985. Reprinted by permission of John Wiley & Sons, Inc.

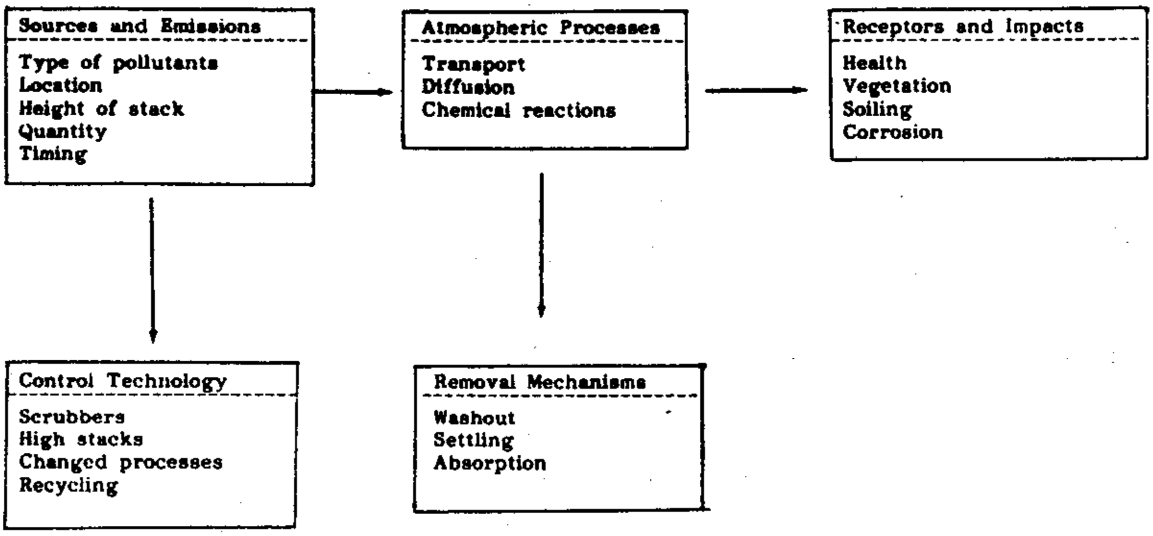


Figure IV.24. The air quality system.

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4. Refuse and Solid Waste Disposal Including Hazardous Waste

Municipal solid wastes collection and disposal can be a significant environmental problem as population concentrations grow. The adverse impacts of a dumping ground or sanitary landfill include:

- Unsightly litter,
- Vermin and flies as disease carriers,
- Fumes and smoke from smoldering fires,
- Leaching contamination of surface water and groundwater,
- Traffic from trucks,
- Lowered value and use of adjacent land, and
- Slum housing of scavengers.

A new dimension has been added in recent years as more chemicals are introduced into agriculture, commerce, and household use. These valuable materials perform many worthwhile functions and are indicators of the state of development in many ways. But when the chemicals escape into the environment, they may produce unwanted effects on human health and ecosystems. The contamination often occurs when containers or used chemicals are discarded in trash. The municipal waste then becomes hazardous due to the presence of compounds that are toxic, flammable, explosive, or corrosive. Of course, industrial wastes may present large volumes of hazardous chemicals that also must be managed properly and may require special landfills. Hospital wastes are also hazardous.

The most common hazardous chemicals encountered as industrialization occurs include:

Metals: Cadmium, chromium (hexavalent), lead, mercury
Pesticides: DDT, arsenicals, paraquat
Solvents: Trichloroethylene, perchloroethylene, benzene
Cyanide (metal processing wastes)
Polychlorinated biphenyls (PCB)
Volatile organic compounds (VOC): Chloroform, carbon tetrachloride
Highly toxic organic intermediates: Aniline, phosgene
Bulk chemicals: Chlorine, ammonia

An EIA for tourism or human settlement development should consider siting of waste disposal facilities capable of handling hazardous chemicals as well as ordinary trash. Some guidelines for the location of landfills or waste facilities are:

Desirable conditions	Unacceptable conditions
Upland, claypit	Wet lowland, quarry, sand, or gravel pit
Flat to gentle slope	Floodplain
> 50 ft to bedrock	Steep slope
Low rainfall	Bordering parks, residential or recreational areas
Drainage toward site	< 0.5 mi from potable wells
Impermeable soil	
Separation of waste categories	

V. ENVIRONMENTAL SCIENCES AS THE BASIS OF EIA

FIGURES AND TABLES

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V. ENVIRONMENTAL SCIENCES
AS THE BASIS OF EIA

V.A. ECOLOGY AND ECOSYSTEMS

As in any science, ecological data from observations and experiments lead to generalizations that explain cause-effect relationships. As these explanations are accepted and found to hold true, they become principles, concepts, or theories useful to environmental managers. Some of the more important principles for tropical island ecosystems are discussed here.

1. Ecological Principles and Concepts

The four higher levels of ecological organization are the individual organism (plant or animal), a population of the same organism (species), a community of different plants and animals, and an ecosystem (i.e., a biotic community in interaction with its physical environment--sunlight, water, air, and soil). People are a part of the ecosystems in which they live.

a. Productivity. The source of energy in ecosystems is sunlight that is converted in photosynthesis, combining carbon from the carbon dioxide in the atmosphere with water to form plant matter. Primary productivity is the weight of plant material formed daily.

b. Biomass is the amount of material that accumulates per unit area, and this plant food is eaten by a succession of animals. Only a portion of the chemical energy stored in plants and animals is passed on to the next higher stage as is shown in Figure V.1. The pyramid of productivity means that the plant community controls the size of animal populations. Thus in EIA, the primary productivity of an ecosystem is an important clue to its health, sustainability, and usefulness in development.

c. The biosphere comprises all the ecosystems of the world and people depend on its continued functioning for many services such as oxygen generation and water purification.

d. Populations grow at a rate determined by the excess of births over deaths, which, in turn, depend on many environmental factors such as food supply, predators, habitat, and nutrients.

e. Limiting Factors. The health and productivity of an ecosystem depend on many factors, any one of which may set a limit on its biological potential. For land plants, these include nutrient elements (nitrogen, phosphorus, potassium, carbon), water, pests, energy, and soil organic matter. For marine plants, light, water circulation, nitrogen, phosphorus, and substrate composition are the most important limiting factors. Understanding and manipulating these limiting factors are valuable in environmental management.

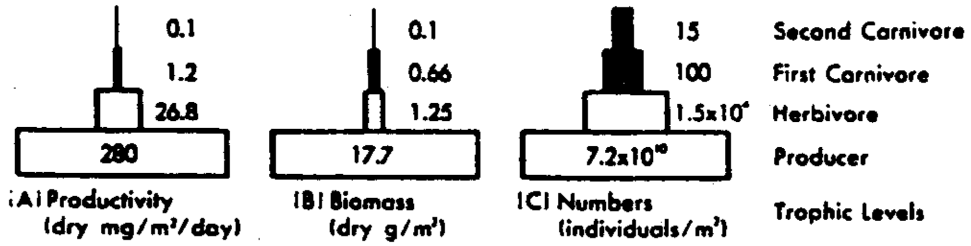

Figure V.1. Pyramids of productivity, biomass, and numbers for an experimental pond. (Reprinted with permission of Macmillan Publishing Company from Communities and Ecosystems by Robert H. Whittaker. Copyright © 1975 by Robert H. Whittaker.)

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f. Food Webs, Trophic Levels. Energy flows through an ecosystem according to who eats whom. Primary producers (green plants) fix solar energy into plant material (biomass). Consumers include detritovorous (detritus eating), herbivorous (plant eating), and carnivorous (meat eating) animals that complete the chain. At each consumption level, only a part (up to ~ 10 percent) of the energy is converted to the consumer's own biomass so rarely are there more than five to six steps in the chain. Species that eat the most different foods are the most successful. The large number of species in tropical ecosystems offers many trophic interactions and thus confer stability and resilience. The major components of the food web of tropical insular reef systems in Oceania are shown in Figure V.2.

g. Carrying capacity is the number of individuals that an environment can support, but the exact level fluctuates with weather, natural hazards, and human management actions. Carrying capacity is more difficult to define quantitatively for natural systems compared to managed systems. For example, intensive agriculture supports far more plants and biomass per unit area than in an undisturbed field, but this carrying capacity is dependent on constant inputs of fertilizer and mechanical energy from outside the system (see Figure V.3), and constant protection from competitors and pests (e.g., weeds, insects).

h. Natural Variation. Nature is not balanced or constant over time and space but continually fluctuates within a range of conditions. For example, the number of young fish "recruited" each year from a spawning ground will vary widely; or the composition of communities of reef animals or forest plants changes with time as well as location. Many development activities attempt to force uniformity and stability on natural systems. For example, monocrop agriculture and constant year-to-year crop yields are economically desirable. Countering natural variability always entails extra management costs (e.g., labor, energy, fertilizer) and often risks degradation of the environment if not carefully and adequately carried out.

i. Succession. The number and kind of species in an ecosystem change over time from immature to mature stages. Natural and human disturbances such as dredging, earthquakes, lava flows, catastrophic

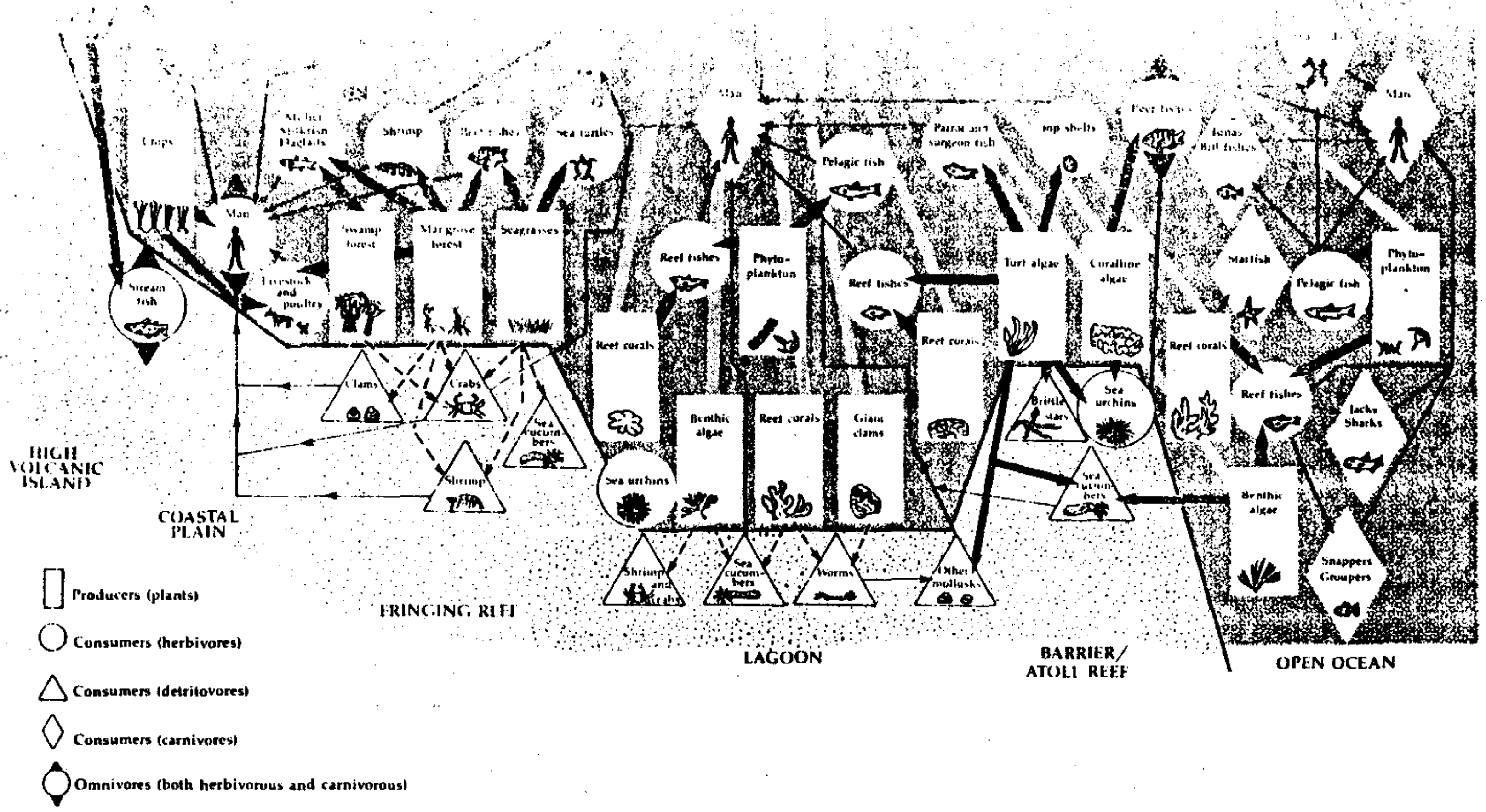

Figure V.2. Flow of energy from the sun and through the food webs of major ecological and subsistence systems characterizing the tropical reefs and islands of Oceania.

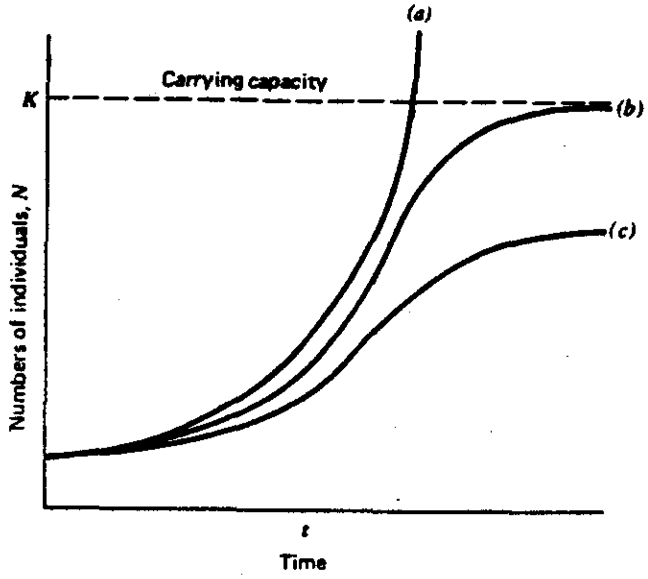

Figure V.3. Population growth and carrying capacity. (a) The exponential curve of population growth; (b) the sigmoidal or logistic curve of population growth of a species in the presence of a limiting resource. K is the maximum sustainable population, or "carrying capacity," on this resource base. (c) A possible growth curve of a species in the presence of competition from another species for the limiting resource (Source: Ecology, Impact Assessment, and Environmental Planning, by Walter E. Westman. Copyright © 1985. Reprinted by permission of John Wiley & Sons, Inc.).

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storms, or fire disrupt the trend and set back the biological community to a less mature stage. Young ecosystems have higher net primary productivity (photosynthesis), few species, respond rapidly to nutrients, and produce higher yields. For these reasons, aquaculturalists, farmers, and foresters continually disrupt the maturation process and return the system to an immature stage to exploit the "net" or exportable production. Mature systems (e.g., coral reefs or forests) are more complex, maintain themselves, and are not displaced except by a catastrophe. They may have high gross production, but net production is low or near zero. Mature systems are valuable for recreation, aesthetics, and many subsistence economies.

j. Biogeochemical Cycles. Organic matter, including living organisms, is mostly the product of interactions between carbon dioxide, oxygen, and water, controlled by limiting substances termed "nutrients," including nitrogen and phosphorus. In this sense, nutrients act as fertilizers to stimulate plant growth, are eaten, and then become waste by-products of animal growth and decay. The nutrients that make up and maintain organisms flow from the inorganic environment of air, water, and soil to plants and animals. When these die or shed leaves and skin, the chemical elements are returned to the environment, each along a different pathway and at a different rate. Some nutrients, such as nitrogen, cycle through the air on a worldwide

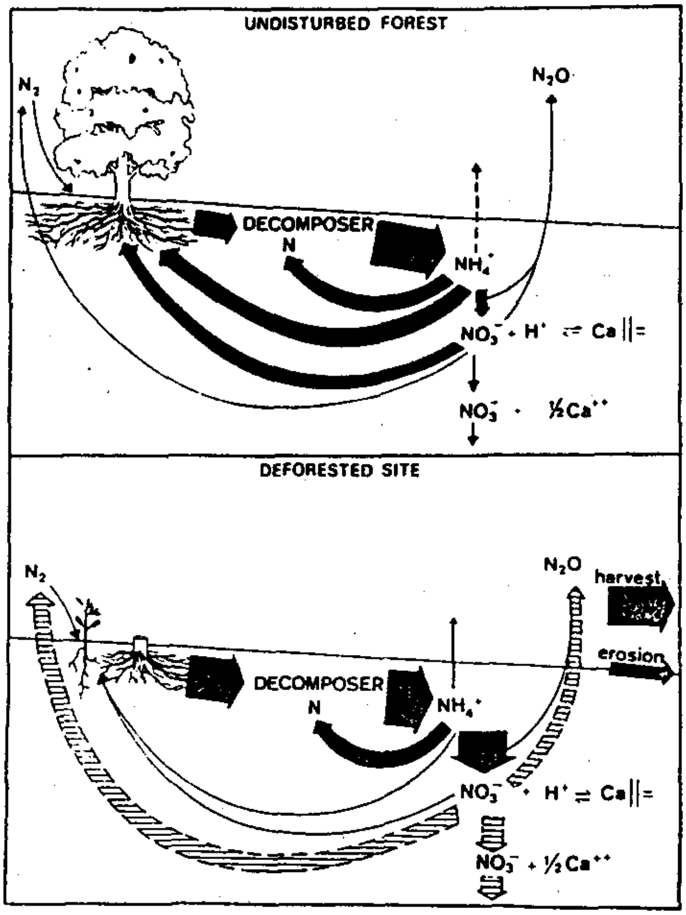

Figure V.4. The nitrogen cycle in an undisturbed forest and a deforested site. The system represented is a relatively fertile site before and 2-3 years after deforestation. Dashed arrows represent possible alternative pathways for losses of nitrogen from the site (Source: Vitousek 1983:230. Reprinted with permission of the publisher).

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scale while others, such as phosphorus, move locally within a small area of forest. Figures V.4 and V.5 show two typical biogeochemical cycles.

k. Diversity. The ability of an ecosystem (coral reef, mangrove forest, salt marsh) to persist and recover from storms or development disturbances depends, to some extent, on the variety of animals and plants that it contains. While there is no rigorous connection between diversity and stability or maturity, the simplification of a community composition due to the actions of development often means less resistance to subsequent stresses and less capacity for resilience or recovery. Gross productivity is also less (but net productivity is more) in simplified natural systems than in those with a large number of species. Stated in another way, the greater number of species allows the system to be more efficient. There are few outside opportunities for exploitation, unless the diverse mature system is disrupted.

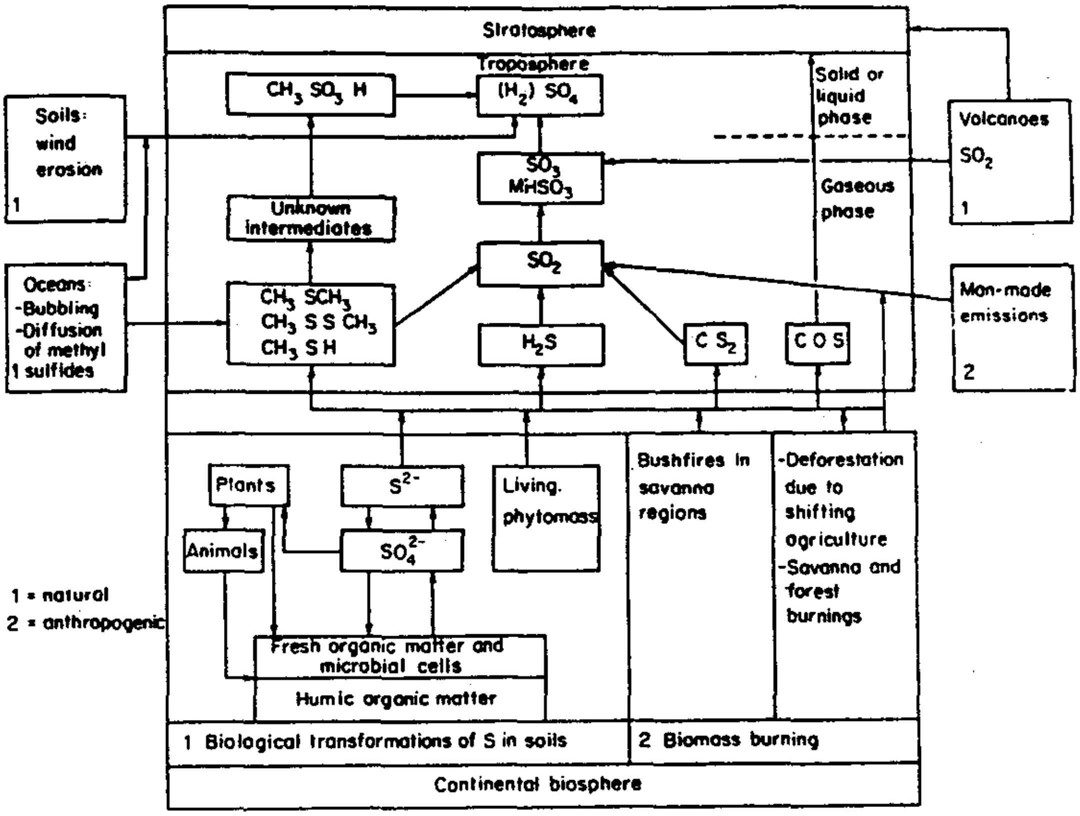

Figure V.5. Simplified sulfur cycle in the tropics (Source: Vitousek 1983:46. Reprinted with permission of the publisher).

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2. Island Biogeography

Tropical island ecosystems including land, reef, and volcanic features are separated geographically from adjacent ecosystems by expanses of deep ocean. This isolation controls the number and kinds of plants and animals that can successfully colonize and survive on islands where land dispersal and migration are not possible and where colonization must rely on the atmosphere and ocean for transport. Smaller islands and reefs, lower islands, and island ecosystems separated by greater distances from their nearest neighbors are more isolated biologically. Low lying islands and coasts and many upland habitats on islands are vulnerable to natural catastrophes such as lava flows, landslides, floods, earthquakes, tsunamis, large waves, tropical storms, and sea level and temperature fluctuations attributed to the ice ages and other weather anomalies. In response to these conditions over a period of thousands to millions of years, the plants and animals on each island have evolved differently than their counterparts on other islands and continents. In particular:

- Many species fail to establish on some island and associated marine habitats.

- Island species are more vulnerable to local extinction (extirpation) from many factors.

- "Successful" island species evolve into new forms to fill the voids and niches unoccupied by "unsuccessful" species.

- Island ecosystems tend to show higher numbers of unique (endemic) species and many "missing" species.

- Tropical marine species tend to be less isolated because the ocean is more efficient in transporting larvae, eggs, and adults compared to the atmosphere.

- Higher elevation birds, plants, insects, and snails tend to be more isolated than lowland or coastal terrestrial species. Species on lowlands or along the coasts can rely on more dispersal mechanisms, atmospheric transport, transport by birds, as well as the rafting and drifting of floating seeds, spores, juveniles, and adults between islands.

- There tend to be fewer endemic coastal species compared to higher elevation terrestrial species. For example, many beach and strand plants are widely distributed throughout the coastal tropics.

- In contrast, large, high island chains have many unique terrestrial species in upper elevations (e.g., on Hawaii, Galapagos, New Guinea, Borneo, Fiji, and Samoa).

The colonizations and migrations of the Pacific islanders during the past several thousand years and the more recent colonization of Europeans, Asians, and Africans to many tropical islands have reduced or eliminated many of the previously existing natural geographic barriers and isolation. Canoes, ships, airplanes, and cargoes now carry new plant, pest, animal, and seed species to islands. Many of these so-called "exotic," "alien," or "introduced" species have successfully established and displaced endemic island species, causing many extinctions of birds, plants, snails, and other unknown species in places such as Hawaii and the Mariana Islands. Flightless birds (such as rails) and waterbirds are particularly vulnerable to extinction after predators such as rats, cats, dogs, pigs, mongooses, and snakes were introduced accidentally or intentionally to islands. The release and establishment of range and foraging species on islands such as rabbits, deer, sheep, goats, cattle, and pigs resulted in habitat loss from overgrazing, mass wasting of soils, and the subsequent extinction of plants and associated bird species. Terrestrial upland species on islands are also vulnerable to agricultural development, ranching, logging, deforestation, and hunting practices that involve fire or exposure of soil to erosion and colonization by exotic species. Stemming the continuing loss of endemic island species in the tropics is one of the most significant ecological and environmental challenges facing island nations and cultures today.

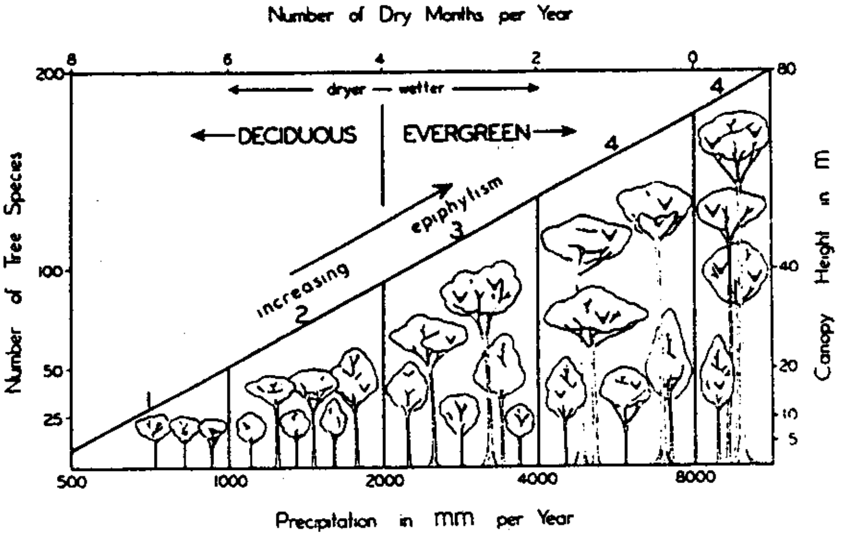

Figure V.6. A gradient or ecocline of mean annual precipitation for the tropical lowland zone indicates with increasing precipitation, in general, the complexity of the forest increases through increased diversity and ecological stratification (Source: Ecological Aspects of Development in the Humid Tropics. Copyright © 1982 by the National Academy of Sciences. Reprinted by permission).

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3. Tropical Forest Ecosystems

In the tropics, literally between the tropics of Cancer and Capricorn, uniform solar radiation leads to a year-round warm climate with the primary differences in temperature due to elevation. The extent of vegetation is strongly correlated with the amount and seasonality of rainfall (Figure V.6). Evapotranspiration is the combined loss of water from vegetation through evaporation from the leaf surfaces and through migration of soil moisture up the plant stem (see Section V.D, "Hydrology"). The forest has major interactions with other water resources characterizing tropical island and reef systems (see Section IV.A, "Increased Agricultural Production, Forestry, and Agroforestry").

The EIA should recognize the possible impacts of development on forest ecosystems, including:

- forest harvesting projects of any kind,
- extension of agriculture or grazing into forest areas,
- transmigration or resettlement schemes that open up new lands,
- improved transportation into or through forested areas (such as for security of frontiers or mining),
- energy development involving wood fuel (such as dendrothermal plants),

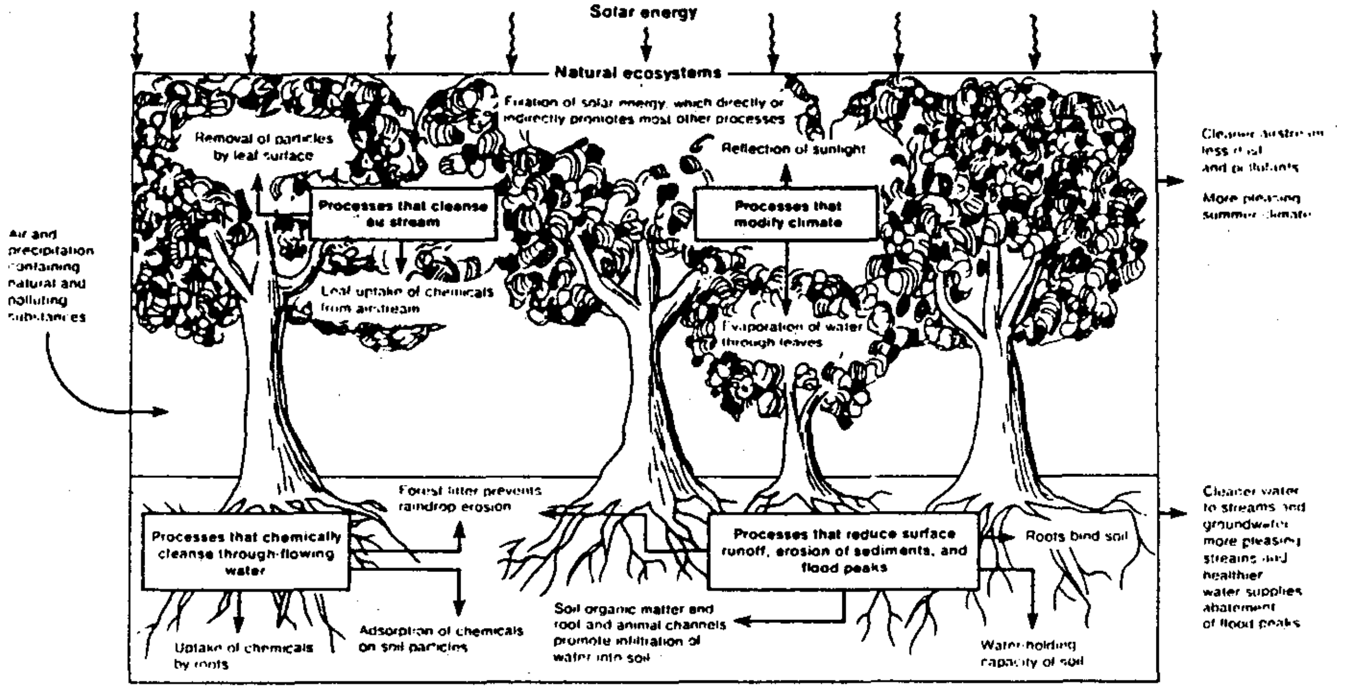


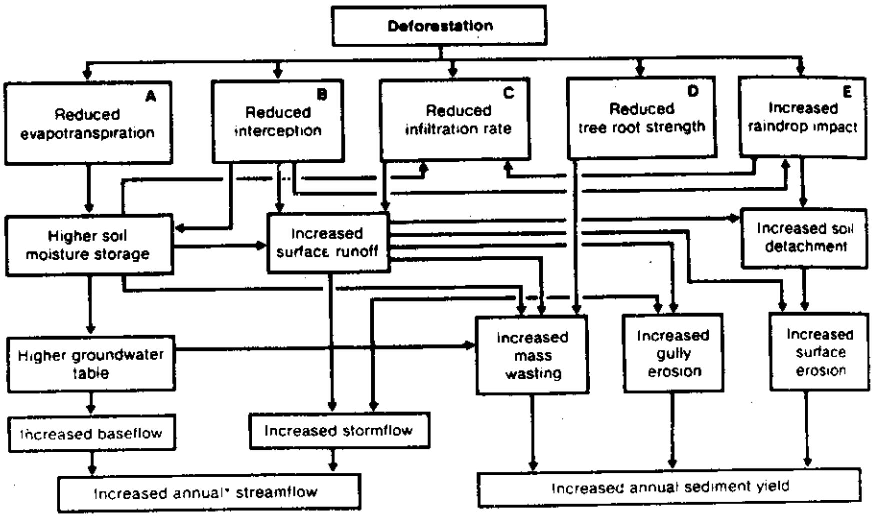
Figure V.7. Some forest ecosystem processes providing services valued by society (Source: F.H. Bormann, "An Inseparable Linkage: Conservation of Natural Ecosystems and the Conservation of Fossil Energy." Bioscience 26(12)754-760. Copyright © 1976 by the American Institute of Biological Sciences. Reprinted by permission of the publisher and the author).

- reservoirs located in or near forestland, and
- establishment of forests for productive or rehabilitative purposes.

In addition to forest products of wood and wildlife, valuable services are performed by forest ecosystems for society (see Figure V.7).

The forest ecosystem is stratified into layers: three leaf canopies (tree tops, understory, and small trees), shrubs, groundcover, litter, and soil biota. An enormous variety of plants and animals is possible: each hectare may contain hundreds of plant species, hundreds of kinds of mammals and birds, and thousands of different insects. The essential nutrients are almost all bound in the biomass and recycled quickly and locally with a very short residence time in the soil. Decomposition at the high temperatures is rapid, releasing the nutrients from decaying plant material.

Food chains are short, usually two to five links. In summary, the humid tropical forest ecosystem is diverse and stable if it remains undisturbed. The soils are acid, infertile, and easily leached. The hydrologic cycle is dominated by the state of the



Where deforestation is followed by severe land degradation, some reduction in both the volume and duration of dry season flows ultimately may be produced.

Figure V.8. Some likely hydrologic changes following deforestation (<u>Source</u>: Cassells et al. 1983:80. Reprinted by permission of the publisher).

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vegetation in forestlands with deforestation responsible for many potential hydrological changes (see Figure V.8).

4. Coastal Ecosystems

The coastal zone is a place of rapid transition from terrestrial to marine influences. Tides and surf entering freshwater streams and shallow waters make this environment one of constantly fluctuating conditions, and many organisms live at the extremes of their range of tolerance (see Figure V.9). Thus, additional stresses from development activities can have particularly severe effects (see Table V.1). The structure and functions of some coastal ecosystems are listed.

a. Deltas and estuaries are highly productive because of the nutrients brought in by fresh water and their mixing with marine waters. The dynamics of changing shape and size of these ecosystems are affected by:

- Freshwater discharge--related to the incidence and pattern of rainfall in the river catchment.
- Terrestrial sediment load--the nature and abundance is largely determined by the geology, vegetation coverage, and type of soil in the catchment area.
- Shore vegetation, such as mangroves, normally colonizes the intertidal zone, particularly along the protected shoreline.

- Nearshore processes include tides and waves and the associated current patterns.
- Changes in land and sea level are due to land subsidence, submergence, or worldwide sea level changes.

Estuaries are gateways for fish that migrate between inland and coastal waters as a part of their lifecycles.

b. Mangrove forests are highly productive because of their ability to live on shallow marine flats, trap sunlight, and produce energy in the form of leaf litter that supports the remainder of the system. The trees also trap nutrient-rich terrigenous sediments and offer diverse shelter and habitat to many birds, fish, and shellfish. The dynamics of these ecosystems are affected by:

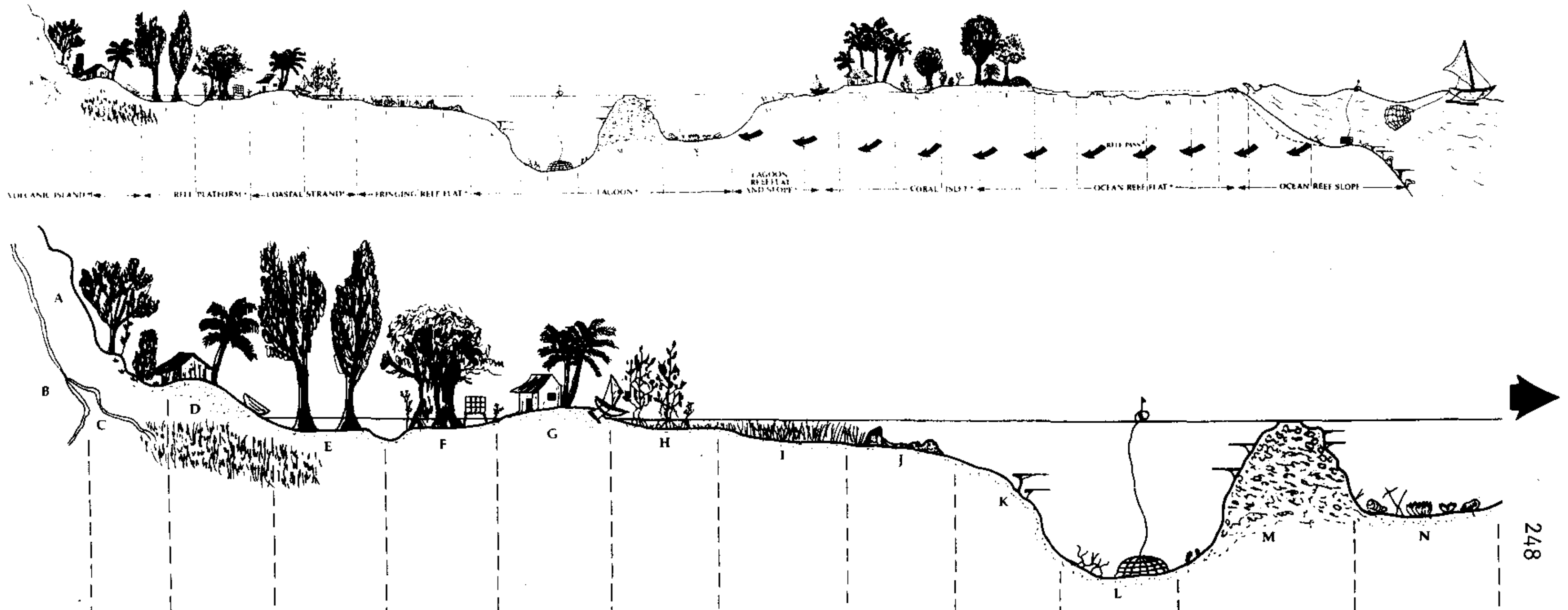
- freshwater discharge--related to surface water and groundwater movement from land areas,
- mixing with marine waters--mangroves compete successfully with other trees due to tolerance to marine salinities,
- protection from storm and wave action afforded by location within embayments or presence of offshore seagrass flats and coral reefs,
- nutrient replenishment from terrigenous sediment discharges,
- recycling of much of the locally generated productivity through detritus and carnivorous fin and shellfish, and
- water circulation through the system to remove waste products and move/recycle nutrients.

Mangroves are gateways for fish, shellfish, and their larvae that migrate between inland and offshore waters during part of their lifestyles. The three-dimensional habitats of mangroves serve as excellent nursery and spawning grounds for many species. Mangroves also provide natural protection against shoreline erosion.

c. Other Wetlands. Tidal swamp forests are less widely distributed than mangroves but most often occur inland of mangrove forests where coastal waters are subject to tidal fluctuation but which are essentially fresh (nonmarine or brackish). Tidal swamp forests are highly productive for similar reasons: ability to grow in coastal waters, trapping sunlight and producing leaf fall and shelter for virtually the remainder of the ecosystem.

The dynamics of these ecosystems are affected by:

- tidal fluctuations that cause water to flow through the swamps, removing waste products and recycling nutrients;



A HIGH VOLCANIC SLOPES	**C ESTUARY***	**D COASTAL PLAIN +**	**E TIDAL SWAMP FOREST*/ COASTAL MARSHES**	**F CLOSED MANGROVES***	**G CORAL STRAND***	**H OPEN MANGROVES +**	**I SEAGRASS MEADOWS +**	**J OUTER FRINGING REEF FLAT +**	**K LAGOON REEF SLOPE +**	**L DEEP LAGOON FLOOR +**	**M LAGOON PINNACLES AND PATCH REEFS +**	**N SHALLOW LAGOON SAND TERRACE +**
• Hardwood forests and lumber • Forest birds • Precious minerals • Bog forests • Soils **B STREAM*** • Water supply • Diadromous fish and shellfish • Hydropower	• Fish spawning and nursery grounds • Fish and shellfish	• Primary settlements • Agriculture • Ranching • Garden plots • Ports	• Lumber • Crabs • Fish • Livery corrals • Inland waterways • Flood control • Groundwater recharge	• Firewood • Poles • Mangrove crabs • Other shellfish • Brackish-water fish • Aquaculture (tambak) ponds	• Temporary shelters • Aquaculture • Garden plots • Canoe storage and launch	• Shore protection • Littoral shellfish • Throw netting	• Turtle feeding and capture • Schooling fish (netting) • Cuttle fish and octopus	• Coral rock for house construction • Coral lime kiln material • Spearfishing	• Spearfishing • Snorkeling	• Bottom-trapping • Bait fish capture • Sand for construction	• Spearfishing • Oysters or mother-of-pearl • Pearls and fish tackle	• Giant clam harvest and culture • Helmet, conches, and shells

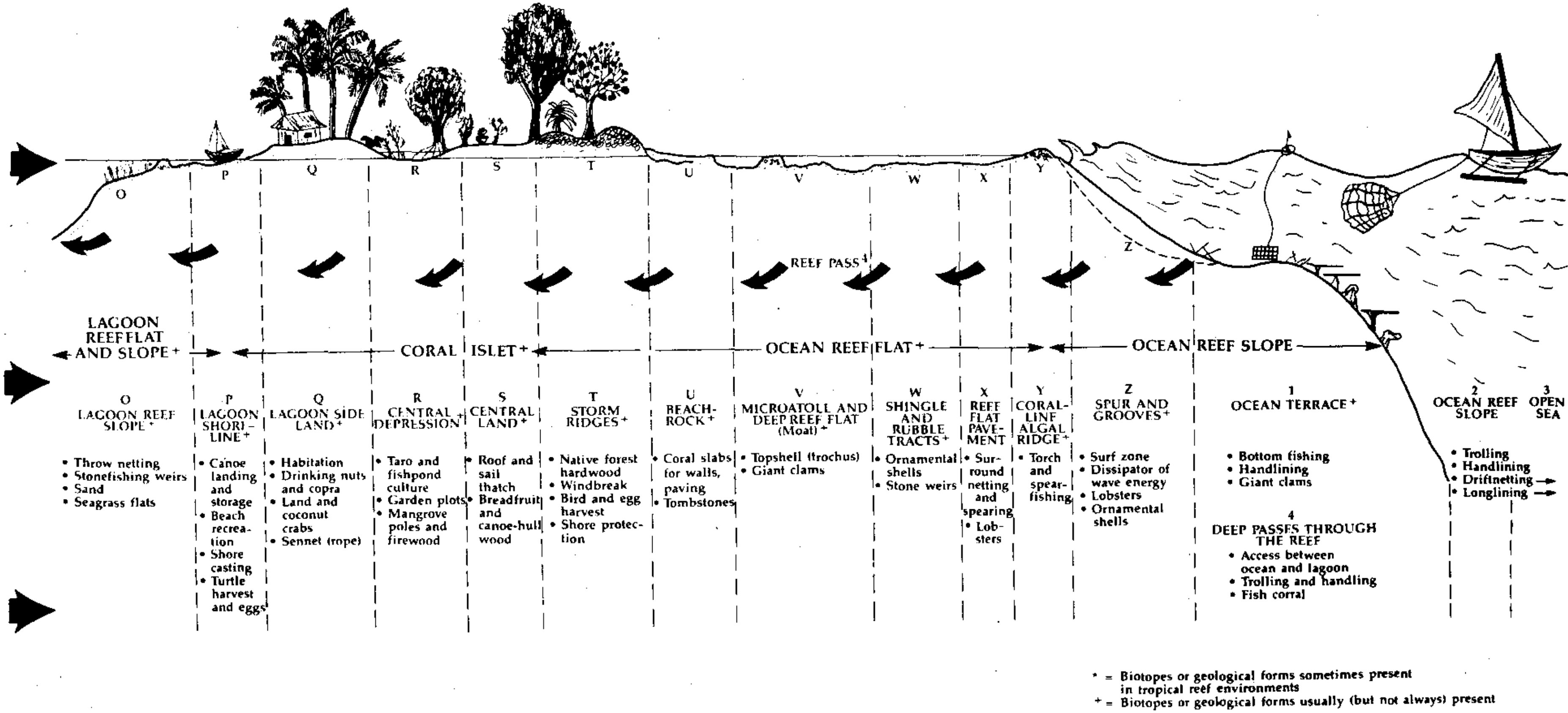


Figure V.9. Tropical high and low island ecology and subsistence culture in Oceania.

Table V.1 Major impacts of development on coastal ecosystems

Ecosystem	Uses and value	Sensitivity to changes in the environment	Hazards from development activities	Mitigating measures
Coral reef	<u>Sustainable</u> 1. Marine fisheries are dependent on a reef system for support 2. Local fisheries catch is directly from the reef 3. Tourism related to snorkeling and scuba diving to view corals and fish 4. Protection of beaches and islands from storm surge and wave erosion 5. High aquaculture potential (giant clams, pearl oysters, etc.) <u>Not sustainable</u> 6. Harvesting of coral for jewelry 7. Harvesting of exotic marine organisms for aquarium market 8. Mining for lime production	1. Prolonged fresh water flows that reduce salinity 2. Sediments that reduce light, interfere with filter feeding, and accumulate on bottom 3. Water temperature changes beyond tolerance of coral 4. Toxic chemicals from land or ships 5. Breakage by storms, boat anchors, blasting 6. Excessive nutrients that cause "blooms" of phytoplankton or competition from benthic algae 7. Oil spills due to toxic, light, temperature, and oxygen effects 8. Reduced water flow that reduces removal of sediment and waste products 9. Changes in sea level causing desiccation or increased exposure to wave action	1. Dredging, filling, and coastal construction practices 2. Discharge of mine tailings, storm runoff 3. Upland soil erosion from agriculture, roads, construction 4. Freshwater diversions 5. Sewage outfalls, discharges from fish and agricultural processing 6. Industrial discharges of oil and pollutants 7. Heated water discharges 8. Destructive and overexploitive fishing practices 9. Offshore petroleum and recovery	1. Site nonwater dependent development away from reef areas to the extent possible 2. Create and protect permanent reef parks and preserves as compensation for areas damaged 3. Contain sediment on land in settling ponds and in water with silt curtains 4. Use deep ocean outfalls for sewage and industrial wastes 5. Set and enforce regulations against destructive and overexploitive fishing and coral harvesting, and pollution from land or ships 6. Control construction that modifies circulation, water currents, and water levels in lagoons and coastal areas
Mangroves and other wetlands	1. Production and maintenance of nearshore fisheries (fin and shellfish) 2. Storm protection for low lying land 3. Trapping of nutrients and sediments from drainage 4. Wood and other forest products	1. Cessation of tidal flushing 2. Oil spills 3. Excess siltation 4. Salinity change 5. Excessive harvesting	1. Damming, dredging, bulkheading, impoundment, etc., that change the topography and water flow 2. Sediment production 3. Freshwater diversions, discharges, groundwater pumping 4. Clear-cutting or deforestation 5. Land reclamation	1. Maintain natural patterns of water movement 2. Set and enforce harvesting limits 3. Establish buffer zones

Estuaries and lagoons	1. High biological productivity--fish and shellfish 2. Harbor and navigation 3. Fish and wildlife habitat, breeding grounds for migratory species 4. Commercial and residential land	1. Pollution from chemicals, oil and sewage leading to contamination of fish and shellfish 2. Siltation of floor, smothering of benthic organism 3. Change in circulation pattern	1. Dredging, filling, construction 2. Spills of chemicals and oil from land or ships 3. Upland erosion and freshwater impoundment 4. Excess nutrients from agriculture and aquaculture	1. Sewage and waste treatment 2. Deep ocean outfalls 3. Lagoons and settling basins for storm runoff 4. Use of piles instead of solid fill 5. Seasonal operation of dredge and fill to avoid biologically sensitive periods
Beaches	1. Construction material 2. Tourism destination sites 3. Nesting areas for rare sea turtles and marine mammals 4. Boat launching and retrieval 5. Shoreline stabilization	1. Change in current patterns affecting accretion/erosion 2. Overexploitation if sand removal in excess of natural replenishment 3. Increased wave action from loss of protection from dredged reefs	1. Coastal engineering works (e.g., groins and seawalls) that alter longshore currents or wave forces 2. Coastal dredging or dune mining 3. Coastal transportation (docks, airfields, roads) 4. Placement of damaging property too close to shoreline	1. Understand the natural beach system 2. Use a setback line and foredune ridge for construction 3. Minimize structural intrusions into the water 4. Shoreline management
Seagrass	1. High biological productivity--fish and shellfish 2. Nursery grounds for reef and mangrove species 3. Beach sand replenishment and stabilization source 4. Synergistic interactions with onshore mangroves and offshore coral reefs 5. Feeding grounds for rare turtles and mammals	1. Pollution from chemicals 2. Change in current patterns causing either scouring or stagnation 3. Changes in sedimentation causing accumulation and burial 4. Changes in longshore movement of sand 5. Dredging of offshore reefs 6. Denudation of onshore mangroves	1. Dredging, filling, and construction of coastal structures 2. Oil and chemical spills 3. Damming or blockage of water flow and sediment movement	1. Understand effects of proposed project on sediment or water movement 2. Avoid damage to adjacent reef and mangroves 3. Use culverts and bridge openings in causeways 4. Locate nonwater dependent facilities onshore

- stability of physical barriers (e.g., mangrove fringe, coastal strands) to retain fresh water and keep out marine water;
- nutrient replenishment from terrigenous sediment discharges;
- excessive sedimentation causing burial and conversion of swamps to bottomland and terrestrial habitats;
- maintenance of upper canopies/overstory to maintain shade and high humidities; and
- recycling of locally generated productivity through detritous and carnivorous fin and shellfish.

Tidal swamp forests serve as transition zones between dry land and offshore marine and estuarine environments. They are gateways for migrating fish, shellfish, landcrabs, and their larvae during a part of their lifecycles. These forests often achieve extensive development (e.g., in Sumatra, Kalimantan) over many kilometers within gulfs and deltas where high levels of rainfall, freshwater discharge, and tidal fluctuations occur.

Marshes are wetlands dominated by grasses such as sedges, rushes, or reeds. In coastal areas, marshes are often interspersed with woody swamps and support many of the same values and functions, including natural groundwater recharge, flood control, filtering of sediments and nutrients, and habitat for waterfowl and shellfish. Coastal salt marshes are among the most productive of coastal ecosystems.

d. Seagrass meadows are common on shallow, exposed platforms, especially on the middle and back zones of reef flats, seaward of the mangrove forests and landward of the outer coral-dominated edge of the reef. Seagrass meadows are highly productive due to the rapid growth of the grasses in bright sunlight and shallow water, and export considerable productivity in the form of detached or decayed grass "blades" (thalli) and fin and shellfish. The dynamics of the seagrass meadow are affected by:

- tidal currents and moderate wave action that flush sediment and detached thalli from the meadows;
- offshore protection from severe wave action afforded by coral reefs;
- excessive shoaling or sedimentation from either landward or seaward sources that can bury the meadows or convert them to sand or mud flats;
- adequate salinities that afford the seagrasses a competitive advantage over other benthic communities less tolerant of marine water;
- nutrient replenishment from terrigenous sediment discharges;

- substrate hardness, stability, and elevation that control the ability of seagrasses to attach and form "sod" (rooting) layers; and

- excessive water depth or turbidity where light limits the growth rate of the seagrasses.

Seagrass offers low to medium profile, three-dimensional habitat for many herbivorous, detrivorous, and carnivorous finfish, shellfish, and their larvae that feed and take shelter within the seagrass blades and rooting layers. The juveniles of many reef and offshore fishes use seagrass meadows as nursery grounds. Seagrass meadows also serve as essentially feeding habitat for rare species of marine turtles and marine mammals (dugongs, manatees) and are migratory pathways for many aquatic species between mangroves, coral reefs, and other coastal habitats.

e. White sand beaches are commonly distributed thoughout the tropics wherever there are reefs, sand flats, or seagrass meadows offshore that provide the sources of calcareous sand. Less common are red, black, and green sand beaches derived from the breakdown of volcanic rock. White sand is produced from the physical and biological production and erosion of carbonate skeletal remains of corals, mollusks, sea urchins and other echinoderms, sea cucumbers, foraminifera, crustose coralline red algae, and sand-producing green algae. Sandy beaches are dynamic and constantly changing height, width, and slope because of the effects of wind, waves, water currents, tides, storms, and seasonal changes that suspend, move, and settle out sand particles. Sand beaches are a part of larger systems called "cells," which include sand berms and dunes to landward and offshore sand reservoirs to seaward. Beaches often change their profile in response to seasonal changes in the factors that transport sand up or down the coast or transport sand farther onshore or offshore. The dynamics of beach systems are affected by:

- changes in wave action (height, frequency, wavelength), water currents (either wind, wave, or tidal driven), and water level;

- interruption in the replenishment of beach sand from offshore updrift sources due to shoreline structures, dredging, landfill extension, and navigation channels;

- climatic anomalies such as periods of higher sea level, storm frequency, or higher waves or waters from an abnormal direction;

- mining of beach sand or mining of offshore sand reservoirs that replenish beaches;

- modification of riverine discharges due to channelization, jetties, or deflecting structures; and

- increased incidence or magnitude of tropical storms.

Sandy beaches serve many important ecological and socioeconomic functions: recreational sites; tourism destination areas; convenient sites for storage, launching, and retrieval of canoes and skiffs; primary nesting habitat for rare sea turtles, seals, and other marine mammals and reptiles; and domestic uses (household garden and soil conditioning). Construction uses or commercial mining of beach sand are potentially nonsustainable. The construction of permanent buildings and facilities too close to dynamic beaches can have serious socioeconomic impacts and eventually threaten the beaches themselves during subsequent efforts to protect properties threatened during natural cycles of beach retreat.

f. Coral reef communities normally dominate the outer edge and slopes of shallow tropical reef platforms and also form the dominant habitat in most barrier reef or atoll reef lagoons. The upward growth of coral communities over the thousands of years since the last Ice Age has created the shallow coastal platforms surrounding many tropical islands, providing the foundation for many other ecosystems, including mangroves, tidal swamp forests, seagrass meadows, and the source of sand and stability for beaches. Coral islands, shoals, and cays also form atop shallow reefs from the skeletal remains of coral reef organisms, and the mass of many higher islands and continental lands are composed of the remains. The physical presence of offshore reefs protects island lands and shorelines from wave attack, typhoons, and erosion. The dominant organisms within coral reef communities are reef corals that contribute much of the bulk or "building blocks" to the reef and coralline algae that cement the remains of corals and other calcareous organisms (mollusks, echinoderms) to form the rigid reef structure. The ability of coral communities to grow and sustain highly productive ecosystems in nutrient-low environments and to build rigid structures in the face of persistent wave action has allowed them to dominate environments ill suited for other ecosystems. The dynamics of coral reefs are affected by:

- excessive terrigenous or marine sedimentation that buries corals and other bottom-dwelling reef organisms and inhibits larval settlement;

- excessive dilution of seawater from freshwater runoff;

- circulation from winds, tidal fluctuations, and wave-driven currents;

- eutrophication and nutrient enrichment that allow algae or other benthic organisms (sea urchins, sponges, etc.) to compete against and displace reef corals and coralline algae;

- reduction of sunlight and consequent decreased primary productivity of reef corals and other producers on the reef;

- frequency and magnitude of earthquakes, lava flows, and subsidence;

- exposure to catastrophic storms and large waves;

- the capacity of landward ecosystems (mangroves, seagrasses, coastal forests) to trap sediment and control runoff of eroded soils;
- shoreline and offshore dredging and filling that bury or remove coral communities or change currents and circulation;
- prolonged exposure to air (lowered sea level) and high temperatures; and
- prolonged exposure to reduced dissolved oxygen levels.

Coral reefs provide many useful functions including protection of human settlement areas from natural coastal hazards, sources of many varieties of subsistence foods, recreational opportunities (sandy beaches, snorkeling, diving), and natural protection for ports and docks. For economic development, reefs provide (1) a major source of sand and coral for construction materials, (2) hard armor stone for shoreline protective structure, and (3) opportunities for resort development, commercial fishing and aquaculture, and landfill expansion. Some modern uses of reefs impair the function and structure of coral reefs and their value for other purposes (see Section IV.F, "Coastal Construction"). Coral reefs are often closely linked to other productive tropical ecosystems, particularly mangrove forests and seagrass beds. The larval forms of many reef species spend portions of their lifecycles in other systems. Productivity, nutrients, and water flow also link the coastal systems.

5. Subsistence-Based Economies and Ecosystems

Thousands of years of islander habitation on remote atolls and volcanic islands in the tropics led to the development of sophisticated subsistence-based cultures and practices that maximized sustainable and diverse use of limited available natural resources (Figure V.9). A variety of uses and functions were devised for each resource such as vegetation, fish, shellfish, sea turtles, coral rock, bones, and seabirds to assist in seafaring, fishing, agriculture, handicrafts, diet, construction, and other cultural practices. Resources such as coconuts, trees, hardwood trees, breadfruit, and large shells were especially valuable given the lack of good soils, good toolmaking materials (such as metals and hard minerals), clays for earthenware, large logs, and diversified fruits and vegetables and other limitations that characterize the resources of most low coral islands on atolls and barrier reefs. The need to maximize and diversify the use of limited natural resources was essential for continuous survival on many islands over the centuries. (Table V.2 lists traditional uses of vegetation.)

The advent of Western and European explorers and colonists in the tropical Pacific islands during the past several centuries led to shifts from a subsistence-based culture wholly dependent on natural resources to a mixture of cash and subsistence economies.

During the past century, plantation agriculture and urbanization led to the replacement of native vegetation species with commercial varieties of cash crops. Work on plantations diverted effort from subsistence

Table V.2. Frequency of usage for specified purposes of 140 Pacific island coastal plant species

Purpose/use	Ferns x/10	Herbs x/17	Grasses/ sedges x/11	Vines/ lianas x/14	Shrubs x/26	Trees x/62	Total x/140
Medicinal/health	6	13	4	10	21	49	103
General construction	-	-	-	-	5	54	59
Body ornamentation	6	6	3	6	12	26	59
Firewood/fuel	-	-	-	-	6	40	46
Cultivated/ornamental	4	3	-	2	10	20	39
Tools/toolmaking	-	-	-	-	3	32	35
Emergency/famine foods	4	5	2	2	3	18	34
Ceremony/ritual	2	3	-	5	5	18	33
Boat/canoe building	-	-	1	-	3	25	29
Dyes/pigments	-	-	-	1	3	23	27
Cordage/fiber	2	2	2	6	3	9	24
Games/toys	-	-	1	3	4	16	24
Fishing equipment	-	-	-	-	6	17	23
Supplementary foods	2	2	-	1	3	14	22
Scenting oil/perfumery	1	1	1	1	6	10	20
Woodcarving	-	-	-	-	1	18	19
Weapons/traps	-	-	-	-	5	14	19
Legends/mythology	-	-	-	-	3	15	18
Fertilizer/mulching	-	2	-	1	4	10	17
Handicrafts	1	1	3	2	1	8	16
Magic/sorcery	-	3	1	1	3	8	16
Animal feed	1	4	-	2	2	7	16
Food parcelization	2	1	-	1	1	10	15
Cooking equipment	-	-	-	-	1	12	13
Clothing	-	1	3	-	1	8	13
Fish poisons	-	-	-	3	4	4	11
Export/local sale	-	1	-	-	2	8	11
Adhesive/caulking	-	1	-	1	-	9	11
Musical instruments	-	-	-	-	1	9	10
Containers	-	-	-	-	1	7	8
Fire by friction	-	-	-	-	1	7	8
Repellents/fumigants	-	-	-	-	2	6	8
Tannin/preservative	-	-	-	-	1	6	7
Soap/shampoo	-	-	-	2	3	2	7
Wild animal food	-	-	-	-	2	5	7
Living fence/hedge	-	1	-	-	1	4	6
Antitoxins	-	1	-	1	1	3	6
Staple food	-	1	-	-	-	5	6
Drinks/beverage	-	1	-	2	1	1	5
Strainers/filters	-	-	2	-	-	3	5
Land reclamation	-	-	-	-	-	5	5
Calendars/clocks	-	-	-	-	-	5	5
Thatching/roofing	-	-	-	-	1	3	4
Illumination	-	-	-	-	-	4	4
Combs	-	-	-	-	-	4	4
Animal cages/roosts	-	-	-	-	-	4	4
Oils/lubricants	-	-	-	-	-	3	3
Brushes	-	-	-	-	-	3	3
Fans	-	-	-	-	-	3	3
Corks	-	-	-	-	-	3	3
Contraceptives	-	-	-	-	2	1	3
Other uses*	-	-	-	-	5	27	32
Total	31	53	23	53	143	625	928
No uses	-	2	4	-	1	-	7

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* Other uses include stimulants/teas, aphrodisiacs, contraceptives, masticants/chewing gum, abrasives, tooth brushes, cigarette wrappers, coconut-climbing bandages or harnesses, measuring tapes, fireworks, windbreaks, sand screens, ladders, tethering posts, fish bait, punishment, communication/language, and computation or counting (after R. Thaman, pers. com., 1989).

activities and increased the dependence of islanders on purchased processed foods and other goods bought with earned wages. Western culture also emphasized the role of higher education in getting ahead in life, finding a good job, buying luxury and material goods, and improving one's standard of living. At the same time, Western education was ignorant of the many values of subsistence resources and practices, including a more wholesome diet and reliance on fresh foods. As a consequence, much of the important subsistence lore of the island cultures is gradually dying out as younger, Western-educated generations of islanders seek Western style jobs, lifestyles, and economic opportunities in urban centers. With aspiration for white-collar jobs and business opportunities in the towns, cities, and government centers, much of the young adult workforce has migrated away from remote villages and islands, leaving behind a population with a higher proportion of elder people, children, and women who continue to rely on subsistence living. Urban islanders and wage earners are also more dependent on processed and prepared foods of less dietary value. General nutrition, public health, and sanitation have deteriorated in many urban centers due to poor diet, crowding, contaminated water supply, communicable diseases, alcoholism, and other symptoms of urban lifestyles. Inadequate government services and planning have also led to slum-like conditions in many urban centers.

Although earlier subsistence-based economies and lifestyles were harsh and demanding on the island populations, the benefits of a healthy diet, rich cultural heritage, fishing and seafaring skills, and other subsistence-based opportunities and knowledge are worthy of protection and preservation in the modern islander society. A major challenge of many tropical island nations will be to record, preserve, and restore much of the subsistence cultures and practices before the knowledgeable elders pass away. Education and vocational attitudes will need to adapt to the realities of the limitations in the natural resources and ecosystems of many Pacific islands and the vast knowledge and lore of many traditional cultures in exploiting and sustaining the uses of these resources for a variety of purposes and functions over many hundreds to thousands of years. Going back to the old ways may not be desired, but protection of important ecosystems and traditional practices to allow a mixture of the old and new may be of critical importance for future generations of islanders.

6. Summary

Collectively, coastal ecosystems provide tropical islanders with most of their natural protein sources, much of their building materials and firewood, much of their rock supplies and most sand, many recreational opportunities, protection and buffering from coastal hazards, and several other important economic development opportunities (e.g., tourism, commercial fishing, mariculture, sand collection, lumber and hardwood harvest, perhaps power generation, and coastal transportation). The closeness and linkages among several important and productive coastal ecosystems have enabled Pacific islanders to occupy the tropics and maintain a diverse, uninterrupted subsistence-based culture for thousands of years (see Figure V.9). A vital challenge to all tropical island nations will be to protect their cultural and subsistence heritage while accommodating sustainable economic development to improve standards of living, health care, and diversified lifestyles and opportunities.

V.B. SOILS

(prepared by John Morrison)

Soils are heterogeneous, multicomponent, multiphase materials found at the Earth's surface. Their genesis, behavior, and management are determined by physical, chemical, and biological processes often acting simultaneously. Soils frequently require substantial periods of time for formation; yet, they can be destroyed in hours or days by careless human activity. Thus, a good understanding of the basic properties is a prerequisite for sensible soil management.

Soils, which occur at Earth's surface and represent a small part of the geological cycle, are not just weathered rock. Many definitions of soils have been suggested.

- upper part of the earth's crust in which plants grow;
- outer layer of the earth in and on which organic life exists--as distinct from lifeless lithosphere, which is the outer mineral crust of the earth;
- upper weathering part of the earth's crust; and
- soil embraces not only lifeless constituents but also living organisms within it, including roots and other underground parts of plants.

One of the best definitions is:

> The Soil is a natural body of animal, mineral and organic constituents <u>differentiated into horizons of variable depth</u> which differ from the material below in morphology, physical make-up, chemical properties and composition, and biological characteristics (Joffe 1949).

The words underlined are vitally important because the formation of horizons distinguishes soil from weathered rock, which does not exhibit horizons. The succession of horizons from the surface of the soil to the parent material ("the initial state of the soil," that is, the consolidated or unconsolidated material from which the soil has developed) is called the "soil profile" (see Figure V.10).

The horizons are labeled A, B, C, with the parent material called the C horizon. The type and order of horizons enable soil scientists to obtain information about the soil-forming processes. The soil itself is normally developed in material that has already been weathered from solid rocks. This weathered mantle, or Regolith, can be as deep as 50 m in the humid tropics. The horizons above the parent material are collectively termed the "solum." There are different kinds of soil with different properties such as color, texture, chemical composition, structure, and organic matter content.

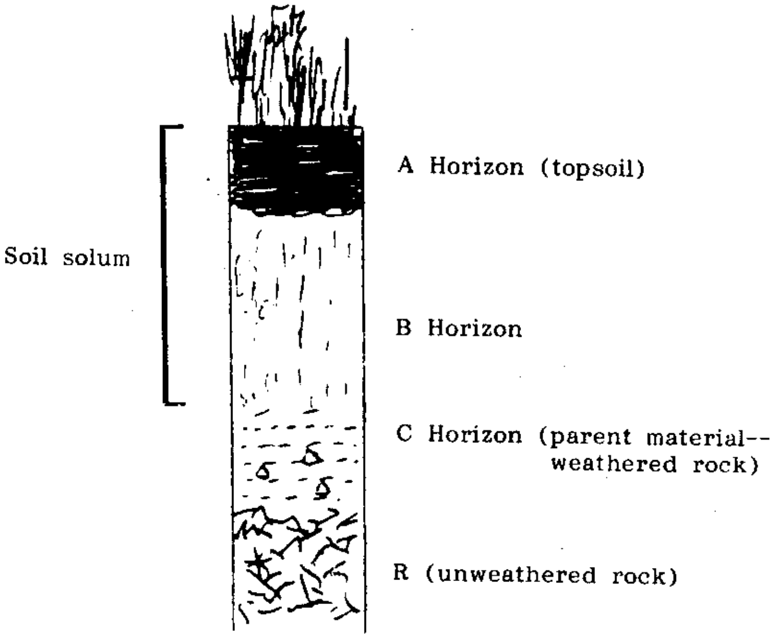

Figure V.10. A soil profile.

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1. Physical Properties of Soils

a. Composition of Soils. Soils are composed of four main constituents (see Figure V.11): mineral matter, organic matter, air, and water.

Mineral matter includes all those minerals derived from the parent material by weathering, as well as those formed in the soil by recombination of substances in the soil solution. The organic matter is mostly derived from decaying vegetable matter, which is broken down and decomposed by the action of the many different forms of animal life living in the soil.

Normally air and water occupy the spaces between the structures of the soil; but if a soil is saturated with water, most of the air is driven out. In a freely drained soil, some water is present as thin films around the mineral particles, leaving the spaces or fissures and holes open for the penetration of the atmosphere.

b. Soil Color. Soil colors are defined using Munsell color charts. The various colors are indicative of certain soil properties (e.g., reds indicate the presence of significant amounts of iron compounds, grey colors indicate saturation with water, black/dark brown indicate the presence of organic matter, whereas mottles--red/grey/orange/yellow/white patchy/spotted mixed colors--may indicate periodic saturation with water and drying out).

c. Soil Texture and Particle Size Distribution. The texture of a soil refers to the feel of the moist soil resulting from mixture of

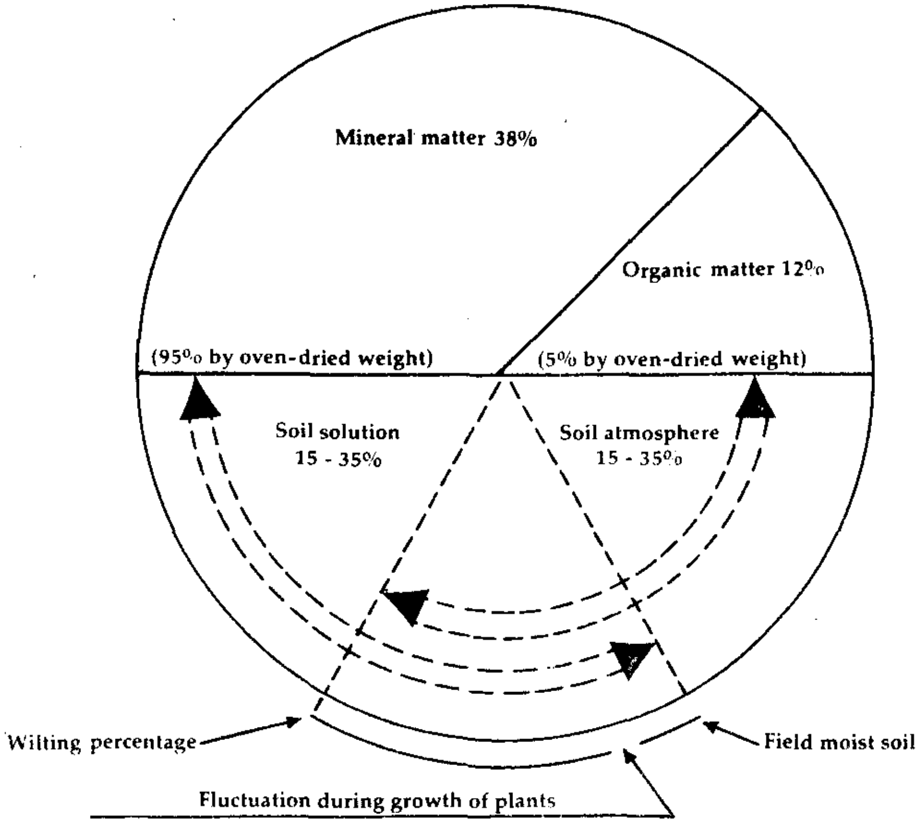

Figure V.11. Percentage composition of soil (volume basis).

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the constituent mineral particles and organic matter--an approximate measure of particle size distribution. Texture is determined by rubbing the moist soil between finger and thumb, an act that requires some experience.

Some soils may have the same texture but may not have the same particle size distribution (and vice versa), mainly because of variations in organic matter, type of clay, shapes of particles, and degree of aggregation (e.g., a large amount of organic matter makes soil appear to have a higher silt content).

Soil particles are divided initially into two classes:

LARGER SEPARATES - material > 2 mm diameter (including gravel)
FINE EARTH - material < 2 mm diameter

A study of the larger fragments can often give clues as to the origin of the formation of the parent material and the soil itself.

- shape of stones: round, angular, subangular;
- orientation of stones; and
- faceted stones (wind-blown fine particles blown against them).

The fine earth is divided into sand, silt, and clay--the size limits of which vary between workers--but normally either the International or USDA schemes are adopted (see Figure V.12). According to the relative amounts of sand, silt, and clay, twelve classes have been created and are usually presented in a triangular diagram (see Figure V.13). The accurate determination of particle size distribution is fairly long and tedious.

The different soil textures have properties that affect the management and economic use of the soil. Coarse-textured, sandy soils are usually freely drained. In a dry summer, however, sandy soils may suffer from drought but cultivation is fairly easy. Frequently, clay soils are poorly drained, and the expense of installing a drainage system can be large. Cultivation is always likely to be difficult, although in a dry year, these soils may produce better crops than those in a sandy soil. Silty soils are troublesome in that they must be cultivated within certain moisture limits; otherwise, they become cloddy and preparing the seed-bed is difficult. Also, heavy rain causes surface sealing that inhibits seedling emergence and encourages sheet erosion.

d. <u>Soil Structure</u>. "Structure" is described as the way the soil particles aggregate to form soil aggregates, or "peds."

Four primary types of soil structure are recognized (see Figure V.14): platy, prismlike, blocklike, and spheroidal.

Soils that have no definite structure are referred to as "structureless." If the soil breaks up with a series of horizontal cracks, it is called "platy"; this type of structure is often inherited from the parent material. If the soil breaks up with a series of vertical cracks, prisms of various sizes are produced; these may have level tops (prismatic) or rounded tops (columnar).

Blocklike structure is very common and may be of two types: "blocky (angular)"--sides of blocks meet at sharp angles, corners are sharp; "blocky (subangular)"--the corners are rounded.

All rounded aggregates may be called "spheroidal," although the term more properly refers to those not more than 1.25 cm in diameter. They also may be called "granular" (if porous) or "crumb" (if very porous).

Soil structure plays an important part in determining the behavior of a soil. The shape and stability of the peds determine the macroporosity of the soil and hence the movement of water and gases through the soil. The structural stability is determined by the particle size distribution (texture), the nature of the clay fraction, the amount of organic matter, and the extent to which the soil is disturbed. Cycles of wetting and drying tend to encourage good structure formation.

The structure of the plow layer is affected by management practices, and where aeration and drainage limit plant growth,

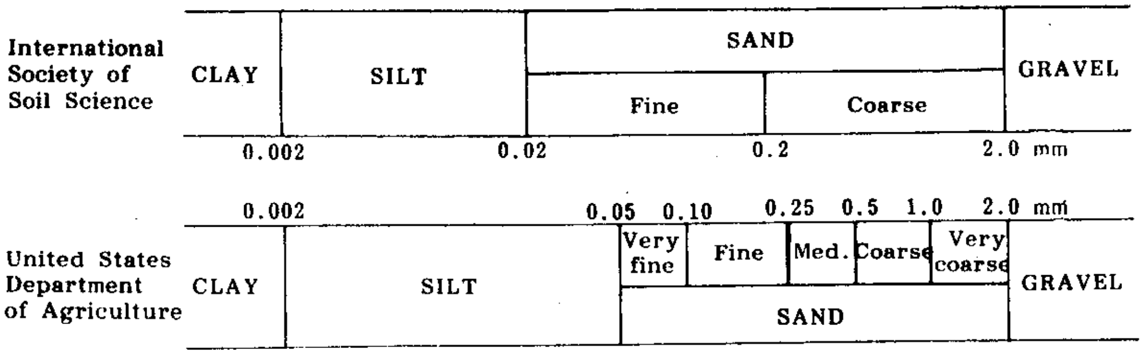

Figure V.12. Classification of soil particles according to size by two systems (particle diameter in logarithmic scale).

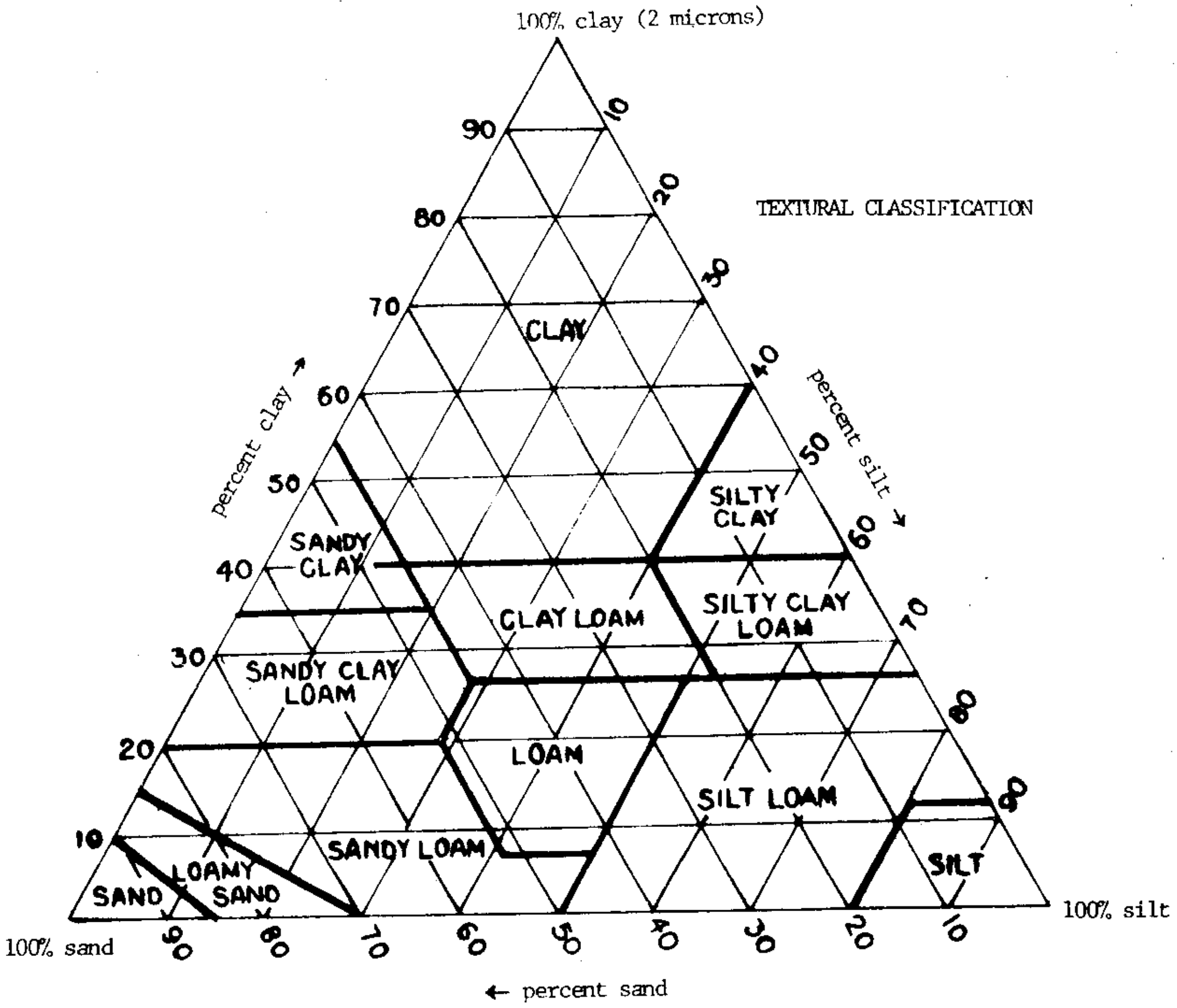

Figure V.13. Textural classification of soils.

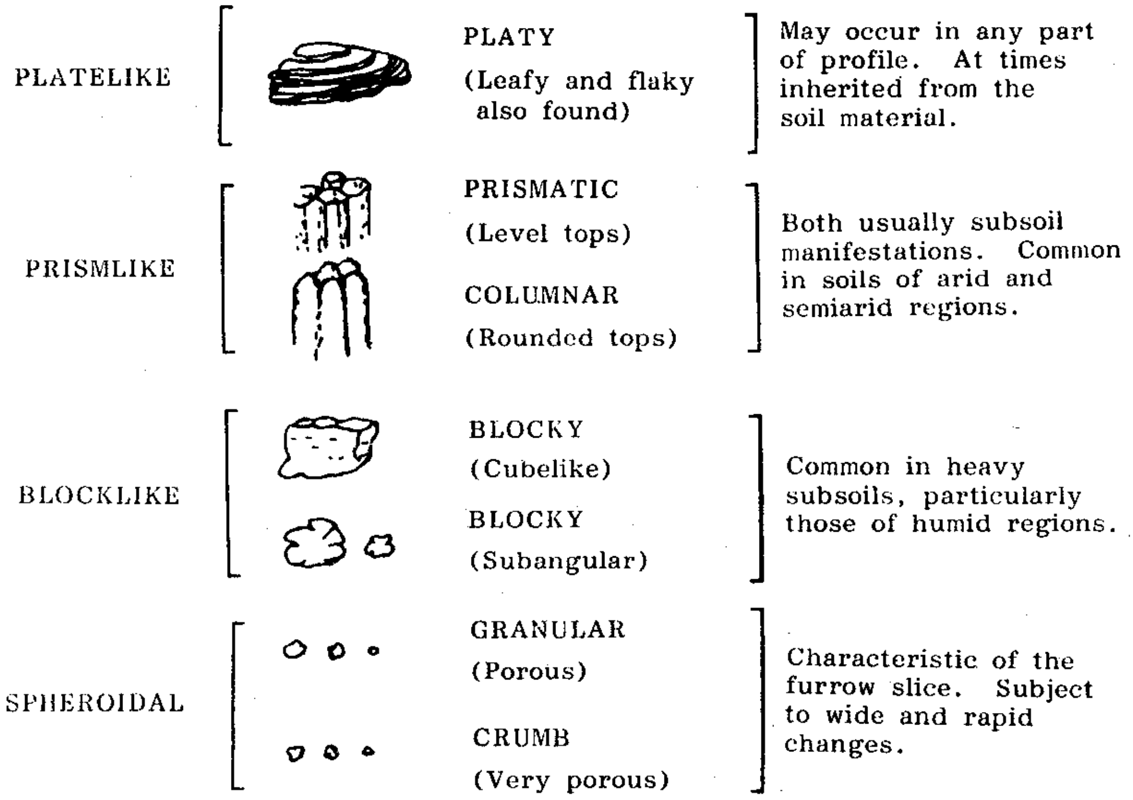

Figure V.14. Various structural types found in soils. (Reprinted with permission of Macmillan Publishing Company from <u>The Nature and Properties of Soils</u>, 9th ed., by Nyle C. Brady. Copyright © 1984 by Macmillan Publishing Company.)

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cropping systems that maintain greater aggregation are likely to result in higher crop yields. Greatest aggregation is usually found where cultivation is least frequent and where the layer is most often supporting an actively growing plant canopy. An actively growing plant canopy assists aggregation because (1) it intercepts raindrops, which, if falling directly on the ground, tend to break up aggregates; (2) its continuous microbial activity is associated with a constant source of organic matter; and (3) roots and root hairs penetrating the soil produce lines of weakness along with the soil mass which may break into granules.

e. Soil Organic Matter. The content of organic matter in a soil is critical for retaining and cycling of nutrients, for retaining moisture, and for developing and maintenance of structure. Natural or human processes (e.g., land clearing, burning), which lower the organic matter content, have a detrimental effect on the soil in its ability to sustain plant growth.

f. Microbiology. When plant residues fall on the soil surface, they are immediately attacked by microorganisms that break down the residues by using some of the components for their own use and

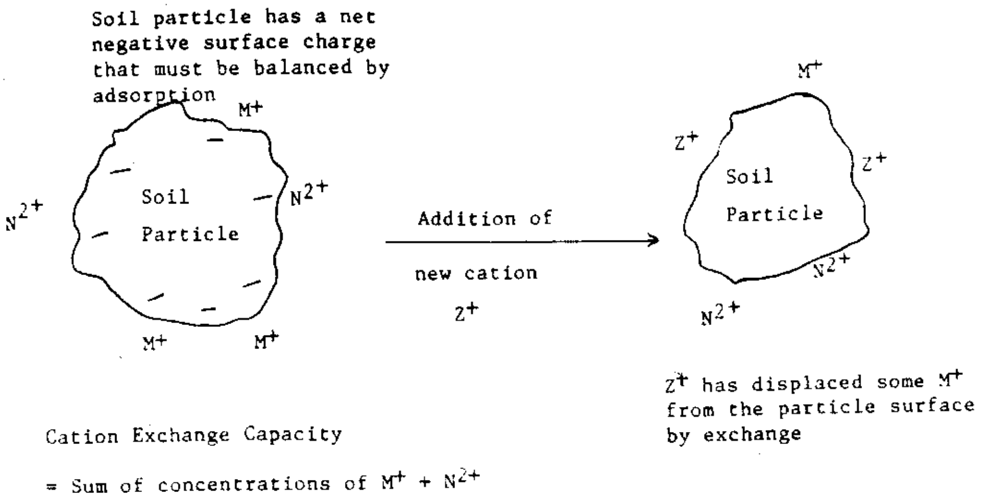

Figure V.15. Cation exchange.

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facilitating the incorporation of organic matter into the soil. Earthworms, bacteria, fungi, actinomycetes, and algae all have important roles to play in the cycling of nutrients. Maintenance of an active microflora is necessary for good soil performance.

g. Soil Chemical Properties. The most important soil chemical properties relate to surface properties of the soil particles. These particles, both organic and inorganic and intimate mixtures, have a net charge, usually negative, that must be balanced by incorporating exchangeable cations (see Figure V.15). The amount of cations retained (the cation exchange capacity, CEC) is an important soil property. CEC is determined by surface area (i.e., particle size distribution), mineralogy, and amount of organic matter. In soils with oxide minerals that have a low CEC, the presence of organic matter to retain nutrient cations (e.g., potassium, ammonium, calcium) is critical.

Other important soil chemical properties are the amount and composition of organic matter, the concentration of exchangeable bases (calcium, magnesium, potassium, sodium), and the soil reaction (pH). The soil reaction is determined by measuring the pH of a suspension of the soil in water or in a diluted salt solution. A low ($pH < 5$) reaction may indicate potential toxicity problems associated with aluminum and manganese, whereas a high ($pH > 7.5$) value may indicate problems relating to micronutrient availability (e.g., iron, zinc, copper).

2. Predicting/Estimating Erosion

(prepared by William Clarke)

The universal soil loss equation (USLE) provides a methodology for calculating and predicting sheet, or inter-rill, erosion, the more or less even removal of soil layers from the surface of a unit of land

(Wischmeier and Smith 1978). The equation was developed and tested in the United States at more than 200 locations over a 50-year period but generally required adjustment of the parameter values when used in other areas. Nonetheless, even if the values are not wholly accurate, the USLE is useful in calling attention to the factors that cause soil erosion. Each must be considered in any attempt to mitigate erosion losses. The USLE factors are:

A	=	R	x	K	x	L	x	S	x	C	x	P
Soil loss		Rainfall factor		Soil Erodibility factor		Length of slope		Degree of slope		Cropping practices		Erosion control

A is expressed in metric tons per ha per year.

R, or erosivity, the power of the rain to erode, is assigned a value (erosion index) dependent on rainfall characteristics such as drop size and storm intensity (see Figure III.8, p. 93). Erosivity is high in the humid tropics.

K, soil erodibility, is a function of soil properties.

L and S are the topographic factors; the longer and steeper the slope, the higher their values in the equation and the greater the potential for erosion.

C, the cropping or cover factor, is a function of crop type, residue management, tillage practices, and crop calendar. For example, C values for different covers in West Africa have been calculated as (Roose 1977):

Bare soil	1.0
Dense rainforest	0.001
Ungrazed grassland	0.01
Rice	0.1-0.2
Cassava	0.22-0.8
Coffee, cocoa with cover crops	0.1-0.3

P is erosion control (practices such as contour plowing; terracing; planting lines of trees, shrubs, or grasses along contour lines, e.g., vetiver grass in Fiji's sugar lands).

a. <u>Measuring Erosion</u>. Losses from soil erosion can also be directly measured or monitored by (1) trapping and measuring the quantity of soil removed by overland flow from a measured runoff plot and then calculating losses from larger unit area such as a hectare, (2) measuring changes in soil level in the field and calculating losses in t/ha/yr, and (3) measuring sediment yield in runoff water from a whole watershed. These methods require some equipment (mostly simple) and technical expertise, but are not complex or expensive.

b. <u>Evaluating Erosion</u>. Erosion inevitably reduces soil productivity. How great the reduction depends on the amount removed.

But how much is too much? This question is not easily answered, and it is generally agreed that a certain amount of soil loss in agriculture is inevitable. Ideally the loss should not exceed the rate of soil formation from parent rock and decomposed vegetation, but there is no agreement in the literature on the rate of soil formation; estimates range from 1.3 to 750 yr/cm (El-Swaify 1988:11). A commonly cited, generalized upper limit of permissible, or tolerable, soil loss is about 11 t/ha/yr, but the "permissibility" of such a loss depends on many local factors such as the fertility and drainage characteristics of the subsoil. Many soils are vulnerable to a decline in productivity at a rate of loss from erosion considerably lower than 11 t/ha/yr. Downstream damage from sedimentation must also be considered in setting tolerance limits to the rate of soil erosion. Few quantitative data on soil erosion exist in the South Pacific, except from Fiji where measurements show losses far above the ideal tolerance limit (e.g., more than 70 t/ha/yr in sugarcane and pineapple fields) (Eyles 1987; Clarke and Morrison 1987).

The depth of the A horizon (Figure V.10) is the most important factor in establishing a tolerable erosion rate. Once the topsoil is gone, agricultural productivity is drastically reduced.

V.C. POLLUTION

1. Water Pollution

Water is used for many development purposes, and any loss of beneficial use due to pollution amounts to economic as well as ecological and human health damage. Figure V.16 shows how sources of wastewater may pollute water supplies taken from surface streams and lakes or underground aquifers. Figure V.17 diagrams how specific pollutants from major sources impact beneficial uses.

For developing countries in Oceania, the most widespread environmental problem is the safe disposal of human wastes and urban sewage (Dahl 1984). There are few sewage collection systems even in urban areas. Treatment facilities are often not properly operated or maintained nor are they sited sufficiently far from potable water sources. The result is serious pollution of freshwater supplies and coastal waters important to tourism and fishing.

Portions of the following discussion are excerpted from Carpenter (1983).

a. BOD. One of the most important measures of water quality is biological oxygen demand (BOD)--the amount of oxygen used by biological organisms to consume dissolved or suspended biodegradable organic waste materials. The standard parameter is BOD_5 (i.e., a test measuring the amount of oxygen consumed at $20^{\circ}C$ in 5 days). The chemical oxygen demand (COD) is a similar measure--the amount of oxygen from potassium dichromate (an oxidizing agent) in sulfuric acid that is needed to oxidize all the carbon-containing pollutants (see Table V.3).

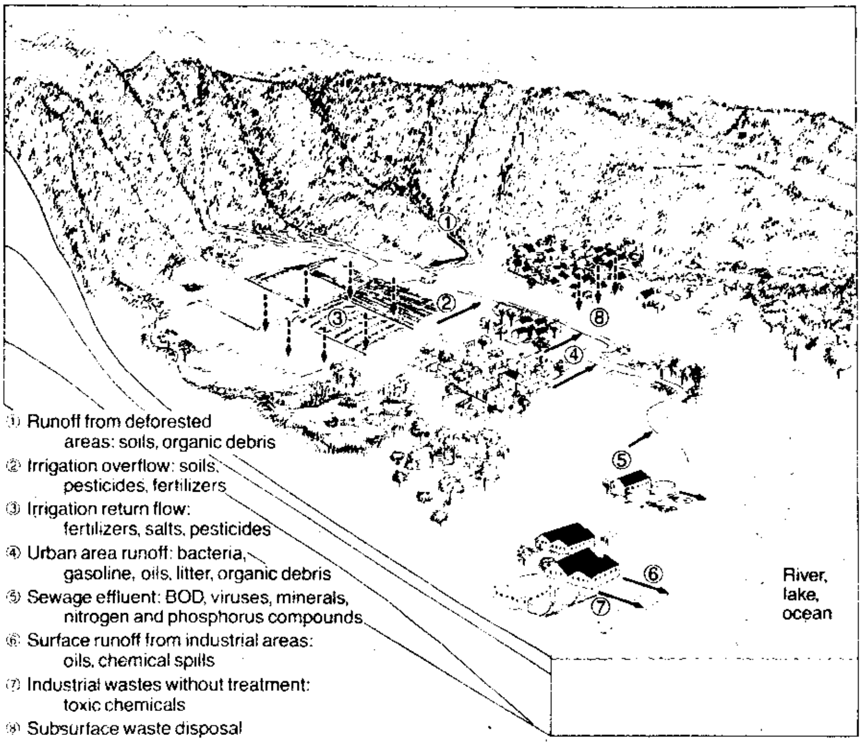

Figure V.16. Paths of wastewater in hydrologic cycle (Source: Carpenter 1983:391).

Decomposition of organic wastes thus consumes oxygen dissolved in water--the same oxygen that is required by fish and shellfish. The higher the BOD, the worse the quality of the water. The dissolved oxygen is virtually depleted when the BOD exceeds 10 mg/l. Then anaerobic bacteria take over and produce foul-smelling hydrogen sulfide, ammonia, and methane from the remaining organic wastes.

b. Diseases, Pathogenic Organisms. Waterborne pathogens, organisms that produce many infectious diseases, usually originate in human and animal waste matter from municipal sewage, hospital sewage, and garbage.

Infectious diseases can be spread through three major water uses: potable (drinking) water, recreational waters, and faunal growing waters, particularly shellfish beds. The following groups of organisms contain pathogens that can be transmitted by polluted water: (1) bacteria, (2) protozoa, (3) parasitic helminths (e.g., roundworms, flukes), and (4) viruses. The rapid development of high population densities without control of sewage disposal and without stringent isolation and treatment of drinking water supplies increases the danger of waterborne infections of typhoid and bacillary dysentary caused by the bacteria Salmonella and Shigella, respectively. Cholera, a disease of extreme severity, still can destroy nearly entire communities where it is endemic in Asia. Cholera is rare in developed countries because of the high level of hygiene and adequate sewage treatment facilities, as well as drinking water disinfection.

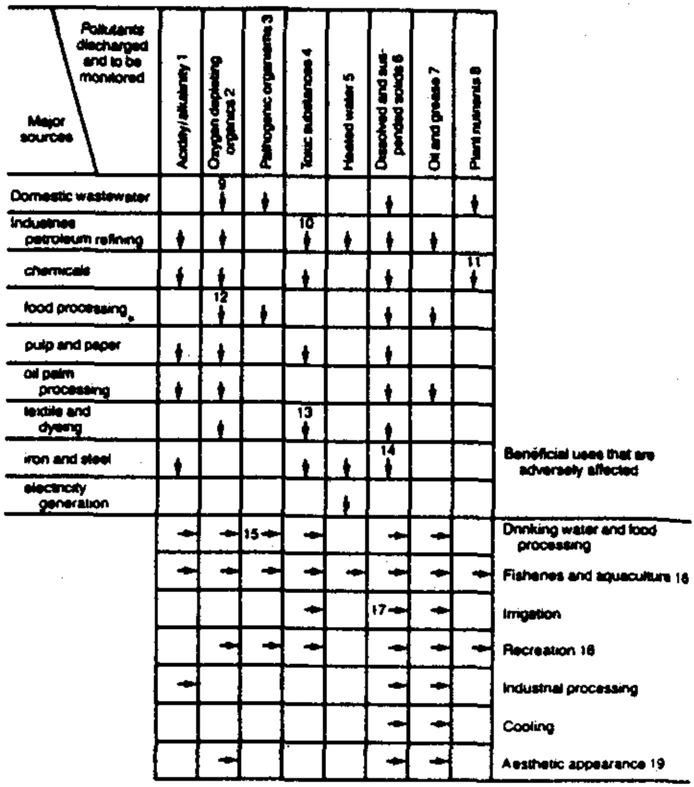

Figure V.17. Sequence diagram of major sources, pollutants discharged, and their effects on beneficial uses of water (Source: Carpenter 1983;404).

Notes for Figure V.17

1. Variations in acidity/alkalinity can damage or kill aquatic plants and animals, and can affect the assimilative capacity of streams and the rate of biodegradation in sewage treatment plants.
2. The dissolved oxygen in receiving waters is used up by bacteria when they oxidize dissolved carbonaceous (organic) material to carbon dioxide, and the oxygen is therefore not available to fish and shellfish. The organic content is expressed as BOD (biological oxygen demand) or COD (chemical oxygen demand).
3. Fecal contamination often is measured in terms of indicator organisms such as coliform bacteria, *Enterococci* and *Clostridium* species. Viruses are difficult to detect by any rapid test method.
4. Heavy metals (e.g., lead, cadmium, mercury), cyanides, phenols, ammonia, sulfides, pesticides.
5. Thermal pollution can affect organisms directly and can reduce the amount of dissolved oxygen in the water at elevated temperatures.
6. Turbidity can reduce light penetration and kill aquatic plants. Dissolved salts affect human health and plant growth, and damage piping and equipment. Hardness is due to calcium and magnesium salts.
7. Immiscible liquids and solids may form films, emulsified droplets, or suspended particles.
8. Nitrates, ammonia, and phosphates promote growth of algae and aquatic weeds. Eutrophication is an excessive content of plant nutrients that leads to heavy growth in the receiving waterbody.
9. Primary treatment of sewage separates floating and settleable matter. Secondary treatment provides for bacterial oxidation of suspended and dissolved organic matter.
10. Phenols, ammonia, sulfides, and acids are common.
11. Fertilizer and detergent manufacturing.
12. Vegetable canning operations are concentrated at harvest times and may discharge BOD equivalent to that of a large city population. Such a surge of organic matter can exceed the assimilative capacity of the receiving water.
13. For example, rayon processing and synthetic dyes.
14. Pickling liquors may be quite acidic as well as high in salt content.
15. Chlorination can kill most hazardous microorganisms if properly applied. Some viruses are very difficult to kill.
16. Naturally occurring animals (fish and shellfish) in receiving waters will have adapted to very specific water quality requirements. Slight changes may decrease reproductive success even if adults show no apparent damage.
17. Irrigation water returned as excess from fields may pick up soluble salts, and thus pollute the stream into which it is discharged.
18. Recreation that includes swimming and other water contact requires water quality almost as high as that for drinking water.
19. Odors, floating noxious materials, color, and turbidity degrade the use of water, even if only for aesthetic purposes.

Table V.3. Typical BOD and COD (mg/l)

Water source	BOD	COD
Natural fresh water	1-2	3
Raw municipal sewage	100-300	--
Industrial wastewater	500	2000
Pulp & paper wastewater	1000	2000
Pigpen drainage	2000	--

Immunization also can protect the population from typhoid fever and, to some extent, cholera.

Because many viruses are resistant to conventional water treatment and disinfection, viral infections are still a menace to developed countries as well as to developing countries. Explosive outbreaks of infectious hepatitis are common, particularly where water treatment has failed. Other enteroviruses include polio, Coxsackie, echo, and rotavirus. Rotavirus is responsible for thousands of cases of infantile diarrhea annually in Asian countries, according to recent research studies. This virus may be responsible for high infant mortality rates in several developing countries.

Parasitic trematodes or flukes, although not microorganisms, are by far the most important waterborne pathogens for human beings. These organisms are tiny worms. Most of these, except Giardia, can be controlled through adequate water treatment and chlorination.

Detection of fecally contaminated water in the United States depends on identifying Escherichia coli (coliforms), which is a bacterium normally found in the intestinal tract of warm-blooded animals and human beings. The number of total coliforms permitted in water is dependent on the purpose for which the water is to be used and the population density it serves. The standards for drinking water are more stringent than those for recreational waters, and it must be emphasized that standards set using coliform counts are arbitrary. They represent a measure of possible human fecal contamination and the potential presence of pathogens. The potential presence of disease-producing organisms is only a statistical possibility related to the level of the coliforms in the water. The standards used in the United States, which correlate with the recommendations of the World Health Organization (WHO), are < 50/100 ml for drinking water, < 240/100 ml for swimming, and < 70/100 ml for growth of fish and shellfish. Streptococcus is another indicator of fecal contamination.

c. Toxic Substances. The toxicants causing water pollution can be classified into four subcategories:

- Nonmetallic inorganic toxicants (e.g., cyanide and fluoride);

- Heavy metals and submetallic inorganic toxicants (e.g., mercury, cadmium, lead, chromium, and arsenic);
- Easily degradable organic toxicants (e.g., volatile phenols, aldehydes, and benzene); and
- Refractory organic toxicants (e.g., DDT, BHC, dieldrin, aldrin, polychlorinated biphenyl, polycyclic aromatic hydrocarbons, and aromatic amines).

Traces of toxicants can be highly concentrated through the food web (nutrient web) of organisms. The food web is the relationship between a population of organisms of one family and that of another, the latter being used by the former as food. That is, big fishes eat small fishes, small fishes eat shrimps, shrimps eat small worms, worms eat algae, and algae use the dead bodies of fishes, shrimps, and excreta as nutrients and breed. The nondegradable heavy metals and organic toxicants (such as DDT) would be gradually enriched or concentrated. For example, the "Minamata disease" in Japan was caused by methyl mercury concentrated through the food chain. The "Ouch-Ouch disease" was brought about by cadmium concentrated through the food chain of plants. In many countries, regulations strictly govern the use and discharge of chemical toxicants. In view of the complicated characteristics of the chemical toxicants and the fact that they are difficult to remove, great attention must be paid to keeping them out of water resources.

d. Radiation. Radiation pollution of water is caused by radioactive substances (radionuclides) that, in the process of decay, emit radiation of alpha and beta particles and gamma rays. The level of radiation emission decreases with time. The level can be long for certain species of radionuclides such as radium and strontium (the half life for radium 226 and strontium 90 is 1,620 years and 29 years, respectively).

Radiation is harmful when absorbed in living tissue in quantities substantially above that of natural background. The injuries resulting from overexposure can be acute radiation sickness (blood changes or leukemia, nausea, pyrexia, and vomiting), followed by death or long-term genetic effects that produce mutations in offspring. It is therefore necessary to prevent excessive levels of radiation from reaching any organisms, whether human, fish, or invertebrate.

The major sources of radionuclides are mining of uranium and other radionuclides, wastes from industrial uses of atomic energy, detonation of nuclear weapons, and research and medicinal use of radioactive substances.

e. Oil. Oil pollution may be caused by oil discharged by industries, the washing of oil tanker holds and parts of tankers, accidents, oil extraction processes and oil in bilge waters. One ml of oil can cover as much as 12 m^2 of water surface. Oil films may attach to particles and aquatic organisms, then diffuse or settle in the water. Oil in waterbodies can be degraded by photochemical oxidation or bio-oxidation.

Oil pollution can damage seashores and reduce resort values for tourism, and can attach to fish eggs and fish, hampering their activity and lowering their market value because of tainted taste. Oil also adheres to waterfowl, destroying the waterproofing and heat preservation abilities of their feathers.

f. Temperature. Thermal pollution is commonly caused by a plume of water with an excessively high temperature entering the receiving water. Thermal pollution may lead to reduction of dissolved oxygen, increases in toxicity of certain toxicants, failure of fish to breed, and accelerated growth of unwanted bacteria and aquatic plants. In the tropics, many aquatic species live close to their upper lethal temperature limits and a few degrees rise can be fatal.

Temperature measurements in receiving waters are also useful indicators of changing circulation patterns and stratification. Coastal construction and structures often change circulation patterns which can be diagnosed easily using temperature measurements. In the tropics, surface waters tend to be heated quickly by sunlight and changes in flushing, and current patterns can reduce turnover and exchange rates of waters in embayments and lagoons causing higher temperatures. A rapid decrease in water temperature with greater depth may also indicate sluggish circulation conditions, stagnation, or stratification.

g. Hardness. "Hardness" of water is due to dissolved salts of calcium and magnesium. Given natural geographical conditions, changes in hardness are comparatively small over time. Therefore, persistent increases in underground water hardness possibly may indicate human-induced pollution or substantial changes in the hydrologic regime.

The sanitary standards of water hardness vary considerably. Hardness should not be present in concentrations that will cause excessive soap consumption or that will cause objectionable scale buildup in heating vessels and pipes. The criteria for objectionable hardness must be tailored to fit the requirements of each community.

h. Salinity. Salinity is a common water quality indicator of seawater or ocean water condition or influence. Normal seawater has a salinity of about 35 o/oo (parts per thousand), whereas fresh water has a salinity of less than 0.05 o/oo. The presence of intermediate salinity values in surface waters indicates estuarine conditions or the mixing of fresh and ocean waters such as at stream mouths. The presence of intermediate salinity levels in groundwater indicates seawater infiltration or contamination. Rising salinity levels in groundwater bodies near the coast may indicate excessive withdrawal of water supply beyond natural replenishment capabilities, which, in turn, allows seawater infiltration and degradation of water supply and quality.

i. Plant Nutrients: Eutrophication. Domestic sewage, wastes from food processing industries, and fertilizer and chemical manufacturing spillage are major sources of the plant nutrients phosphorus and nitrogen in waterbodies. Detergents increase phosphorus content in domestic sewage, and agricultural runoff and animal manure are also major contributors.

The more abundant the plant nutrient supply, the denser the vegetation, provided other environmental factors are favorable. The phenomenon of eutrophication refers to the effects of adding excessive nutrients to a body of water, as represented by the rapid growth of surface organisms such as planktonic algae and aquatic weeds (macrophytes).

Abundant algal growth in a eutrophic (nutrient-rich) waterbody forms "water bloom" or "scum." Algal plants are diverse in shape, color, size, and habitat. When present in sufficient numbers, they impart a green, yellow, red, or black color to the water. Some species of algae causing "water bloom" smell bad and produce toxicants during their metabolic process. A beneficial role of algae is the daytime production of oxygen that can lead to oversaturation of dissolved oxygen in the surface water layer. However, at night, photosynthesis ceases and both the algae and aquatic animals consume oxygen. Also the planktonic algae can block off the sunlight at depth and prevent the photosynthetic action of benthic plants. Under certain conditions, the population of algae may die, and the subsequent decomposition depletes the dissolved oxygen in the entire waterbody and produces a foul smell and taste. Another serious consequence is the accumulation of organic matter at the bottom of the waterbody leading to excessive consumption and depletion of dissolved oxygen near the bottom. Prolonged anoxic conditions can kill off benthic ecosystems requiring oxygen and cause the generation of toxic substances such as hydrogen sulfide.

Other undesirable consequences of excessive plant growth include clogged waterways, added difficulties in water purification for drinking, and diminished aesthetic value.

j. Flowing Surface Waters. After the wastes enter a receiving stream, changes occur to deteriorate the stream water quality. Oxygen from the air is continuously dissolved in water through the aeration process. The rate of BOD, combined with the rate at which oxygen is restored to the water from the atmosphere, determines the level of dissolved oxygen (DO). In flowing water, the combined effect of an organic waste discharged at a specific location and reaeration in the stream results first in a decrease and then in an increase in DO as the waste is carried downstream. This phenomenon is illustrated by a characteristic curve known as the "oxygen sag" (see Figure II.13). The low point on the oxygen sag has been a governing factor in planning or determining the site or capacity and the design of waste treatment plants with reference to the natural reaeration of the stream. The variation in DO may be of particular importance for certain types of water uses; for example, fisheries require a minimum DO of 5 mg/l.

Bacteria and sewage fungi predominate in the zone where oxygen becomes a severely limiting factor. These decline farther downstream and algae may bloom, benefiting from the increase in mineral nutrients. Eventually, these also decline. Low oxygen levels cause a reduction in the number of species of large invertebrates; highly specialized sewage organisms such as tubificid worms, midge larvae, and other undesirable forms that can tolerate these conditions increase in number due to the large supply of food and little interspecies competition. Increasing dilution occurs with downstream flow and, as the river oxygen and minerals return to normal, the number of species able to survive increases and the strong numerical predominance of particular species tends to disappear. A gradual return to a community occurs, as found upstream of the discharge. The water has then purified itself and has recovered from the discharge.

The velocity and direction of flowing waters (whether fresh water or marine) are most commonly measured using drogues, current meters, dyes, or other drifting devices. Even painted green coconuts can serve as useful drifting devices that can be tracked to estimate current patterns in ocean and lagoon environments. A drogue is a subsurface drift body attached to a floating flag or other device which projects above the surface and which can be tracked by shoreline observation or by boat. The location of the drogue is reported at various time intervals which provide estimates of current velocity and direction. Current meters are established at specific stationary sites and monitor the velocity and direction of water flowing past them. Dyes, drift cards, and other devices can be tracked visually. Changes in the concentration (dilution) and distance of dye movement over time also provide estimates of mixing and diffusion as well as current velocity and direction.

2. Air Pollution

The behavior of the plume from a smoke stack depends on atmospheric conditions as shown in Figure V.18. Various models are available to predict the concentration of a pollutant at some point downwind (see Figure V.19). The Gaussian model incorporates the dispersion due to turbulence in the air and is frequently specified for use by the TOR for an EIA.

A windrose (Figure V.20) is a concise presentation of velocity and direction data that can be used to predict the movement of polluted air. For tourism development, odors are more than a mere nuisance; thus, the location of a fish cannery or sewage treatment plant in relation to hotels must take into account the prevailing winds.

Information on sources, emissions, and diffusion on the AQMR map is next combined with data on population and other sensitive receptors to predict impacts. For example, the concentrations of pollutants may be plotted as in Figure V.21 to reveal problem areas. Ambient air quality standards are used to judge whether unacceptable concentrations will be present. Typical standards are shown in Table V.4.

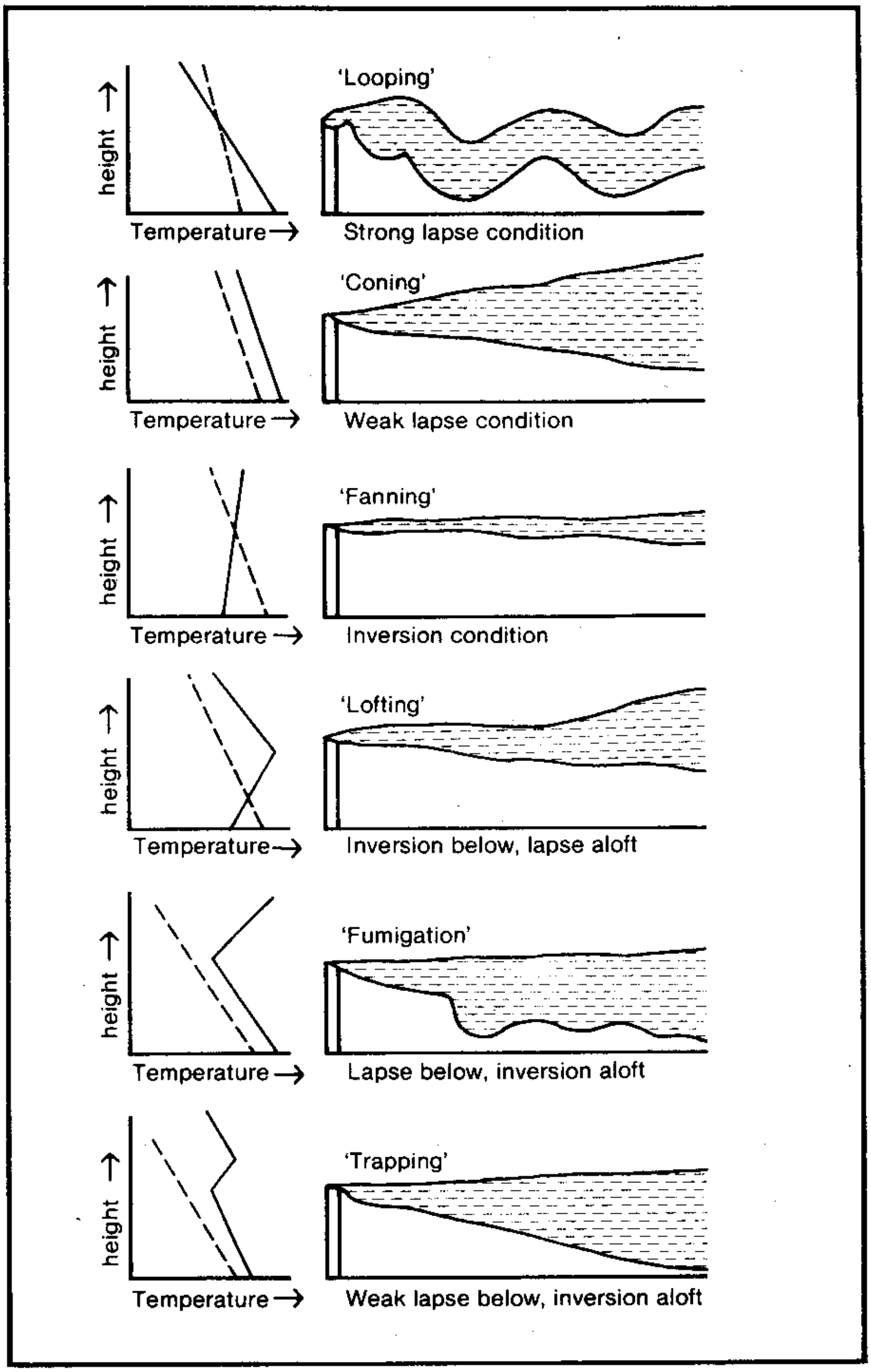

Figure V.18. Six types of plume behavior under various conditions of stability and instability. The broken lines at left are dry adiabatic lapse rates. The solid lines are existing lapse rates (as reproduced in Sham 1979).

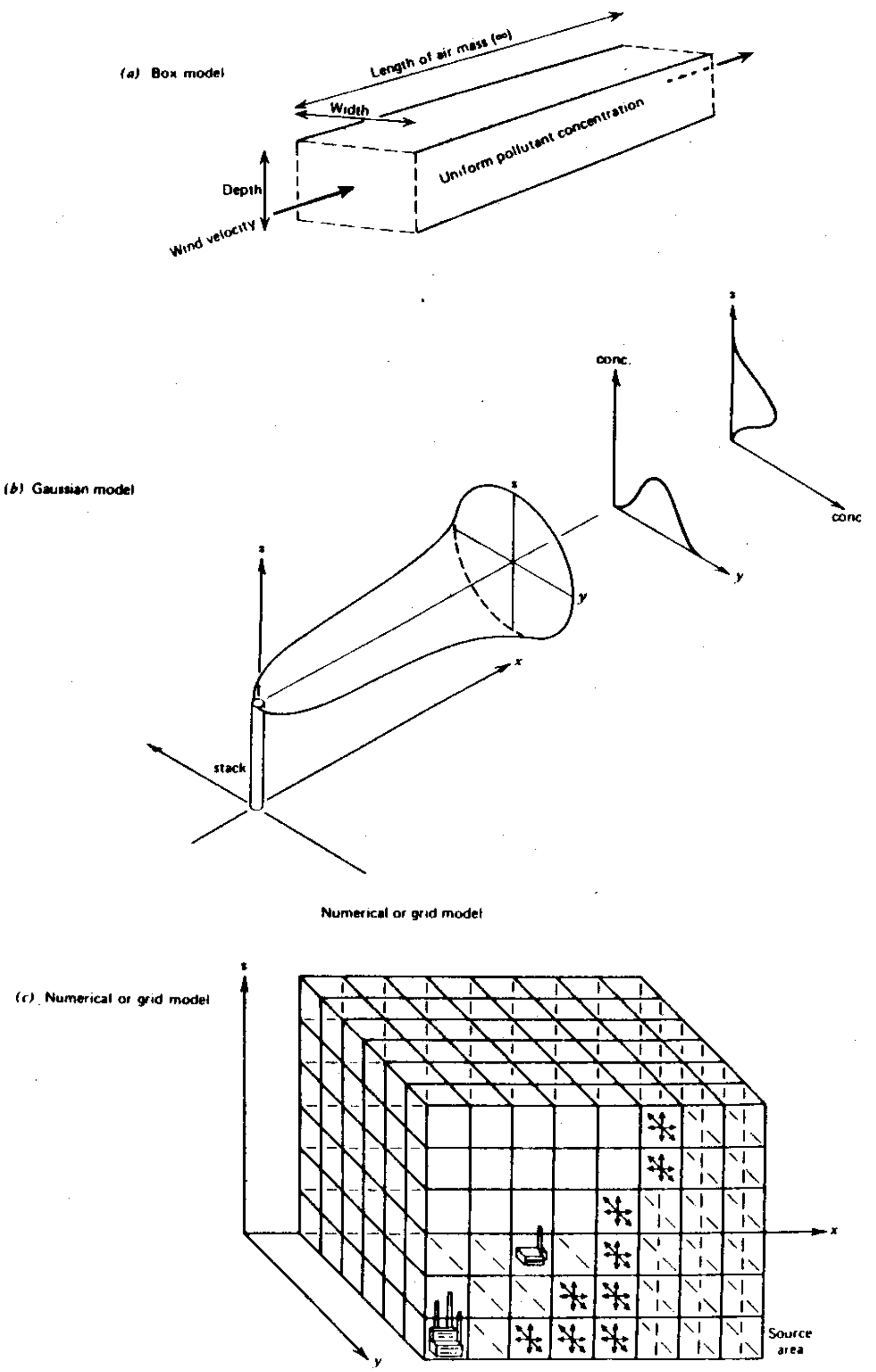

Figure V.19. Conceptual diagrams of air pollutant dispersion for three model types (Source: Ecology, Impact Assessment, and Environmental Planning, by Walter E. Westman. Copyright © 1985. Reprinted by permission of John Wiley & Sons, Inc.).

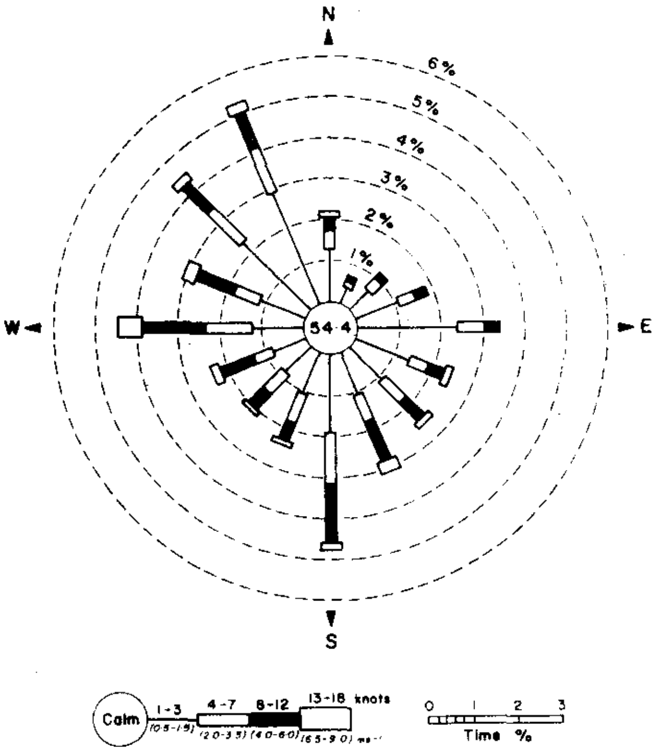

Figure V.20. Annual windrose for Subang Airport, 1968-72 (Source: Malaysian Meteorological Service).

Table V.4. **Ambient air quality standards**

Pollutant	Averaging time (hrs)	Range	Median	U.S.	WHO guidelines
Particulate	8	50-500	210	--	--
matter	24	50-500	150	260	100-150 μg/m^3
Carbon	1	15-40	40	40	40 mg/m^3
monoxide	8	1-20	10	10	10 mg/m^3
Sulfur	24	50-380	250	365	--
dioxide	1 year				40-60 μg/m^3
Nitrogen	1	--	--	--	190-320 μg/m^3
oxides	24	20-250	100	--	--
	1 year	--	--	100	--
Photo-chemical oxidants	1	100-250	200	240	100-200 μg/m^3

Note: The concentration of a pollutant at any one point varies over time due to emissions rates and atmospheric disturbances. Therefore, some sampling time is specified to average out the variation. The range of standards among different countries reflects uncertainties in toxicological (dose-response) data. In many countries, standards are goals to be achieved as development progresses. Compliance is expressed as the % of time that the standards are met.

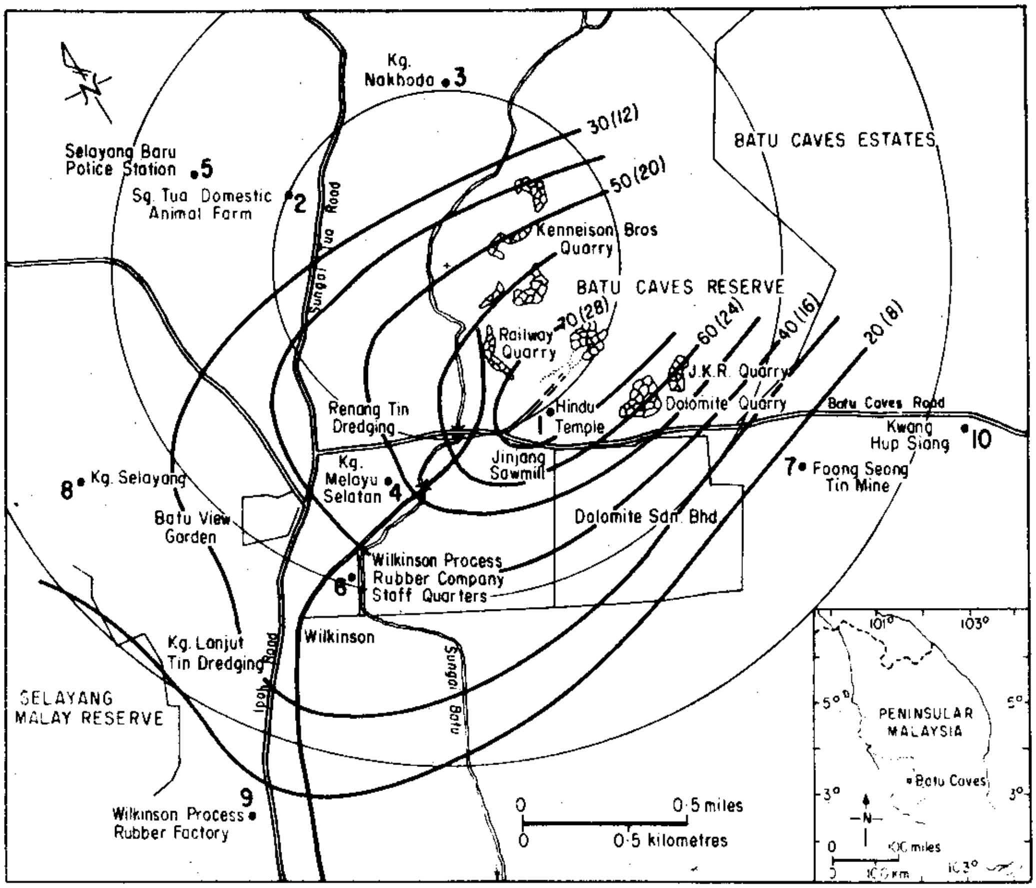

Figure V.21. Average concentrations of dustfall in and around Batu Caves, averaged over three years (1973-75). Figures are given in tons/mi^2/month. Equivalent values in metric tons/km^2/month are given in brackets (combination of Figures 38 and 39 from Sham 1979).

V.D. HYDROLOGY AND OCEANOGRAPHY OF TROPICAL ISLANDS

1. <u>Atoll and Barrier Reefs and Islands</u>

a. Climate and Hydrology of Low Coral Islands. Coral islands and reefs at low latitudes, although characterized by a tropical marine climate that varies little in temperature and humidity, show high variation in precipitation. The nearly constant high temperatures result from uniform solar radiation with little seasonal variation in the length of daylight hours attributed to the low latitude position. The uniformity of temperature prevails on a daily as well as a seasonal basis resulting from high humidity, which prevents radiative cooling at night (Figure V.22).

- Temperature. The average monthly temperatures range from 75 to 90° F depending on latitude and season in the tropics. Mean monthly temperatures vary from 2 to 10° F over the year, increasing with latitude. Temperatures vary from 10 to 20° F during the day (lowest in early morning and highest in the afternoon). Over a yearly cycle, the lowest recorded temperatures are about 70° F, and highest temperatures about 95° F. Shade readings over 90° F are uncommon, but air temperatures can exceed 100° F in direct sunlight.

- Humidity. In the tropics, relative humidity averages between 70 and 90 percent over the year with little annual variation. Humidity approaches 100 percent during and after intense rainstorms (squalls).

- Winds. In the Northern Hemisphere, tradewinds from the northeast direction dominate most of the year but are strongest from November to June. Summer winds tend to be weaker with some slack wind periods. Tradewinds tend to be stronger in higher latitudes, but rarely do wind speeds exceed 35 knots except during the passage of severe squalls. Winds are, of course, severe during passage of tropical storms.

The oceanographic and climatic equator in the tropical Pacific lies at about 5° N latitude. The tradewinds south of this latitude move from the southeast, compared to the northeast at latitudes north of 5° N, and the wet and dry seasons occur at opposite times of the year. The convergence of the two tradewind belts at this latitude causes the air masses to rise (the doldrums), dumping large quantities of rainfall. The doldrum belt is also the spawning ground for tropical storms that move either to the south or north of the doldrums during intensification.

- Rainfall. Average precipitation levels vary considerably with latitude and time of year. The higher latitude low coral islands are drier with annual precipitation levels of 25 to 50 inches (635 to 1270 mm). Toward the tropical convergence zone, precipitation approaches 100 to 200 inches (2540 to 5080 mm) a year. Year-to-year variation in rainfall is considerable on individual islands. Intense tropical storms of short duration contribute to much of the total rainfall, and storm occurrences are quite variable from one year to the next for a particular coral island, barrier reef, or atoll. There may be variations in precipitation even among different parts of the same larger atolls or barrier reefs. The lack of elevated land features, which otherwise might control local weather, and remote air circulation patterns contribute to the variability in rainfall.

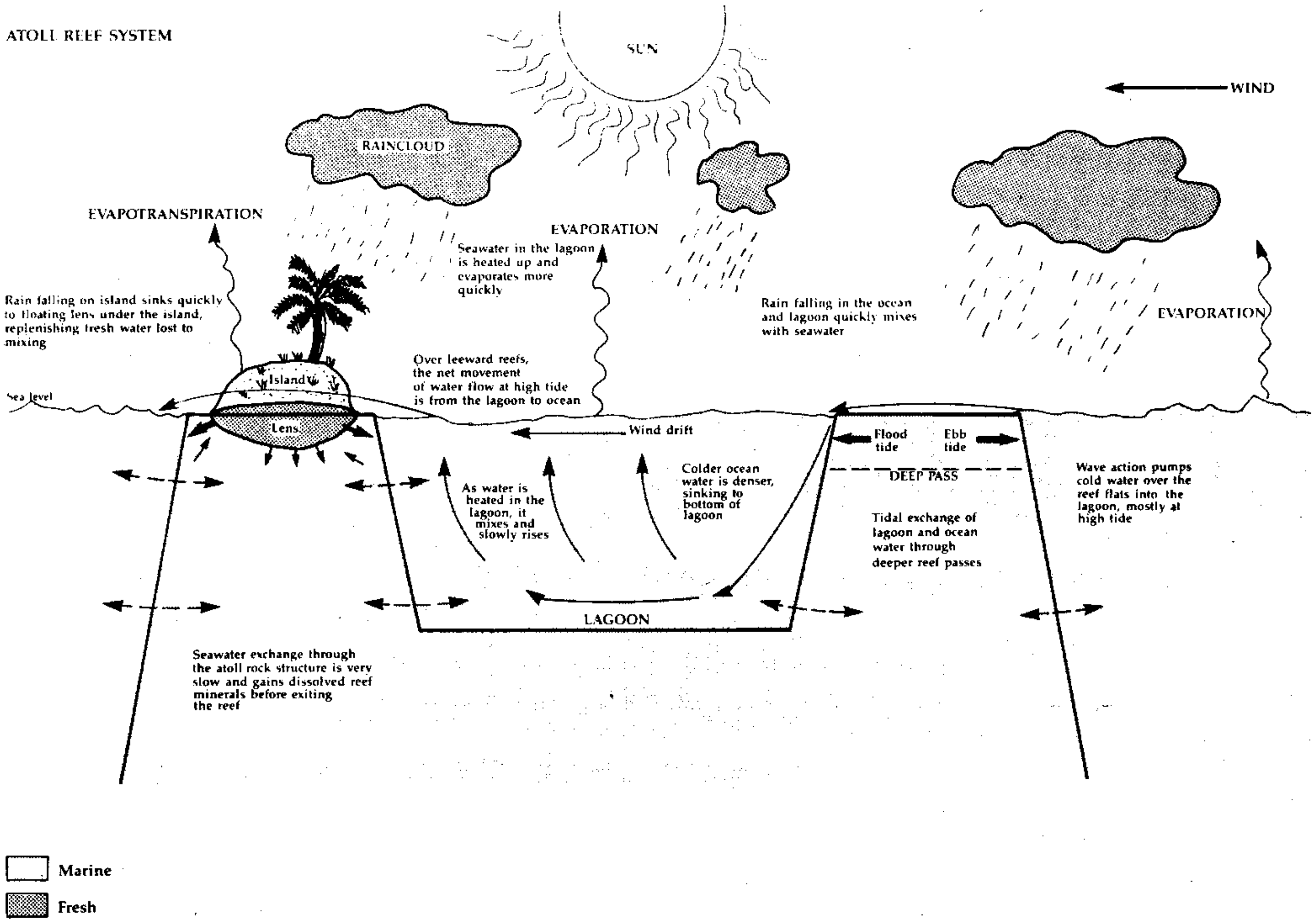

Figure V.22. Principal pathways of marine and freshwater flow through atoll ecosystem. Wave action, rainfall rates, solar heating, the size and position of islands, the size and depth of the lagoon, the depth and size of passes, the geomorphology of the reef, and the direction and intensity of wind and waves are the major factors affecting the hydrology and oceanography of atolls.

- Hydrology. Fresh surface waterbodies such as lakes are rare on coral islands. The flat landscape, permeability of rock structure, and the composition of soils and reef-derived sediments prevent the occurrence of streams. Many coral islands have central depressions with small brackish water ponds. Less saline ponds are used to grow taro and fish (especially milkfish).

Fresh groundwater on barrier and atoll islands takes the form of a lens of freshwater floating on top of deeper, denser marine waters in the subsurface island and reef rock strata. Rainwater percolates down through the surface to collect in the lens, and the consistency and permeability of the rock strata maintain the integrity of the lens, slowing the mixing of the freshwater lens with surrounding marine water. The thickness and size of the lens system for a particular island depend on many factors but tend to be larger for wider and larger islands subjected to higher rainfall.

The distribution of impermeable rock (such as beachrock, conglomerates, breccia), tidal fluctuations, and other gravitational forces influences the mixing rates of the fresh groundwater with surrounding marine waters and, therefore, influence the size and salinity of the lens. Mineral dissolution and salt spray from wind and breaking waves also increase the salinity of groundwater lenses. The small size and narrow shape of many islands, especially the drier islands, prevent formation of groundwater lenses with potable (fresh) water, thus discouraging permanent human habitation. Although Pacific islands often rely on rainwater catchment to provide potable water for drinking and other domestic uses, they also rely on groundwater during drought and on more crowded islands. It is no coincidence that many uninhabited atolls are found in the drier zones.

2. Oceanography of Atoll and Barrier Reefs

a. Tides. Tides in the tropical Pacific are most often semi-diurnal with generally two uneven high tides and two uneven low tides during a daily cycle. Average tidal range varies from about 2 to more than 6 feet during a cycle. During monthly neap tide conditions, tidal ranges can be less, while during spring tides, they are greater. Regional location generally determines maximum and average tidal ranges.

In the low latitudes, most shallow reef flats lie at about mean lower low water, barely uncovering at most low tides. However, on many windward barrier or atoll reefs, the outer reef flats include a coralline algal ridge feature near the surf zone projecting 2 or more feet above mean lower low water, rendering boat passage through the surf and over the reef near impossible and extremely hazardous, even at high tide. At higher latitudes, reef flats tend to be slightly submerged (at a lower level) during low tide due to less tolerance by corals and other reef life to greater temperature variations.

b. Water Currents. Three major currents flow through the tropical Pacific. The North Pacific Equatorial Current is a broad current system moving westward near latitudes of 10 to 20° N. The narrow but strong Pacific Equatorial Counter Current flows eastward between latitudes of 5 and 6° N. The South Pacific Equatorial Current flows westward between latitudes of 0 to 10° S. Similar currents are also situated at low latitudes in the tropical Atlantic.

The prevailing tradewinds generate moderate to large swells in open seas that steepen and break along the upper ocean slopes of reefs facing windward. This wave action piles up water on the outer edge of the reef flats and drives water over the reef ridge where it runs "downhill" across the reef into the lagoon or passes. These wave-driven currents are particularly strong at high tide, can achieve speeds of 1 to 4 knots, and are generally unidirectional on windward reefs (toward the lagoon), no matter what the state of the tide. These currents are a major source of ocean water exchanging with lagoon waters and help to keep lagoons relatively well mixed. Where wave-driven water currents push over reefs and against island shorelines (wave set up), water levels can be elevated 2 or more feet above ambient sea level. As water seeks the path of least resistance in running downhill into the lagoon, very strong currents can be generated, especially through restricted openings between adjacent islands on the reef flat. These are major factors in the design of causeways on windward ocean reef flats to link individual coral islands along barrier or atoll reefs.

Tidal currents are also significant along the lagoon, pass, and ocean faces of barrier and atoll reefs. Tidal currents are especially strong within narrow deeper passes of atolls of barrier reefs with large lagoons and few openings through the reef, achieving up to speeds of 8 knots or more in narrow channels through the reef of some nearly "closed" lagoons. During a flooding (rising) tide, sea level on the ocean side eventually becomes higher than lagoon sea level, causing waters to run "downhill" rapidly through the passes into the lagoon. During an ebbing (falling) tide, ocean sea level eventually drops below that of the lagoon causing currents to slacken and then reverse and flow quickly "downhill" out of the lagoon. Lagoon circulation and water quality are greatly influenced by tidal exchange and the cross-sectional size and position of passes through the atoll reef. Navigation through narrow meandering passes with swift currents can be hazardous.

c. Waves. As described earlier, most prevailing wave energy is directed toward the windward (northeast to southeast) sides of reefs and islands and is generated by tradewind swells. However, infrequent tropical storms and high latitude polar storms generate large swells and breaking waves that significantly affect low lying coral islands. Tropical storms (including typhoons) can originate from any direction and generate wave action in all directions. Large waves generated by storms in the Aleutian Islands/Bering Sea approach reefs and coral islands from the north, especially during the northern winter, while Antarctic storms generate large waves approaching reefs and islands from the south, especially during the southern winter. The prevailing nature of the tradewind waves and the catastrophic nature of infrequent but large storm waves greatly influence the configuration and morphology of islands and reefs in the tropical Pacific.

Tradewind breaking waves approach heights of 5 to 15 feet while storm waves are often greater. The presence of the coralline algal ridge on the outer edge of windward reefs offers additional protection to nearby islands from wave attack. The structure of windward reef slopes (e.g., spur and groove formations) also is more resistant to wave damage and is better configured to dissipate wave energy. Open atolls or barrier reefs with wide or numerous passes through the reef can allow large waves to enter the lagoon and break on lagoon shorelines.

Coral islands with land areas averaging about 10 feet or less above sea level are vulnerable to storm surge inundation and wave attack during typhoons. Although infrequent, severe storms can have long lasting effects on coral islands including disruption of the groundwater lenses, leveling of villages and vegetation, destruction of crops intolerant to salinity, and shoreline and island erosion. Over the centuries and millennia, the Pacific islanders have tended to establish villages on the most protected (lagoon) shorelines of the larger islands, on atolls, or on volcanic islands within barrier reefs, probably in response to previous catastrophic storm events.

d. Circulation. Circulation in lagoons varies from reef system to reef system and depends upon width, depth, and number of passes through the reef; depth and number of reef pinnacles in the lagoon; and the proportion of perimeter atoll of barrier reef covered with islands. Passes promote exchange of water between the ocean and lagoon while islands block movement of water over shallower reefs. Atolls or barrier reefs with well-mixed lagoons have proportionately fewer islands and proportionately larger passes. Lagoon circulation is most sluggish or restricted in "closed" atolls lacking deep passes or having proportionately greater island distribution. The construction of causeways as proposed on Bikini and Kwajalein, and as accomplished on other atolls (Tarawa, Canton, Majuro, Palmyra), can restrict lagoon circulation and may degrade water quality. The average residence time of water in such lagoons is lengthened, increasing the duration and concentrations of pollutants discharged into the lagoon.

3. Climate and Hydrology of High Tropical Islands

The climate, hydrology, and oceanography around high tropical islands are similar but differ in several important aspects (see Figure V.23).

The upper slopes and crests of islands greater than 500 m in elevation tend to be cooler and more moist, and can be characterized by even temperate or boreal climate for particularly high "tropical" islands (e.g., the 4000-m volcanic peaks in Hawaii). The windward sides and crest of the peaks tend to be very wet at elevations of 500 to 1500 m due to the dumping of rainwater by the tradewinds as they rise and cool during passage over the peaks. This "orographic effect" can sustain average annual precipitation rates of 100 to 400 inches (2500 to 10,000 mm) or more per year, depending on the latitude and height of the peak. The downstream side of the peaks tends to be more

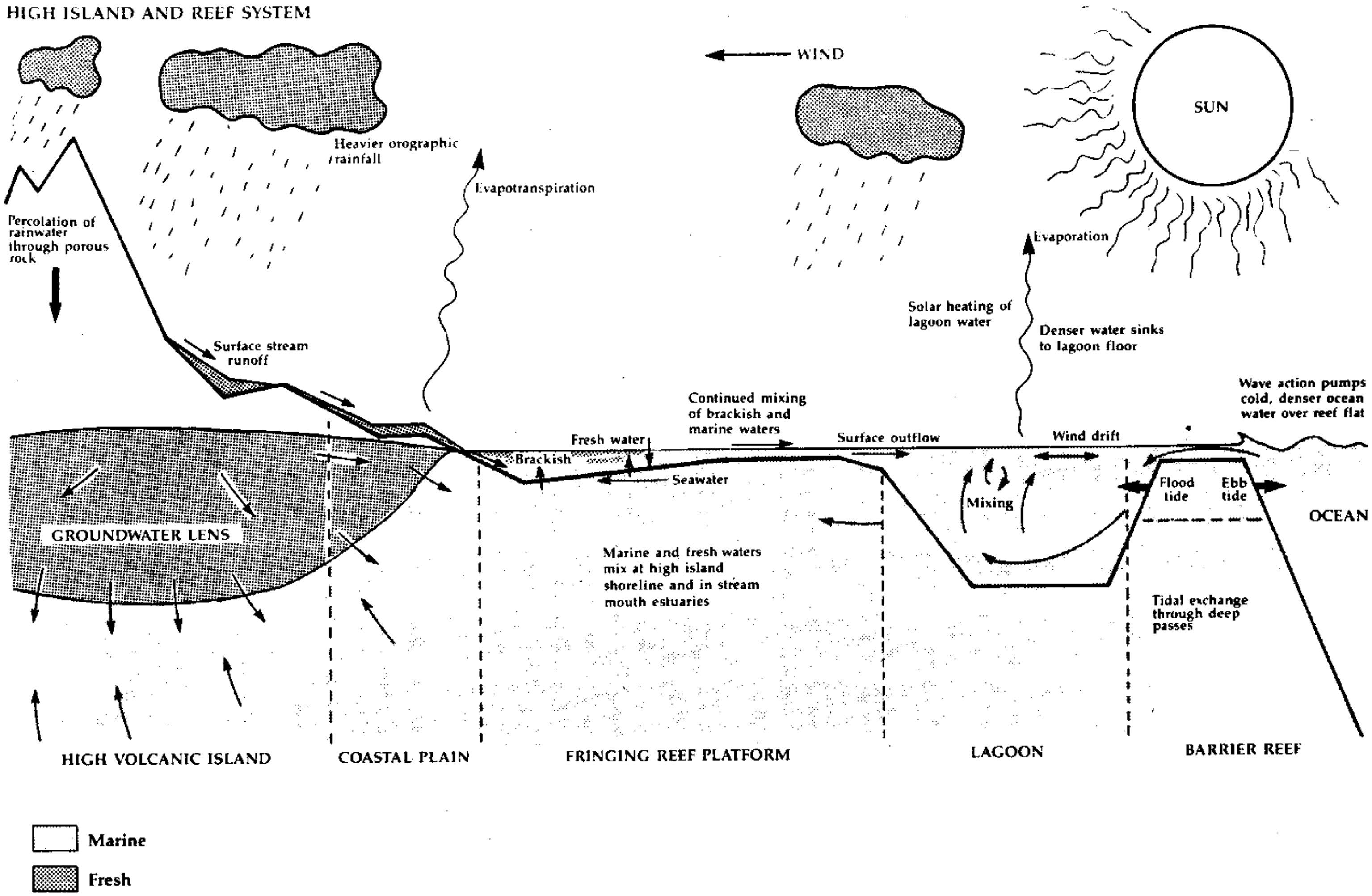

Figure V.23. Principal pathways of marine and freshwater flow through tropical high island and reef systems. Wave action, wind, and tidal exchange are primarily responsible for movement of marine waters toward islands. Fresh waters are concentrated in surface waters and groundwaters of high islands with gravity primarily responsible for its movement away from high islands. Mixing is facilitated by water density differences caused by temperature and salt content (colder, more saline water being denser).

arid or even desert-like due to the "rain shadow effect," since most rainwater (and humidity) in the tradewinds is dumped on the windward sides of the islands during initial ascent.

Winds tend to be more variable on high islands with moderate or typical tradewind conditions on the windward side of the island. Low winds characterize the back or leeward side, and strong winds characterize the other two sides of the islands as the winds accelerate while bending around the islands. The presence of steeper ridges and cliffs can also modify local wind conditions.

Groundwater resources are dramatically more abundant on high islands; but depending on island shape, these resources may or may not be accessible for development. Due to generally larger land area and the higher levels of rainfall, high island masses have much larger potable groundwater lenses capable of supporting larger human populations and irrigation agriculture. Weathered volcanic islands also tend to have more impermeable rock and soil strata, which support surface water runoff and development of stream, river, pond, lake, freshwater swamp, and marsh systems.

4. Oceanography of High Tropical Islands

Waves, tidal fluctuations, other water currents, and water circulation differ in several aspects from the oceanography of coral atolls and barrier reefs.

Because wave action and tidal fluctuations tend to be smaller in lagoons, shorelines of high volcanic islands within lagoons are exposed to lower wave and tidal energy. Circulation and water clarity within lagoons are lower to begin with; and near the shorelines of high islands, they are often lower still due to terrigenous runoff and soil erosion from steep volcanic slopes. Coral reef development around the fringes of high islands within lagoons also tends to be controlled by sedimentation, freshwater runoff, and less light penetration at depth.

In contrast, high tropical volcanic islands not within lagoons can be exposed to rigorous wave, current, and tidal energy, depending on the presence, width, and depth of the fringing reefs that surround them. Without the natural protection otherwise afforded by reefs, open ocean tradewind and storm surf can strike much closer to high island shorelines, generating vigorous currents and greater exposure of coastal lands to attack and erosion. Fringing reefs, if they surround the island, tend to have more deep channels through the reef opposite the sites of coastal stream and riverine discharges, since freshwater inhibits coral reef development. Tradewind swells steepen and break as waves on the upper ocean slopes of windward facing reefs. This surf action pushes water up and in a landward direction. These wave-driven currents run along the coast and frequently exit back to the sea through deeper channels where waves do not break. Elsewhere, rip currents are set up at periodic intervals along the high island coast, allowing wave-driven water currents to return to the sea.

Tidal fluctuations tend to be more variable off high islands exposed to the open sea. The magnitude of tidal fluctuations are regionally determined to some extent, but inland seas or gulfs of particularly large volcanic islands can have the bathymetry to amplify tidal fluctuations. In some embayments or gulfs, tidal fluctuations exceed 5 m or more (e.g., in Sulawesi, Kalimantan).

5. The Hydrologic Cycle
(adapted from Cassells et al. 1983)

Water moves in a continuous cycle--from the atmosphere to the earth by precipitation, and from earth back to the atmosphere by evaporation. This continuous water movement is called the hydrologic cycle. Its principal components and pathways are illustrated in Figure V.24.

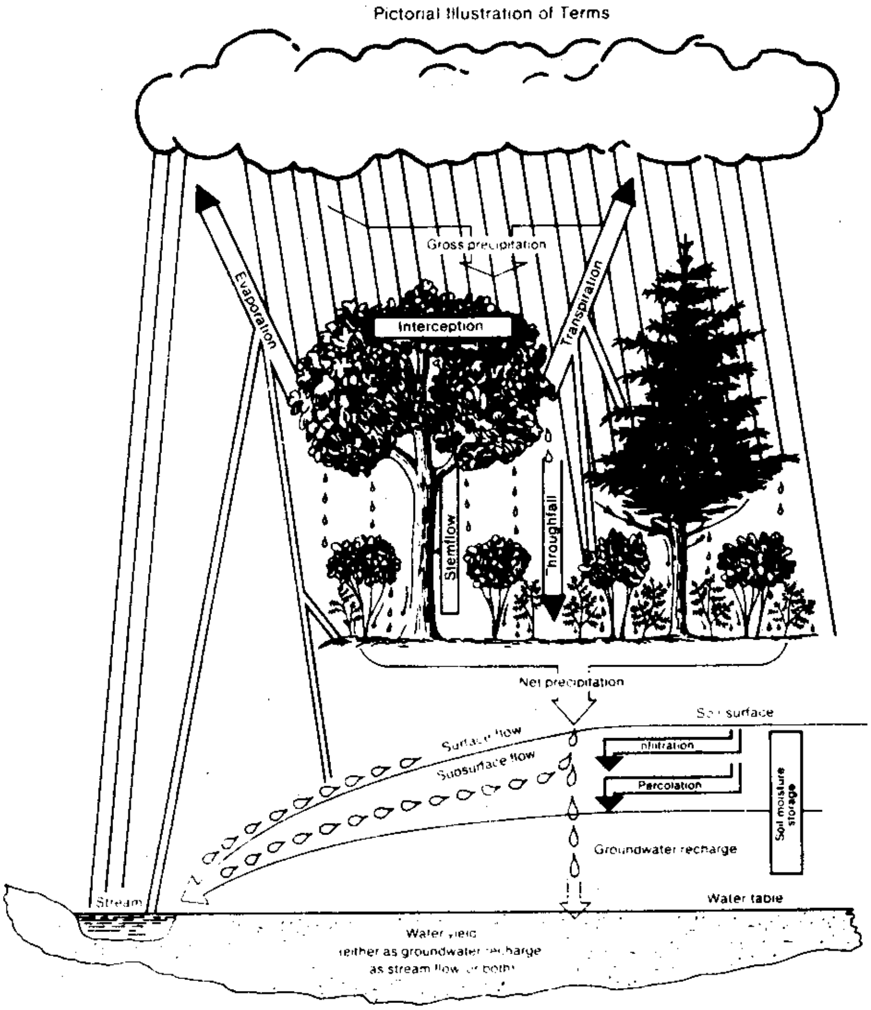

Figure V.24. Illustration of terms in the hydrologic cycle (Source: Carpenter 1983:56. Reprinted by permission of the publisher).

a. Precipitation. Water inputs may enter the hydrologic cycle as any form of precipitation including rain, snow, hail, or direct condensation from atmospheric moisture. The impacts of development activities in forested watersheds on many hydrological processes are influenced significantly by the intensity, duration, and location of rainfall events. Planners and watershed managers should be aware of the precipitation patterns in their geographical areas of interest. Precipitation information should be obtained from the meteorology station nearest to the project area. In the absense of local precipitation records, local residents should be consulted and their knowledge systematized in a general way.

The substantial variation in rainfall that can result from differences in elevation on even a small island, such as Oahu in the Hawaiian group, is shown in Figure V.25.

b. Interception. Not all of the precipitation that falls on a forested watershed will reach the forest floor. The various layers of the forest--the trees, the shrubs, the herbs and grasses growing on the forest floor, and the forest litter layer--will all intercept varying proportions of the gross precipitation. Some of this intercepted precipitation will reach the forest floor eventually through other pathways such as stemflow or crown drip (Figure V.24). The remainder will be lost from the land sector of the hydrologic cycle, returning instead to the atmosphere by direct evaporation from the surface of the vegetation.

The amount of interception loss is determined primarily by the duration and frequency of rainfall. The highest percentage interception losses are associated with low-intensity precipitation events. Anyone who has taken shelter under a tree canopy during a storm is taking advantage of the interception role of tree crowns. In light rain, almost 100 percent of the precipitation may be intercepted. Annual interception losses vary greatly from different forest types in different regions, ranging from 3 to 25 percent as a general rule.

c. Throughfall, Crown Drip, and Stemflow. Some water passes down the branches and stems to reach the earth as stemflow (Figure V.24). Water also falls from the branches and leaves of the vegetation (crown drip) to join rainfall that has penetrated the tree crowns without interception as throughfall. As with interception losses, throughfall will vary with the type and location of the forest and with precipitation intensity and duration. Throughfall figures reported from a wide range of forest areas commonly approach 70 to 80 percent of gross precipitation, or about the reciprocal of interception loss.

d. Infiltration and Percolation. The process by which water enters the soil surface is called infiltration. If water is applied to a dry, medium-textured soil, a rapid initial rate of infiltration will result. The infiltration depends on soil texture and structure (pore spaces), moisture content, the concentration of suspended material in the water, water temperature, and time. As time passes

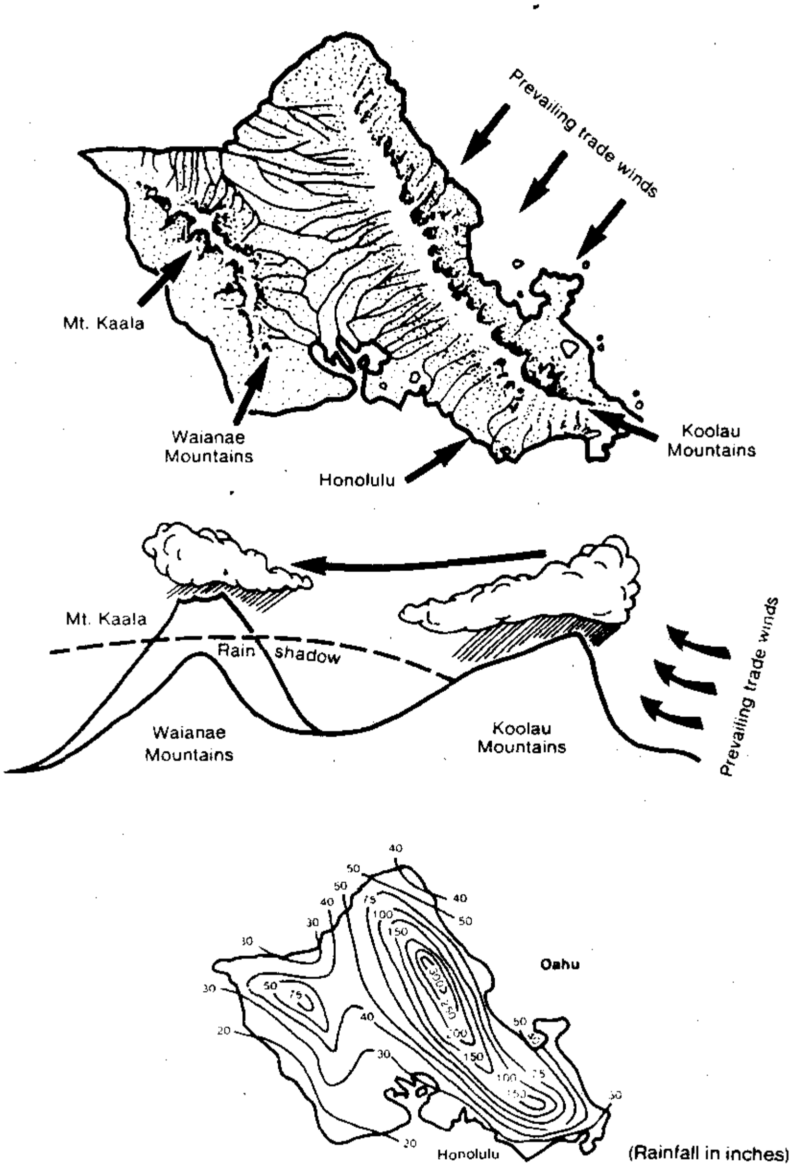

Figure V.25. Precipitation pattern on Oahu, Hawaii (Source: Carlquist 1980. Reprinted by permission of the publisher).

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and the soil water content increases, the infiltration rate will taper off and eventually become constant. At this time, infiltration is only as rapid as the rate at which the soil pore spaces can drain under the influence of gravity alone. This process of water movement through the soil profile due to capillary and gravitational forces is called "percolation."

e. Soil Moisture. Moisture held in the soil often provides significant water storage in the land portion of the hydrologic cycle. Capillary forces between soil and water particles enable the soil to hold a certain amount of water against the force of gravity. It is this capillary water that is available to plants for transpiration and growth.

The maximum amount of capillary water that can be held by the soil is known as the soil's field capacity. In dry periods the amount of water in the soil gradually will be reduced by evaporation and transpiration from the forest vegetation. As the amount of moisture in the soil is reduced, the force with which the soil particles hold the remaining soil water--the soil suction--becomes greater. Eventually, soil suction becomes sufficient to prevent the plants from extracting further soil water, and they begin to wilt. The moisture content of the soil at which this happens is called the soil's "wilting point."

f. Surface Storage. Temporary precipitation storage locations that can delay runoff from reaching a stream are formed by small ponding depressions on the ground surface or behind soil litter, tree roots, or fallen trees. The contribution of this storage capacity is difficult to measure, but it is an important factor in preventing surface runoff from low-intensity storms and in delaying streamflow after the onset of surface runoff. This temporarily stored water becomes available for infiltration or evaporation at the end of a storm. Certain land-use practices such as terracing use the same principle to reduce runoff and make more water available for agricultural crops.

g. Surface Runoff. Surface runoff occurs when water falls on a soil surface at a rate faster than the soil's capacity to transmit it by infiltration and percolation. Given the highly permeable nature of most island soils, widespread surface runoff is not common. In some forested watersheds, the infiltration capacity and temporary storage are sufficient to absorb runoff from other areas, as well as the net precipitation from the prevailing rainfall intensities.

h. Subsurface Flow. Subsurface flow, sometimes called "interflow," is that part of the net precipitation that infiltrates into the soil and moves downhill to reach a stream channel. In some cases, subsurface flow occurs when water entering the soil reaches bedrock or a relatively impermeable, finer-textured layer in the soil. It will then begin to flow downhill above this interface.

i. Variable Source Areas. Although watersheds are convenient integral units for planning purposes, they are not homogeneous. Variability in soils, slope, geology, topography, vegetation, and groundwater alters the disposition of water in the hydrologic cycle.

Groundwater recharge areas and variable source areas may be the most important area in a watershed to protect from adverse human activity. Variabile source areas are saturated soils along river banks or in natural depressions that are incapable of accepting high infiltration rates at the onset of a storm. These areas are often the only areas exhibiting surface runoff in the watershed, and they expand during a storm as additional water moves downslope.

The protection of riparian (stream bordering) vegetation in variable source areas is important, because the vegetation helps to remove excess water, to reduce erosion by overland flow, and, to a certain extent, to filter out suspended material in the surface flow. Removal of riparian vegetation results in loss of the vegetation's filter-buffer function, as well as in increased streamflow and the likelihood of streambank erosion.

j. Groundwater. Underground water that fully saturates the soil is known as "groundwater." Its upper boundary is called the "water table." The groundwater reservoir is maintained largely by recharge from water percolating down from the upper soil layers during and after rainfall, or by lateral flow from another source area along a hydraulic gradient.

k. Evaporation and Transpiration. Water is lost from the forested watershed by the processes of evaporation and transpiration. Evaporation is the process by which a liquid is changed to a vapor or gas. The prime energy source for evaporation is solar radiation. The amount of evaporation is affected by wind speed, the degree of turbulence above the evaporating surface, and the vapor pressure difference between the water surface and the unsaturated air around it. Evaporation losses increase as the forest canopy is reduced.

Transpiration is the process by which water passes through the living plants to leaf surfaces and is then evaporated into the atmosphere as water vapor. During the growing season, plants transpire large amounts of water, if it is available. This transfer of water is an important component of the complete hydrologic cycle. By manipulating the extent and density of forest cover in a watershed, watershed managers can deliberately or inadvertently change the rate of water loss by transpiration. The greater the precentage of forest canopy removed, the lower the transpiration loss.

The term "evapotranspiration" is often used to indicate the combined amount of water evaporated from the watershed surface and transpired through the vegetation.

l. Streamflow. The drainage system transports water from all parts of the watershed to its outlet as streamflow. The various hydrological processes leading to streamflow--precipitation, interception, stemflow, throughfall, evapotranspiration, crown drip, infiltration, soil moisture, surface runoff, subsurface flow, surface storage, variable source areas, and groundwater storage--have been discussed. The combined effect of these processes will produce a particular streamflow pattern at any one time in a forested watershed.

m. The Water Budget. The various hydrologic processes discussed earlier in this section interact dynamically with one another. Changes in the level or rate of one variable will affect the rates or levels in other variables. The water budget model is a useful tool in watershed management because it provides a basis for studying these changes and determining the hydrologic impacts of land-use activities.

The model is simply an application of the conservation of mass principle to the hydrologic cycle. For a given watershed unit, and for a set time period, this principle can be stated as follows:

$$I - O = \Delta S$$

where I = the input of water into the watershed,
O = the output of water from the watershed, and
ΔS = the change in water storage within the watershed.

Substituting the components of the hydrologic cycle, the water budget becomes:

$$P = (Q + ET) \pm L + \Delta S$$

where P = total precipitation,
Q = total streamflow,
ET = total evaporation and transpiration losses,
L = leakage out of the catchment by deep seepage (-), leakage into the catchment from and adjacent watershed unit (+), and
ΔS = change in water storage within the watershed.

If all but one component is known or can be estimated, the unknown parameter can be determined as a residual.

Many of the components in the water budget equation represent the combined effects of several hydrologic processes. For example, in nonfog drip areas:

$$P = p_t + p_{cd} + p_s + p_i$$

where P = gross precipitation,
p_t = throughfall,
p_{cd} = crown drip,
p_s = stemflow, and
p_i = interception.

Quantitative measurement of these processes and understanding the physical processes that govern their operation are essential if the implications of land-use changes are to be appreciated fully. Measurements are difficult, and seepage out of or into the catchment is a very troublesome problem. Measurements are also quite costly, especially in remote mountain watersheds. Annual water budgets are used frequently in these studies because it is usually realistic to assume that changes in watershed storage over a year will be small; small enough in some cases to be ignored. Where little leakage into or out of the watershed also occurs, the water budget equation can be simplified to:

$$Q = P - ET; \text{ or}$$
$$\text{Streamflow} = \text{total precipitation} - \text{evapotranspiration.}$$

If, for example, changes in precipitation caused by any particular development activity are known or can be estimated, using the preceding equation will allow for a prediction of the impact this action will have on annual streamflow.

VI. APPENDIX

EXCERPTS FROM ASIAN DEVELOPMENT BANK ENVIRONMENTAL GUIDELINES

The ADB Environmental Guidelines for each major development sector follow a general format, including:

- Initial environmental examination checklist of environmental parameters
- Terms-of-reference for follow-up EIA for selected critical environmental parameters
- Significant environmental problems which may not be adequately accounted for in conventional project planning and design

The performer of an EIA should consult the full text of the ADB Environmental Guidelines for the specific development sector under consideration. The types of projects and the page number of the related guideline excerpts are:

See Section VII, "References," for various ADB documents, 1987 and 1988.

ENVIRONMENTAL GUIDELINES FOR AIRPORT PROJECTS

Significant environmental problems associated with airport projects which may not be adequately accounted for in conventional project planning and design:

1. Airport Wastes and Pollution Runoff: Pollution from the airport in the form of sanitary wastes (liquid and solid) and runoff, especially from paved surfaces, containing oils, chemicals, etc., can seriously degrade water quality. Usually the "first flush" of surface runoff, after rain begins, will contain most of the pollutants discharged to the ground between rains. On some atolls, the runway is actually used as the collection device for a water supply.

1.1 Disruption of Surface Hydrology: Airport site location often results in significant alteration in the surface waterways hydrology in the vicinity, which of course can affect all beneficial uses of the waterways, including water supply for communities and industry, irrigation, fisheries, recreation, and navigation.

1.2 Disruption of Groundwater Hydrology: Changes in groundwater hydrology stemming from airport location (or operations) can impair the yields of wells in the vicinity.

1.3 Sanitary Waste Disposal: In situations where connection to a municipal sewerage system is not feasible, an alternative (when isolation from groundwater can be assumed) is use of a simple septic tank system (12-hour retention), followed by ponding with retention of one week or more. Chlorinated pond effluent may be used for irrigation of airport green areas during the dry season (and discharged to waterways when not needed for irrigation), especially when the ponding can be planned to form an attractive system of artificial lakes.

2. Changes in Nearby Land Values: Airports often result in major changes in nearby land values, both (1) positive increases due to the increased commercial value of many of the properties, and (2) negative effects or decreases due mainly to noise, traffic congestion, and degradation of aesthetics. The EIA should include evaluation of these effects. Use of landscaping, including trees and ponds, can be helpful. A peripheral pond can be advantageously used as the treatment system for airport sanitary sewage.

3. Environmental Aesthetics Degradation: This can be a serious problem; hence, it is an important parameter to consider in airport site selection as well as planning/design.

4. Encroachment into Precious Ecology Areas

4.1 Terrestrial Ecology/Forest and Wildlife: New airports opening up rural areas for development will also pose hazards to forests and wildlife.

4.2 Estuarine Swamplands: Major airports in urbanizing regions are often located near the seacoast and estuarine zones. A compensating measure is to convert nearby estuarine areas having similar ecological characteristics into permanent preserves.

5. Noise Disturbances: Requires delineation of iso-noise contours expected to occur during both daytime and nighttime operations. This will delineate zones which will require resettlement or compensation for serious loss in property values.

6. Air Pollution Emissions: These originate primarily from airplanes and other airport vehicles, and from losses/evaporation of fuels.

7. Construction Stage Problems

7.1 Erosion and Silt Runoff During Construction: The project construction plan should include provision for control of sediment transport during the construction stage, including use of temporary holding ponds if necessary.

7.2 Resurfacing of Exposed Areas: The construction plan should include provision for immediate resurfacing/replanting of exposed areas.

8. Post-Construction Monitoring: The project operations plan should provide for continuing periodic post-construction monitoring program for assessing the actual environmental impacts of the project and for recommending needed correction measures.

ENVIRONMENTAL GUIDELINES FOR HIGHWAY AND ROAD (H/R) PROJECTS

Construction Stage

1. Construction operations should protect against excessive soil erosion/silt runoff from cut-and-fill areas, including use of temporary holding ponds if needed.

2. Exposed areas should be quickly given proper resurfacing/replanting.

3. Encroachment: The proposed highways and roads should not encroach on unique ecological resources or historical/cultural monuments, and feasible rerouting should be identified.

4. Impairment of Fisheries/Aquatic Ecology and Other Beneficial Water Uses: By changes in surface hydrology.

5. Erosion and Siltation: From exposed areas which are not properly resurfaced or replanted.

6. Air Pollution Hazards: Discharge of air pollutants from motor vehicles, especially carbon monoxide, which under adverse weather conditions could cause serious air pollution hazards to nearby areas or communities.

7. Highway Runoff Pollution: Surface runoff from highways may contain sufficient petroleum drippage plus spilled materials (including toxic hazardous materials) which can adversely affect aquatic ecology and environmental aesthetics.

8. Highway Spills: One of the most serious hazards posed by highways is accidental spills of hazardous materials. The EIA should review the existing system for controlling and cleaning up such spills including appropriate recommendations, from the regional point of view.

9. Construction Stage Problems: Erosion and Silt Runoff protect against excessive erosion/silt runoff from cut-and-fill areas, including use of temporary holding ponds if required.

10. Post-Construction Monitoring: Make provision for continuing post-construction monitoring for assessing the actual environmental impacts of the project and for recommending needed connection measures.

For rural roads, provide for reasonably equitable service to all residents. Assess potential for nuisance dust from unsealed road surfaces.

ENVIRONMENTAL GUIDELINES FOR PORTS AND HARBOURS

1. Displacement Due to Harbour Location: Selection of the harbour site should consider possible irrevocable losses due to displacements of (1) fisheries reproduction and capture zones, (2) fragile ecological zones, including corals and zones of outstanding aesthetic beauty, (3) estuarine/mangrove swamp zones needed for fisheries and/or for wildlife protection, and (4) historical/cultural/religious monuments or sites. Where resettlement will be necessary, this will be a part of the overall project cost.

2. Discharge of Dredging Spoils: Discharges of dredging spoils, if not carefully planned, can be damaging to (1) marine ecology including fisheries reproduction zones and fragile organisms including corals, (2) recreational beaches and resorts, (3) impairment or destruction of estuarine mangroves and the associated fisheries production, (4) discoloration of nearshore coastal waters with gross impairment of environmental aesthetics and hence of recreational, resort, and tourist values. All four of these types of damage have occurred extensively at Phuket in southern Thailand, from both onshore and offshore hydraulic tin-mining operations. Dredging spoils may often be used for reclamation of low lying coastal lands without ecological damage.

3. Oil Spill and Leakage Hazard: Whenever ports are used as transfer points for crude oil or refined products involving hauling by oil tankers, there will always be the hazard of a major oil spill. And the provision of ports and harbours for this purpose may introduce this hazard of spills which can be very deleterious to marine and coastal ecology and to coastal tourist resorts. Whenever this threat exists, the agencies sponsoring the new (or improved) port should include, as part of the feasibility study, discussion of measures for prevention of spills and for emergency response. Preferably this can be done as a component of a National Emergency Oil Spill Cleanup Plan (NEOSCP) such as that operated by the private sector petroleum refinery companies in the Gulf of Thailand, on behalf of the Thai Government.

3.1 Oil Leakage and Spills Within the Harbour: The detailed EIA should describe the operation and maintenance procedures and precautions to be used for controlling/preventing leakage/spills during transfer of petroleum crudes or refined products from ship-to-shore to other installations, including prevention of discharges of bilge waters, plus the provisions to be made (both for facilities and for operations) for emergency cleanup of spills that might occur.

4. Harbour Sanitation/Management of Pollutants

4.1 Need for Special Attention: Ports and harbours around the world have traditionally been regarded as "appropriate for insanitary conditions." Only in recent years has it been recognized that it is feasible to maintain clean harbours provided special care must be exercised in planning and designing the harbour to incorporate the needed controls. The problem is that P&H projects have conventionally been (and are still being) planned and designed as if they represent "ordinary urbanizing areas," but they are not. Planning/design must accommodate the special needs for (1) water supply and (2) management of liquid and solid wastes from offices, residences, commercial establishments, and industries in the harbour complex. Otherwise, the cost of correcting the sanitation problem after the fact is relatively very high and therefore is not likely to happen in the developing countries.

4.2 Wastes Escaping from Harbour: In the absence of adequate facilities for treatment and disposal of solid wastes, these materials (especially floatables) may escape from the P&H area and travel along the coast and be deposited at beaches or elsewhere causing damage to property and ecology.

4.3 Air Pollution Emissions: Dusts such as from handling tapioca powder and coal require special equipment and measures to hold down emissions.

4.4 Hazardous Materials: Another serious problem arises from handling of hazardous materials including inflammables, explosives, and toxics. The EIA must include discussion of how any such hazards can be minimized and how spills can be controlled.

5. Operation and Maintenance Skills: A common mistake in the planning of environmental control facilities in developing countries is specification of control methods used in the industrialized countries with the assumption that these systems, which usually depend on availability of skilled operations personnel, will function at the same level of efficiency as in the industrialized countries. This is not the case; hence, the EIA must recognize and deal with the realities of this problem.

6. Environmental Monitoring

6.1 An essential aspect of environmental protection in both industrialized and developing countries is continuing periodic monitoring of project effects on environment, both within and outside of the harbour. This is a new concept in the project implementation process, and the technology for planning, establishing, operating, administering, and financing the necessary minimum monitoring programs is still in the beginning stages. The objective is to ascertain the onset of unacceptable environmental degradation so that corrections may be made in a timely manner.

6.2 The TOR for the EI should require the consultant to prepare and recommend the minimum necessary program, covering all sensitive affected environmental parameters including technical, institutional, management, and financial aspects together with recommendations for funding and with an approximate benefit/cost analysis that justifies the monitoring program.

7. Occupational Health/Industrial Hygiene: The EIA should also present the recommended occupational health program, including measures for protecting P&H personnel from occupation-related routine and emergency hazards (for example, a major fire or release of toxics to the harbour environment).

8. Marine Disposal of Waters: Disposal of sanitary and industrial sewages from shore complexes is one of the most difficult problems in harbour pollution control. It is often feasible to use a submarine outfall to discharge waste effluents into the nearby unconfined coastal waters where the tremendous diluting/absorbing capacities of these waters greatly simplify the entire treatment and disposal process. Treatment requirements for discharge to confined coastal or inland waters, where the treatment process must remove a wide variety of pollutants which are harmful to marine ecology and environment, are high compared to open-sea discharge where about the only treatment requirement is for removal of floatables, a relatively simple treatment process.

9. Communicable Disease Hazards During Construction: For major construction projects requiring importation of workers from other regions, there may be serious hazards of outbreaks of communicable diseases should any of the imported workers be disease carriers, especially outbreaks of malaria. For this reason the construction operations should include provision for control of Anopheline mosquitoes in the worker-camp areas.

10. Special Sanitation Requirements: The evaluations made of actual "sanitation mess" situations in the USA and elsewhere have shown that the following measures must be incorporated into the planning/design of the port/harbour complex if it is expected to be able to maintain an acceptable level of sanitation in the port/harbour area, including consideration both of shipping and of shore installations:

    Provision of an adequate water supply distribution system recognizing the extraordinary water supply demands in port/harbour complexes (usually considerably higher than for other urban zones), including pier installations for hose connections for furnishing fresh water to ships.

    Provision of an adequate sewage collection, treatment, and disposal system serving the entire complex, including a shoreline interceptor for receiving liquid wastes from all shoreline installations. (In conventional practice, such an interceptor is usually not provided because it is expected these installations will discharge directly into the harbour waters.)

    Provision of special hose connections so ships can readily connect to them and discharge their sewage, bilge waters, and other liquid wastes into the sewage collection system. (Without these, it can be expected that most ships will discharge raw sewage and bilge waters directly into the harbour waters.)

    With respect to treatment of the collected wastes, special attention should be given to provisions for removal of oils and all other floatable materials.

Provision of a comprehensive solid waste management system for the entire complex including provisions so that ships can readily be serviced by the system. (Otherwise the ships will likely dump the wastes into the harbour.)

ENVIRONMENTAL GUIDELINES FOR COMMUNITY SEWERAGE AND EXCRETA DISPOSAL SYSTEMS (SERs)

1. Problems Relating to Siting of Facilities

1.1 Routing of Sewers: Route sewers to minimize interference with other utilities (avoid placing sewers near water lines), construction traffic problems on streets, and blocking building access.

1.2 Site Selection for Treatment/Pumping Plants: Select sites which minimize hazards of operation, nuisances (taking wind conditions into account).

2. Problems Relating to Design Phase

2.1 Overflow Hazards: Have standby power to prevent overflows and/or bypassing of pumping and treatment plants, resulting in flooding of neighboring properties with raw sewage and in releasing untreated sewage to environment.

2.2 Protection of Receiving Waters: Achieve levels of treatment which will furnish proper protection of downstream water quality (fresh water, estuarine, marine) needed for beneficial uses of receiving waters including uses of community and industrial water supply, fisheries, recreation, and irrigation.

2.3 Receiving Water Standards: Avoid promulgation of environmental quality standards which are not realistic in terms of achievable levels of environmental sanitation/pollution control.

2.4 Sludge Disposal: Provide for disposal of excess treatment plant sludge at acceptable sites and under acceptable conditions. Generally this sludge is disposed of onto agricultural lands. Because the sludge often contains pathogenic organisms, it may be necessary to destroy these pathogens, for example, by use of a forced air composting process. The sludge may also be disposed of by sanitary landfilling.

2.5 Industrial Waste Discharges to Sewer System: Control inputs of waste effluents from industries which can damage the sewer system, or interfere with treatment processes, or which contain toxic substances which will not be removed by the treatment system and thus pass through the plant and impose adverse effects on environment.

3. Problems During Construction Stage

3.1 Control of silt runoff during construction (may require use of temporary holding ponds).

3.2 Resurfacing/replanting of exposed areas, both to avoid erosion and to preserve environmental aesthetics.

4. Problems During Operation Stage

4.1 Health and Safety Hazards to Workmen

- Hazards from working in sewers from toxic gases and from hazardous materials which may be contained in sewage flow
- Hazards of communicable disease from exposure to pathogens in sewage and sludges
- Hazards of trench cave-in during sewer construction

4.2 Operations Monitoring: This is essential for ensuring proper system functioning. Monitoring program usually includes (1) sampling/analysis of effluent characteristics and of impacts on receiving water quality, (2) attention to complaints of odors, noise, and other nuisances, and (3) special investigation of communicable disease outbreaks which might be attributed to sewage pollution.

5. Environmental Problems for Use of Subsurface Leaching Systems (Septic Tanks) for Individual Building Excreta Disposal

5.1 Overflow Hazards: Hazard of overflows of sewage due to inadequate leaching capacity (due to impermeable soils or high groundwater, or both).

5.2 Groundwater Pollution Hazards: Design and location of subsurface leaching units must consider potentials for polluting groundwater used for water supply.

5.3 Inadequate trench backfilling causing subsequent street settlement.

5.4 Design of subsurface leaching systems should be tailored to suit soil permeability and groundwater conditions.

5.5 Use of subsurface disposal systems depends on having sludge removal service. (The regular service often tends to avoid servicing slum areas, where the service is most needed.)

5.6 Control of industrial waste discharges into public sewer system usually requires implementation of a permit system.

5.7 Use of regional systems serving two or more communities may be advantageous.

5.8 Use of ocean disposal, if feasible and properly carried out, may achieve large economics, both for sanitary and industrial wastes.

5.9 Sewerage system planning should envision progressive expansion of sewer system to include areas now using subsurface leaching, when these areas are sufficiently developed to afford sewerage.

5.10 Potentials for use of sewage treatment plant effluent for irrigation.

ENVIRONMENTAL EFFECTS COMMONLY ASSOCIATED WITH PROJECTS FOR URBAN DEVELOPMENT

The types of infrastructure included in Urban Development Projects (UDPs) may include the entire range of community facilities, namely water supply (WS), sewerage and excreta disposal (SED), drainage, solid waste management (SWM), electricity and gas fuel distribution, public buildings including schools, streets, and related facilities.

The following guidelines are limited to the concept of multiple component UDPs.

1. <u>Environmental Effects Due To Project Location</u>

1.1 <u>Resettlement</u>: Squatters living illegally on lands to be used for the project.

1.2 <u>Land Values</u>: The project components affect adjacent land values, both positively and negatively.

1.3 <u>Downstream Pollution</u>: The waste absorption capacity of a stream may be used up by an upstream community.

1.4 <u>Water Supply Rights</u>: Urban water supply may conflict with the needs of other beneficial water users in the region.

1.5 <u>Historical/Cultural Monuments or Values</u>

2. <u>Environmental Problems Relating to Inadequacies in Project Design</u>

2.1 <u>Interference with Other Utilities in Same Streets</u>

2.2 <u>Loss of Community Recreational Areas</u>: This occurs from use of space preciously reserved for parks, playgrounds, and greenbelts.

2.3 <u>Traffic Congestion and Related Smog and Noise Problems</u>

2.4 Intensification of Water Pollution: Provision of sewers or of additional sewers, without matching treatment and disposal facilities, will usually intensify pollution in the streams which receive the waste effluents.

2.5 Sewage/Sanitation Problem: Provision of a community water supply system, or improvements to it, will lead to increasing production of sanitary sewage which, if not properly managed, will intensify community sanitation problems including health hazards which may offset the health benefits to result from improved water supply.

2.6 Poor People Equities

2.7 Slum Hazards

2.8 Solid Waste Management: Does the new situation indicate need for preparation of a comprehensive plan of SWM for the urbanizing area?

2.9 Drainage

2.10 Hazardous Materials Spills: Will the improved transportation system introduce or intensify hazards of spills of hazardous materials and, if so, what is the proposed solution?

3. Environmental Problems During Construction Stage

3.1 Hazards to Workers (and nearby residents)

- From accidents (including fires and explosions)
- From hazardous materials
- Communicable disease hazards
  - From inadequate worker camp sanitation
  - From disease carriers from other regions
- From emissions of noise, vibrations, dusts, and fumes from construction operations

3.2 Uncovered Cut-and-Fill Areas: These result in soil erosion/silt runoff and depreciation of environmental aesthetics.

4. Environmental Problems During Regular Operations

4.1 Occupational Health Programs for Operations Staff

4.2 Quality of Operations and Maintenance (O&M) Performance: A common problem in DCs is provision of UDPs without safeguards to ensure that competent O&M staff and adequate minimum feasible budgets will be made available for O&M.

4.3 Nuisance/Health/Pollution Hazards to Community Due to Inadequate O&M: This includes dusts, fumes, odors, pollutants, hazardous materials spills, and other emissions which can affect both workers and community residents and property and structures.

4.4 Monitoring: A "minimum necessary" monitoring program is needed to ensure compliance with the essential environmental constraints, including furnishing of feed-back information on needs for corrections.

ENVIRONMENTAL PROBLEMS COMMONLY ASSOCIATED WITH COMMUNITY WATER SUPPLY SYSTEMS (CWSSs) WHICH MAY NOT NORMALLY BE CONSIDERED IN PROJECT PLANNING AND DESIGN

1. Problems Relating to Project Siting

1.1 Pollution of water supply source by upstream waste inflows from communities, industries, agricultural runoff, and soil erosion runoff.

1.2 For groundwater sources, hazard of land subsidence caused by excessive groundwater pumping.

2. Problems Relating to Design Phase (including assumptions made in design phase of O&M services to be provided)

2.1 Polluted/contaminated water served in DS (distribution system) due to one or more of the following:

- Inadequate O&M for filters and chlorinators
- Lack of chlorine residual monitoring in DS
- Pressure fluctuations and leakages in DS causing inflow of pollutants/contaminants

2.2 Inadequate protection of water source (intakes or wells) from surface runoff pollution.

2.3 Excessive growth of algae in distribution reservoirs.

2.4 Increase in production of sewage beyond capabilities of community SER facilities.

2.5 Inadequate disposal of sludges from water treatment plants: These sludges can generally be satisfactorily disposed of by engineered landfilling.

2.6 Unsatisfactory raw water quality due to excessive TDS (total dissolved solids), chlorides, nitrates, fluorides, and other constituents present at concentrations above acceptable limits and which cannot be removed by feasible treatment processes.

3. Problems During Construction Stage

3.1 Erosion and Silt Runoff During Construction

3.2 Resurfacing of Exposed Areas

4. Problems Resulting from O&M Inadequacies

4.1 Delivery of water to DS which is unsafe due to poor O&M of treatment processes (especially mud accumulations in filters) and inadequate chlorination.

4.2 Lack of adequate monitoring of chlorine residuals in DS as a check on safety of water in DS.

4.3 Delivery of water to DS which is corrosive due to inadequate attention to feeding of corrective chemicals.

5. Other Aspects of CWWs of Environmental Interest to Be Managed By Competent Project Planning

5.1 Depth of pipe trenches (sufficient to prevent damage from surface traffic).

5.2 Attention to routing of distribution system piping (to avoid passing through areas heavily contaminated with sanitary/industrial wastes).

5.3 Hazards from water and sewer pipes in same trench.

5.4 Need for standby power and/or elevated storage to ensure continuity of pressure in the DS.

5.5 Need to ensure availability of raw water supply for emergency purposes in case of breakdown of transmission lines, dry-up of supply in drought periods, etc.

5.6 Prevention of cross-connections in DS connections to buildings.

ENVIRONMENTAL ASPECTS COMMONLY ASSOCIATED WITH MAJOR DAM/RESERVOIR PROJECTS (including hydropower)

1. Environmental Problems Due to Project Location

1.1 Resettlement of population in inundated area.

1.2 Encroachment into Watershed: The access roads built for the project and the new lake often serve to accelerate movement into the watershed by farmers, hunters, and timber exploiters.

1.3 Encroachment on Historical/Cultural Monuments/Areas

1.4 Watershed Erosion/Silt Runoff: If the existing or projected erosion/silt runoff in the watershed is sufficient to jeopardize the life of the dam, consideration must be given to expanding the project to include a watershed reforestation and or regreening program (to be included in the project's core budget).

1.5 Impairment of Downstream Navigation

1.6 Impairment of Groundwater Hydrology

1.7 Migration of Valuable Fish Species

1.8 Inundation of Mineral Resources

2. Environmental Problems Associated With Design (including assumptions on O&M)

2.1 Erosion from construction of access roads without suitable provisions for resurfacing or revegetating the exposed areas.

2.2 Pre-Impoundment Reservoir Site Preparation: If the reservoir fishery will be important, it is generally preferable to clear the reservoir site to permit net fishing.

3. Environmental Problems Due to Construction

3.1 Soil Erosion/Silt Runoff: From erosion in borrow and cut-and-fill areas due to lack of adequate planning and controls during construction, and lack of resurfacing exposed areas.

4. Environmental Problems Relating to Project Operations

4.1 Downstream Flow Variations

4.2 Damage to Downstream Inundation Fisheries: Although the lessening of flood flows by the reservoir will reduce downstream flooding hazards, this can also reduce inundation fisheries (traditionally an important source of protein for rural poor).

4.3 Downstream Erosion: Release of turbidity free waters often results in considerable downstream erosion of banks and river beds.

4.4 Lack of Reservoir Management: The reservoir usually becomes a rich fishery, resulting in establishment of fishing villages around the lake. Without proper reservoir management, (1) fishery yields will be less than they should be; (2) fishing will be overexploited and illegal methods utilized; (3) fishing rights will often be taken over by immigrants who displace local fishermen; (4) new villages may become sanitation/public health messes; and (5) social conflicts may occur in drawdown agriculture.

4.5 Eutrophication: Trapping of nutrients in reservoir may result in (1) impairment of water quality for downstream beneficial uses, and (2) weed blooms which interfere with power generation and with operation of irrigation canals.

5. Potential Environmental Enhancement Measures

5.1 Reservoir Fishery

5.2 Drawdown Agriculture

5.3 Downstream Community Water

5.4 Downstream Aquaculture

5.5 Forestry/Wildlife Reserves: Because of the adverse effects of the project in facilitating and accelerating encroachment into the upper watershed, it may be desirable to include (as a project component) provision of forest/wildlife parks/resources in the upper watershed while this is still feasible.

ENVIRONMENTAL EFFECTS COMMONLY ASSOCIATED WITH PROJECTS IN THERMAL POWER (exclusive of mining of fossil fuels)

1. Environmental Effects Due to Project Location

1.1 Cooling Water Abstraction: Are the available water supply resources in the region sufficient to meet project needs for cooling water without disruption of existing beneficial water uses?

1.2 Regional Flooding and Drainage Hazards

1.3 Waste Emissions Problems: Is this siting appropriate with respect to achieving proper disposal of liquid, gaseous, or solid wastes?

2. Environmental Problems Relating to Planning and Design (including assumptions on quality of O&M)

2.1 Cooling Water System: For "once through" cooling water systems, is the design appropriate considering other water rights allocations and effects of plant processing (heating, mechanical abrasion of microorganisms, and chemicals added to the cooling water) on downstream beneficial water uses? Is the cooling water intake design adequate for screening out fish?

2.2 Air Pollution Control Equipment: Is the selection of sophisticated equipment for controlling pollution emissions consistent with realistic expectations on O&M quality levels for the DMC, including provisions for training?

2.3 Boiler Sludges (Bottom Ash): Does the design provide for proper disposal of steam-boiler sludges when these are periodically cleaned? If access to the open sea is feasible, it may be advantageous to dispose of this at sea. Usually disposal is by landfilling.

3. Environmental Problems Relating to Operations

3.1 Adequacy of O&M Funding

3.2 Occupational Health and Safety

3.3 Nuisances from Hauling Fuel: Will the noise, traffic, and dust emissions along access routes be excessive?

3.4 Surface Runoff from Plant Yard: Will this runoff contain sufficient amounts of pickup of fuel, oils, and other pollutants so that treatment of the runoff will be needed?

4. Realization of Feasible Enhancement Measures: Possibilities which have been feasible for large industrial plants include provision of good water supplies for rural villages in the vicinities, and for power plants, rural electrification in the plant vicinity or sub-region.

5. Impacts from Power Transmission Facilities

5.1 Encroachment on Rare Habitats

5.2 Depreciation of Environmental Aesthetics

5.3 Continuing Erosion from Exposed Areas

ENVIRONMENTAL EFFECTS COMMONLY ASSOCIATED WITH PROJECTS FOR INDUSTRIES

1. Environmental Effects Due to Project Location

1.1 Importance of Site: Generally, industries which are heavy waste polluters should not be located in ecologically/environmentally sensitive areas nor in areas already overcongested with such industries. One of the purposes of the EIA is to ascertain whether the selected site is a good choice or not, and if not, whether the proposed industrial waste management system (IWMS) can be expected to function effectively given the high O&M costs and the likely level of O&M quality.

1.2 Buffer Strip: In order to protect the adjacent public from nuisances stemming from plant operations, including noise and pollutant emission, a buffer strip of about 30 m should be furnished around potential nuisance sources, including the IWMS components.

1.3 Nuisances/Hazards to Neighbors

1.4 Effects on Adjacent Property Values

1.5 Plant Drainage

1.6 Encroachments Affecting Ecology

1.7 Socioeconomic Impacts: Determine whether special management measures need be undertaken to avoid serious social conflicts including possible training of local job candidates, public relations before, during, and after construction, and furnishing of wells for community water supply to make up for apprehensions, for example, about pollution of stream water which may be used for water supply purposes.

1.8 Water Supply and Hydrology

1.9 Environmental Aesthetics: Industrial structures are rarely designed to minimize adverse impacts on environmental aesthetics--they often "stick out like sore thumbs." Architectural design should blend the structures into the landscape and use trees for screening if important environmental aesthetics are involved.

2. Environmental Pollution Problems Related to Design Inadequacies (including assumptions on operations)

The FS (feasibility study) or FS/EIA should include schematic drawings showing the following:

2.1 The plant manufacturing processes including the specific sources of all waste emissions (e.g., liquid, solid, and gaseous wastes, with each of these quantified as to total amount, characteristics, and amounts for each characteristic of pollution significance including both total per day and values per unit of manufacturing).

2.2 Mass balances for water supply entering, used up (evaporated, incorporated into product, etc.), and leaving the plant as waste flow.

2.3 Mass balances for each toxic or hazardous substance, including amounts entering or produced in the plant, plus all waste emissions.

2.4 Waste Management System: Design of IWMS needed for protection of downstream uses, based on assumptions for environmental standards which are affordable.

- Cooling water system
- Sanitary wastes
- Yard runoff
- Final holding pond: A virtually essential requirement is a final holding pond for equalizing the waste flows, for "dampening" slug-type discharges, and for furnishing a final "polishing" step in the treatment process.
- Marine waste disposal: If access to unconfined marine waters is feasible, then this disposal alternative will almost always result in a much more economical IWMS.
- Discharge to municipal sewers: With a proper control/permit system, municipal sewerage systems can and should receive acceptable industrial wastes both for cost sharing, to help promote industrial development and to gain superior environmental protection.
- Joint disposal systems: When two or more industries can share in a joint IWMS, their respective costs will be reduced, monitoring will be simplified, and better environmental protection will result.

3. Solid Waste Emissions

3.1 Ordinary Refuse

3.2 Hazardous Solid Waste: This requires special handling by experts in this field of technology.

3.3 Monitoring: The overall monitoring program should include two components: (1) a program carried out by the industry, including both performance of treatment equipment and effects on environment, by the plant staff with outside assistance as needed, and (2) surveillance monitoring by an outside agency, to check the reliability of (1).

4. Environmental Problems During Regular Operations

4.1 Environmental Pollution

4.2 Scarce Environmental Resources

4.3 Nuisances/Hazards to Nearby Residents and Properties

- Noise and vibrations
- Dusts, fumes, and other air pollutants
- Hazardous waste spills on access roads
- Traffic congestion on access roads
- Depreciation of local environmental aesthetics

4.4 Inadequate Occupational Health and Safety Program

ENVIRONMENTAL EFFECTS COMMONLY ASSOCIATED WITH PROJECTS IN NITROGEN FERTILIZER MANUFACTURE

1. Environmental Problems Due to Project Location

1.1 Site selection commonly considers water supply availability but often does not take into account the problems of waste disposal, that is, to choose sites where the adjacent environment is relatively insensitive to waste discharges.

1.2 Regional Flooding and Drainage Hazards: Will the structures be secure against regional flooding hazards? Is the regional drainage pattern inadequate to meet project needs? Should the project be enlarged to obtain reasonable flood protection?

1.3 Disruption of Hydrology: Changes in the hydrology of waterways intercepted by the project, without careful planning, can result (1) in creating or intensifying local flooding problems, and (2) in affecting ecology including fisheries.

2. Environmental Problems Relating to Design (including assumptions on quality of O&M)

2.1 Compatibility of Design With Available O&M Quality: Leakage in NFM plants in developing countries has resulted in total nitrogen emissions far above the international standards for developing countries.

2.2 Water Pollution Control

- Does the design take appropriate account for control of the following, with respect to protection of downstream beneficial water uses (water supply, fisheries, recreation/bathing, animal watering, irrigation), especially during the dry season, for control of discharges in the surface runoff, boiler blowdown, cooling tower blowdown, and other liquid wastes, of:
    - Ammonia and other nitrogen compounds
    - Total dissolved solids
    - Acids and alkalis
    - Oils/grease
    - Toxic chemicals which may be used in the plant processes including compounds added to the cooling tower system including chromium
    - Organic pollutants (BOD) including sanitary waste effluents
    - Pathogens in sanitary waste effluents
    - Solid wastes resulting from plant processes including pollution control
- Does the design include adequate provision for management of sanitary sewage? (Note that it is often possible to handle this problem very economically by using a simple septic tank with the effluent passed to the final holding pond, instead of the usual use of a special biological oxidation system.)

2.3 Air Pollution Control: Does the design limit the discharges of ammonia and other air pollutants to levels acceptable to workers and neighbors?

2.4 Solid Waste Disposal

- Is provision made for adequate disposal of solid wastes from the NFM processes? (See 2.2.)
- Is provision made for adequate disposal of plant sanitary solid waste?

ENVIRONMENTAL EFFECTS COMMONLY ASSOCIATED WITH PROJECTS IN MINING AND MINERAL PROCESSING

1. Environmental Problems Due to Project Location

1.1 Disruption of Hydrology: Changes in the hydrology of waterways intercepted by the project, without careful planning, can result (1) in creating or intensifying local flooding problems, and (2) in affecting aquatic ecology including fisheries.

1.2 Resettlement of Families Displaced by Project

1.3 Encroachment into Forests/Swamplands

2. Environmental Problems Relating to Planning and Design

2.1 Quality of O&M: In terms of O&M experience in the region, will the O&M capability be adequate (including provisions for training) for operating the selected equipment for mining and for pollution control, including carrying out hazardous mining functions such as blasting?

2.2 Occupational Health and Safety Planning: Will the provisions be appropriately adequate under DMC conditions for protecting the health and safety of the workers from routine working hazards and from hazards of explosions, toxic gases, cave-ins, fires, etc., including provision of appropriate emergency action programs?

2.3 Environmental Pollution Control

- Mine drainage: Will the design provide adequate protection of surface water and groundwater from mine drainage, especially toxic metals, and maintain the water quality suitable for existing beneficial uses?

- Silt runoff: Will the design provide suitable protection against silt runoff from hydraulic sluicing and surface runoff from exposed areas, which otherwise could cause serious downstream water quality impairment and silt deposition?

- Tailings: Will the design provide suitable protection against tailings discharges into the waterways, especially at times of flooding, causing massive downstream transport of tailings with serious adverse effects on water quality and land uses?

- Noise: Does the design for mining operations provide for control of noise within acceptable limits?

- Dusts and fumes emissions

- Mineral processing: Are mineral processing operations involved which, if not protected against, will result in significant discharge of pollutants to waterways and to the air (including dust), solid wastes, and excessive noise? If the processing is a sizable and/or complex operation, it will require its own IEE/EIA separately from the mining per se, tailored to suit the particular type of processing.

3. Realization of Feasible Enhancement Measures: Does the project plan take advantage of opportunities for feasible modifications in the planning/design for incorporating special measures which will significantly enhance environmental values, thereby serving both to offset unavoidable adverse impacts but to improve the project's overall benefit/cost ratio? For mining projects, such measures may include (1) land reclamation in low lying community areas by filling with waste spoils/tailings, and (2) use of the spoils/tailings to produce sand/aggregates valuable for making concrete.

ENVIRONMENTAL EFFECTS COMMONLY ASSOCIATED WITH IRRIGATION PROJECTS

1. Environmental Effects Due to Project Location

1.1 Disruption of Hydrology can result (1) in creating or intensifying local flooding problems and (2) in affecting adequate ecology including fisheries.

1.2 Impediments to Movement of Wildlife/Cattle/People: Suitable crossing ways need to be provided.

1.3 Conflicts in Water Supply Rights: For example, implementation of excessive irrigation projects in the upper Chao Phya Basin in Thailand has tended to "dry up" established water uses in the lower basin during the dry seasons in drought years. Also, proposed transbasin diversions, although technically feasible, may create political problems.

1.4 Regional Flooding and Drainage Hazards: Will the structures be secure against regional flooding hazards?

2. Environmental Problems Relating to Design (including assumptions on O&M)

2.1 Water Quality Problems: Diversion of water from surface streams by decreasing downstream flow can result in increasing the downstream concentrations of dissolved mineral salts and in increasing seawater encroachment into the stream systems. Also, downstream salinity may be increased from return irrigation flows. Such salinity increases may adversely affect many downstream beneficial water uses including community water supply and fisheries.

2.2 Suitability of Natural Water Quality for Irrigation: This includes parameters such as total dissolved solids, chlorides, sodium/calcium ratio, boron, and others.

2.3 Overpumping of Groundwater: This can lead to numerous problems including water rights conflicts, salinization, and ground subsidence.

2.4 Adequacy of Drainage Planning: Insufficient drainage can negate much of the project benefits, such as from salinity encroachment, and can decrease stream capacity from siltation.

2.5 Land Tenure Problems: How will the project benefits be distributed between farmers and landowners?

2.6 Farmer Credit Limitations: Do the farm families have sufficient financial resources to make the needed investments in farm inputs and in land leveling/preparations?

2.7 Feasibility of Cooperatives: Does the project depend on assumed functioning of cooperatives for farm inputs and for marketing beyond the reality of the "track record" for such cooperatives?

2.8 Use of Agriculture Chemicals: Does the project plan provide for competent use of fertilizers and pesticides by the farmers so that proper amounts will be used and so that excessive chemical runoff does not occur causing depreciation of downstream water quality, including problems of toxicity to aquatic fauna and/or eutrophication?

2.9 Selection of Pesticides: Will the project plan result in the use of environmentally acceptable (degradable) pesticides and avoid the use of hard pesticides which will accumulate in soils and stream sediments with potentials for serious effects on ecology?

2.10 Inequities in Water Distribution: Will the project ensure reasonable distribution of water throughout the service area, including provision of practicable turnout facilities?

2.11 Canal Maintenance: Does the design of canals provide for reasonable protection against weed growth which could seriously impair canal capacity? If canal banks are not lined and dependence for removing weeds is placed on assumed levels of O&M, is this assumption realistic? Also, does the design include canal gates needed for flushing?

2.12 Passageways: Does the design incorporate adequate passageways for wildlife/cattle/people? (See 2.1.)

2.13 Scouring Hazards: Does the design incorporate adequate protection against scouring hazards at culverts, control structures, and other special structures?

3. Problems Relating to Operations

3.1 Adequacy of O&M: Is the O&M plan realistic in terms of experience in the project area? If there are questions on the O&M adequacy, how will the canals be cleaned of silt? How will they be cleaned of excessive weeds, etc.?

3.2 Adverse Soil Modifications: Is the project likely to result in adverse soil modifications resulting from (1) water logging, (2) soil salinization, (3) soil alkalinization, (4) nutrient leaching, (5) acid sulfate hazards, and (6) development of soil impermeability from excessive sodium?

3.3 Changes in Groundwater Hydrology: Will the operation of the irrigation system change groundwater levels and adversely affect other beneficial water users?

3.4 Water-Oriented Diseases: Will the changes in surface water hydrology resulting from the canal system induce new communicable diseases or increase the incidence of existing ones, including insect vector diseases such as malaria and schistosomiasis? If the irrigation water is being drawn from a source contaminated with the schistosomiasis snails, are provisions made for screening out the snails before the water enters the irrigation systems?

3.5 Hazards of Toxic Chemicals: Will the use/misuse of toxic agricultural chemicals, especially pesticides, result in impairment of local aquaculture or of downstream fisheries or in impairment of ecology through accumulation in soil and bottom sediments? Will misuse result in occupational health hazards to the farmers?

3.6 Hazards of Fertilizer Runoff: Will the use/misuse of fertilizer result in excessive eutrophication in the irrigation system or in the downstream waterways?

3.7 Aquaculture Water Supply: Will the project distribution system ensure year-round delivery of water to aquaculture operations?

4. Realization of Enhancement Measures

4.1 Does the project include appropriate use of water for improving community water supply and sanitation facilities in the service area?

4.2 Does the project include an appropriate component for making optimal use of water for improving aquaculture in the service area?

ENVIRONMENTAL PROBLEMS COMMONLY ASSOCIATED WITH FISHERIES AND AQUACULTURE PROJECTS

Introduction

1. Environmental Problems Related to Site Selection

1.1 Conflicts wth Other Site (Waterway) Uses: Tourism/recreation and navigation, and for creating more agricultural land by filling of the area.

1.2 Hazards of Serious Pollution: Sites should preferably be upstream of pollution-emitting facilities (such as oil refineries). Single (slug) discharges can raise havoc with the entire fishery/aquaculture (F/A) operations. If pollution hazards do exist, the F/A plan should ensure careful emissions control.

1.3 Remoteness from Marketing/Needs for Freezer Storage

1.4 For Aquaculture, Steady Availability of Freshwater Supply: For dam/reservoir releases, this may conflict with other water use allocations in drought periods. If water is drawn from irrigation canals, canal O&M plan must enable steady delivery of water (not complete shutdown of delivery when cleaning/repairing canals).

1.5 For Aquaculture, Costs for Importing Needed Feed

1.6 Water Quality and Quantity: Water Quality (WQ) suited to the project's needs is basic for F/A operations. This includes, for fisheries, impacts on WQ likely to result from pollution inflows, changes in local hydrology from probable upstream dams or other river development, and possible seawater influx during storms.

1.7 Hurricane and Typhoon Hazards: Facilities design must consider these hazards (for example, the aquaculture facilities in Laguna Lake near Manila are designed to minimize this problem).

1.8 Local Soils Properties: For aquaculture projects, the local soils may not be suitable for furnishing structural stability for berms made from the soil, and may be excessively permeable, and moreover some soil can adversely affect water quality.

1.9 Availability of Juvenile Stock

1.10 Peripheral Development Hazard: This concerns the effects of F/A waterbody region, including destruction of mangroves on which the project may be critically dependent for food.

1.11 Site Filling Hazards (e.g., when accelerating erosion in the upstream watershed reduces the volume of the waterbody used for the F/A operations).

1.12 Security from Poachers: Poaching, either by outsiders or by insiders, can ruin project economics. In some cases it may be desirable to organize the overall operation into a series of sections of a size suited to operation and control by a single family management.

2. Environmental Hazards Relating to Inadequate Design

2.1 Salability of Product: For both F/A projects, an important criterion for economic viability is the presence of a suitable market for the product and the capture or raising of species which will be favored by the intended customers.

2.2 Middlemen Problems: One of the socioeconomic problems commonly involved in projects in F/A is the advent, during the operations phase, of in-migrants who take over the middleman's role, buying fish from fishermen for resale, and without control this practice can reduce the fisherman's earnings to unfair and unacceptably low levels.

2.3 Dredging and Filling

2.4 Disease Hazards can drastically reduce yields, so select species appropriate from the viewpoint of aquaculture disease hazards history in the area and availability of feasible control methods.

2.5 Socioeconomics: In addition to item 2.2, attention needs to be given to favoring local population labor needs, especially of resettlers displaced by the project, and fishermen families in the vicinity whose livelihoods will be impaired by the project, rather than to imported labor (to become permanent new residents).

2.6 Downstream Water Quality: Discharges from aquaculture project, especially those with high rates of productivity employing special aeration and feeding techniques, may need to be treated (by ponding) to prevent downstream WQ and beneficial uses.

2.7 New Species Hazards: Care must be exercised in introducing new species for aquaculture, i.e., to assess the impacts on existing fishery species distribution in the area and region.

2.8 Permit System: A competent management system should be established to manage the new F/A to ensure proper selection of fishermen for fishing rights, for furnishing financial assistance to enable them to get started, for preventing overfishing and illegal fishing methods, for assistance in controlling middlemen (item 2.2), and assistance in marketing based on the use of an appropriate fee system for recovering costs.

2.9 Fishing Village Sanitation: Proper planning and administration (see 2.8) and guidance in the establishment/growth of fishing villages in the project vicinity should be provided, to ensure that these do not turn into "sanitation messes" that pollute the F/A waterbody and threaten public health.

PROJECTS IN WATERSHED DEVELOPMENT

Watershed development (WD) means appropriate economic-cum-environment (E-c-E) use of a watershed, with attention to use/preservation of natural resources for optimal long-term sustained use. Actually, there have been few WD projects per se; rather, the approach has been on a piecemeal basis. The only two "true" watershed development plans to emerge thus far in Asia are those which are components of integrated regional E-c-E planning, such as for Songkhla and the Eastern Seaboard regions of Thailand. Watershed development on an integrated basis is therefore a new concept.

Significant Adverse Environmental Effects

1. Integrated Watershed Development Plan

1.1 Natural Forest and Wildlife Habitat

- Designation of areas of natural forest which are to be retained permanently as natural forest/wildlife habitat, with no development allowed which would significantly alter the natural forest characteristics

- Preparation of programs for reforesting these areas as needed

- Preparation of a plan for continuing timbering of those areas which will not interfere with sustained forest productivity nor alter the basic forest habitat and wildlife

1.2 Land-Use Planning: For the remaining WDA, preparation of an appropriate land-use planning compatible with the available soil/water/climate resources, which delineates areas/places/routes to be used for:

- Forest plantations

- Upland farming (including grazing and aquaculture) and irrigation

- Rural communities and community facilities

- Potential/appropriate dam/reservoir sites including supplementary systems for power generation and transmissions, flood control, community water supply, reservoir fishery development, and other purposes

- Mining and quarrying

- Agroindustries and other industries
- Tourism/recreational development including fishing

1.3 Basic Data Systems (including benefit/cost justifications)

- Preparation of minimum-needed basic hydrologic data collection system, including stream gauging and rainfall and other meteorological stations
- Preparation of appropriate environmental monitoring systems, including baseline surveys, for continuing assessment of status of previous natural environmental values

1.4 Watershed Erosion Control Program: Evaluation of problem and preparation of minimum integrated WDA soil erosion control program to match the delineated land uses, including reforestation and regreening, with benefit/cost justifications.

1.5 Socioeconomic Development: Evaluation and delineation of feasible socioeconomic program so that villagers will be gainfully employed in the integrated WDA noted earlier and will be interested in preserving the natural forest assets rather than in destroying them.

2. Manning and Implementing IWDP Components

2.1 Natural Forest Reforestation

2.2 Upland Plantations

- Methodology: Is the design based on proven experience under similar conditions elsewhere, especially with respect to adaptability to the conditions of hillside slopes?
- Forest Encroachment: Does the proposed plantation area encroach on the reserved natural forest area, and will it result in communities whose populations will be inclined to forest encroachment for fuel or food?
- Soil Erosion: Will the proposed planting regime afford effective protection against soil erosion?
- Wildlife: Does the selection of tree types and intra-tree vegetation/crops take into account possible needs for wildlife enhancement?

2.3 Upland Agriculture (including grazing)

- Forest encroachment
- Soil erosion
- Agricultural water supply

2.4 Rural Villagers

- Site Location: Are the village layouts and sitings suitable in terms of distance to be traveled by the villager from home to work and back?

- Community Facilities: Is provision made for adequate community facilities, especially for domestic water supply, sanitation, and flood protection?

- Home Gardening: Does the home/lot allocation include sufficient area to encourage home gardening as a valuable extra family income?

2.5 Industrial Development

2.6 Mining Development

2.7 Irrigation Projects

2.8 Roads

ENVIRONMENTAL EFFECTS COMMONLY ASSOCIATED WITH FORESTRY PROJECTS

Commercial Logging

1. Project Siting

1.1 Watershed Areas: What will be the likely effects on hydrology, siltation, and water quality, and how will they affect the various users?

1.2 Relation to Other Dedicated Land Uses: Will the proposed project area infringe on other dedicated land uses such as parks and wildlife preservation zones, and mining operations?

1.3 Traditional Forest Uses: In selecting project location, have adequate consideration been given to the different kinds and levels of traditional forest uses by local populations and the expected impacts of the project on these uses?

1.4 Resettlement: Will the proposed project entail resettlement of indigenous populations?

1.5 Relation to Regional/National Forestry Plans: Has project siting taken into account the regional and/or national master plans for forest utilization/conservation? Does it contravene plans for conservation of minimum forest area/types that should be maintained for long-term regional welfare?

1.6 Critical Environmental Areas: Is the project to be located in environmentally critical areas such as land with steep slopes and fragile soils? If so, what will be the effects on soil stability?

1.7 Previous Ecology: Does the selected site contain rare or useful species of wildlife, fish, and plants?

2. Planning and Design

2.1 Benefit/Cost Analysis: Has a benefit/cost analysis been done that clearly addresses costs from erosion/sedimentation, increased peak flows and flood flows, loss of recreational or tourism opportunities?

2.2 Operation and Maintenance: Does the fiscal setup ensure availability of necessary O&M funds, especially for erosion and sedimentation control and forest rehabilitation?

2.3 Data Base for Decision-Making: Will sufficient information be collected on timber stand density, species composition, terrain, logging conditions, and the environmental effects of logging operations to provide the basis for long-term logging and road development plans?

2.4 Road Network Design: Has planning and design of roads adequately considered soil conditions, grades and curves, water drainage, proximity to waterways, and adequate drainage?

2.5 Design of Logging Activities: Does planning and design allow for minimal damage to the residual stand?

2.6 Critical Environmental Areas: Has due consideration been given to critical areas (i.e., those with extreme soil erodibility, rainfall erosivity, and slope gradient/length) for erosion control measures?

2.7 Precious Ecology: Has planning and design taken into account the mitigation/protection/enhancement measures for rare or useful wildlife, fish and plant species, such as provision of buffer strips, of standing food trees, of newly created protected areas around the logging site?

3. Project Operations

3.1 Road Construction

- Limited to the dry season
- Drains spaced properly

- Up-and-down spur roads avoided
- Areas adjacent to logging roads provided with vegetative cover

3.2 Felling

- Minimize loss of seed trees and residual stands.
- Clear cutting should be avoided, particularly in unstable areas.
- Is the felling system being monitored to check compliance with the concession contract?
- Have precautions been taken not to disturb vegetation near waterways and to avoid blocking streams with logging debris?

3.3 Log Conveyance and Allocation

- Cable yarding in hilly regions will cause minimal damage compared to ground skidding.
- Is rational and profitable use being made of residues, and will the logs be allocated to their most appropriate use so optimal benefits are gained from the logged area?

3.4 Riparian Zones

- Enhance the quality of habitat for aquatic resources; provide a "filtering" buffer zone, inhibit rises in stream temperature and provide bank/floodplain stability; provide important habitats for wildlife; and provide a focal point for many recreational activities.
- Keep wheeled and tracked vehicles out of these zones; keep roads and trails as far away as possible; carry out all silvicultural and logging operations by hand or from the outside edge of the riparian zone; avoid burning that would leave the riparian zone exposed during periods of high-intensity rainfall; keep tracers for firebreaks as far uphill as possible.
- Compensation to local people for loss of forest use, such as provision of planting stock and adequate training to enable production of multipurpose species.

4. Post Project

4.1 Rehabilitation and Conservation: Does the project provide for silvicultural treatment of logged-over stands and protection against encroachment and fire after the operation has ceased? If so, has adequate monitoring of such activities been provided? For selectively logged areas, has consideration been given to incorporating the logged-over area as a multiple use zone within a larger conservation unit including nature reserves?

4.2 Road Shutdown: Has provision been made to "put to bed" temporary roads such as spur roads after completion of the operation?

Reforestation

1. Project Siting

- History of forest abuse
- Relation to other dedicated land uses
- Resettlement

2. Planning and Design

2.1 Benefit/Cost Analysis: Has a benefit/cost analysis been done that clearly delineates specific benefits to result from the project (e.g., erosion control); savings in downstream flooding hazard; decreases in sedimentation and turbidity in streams/estuaries/nearshore marine waters, including protection of fisheries and beaches; enhanced opportunities for recreation and tourism; increased fuel sources; enhanced employment opportunities?

2.2 Selection of Tree Species: The use of monoculture planting in extensive areas should be avoided; mixed crops provide greater safety against damage from pests and diseases. Have the physical and environmental site characteristics been adequately studied to help determine which tree species will best adapt to the site? In some cases, attempting to reforest extremely steep and shallow soils may result in less environmental gains than leaving the area in grass/shrub cover.

2.3 Precious Ecology

2.4 Allocation of Benefits to Locals

2.5 Operation and Maintenance

2.6 Data Base for Decision-Making

2.7 Project Financing and Reservoirs: If a major reservoir project is to be developed in the region, has the potential been explored to finance the reforestation project as a component of the reservoir project?

2.8 Appropriate Technology: Is the technology to be used appropriate for developing countries in tropical monsoon areas or is it copied from possibly inappropriate Western models?

2.9 Use of Grasslands: Has the use of grass cover instead of trees been considered in areas where sufficient downstream water supply is a critical concern?

3. Project Operations

3.1 Commercial Logging

3.2 Reduced Water Supplies: Large reforestation projects may reduce supplies of water to downstream users and reservoirs as the trees mature due to increased evapotranspiration rates. Mitigation measures such as shorter harvesting rotations or retaining grassland areas may be needed where sufficient water supply is a critical consideration.

3.3 Chemicals and Fertilizers

3.4 First-Year Operations: A combination of vegetative (reforestation) and mechanical (engineering) control of erosion and overland flow can provide the most effective technique for erosion and water problems in depleted watersheds.

3.5 Soil Conservation Benefits: Soil conservation is perhaps the most profound environmental result of reforestation.

3.6 Socioeconomic Benefits

3.7 Water Resources Benefits

Community Forestry

It is assumed that the main goals of most community forestry projects are timber and fuel production and that most projects involve afforestation and not the use of existing forests.

1. Project Siting

1.1 Siting in Well-Defined Areas: Will the project be located in a well-defined area such as a watershed or a group of villages?

1.2 Historical Patterns of Illegal Land use: Lands that have a history of prior illegal use for grazing may need to be ruled out because of the hazard that these users would try to maintain their "rights" by eliminating the new forest through fire and grazing. Conversely, well-sited and designed projects can serve as an intervention to illegal use of nearby forests by offering similar products without the risk of arrest.

1.3 Critical Environmental Area: Highly unstable lands may need to be avoided because a "working" community forest can require frequent soil-disturbing harvests.

1.4 Essential Surveys: Have the following been surveyed before site selection: climate, soil, and land-use characteristics; past/present types and uses of existing forests including gathering of non-wood products; wood use and needs; market prospects; community social systems; land tenure and other legalities; population characteristics?

1.5 Relation to Other Dedicated Land Uses

1.6 Resettlement

1.7 Siting in Degraded Forest

LAND CLEARING AND REHABILITATION PROJECTS

1. Definition of Land Clearing Project: Land clearing is defined as the removal of vegetation from primary and secondary forested areas or other areas for creating sufficient clear land to permit establishment of farming operations (including the farm communities, as well as cropping and related farming activities such as grazing and aquaculture) or agroindustrial projects.

2. Determining Agricultural Productivity of Forested Areas Under Consideration

2.1 Some forest areas are best suited to continue as forests simply because, once cleared, the resulting land will not be suited to economic agricultural production. Hence an initial requirement is a "baseline survey" to determine the agricultural values of the cleared land for cropping and related agricultural activities. This should include consideration of the following:

- Soil fertility and other soil characteristics (compared to alternative crops or uses)
- Water availability (rainfed and irrigated)
- Erosion control problems (depending on slopes and soil properties)

2.2 Consistency With National Forest Conservation Policy: Are there alternative areas which could be used to avoid this conflict such as degraded/unused areas for agricultural use?

2.3 Size and Location of Cleared Area: The optimal unit for clearing is the area of usable slopes in the lower portion of a watershed. This helps to simplify the farming operations on remaining forest/wildlife areas.

2.4 Optimal Clearing Methods and Procedures: Virtually all clearing methods (including burning, manual clearing, mechanical clearing, and chemical clearing) will degrade soil agricultural productivity to varying degrees depending on the initial soil properties and the clearing conditions (slope, wetness, nutrient levels, organic matter, particle size distribution). The removal of top soil and compaction of the soil often constitute the most serious adverse impacts, resulting in major losses in soil fertility and in soil drainage capabilities. Mechanical methods do the most damage but are often selected because of less demand on time and labor requirements.

Retain vegetation such as tree stumps and shrubs (which take up little land but help preserve soil structure); market the removed products to offset clearing costs; identify low lying areas which could best be used for pond aquaculture; and leave some residual vegetable materials to be returned to the soil for nutrient/organic matter value.

2.5 Essential Post-Clearing Operations: Plant the cleared area immediately following clearance with an appropriate vegetative cover. The selected species will depend on soil characteristics and intended cropping patterns. Hence the proposed clearing plan should constitute a clearing/covering/cropping plan indicating precisely how the newly cleared land will be progressively transformed into sustained agricultural productivity.

2.6 Economic and Socioeconomic Analyses: The proposed project should optimize harvesting and marketing of the cut materials, to help offset project costs.

2.7 Agroforestry: Does the proposed project give adequate attention to the potential of secondary forest areas to ensure sustained timber production (agroforestry)?

2.8 Swamplands: Do proposals for "reclaiming" swamps by filling them give due attention to (1) their current use as flood "buffers"; (2) the alternative of using swamps for aquaculture, which might be more profitable; and (3) hazards of creating an acid sulfate soil which would be nonproductive?

2.9 Roads: Has the proposed project's plan for roads taken into account the environmental hazards commonly associated with roads in developing countries such as impairment of water resources/aquatic habitats/fisheries, silt runoff from exposed areas left uncovered, and its capacity to facilitate encroachment into natural forest areas?

2.10 Use of Degraded Lands: Does the proposed project give due attention to the alternative of using degraded or wastelands instead of forested areas, thereby conserving forest areas and perhaps even enhancing the benefit/cost balance? Such degraded lands or wastelands might include acid sulfate soils and soils/swamp areas degraded by tin mining runoff.

3. Land Clearing in Upland Forests

3.1 Water Hydrology: A drastic change in ecosystem from forest to agriculture will cause significant changes in the hydrology of surface water and groundwater. Extensive road construction for new communities and for access to the new agricultural land can significantly affect both surface water and groundwater hydrology, as can water consumption for domestic use and irrigation. Describe "before" and "after" water flow rates; volumes; seasonal variations; normal, flood, and drought-year flows.

3.2 Water Quality: Adverse impacts on water quality may result from logging operations, including road construction/operation, felling, clearing of ground vegetation, and burning of windrows (if done near streams); disposal of human and domestic wastes in the new communities; and application of fertilizers and pesticides during agricultural operations.

3.3 Soil Fertility, Erosion, and Sedimentation: Describe soil classification; erosivity, stability, texture, bulk density, water-holding capacity, porosity, soil chemistry, and fertility. Describe soil management/conservation measures that will be taken during land-clearing operations and when agricultural activities are operational.

3.4 Aquatic Biology and Fisheries: Fisheries specifically, and water ecology generally, can be affected by (1) erosion/siltation during land clearing and agricultural operation; (2) introduction of pesticides and fertilizers to the waterway from cropland runoff; and (3) heating of streams where adjacent vegetation has been removed.

3.5 Wildlife: Land clearing for agriculture must consider the wildlife parameter in two ways: (1) the project's impact on existing wildlife populations, and (2) wildlife's potential impact on agricultural activity.

3.6 Forests: Describe the forest resources existing in the area, especially as this relates to their regional and national importance.

3.7 Water Supply: Loss of forest cover may adversely affect water supply to the new settlers as well as to established downstream users. The impacts may include (1) deterioration of water quality from erosion, addition of pesticides and other chemicals and human/domestic wastes from the new communities; and (2) disruption in the periodicity of water flow.

ENVIRONMENTAL EFFECTS COMMONLY ASSOCIATED WITH PROJECTS IN COASTAL ZONE DEVELOPMENT

Introduction

The term "coastal zone development" usually refers to projects for planning development of coastal areas to achieve their optimal uses for multibenefit uses including commerce, industry, shipping, recreation, forests (mangroves), drainage/flood control, fisheries/aquaculture, and others. Hence coastal zone planning involves a complex of many interrelating desirable uses and protection needs, and the objective of coastal zone (CZ) regional development planning is to optimize utilization-cum-built-in environmental protection.

Specific Guidelines

1. Environmental Problems Related to Site Location

1.1 Changes in Coastal Hydrology: The potential of disturbing the existing erosion/deposition pattern.

1.2 Changes in Coastal Drainage Pattern: CZ development projects not properly sited commonly result in marked alterations in the coastal land drainage pattern resulting in changes in flooding hazards and in deposition/erosion patterns, and changes in estuarine patterns and resultant changes in estuarine fisheries and aquatic ecology.

1.3 Changes in Coastal Land Uses: CZ development not properly sited may easily lead to overurbanization/industrialization with resulting losses of previous coastal ecology and environmental aesthetics including tourism and recreational values.

2. Environmental Problems Relating to Construction Stage: These problems are similar to those for most major construction projects.

2.1 Problems from Uncontrolled Construction Practices

- Runoff erosion
- Worker accidents
- Sanitation disease hazards
- Insect vector disease hazards
- Hazardous materials handling
- Dust/odors/fumes
- Explosion/fire hazards/hazardous materials spills

- Noise/vibration hazards
- Quarrying/blasting hazards
- Traffic congestion
- Water pollution hazards
- Blockage of wildlife passageways

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VIII. INDEX

designed to provide a scientific information base for the sustainable management of coastal resources in San Miguel Bay.

The objectives of the project were:

- to assess the status and exploitation/utilization of the fishery resources in San Miguel Bay;
- to evaluate the status and stresses/impacts on critical habitats (i.e., water quality) of consequence to the "health" of the fishery resources;
- to assess the socioeconomics of the fisheries and the general socioeconomic/development framework within which it operates; and,
- to elaborate feasible management options, guidelines and strategies (including feasible investment opportunities for alternative livelihood) that maximize benefits from fishery resources utilization/exploitation and minimize sectoral conflicts and/or incompatibilities.

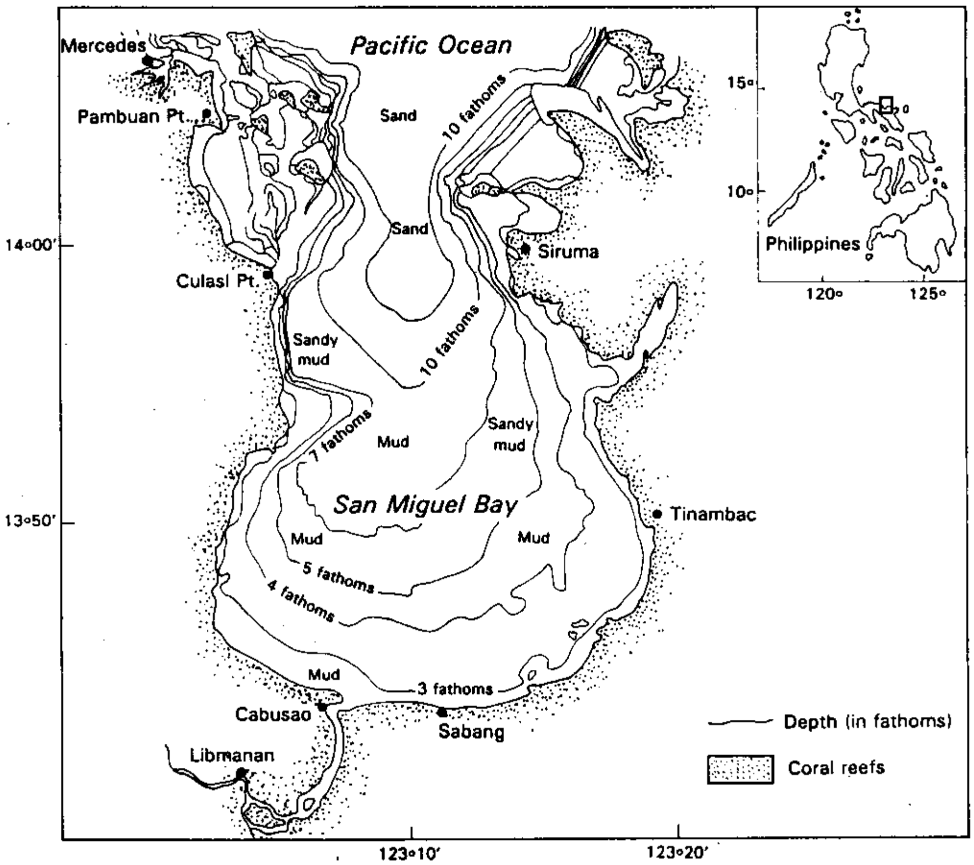

Figure 1. Map of San Miguel Bay, showing bathymetry and sediments.

Project Design and Focus

Given the multidisciplinary approach of the project, five interrelated research components were implemented as follows:

1. **Situational analysis** reviewed existing (both published and unpublished) information relevant to fisheries and other coastal resources. This task also included on-site visits, bathymetric mapping, mapping of coastal habitats using satellite imager and interviews with key informants. A multi-sectoral workshop was also conducted to discuss the preliminary findings and identify key issues related to fisheries management.
2. **Capture fisheries assessment** had two tasks: municipal and commercial fisheries monitoring. Municipal/artisanal gears were monitored for one year with emphasis on total catch and catch per unit effort, species composition of the catch, gear designs and area and time of operation. Three major commercial gears (large trawl, medium trawl and ring net) were also monitored for one year. Relevant information similar to municipal fisheries monitoring was also gathered for the commercial fisheries monitoring.
3. **Ecological habitat assessment** was composed of five tasks: (a) physical oceanographic studies to determine the circulation and dispersion patterns of the bay using a two-dimensional transport model; (b) water quality baseline studies to monitor general water quality parameters (transparency, suspended solids, temperature, dissolved oxygen, salinity and pH), pollution indicators (coliform, pesticides, nutrients and heavy metal content), and productivity (gross production, respiration, chlorophyll-a for phytoplankton and zooplankton biomass); (c) assessment of coral reefs (benthic life forms and reef fishes); (d) assessment of algal and seagrass beds (to assess percentage cover, species composition, biomass and zonation of seagrass and algal beds); and (e) assessment of mangroves.
4. **Socioeconomic and policy analysis** had two tasks: analysis of the socioeconomic facets of the fishery; and analysis of the ecological-socioeconomic interrelationships.
5. **Integration of results and management implications** had two tasks: development of a computerized database system to ensure that all project data are properly stored and easily retrieved for analysis; and assessment of management implications/options.

The REA for San Miguel Bay provided the following outputs as a basis of the formulation of the ICFM plan:

(1) a coastal environmental profile which reviews relevant secondary information;
(2) Thirty-eight technical reports covering capture fisheries assessments, ecological, habitat assessments, socioeconomic and policy analysis and assessments of resource management options;
(3) a computerized project database; and,
(4) an integrated coastal fisheries management (ICFM) plan for the bay. This plan is a result of collaborative efforts among government agencies, management organizations, private groups and other concerned individuals through the Interim

Planning Committee and later the San Miguel Bay Management Council.

The Planning Process

The process in the formulation of the ICFM Plan adopted the multisectoral "overreaching" framework shown in Figure 2. This approach offers the following advantages: it provides a fuller appreciation of development impacts on the aquatic resources or environment as fish production media; it allows an expansion of the scope for feasible management options/interventions; and it gives a better evaluation of the extent that fisheries management goals are being attained.

Figure 3 gives a more detailed description of the framework covering interrelationships between fisheries and other components of the human and natural life support dimensions. The framework adopts the principle that the "healthier" the status of the habitats/environment, then the "healthier" the resources are on which fishing depends. This conservatism dictates that the habitats or ecological integrity be maintained until positive/negative interrelation issues are resolved.

The ICFM plan has several features. First, its formulation was interactive with the conduct of the research activities and includes consultation with the municipal planning and development coordinators of the seven coastal municipalities, including planning officers of Camarines Sur and Camarines Norte, and of the National Economic Development Authority regional and central offices, and other agencies like the Housing and Land Use Regulatory Board.

Second, the planning mode was consultative, i.e., a workshop presenting the coastal environmental profile of San Miguel Bay to resource managers and decisionmakers was held.

Third, planning was not done in isolation, i.e., the ICFM plan was developed in the context of other operating plans. The preparation of the ICFM plan took into account the four planning hierarchies: national, regional, provincial and municipal. At each level, there are three types of plans which operate:

(1) the physical or land use plans, which are basically spatial in focus;

(2) the development plans, which are economic in emphasis;

(3) the agriculture sector plan and fisheries subsector plans, which are directly relevant to the ICFM plan.

Fourth, planning attempted to systematize the process of evaluating the possible management interventions (in terms of programs and projects) in light of the identified fisheries problems. The method adopted was decision analysis. This combines technical assessment of experts and values or preferences of decisionmakers to determine "utility" of alternatives/interventions.

Fifth, management planning was done in a "collaborative" mode between the San Miguel Bay Management Council (SMBMC) and ICLARM. The SMBMC formed the Interim Planning Committee (IPC) to work with ICLARM in developing the plan.

The Management Plan

Non-optimal management of the bay's fisheries is the main problem in San Miguel Bay (Figure 4). A total of 19 issues grouped under five categories were diagnosed during the research and planning process.

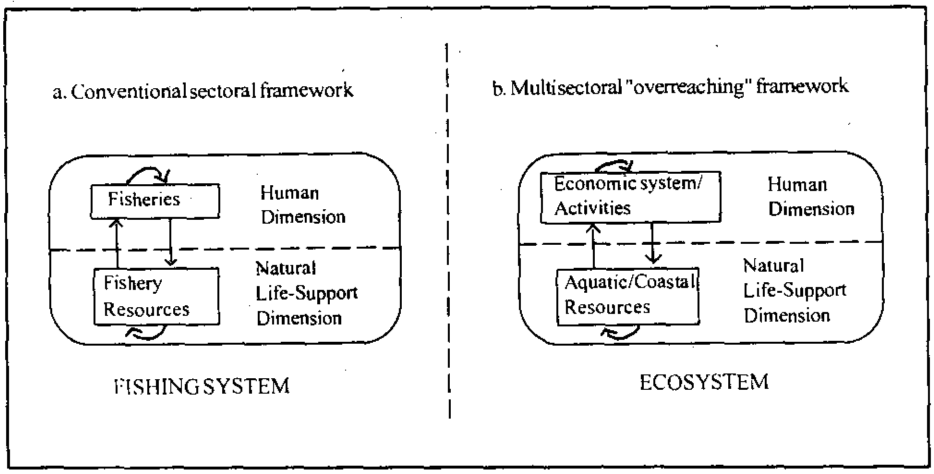

Figure 2. Evolution of the conceptual framework for addressing fisheries development management from a sectoral (a) to a more holistic, cross sectoral (b) perspective.

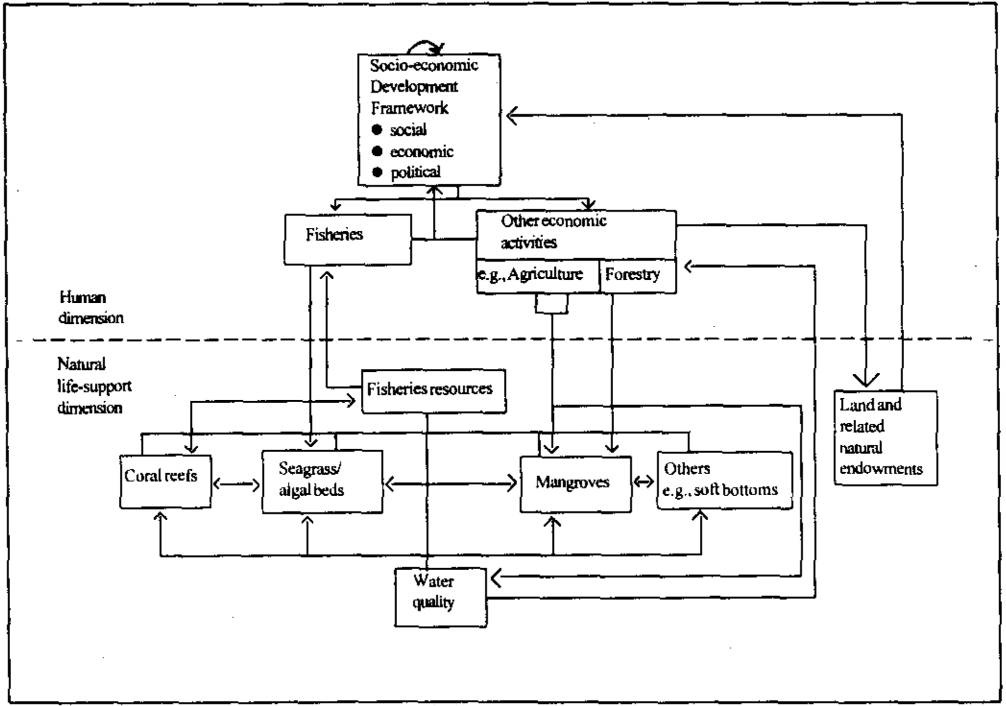

Figure 3. Schematic representation of interrelations between fisheries and other components of the human life-support dimensions.

Ecological issues include resource exploitation and habitat degradation problems, and cover the rate and manner of exploitation of coastal resources (principally fisheries) and man-induced stresses on the natural state of the coastal zone that sustains fisheries.

Economic issues, on the other hand, include the depressed returns from fishing operations and problems (i.e., lack of alternative livelihood, poor infrastructure and inefficient marketing) related to the need to reduce fishing effort.

Social issues deal mainly with equity considerations while the **political and administrative issues** cover constraints to effective implementation of management interventions in the bay.

Given these issues, interventions were formulated, evaluated and subsequently incorporated in the ICFM Plan for San Miguel Bay. A total of 26 projects were deemed of highest utility and included in the plan (Table 1). These are classified into five programs: organizational development; fisheries management; environmental protection; alternative livelihood; and support infrastructure. The implementation and monitoring strategies, arrangements and resource requirements for these projects are detailed in the plan.

Table 1. Projects included in the San Miguel Bay Integrated Coastal Fisheries Management Plan.

Organizational Development Projects
- Operation of the San Miguel Bay Management Council (SMBMC)
- Institutional development for the SMBMC
- Upgrading resource and environmental assessment/monitoring capability
- Improvement of law enforcement capabilities
- Information and education campaign

Fisheries Management Projects
- Enactment of an inter-municipal resolution to ban commercial fishing
- Phase-out of municipal trawlers
- Improvement of the fisheries licensing system
- Marine sanctuaries

Environmental Protection Projects
- Mangrove reforestation
- Upland reforestation
- Stabilization of critical agricultural lands

Alternative Livelihood Projects
- Swine-fattening
- Chicken production
- Goat-fattening
- Small-scale tomato gardening
- Small-scale eggplant gardening
- Small-scale pepper gardening
- Mud crab-fattening
- Oyster culture
- Mussel culture
- Fish processing (sun drying)

Support Infrastructure Projects
- Establishment of ice plant and storage facility
- Improvement of the Mercedes fish port
- Improvement of the Calabanga jetty
- Construction of road between Siruma and Tinambac

Conclusion

Our experience in San Miguel Bay shows that an integrated, multidisciplinary and multi sectoral approach allows fuller evaluation of the issues and impacts on fisheries and a more comprehensive evaluation of appropriate management strategies and interventions. Such an approach best promotes sustainability of fisheries and benefits derived from it. Appropriate packaging of research results into implementable programs of action (mindful of the institutional/administrative context) assures better utilization of research results and recommendations.

The involvement of main stakeholders at key decision nodes facilitated formulation and adoption of the ICFM Plan. The IPC prepared an integrated coastal fisheries management plan with the assistance of ICLARM staff. Members of the IPC include major stakeholders such as local government units and non government organizations. Decision analysis was used as the structuring and integrating tool of the multi-objective evaluation process. Systematic analysis of objectives, problems and alternatives structured the debate and facilitated the formulation of consensus among many parties. The resulting management plan is now being implemented over a five year time frame by SMBMC.■

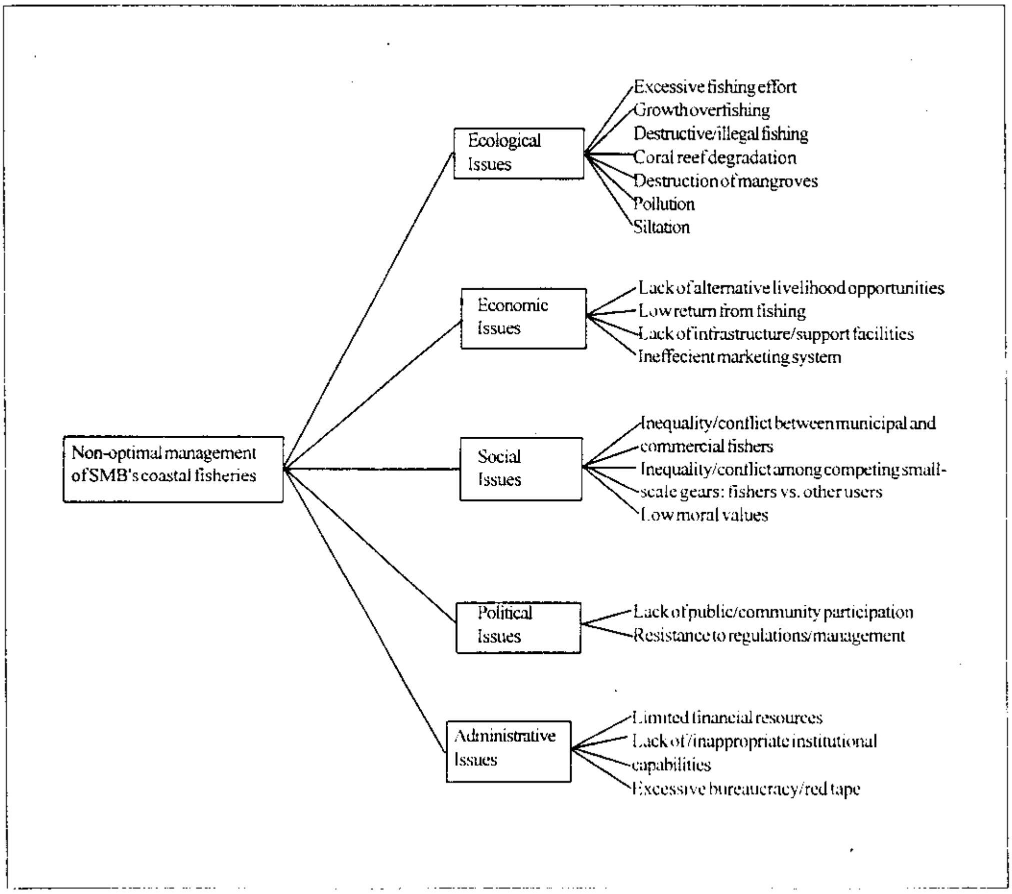

Figure 4. Key fisheries management issues in San Miguel Bay

ABOUT THE EDITORS/AUTHORS

Richard A. Carpenter, M.A., Organic Chemistry, University of Missouri, 1949. He came to the Environment and Policy Institute in 1977 from the National Academy of Sciences/National Research Council where he was executive director of the Commission on Natural Resources. Before establishing that office in 1972, he was chief of the Environmental Policy Division of the Congressional Research Service, Library of Congress. He contributed to the passage and implementation of legislation including the National Environmental Policy Act, which generated the environmental impact statement process in the United States. He began his career as a chemist and has obtained patents in the field. At the East-West Center, Mr. Carpenter has planned and supervised a continuing series of multinational projects in adapting environmental impact assessment and related management information methods to developing country situations. He is a frequent consultant to the World Bank, Asian Development Bank, and the United Nations Development Programme. He also serves as Board Chairman of the Pacific Consortium for Hazardous Waste Research.

James E. Maragos, Ph.D., Oceanography, University of Hawaii, 1972; B.A., Zoology, University of California at Riverside, 1966. He has worked in many tropical Pacific and Asian islands for more than two decades as an instructor, researcher, environmental consultant, and government official. For 15 years, he has served as chief of the Corps of Engineers' Pacific environmental office in Honolulu and was responsible for environmental documentation and planning for several hundred projects. He has authored publications in many fields: atoll geology, coral ecology, taxonomy, zoogeography, pollution and restoration, new ecosystem-based water quality standards, and new methodologies for coastal resource management and planning. Dr. Maragos has served as advisor or associate for many agencies, governments, and international organizations.

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