VOL. 1 3583 PN-AAP-436/62

ISN-33716

PREFACE

This workbook, in two volumes, presents the papers of the second International Seminar on Principles of Environmental Management in Developing Countries, held from 9 to 20 June 1980. The seminar was conducted by the International Environmental Management Institute of Environmental Research & Technology, Inc.

The purpose of the seminar is to strengthen the environmental management, planning, and analytical skills of top-level policy makers and administrators concerned with environmental protection during economic development in developing countries. The seminar presents general principles of environmental management through papers and discussions that reflect years of experience by practicing experts assisting governmental and industrial clients in developing workable solutions to environmental problems.

The papers do not necessarily include all the considerations presented during the seminar. Because of its purpose and design, the workbook should be used as a reference guide rather than a textbook.

The seminar is offered by Environmental Research & Technology, Inc. as a private initiative undertaken without contract or grant support.

Please address your comments or inquiries to the author or to:

John Whitman
International Environmental Management Institute
Environmental Research & Technology, Inc.
696 Virginia Road
Concord, Massachusetts 01742 U.S.A.

Telephone: (617) 369-8910
Telex: 923 335 ENVIRORES CNCM

Copyright © 1980 by International Environmental Management Institute

International Seminar on Principles of Environmental Management in Developing Countries, 9 to 20 June 1980, Concord, Massachusetts, USA

FACULTY

ERT Faculty:

- Dr. Janice Baker: Senior Program Manager at ERT. Responsible for multidisciplinary projects including environmental impact assessments of major industries such as paper mills, power plants, and chemical plants.
- Mr. James Barnes: Director of ERT's Earth Resources Studies Section. Expert in the design and analysis of remote sensing and aerial photography systems and data.
- Mr. David Chang: Vice President and Director of the International Group at ERT. Broad experience includes technical studies involving agricultural modeling and atmospheric analysis.
- Mr. Alberto Costales: Manager of the Latin American Division at ERT. Responsible for developing and implementing a broad range of multidisciplinary and technical projects in Latin America.
- Dr. William Duvel: Senior Program Manager at ERT. Responsible for the development and supervision of major environmental programs, including wastewater treatment, stream pollution surveys, environmental impact statements, facility siting, water quality management planning, and solid/hazardous waste disposal.
- Dr. Bruce Egan: Vice President and General Manager, Air Quality Center at ERT. Leads the Air Quality Center, responsible for providing air quality consulting services and the development and application of air pollution transport and dispersion models.
- Sanford Gaines, Esq.: Assistant Environmental Counsel at ERT. Responsible for providing legal advice and opinion over the complete range of environmental services provided by ERT, including the preparation of expert testimony for hearings and court proceedings.
- Dr. Norman Gaut: President of ERT. Expert in the organization and management of multidisciplinary environmental groups. Conceived and implemented large scale environmental monitoring programs.
- Ms. Barbara Goldsmith: Manager, Program Development, Policy Analysis Division of ERT. Responsible for directing projects on national and international environmental and energy policy issues, including assessing the effects of national environmental regulation on business and industry.
- Mr. James Huston: General Manager, Satellite Information Services at ERT. Mr. Huston is responsible for the design and development of satellite communications applications to large-scale environmental management, including monitoring of water quality over broad geographic regions by in situ instrumentation linked by communications satellites.

ERT Faculty, continued:

- Dr. James Mahoney: Senior Vice President of ERT. Expert in the public policy aspects of environmental regulations. Environmental advisor to major industrial sector groups and consultant to the World Health Organization, World Meteorological Organization, and Organization for Economic Cooperation and Development.
- Dr. Russell Moore: Section Manager at ERT. Responsible for developing and administrating a corporate section specializing in mining analysis and reclamation. Expert in surface mining and reclamation techniques and impacts.
- Mr. Anthony Sacco: Manager of ERT Calibration Services. Expert in the calibration and development of pollution monitoring instrumentation.
- Dr. Leigh Short: Director of ERT's Environmental Engineering Group. Expert in the environmental aspects of the oil industry and the technical and administrative designs and procedures for environmental controls for industry.
- Mr. Michael Smallwood: Environmental Scientist in the Earth Resources Studies Section of ERT. Responsible for the daily operation of the remote sensing laboratory to insure accurate and timely photographic data analysis, data transfer to base maps, and statistical compilation of resource information.
- Mr. John Whitman: Director of the International Environmental Management Institute at ERT. Responsible for designing and implementing strategies that apply educational techniques to solve environmental problems and to ensure successful transfer of technology in international programs.
- Dr. Hugh Willis: Manager of the Senior Program Management Staff at ERT. Responsible for managing and directing large-scale, multidisciplinary studies, including environmental impact assessments of major industrial and public sector projects, including petrochemical complexes, paper mills, and long-distance pipelines.

Visiting Faculty:

- Mr. Robert Bartlett: Vice President, Engineering, Technology World, Inc. Responsible for the design and development of a variety of computer-based electronic systems, currently managing the deployment of a large water monitoring system in Kuwait.
- Dr. Noel Brown: Director, New York Liaison Office and Special Assistant to the Executive Director, United Nations Environment Program.
- Mr. Jozsef Buky: Senior Sanitary Engineer, The World Bank.
- Mr. J. Clive Collins: Agricultural Advisor, Irrigated Field Crops, The World Bank.

Visiting Faculty, continued:

- Dr. Dominic DiToro: Associate Professor, Environmental Engineering and Science Program, Manhattan College, and consultant to ERT.
- Ms. Cynthia Green: Deputy Director, Education and Public Policy, Population Crisis Committee.
- Dr. James Lee: Director, Office of Environmental Affairs, The World Bank.
- Dr. Dade Moeller: Professor and Chairman, Department of Environmental Health Sciences, School of Public Health, Harvard University.
- Mr. Hernan Reitze: Environmental Advisor, Office of Environmental Affairs, The World Bank.
- Mr. William Ruckelshaus, Esq.: Senior Vice President, Weyerhaeuser Company. First Administrator of the U.S. Environmental Protection Agency.
- Dr. Eric Stork: Visiting Professor, Technology and Public Policy, Automotive Transportation Center, Institute for Interdisciplinary Engineering Studies, Purdue University.

TABLE OF CONTENTS

Volume 1

PREFACE

ACKNOWLEDGMENTS

SECTION	TAB
Introduction	1
Opening Addresses:	
• Environment, Development and Human Health	2
• Conservation: A Management Challenge of the Eighties	3
Definition of Environmental Issues	4
Benefit/Cost Analysis of Environmental Programs	5
The Role of Environmental Standards and Regulations in the Management of Industrial Development	6
Environmental Monitoring:	
• Principles of Environmental Monitoring	7
• Remote Sensing	8
• Air Monitoring	9
• Water Monitoring	10
• Case Study: Industrial Zone Water Monitoring System in Kuwait	
Environmental Impact Assessment Methodology	11
The World Bank and the Environment:	
• Agriculture	12
• Water Supply and Waste Disposal	13
• Environmental Policies and Procedures	14
World Population Growth	15
Environmental Health: Radiation Protection	16
• Case Study: Environmental Consequences of Electrical Power Generation by Hydro-electric, Nuclear, and Fossil Fuels	

Volume 2

SECTION	TAB
Sector Considerations:	
• Transportation: Issues Related to Control of Automotive Air Pollution	17
• Petroleum	18
• Extraction	19
Solid Waste Management in Developing Countries	20
Environmental Modeling:	
• Air Modeling	21
• Water Modeling	22
Advanced Environmental Information Systems:	23
• Case Study: Hydrologic Information Service	
Environmental Education and Training	24
ADMINISTRATIVE CASE STUDIES:	
• William D. Ruckelshaus and the Environmental Protection Agency	25
• Develotech Siting Commission (A)	26
• Develotech Siting Commission (B)	27
LIST OF PARTICIPANTS	28
SEMINAR SCHEDULE	29

ACKNOWLEDGMENTS

The International Seminar on Principles of Environmental Management in Developing Countries is a program independently offered by Environmental Research & Technology, Inc. (ERT), a subsidiary of COMSAT (Communications Satellite Corporation).

We would like to acknowledge and thank the following organizations for their contributions to this effort to strengthen environmental management in the developing world, either by sponsoring the attendance of scholarship participants or by providing speakers to take part in the 1979 or 1980 sessions.

- Canadian International Development Agency
- Economic Commission for Latin America
- Food and Agriculture Organization of the United Nations
- German Marshall Fund of the United States
- United Nations Environment Program
- United States Agency for International Development
- United States International Communication Agency
- The World Bank
- World Health Organization

We also wish to thank the members of our International Advisory Board for their voluntary assistance in guiding the development of the seminar:

N. Brown
Jamaica

N. Castaneda
Mexico

C.A. Cochrane
United Kingdom

C. Jeanneret
Canada

M. Kassas
Egypt

F. Lopez de Alba
Mexico

B. Lundholm
Sweden

We would also like to pay particular thanks to Dianne Belanger and Mary Gallagher for their immense contribution in handling the varying needs of over fifty participants from more than 20 countries and international organizations on a daily basis for two weeks with the greatest professional ability, effectiveness, and good humor. All the participants join us in saluting Dianne and Mary.

Finally, we thank the many hundreds of other ERT employees for their cooperation and contribution during the seminar; indeed, the participants were impressed by such a large group of enthusiastic and first-rate professionals working on issues of environmental management.

Norman E. Gaut, President
Environmental Research & Technology, Inc.

James R. Mahoney, Senior Vice President
Environmental Research & Technology, Inc.

John R. Whitman, Director
International Environmental Management Institute

June 1980

INTRODUCTION TO THE SEMINAR

John Whitman
Director
International Environmental Management Institute

June 1980

International Environmental Management Institute
ENVIRONMENTAL RESEARCH & TECHNOLOGY, INC.
Concord, Massachusetts USA

INTRODUCTION TO THE SEMINAR

1. Introduction

Environmental management deals with applying certain principles, techniques, and strategies to prevent environmental problems and to solve those that arise.

Local, regional, and worldwide trends, including a growing population, expanding industrial activity, and changing resource utilization patterns are making environmental management a challenge of increasing complexity and difficulty. However, along with this challenge, we are gaining new experience and developing new and appropriate technologies to help manage environmental problems effectively.

According to the United Nations, in 1972 eleven countries had some form of environmental protection agency. In 1980, one hundred and two countries have ministries, secretaries, departments or other agencies responsible for environmental protection. Many nations, international organizations, and corporations are responding to the need for environmental management by designating officials to be responsible for environmental affairs. New environmental ministries are being established; existing governmental departments are assuming new environmental duties; international financial institutions are forming environmental policies and procedures; and corporations are designating environmental officers.

Environmental protection is rapidly becoming an important issue, not necessarily as a result of environmental laws and regulations, but because sound environmental planning and control makes great sense in financial, technical, and social terms.

In a general sense, environmental management is a component of all of our lives, professions, and occupations. If through our daily living and our jobs we are not having a direct impact on nature, nature is having an impact on us, whether gently through changing seasons, or violently, such as in natural disasters.

In a professional sense, environmental management is composed of knowledge and skills drawn from a broad range of disciplines, including the sciences, technology, law, economics, and the other social sciences. The discipline of management, as an art and science itself, is also crucial to effective environmental problem-solving. Management skills can be applied to formulate goals and objectives, anticipate and identify problems, plan a strategy to accomplish desired ends, and utilize human, financial, and technical resources to implement the strategy.

The disciplines from which environmental management draws knowledge and skills are fairly well advanced. Yet the needs for skilled and effective environmental managers are pressing indeed. This calls for programs that can strengthen and upgrade the capabilities of current and

upcoming environmental policy makers and administrators -- programs that can accelerate their understanding of the issues and acquaint them with newly emerging policy, administrative, and technical options that may help their decisions and actions prove effective.

2. The Purpose and Organization of the International Seminar

The purpose of the seminar is to strengthen the planning, analytical, and management skills of policy makers and administrators concerned with environmental protection during economic development in developing countries.

The design and content of the seminar have been selected to acquaint the top official with the key principles, concepts, issues, and vocabulary basic to environmental management. The seminar is not designed as a technical course. It is meant to be understood by policy makers and administrators with varying backgrounds of education and experience.

These principles of environmental management are generally presented through an integration of different topics. The selected topics do not by any means exhaust the range of topics to which environmental management can be applied. Rather, given obvious constraints, these topics were assembled as representative ones. The presentations and discussions around these topics should help participants generalize from the specific topics to other areas of concern.

The sessions begin with two opening addresses. The first deals with environment, development, and the most basic criterion for environmental quality: human health. The second describes a newly formulated "World Conservation Strategy," which sets forth recommendations for national and international action in environmental management.

The topics that follow are:

- Definition of Environmental Issues
- Benefit/Cost Analysis of Environmental Programs
- Standards and Regulations
- Environmental Monitoring, including Air and Water Monitoring and Remote Sensing
- Environmental Impact Assessment Methodology
- The World Bank Experience in Agriculture, Water and Waste, and Environmental Policies and Procedures
- Environmental Health, specifically Radiation Protection
- Sectoral Considerations in Transportation, Petroleum and Extraction
- Solid Waste Management
- Air and Water Modeling
- Environmental Education and Training

These topics are presented in a way that will acquaint all participants with the important concepts and issues through morning lectures, followed by questions and answers among the entire group. Afternoons are spent by the participants in smaller discussion groups around the morning topics of particular interest to them.

To stimulate and encourage discussion of administrative and technical considerations, three administrative case studies are used. "William D. Ruckelshaus and the Environmental Protection Agency" recounts the experience of Mr. Ruckelshaus as the first administrator of the U.S. EPA. This case study may prove especially valuable to newly appointed environmental ministers. While the study reflects the U.S. experience, it is helpful in leading discussion to reasons the U.S. experience may or may not be appropriate to other countries with different economic, political, social, cultural, and technical realities.

"Develotech Siting Commission, Part A" is a fictitious story about a newly appointed deputy minister of the environment who must help his minister achieve credibility among the public and industry in a country with very serious and pressing environmental and economic problems.

"Develotech Siting Commission, Part B" is a continuation of Part A, focusing on the problem of where to find the most environmentally sound location for a new, $25 billion industrial complex. A decision must be made, and time is very short.

Participants should read these case studies within the first two days, in order to become familiar with the issues they raise. Discussion during the next two weeks will refer to these issues. On the final Thursday of the program, Mr. Ruckelshaus will join the group to lead a discussion of the importance of administrative strategy in environmental management at the national level.

A site visit is scheduled to Fitchburg, Massachusetts, where participants will see how a small town is both dependent on and affected by the main industrial activity: pulp and paper. Tours are arranged in the Litton Industries Pulp and Paper Mill and the Fitchburg Waste and Water Treatment Facility.

A well rounded consideration of environmental management would not be complete without amenities and the arts. Dinners, a dolphin show, a baseball game, and a visit to hear the Boston Pops are included in the program to help make this learning experience an enjoyable and memorable one.

3. Evaluation

A key principle further discussed in the education and training session is the importance of evaluation. Participants will be requested to evaluate the seminar's various aspects. Results will be made available

12

following the seminar (individual results will be anonymous), and will be used to improve future programs.

4. Final Word

The seminar is a collective effort among all of us. Please do not hesitate to bring thoughts, suggestions, and questions to my attention at any time.

Welcome to the seminar!

13

ENVIRONMENT, DEVELOPMENT AND HUMAN HEALTH

Dr. James Lee
Director
Office of Environmental Affairs
The World Bank

9 June 1980

Transcription of the Opening Address
Seminar on Principles of Environmental Management
in Developing Countries

Environmental Research & Technology, Inc.
Concord, Massachusetts USA

14

Environment, Development and Human Health

Dr. James Lee, Director
Office of Environmental Affairs
The World Bank

My task this morning is to set the scene, as it were, to paint the background against which you will be considering the reciprocal interaction of the environment and development and the fate and the future of mankind in this dynamic interplay. I intend to restrict my remarks to the effects of environmental change on the psyche and soma of man, and particularly, how these changes being wrought by development impact on physical and mental health and social well-being in the still developing countries.

Let me this morning quickly set the scene as it pertains to much of the world's population. One certainly must begin with a candid appraisal of the state of development throughout most of the developing world despite the enormous strides that have been made in recent years. Simply stated, it is unacceptable and growing worse. It is unacceptable because hundreds upon hundreds of millions of people are living at levels of deprivation which simply cannot be reconciled with any rational definition of human decency. Throughout the developing nations hunger and malnutrition are sapping energy, are stunting bodies and are slowing minds. Illiteracy is locking out learning and paralyzing opportunity. Unemployment is not only robbing men and women of the minimal means to make their way but leaves their pride broken and their ambition atrophied. Wholly preventable diseases are injuring infants or killing children and are aging adults long before their time. In sum, these hundreds upon hundreds of millions of human lives are being threatened, narrowed, eroded, shortened and finally terminated by a pervasive and persistent poverty that degrades and destroys all that it touches. Someone once said that poverty is our greatest and most serious form of pollution.

This picture is not exaggerated. Throughout the developing world the estimates are that well over a billion human beings are hungry or malnourished. There are well in excess of one hundred million more adult illiterates than there were several decades ago. Underemployment and unemployment entrap roughly one out of four in the labor force. Infant and child mortality is four times greater than it is in the more affluent world and life expectancy is 40% shorter. To alleviate pain and arrest disease there are in some developing countries fewer than one doctor for every fifty thousand people, compared to one for six hundred or less in Sweden. Nearly two billion people harbor intestinal parasites and illnesses disrupt normal activities for roughly one tenth of a person's time. Recurrent illnesses disrupt economic activity often at crucial times such as the planting and harvesting seasons. These facts, and many more similar ones could be cited, are neither pleasant nor comfortable, but they are facts and they symbolize the lives of three quarters or more of the human race, and these numbers are steadily increasing. A recent report, such as the World Development Report, which is issued by the World Bank, the Brandt Commission Report entitled "North South Dialogue, A Program for Survival", the "Year 2000 Report" soon to be released by the United States Government, and the forthcoming "State of the

Environment Report" to be issued by UNEP -- these and others are evidence of the wide-ranging discussion surrounding the nature, meaning and purpose of development goals occurring in the world today. And much of this discussion stems from the disillusion among third world nations arising from the failure to achieve targeted economic growth rates during the last two decades. This disillusion is presently giving way to despair marked by the growing ranks of the poverty stricken, the continuing unequal distribution of economic benefits between and within nations, the struggle to achieve national self reliance to maintain cultural identity to protect the life supporting environment and its resources that are essential to continued, sustainable development.

These attempts to achieve even incremental improvements in the quality of life continue to be frustrated. The penalties of this prolonged and burgeoning state of world economic affairs are now virtually unavoidable, for restlessness has edged towards rebellion and reason has, in some places, succumbed to violence, and it may well prove to be catastrophically costly to both rich and poor countries alike.

You are assembled in this Seminar ostensibly because you each in your own country in your own way is trying to do something about our collective plight. Development is essential to our efforts. It cannot be stopped, it must not be stopped, and I am convinced that environmental and developmental objectives can be pursued in mutual support, for, in point of fact, they are interdependent.

In my opening remarks, I alluded to the reciprocal relationships between environment and development. That such reciprocal relationships also exist between man and his environment is at the very heart of our concern for how the man/environment relationship shapes and determines his health status and how the development process, which brings about changes in these relationships, is likewise a health determinant. For encompassing all things external to the human organism the environment, by benefit or by threat, obviously plays a predominant role in man's health. Some of the adverse effects which I have just mentioned are long standing. They reflect the impact of continuing low socio-economic development. Denied an environmental milieu in which to live in dignity, bereft of adequate access to basic shelter, water, sanitation, waste disposal, transportation and health care, often forced to exist on the margin of the essentials for physiological functioning, they constitute the billions who are chronically sick and debilitated. At the same time in our well-meaning efforts to alleviate these conditions of economic and social deprivation through the provision of economic development, we inadvertently and all too often fail to realize that the very process and consequences of development are not without their own threats to physical and mental health and social well being.

The unforeseen consequences of changes in the man/environment relationships stem in great measure from our traditional regard for the environment as a series of isolated compartments rather than as a highly integrated continuum of strongly interdependent factors. Multiple factors act singly or in combination; they can act sequentially or simultaneously in their threats to the health of man.

16

The evolution of the human race from relatively simple biological systems to its present complex state has been the product of the interaction between the total environment and inheritable traits. Slowly occurring changes in the natural environment over the two million or more years of human evolution allowed biological and later cultural adaptation to take place. Now the soon to be six billion humans are faced with environmental changes of such magnitude and rapidity as to seriously challenge their adaptive mechanisms. It may come as something of a surprise to you that the internal regulating mechanisms, the internal regulating properties of man evolved and matured over the millions of years during which external selection inducing changes were slow and naturally occurring. The regulatory mechanisms to achieve the constancy of the internal environment of each of us here this morning is genetically related to the enormously greater period of man's evolutionary history quite unlike that which he faces today.

Let me digress for just a moment. If we were to look at a time line of man's evolution beginning over two million years ago, we find that man's evolutionary history over this long period of time involved a naturally occurring environment to which he adapted through biological evolution, biological adaptation and later by cultural adaptation. The time that we are concerned with now is roughly five thousand years, merely a blip, a mere second on the human evolutionary clock.

So increasingly crammed and crowded into an urban setting, assaulted by environmental stimuli associated with an environmental milieu fashioned largely over the past two hundred years, a mere fraction of time on the human evolutionary clock, we find today these urban and peri-urban dwellers to be ill equipped to successfully internalize the barrage of threats to internal homeostasis. What we see in fact, ladies and gentlemen, is contemporary man equipped with paleolithic hunter/gatherer genetic equipment facing up to an ambiance with which it has had no previous evolutionary experience. To the extent it fails to adapt, or maladapts, the result is organismic disfunction, and disintegration and pathogenesis of one kind or another is bound to ensue.

Well, so much for an all too brief review of the ecology of disease. It's a fascinating subject. When I tell my colleagues in the Bank that we cannot use a certain herbicide, we cannot use a certain pesticide or we cannot use a certain whatever the case may be, they say, "Well, why is that?" The truth of the matter is that man is not equipped to detoxify or internalize properly, or to adapt to that threat. When I say to my friends at the industrial department at the Bank, only so much fluorides can be released; that, and no more, the question is,"Why is that?" You know how toxic fluorides are and that man is unable to detoxify them; unable to develop in that short period of time the necessary enzymes for that detoxification to take place, so he is really ill-equipped; he is paleolithic, hunter/gatherer man with genetic equipment that was given to him over this long period of time finding himself here today the recipient of a barrage of multiple, synergistic potentiating insults to the internal constancy and homeostasis of the human organism.

What I want to leave with you this morning is a concept: Do not think that more and more development, of the kind we are seemingly caught up in, will solve the world's

17

social ills. As we will learn from our next speaker, development that continues on the patterns of the past, namely, overconsumption, environmental degradation, resource depletion, will likewise not be without its threats to the very people that it seeks to help. While admittedly we do not fully understand the implications of the massive tinkering with the global ecology in which we are engaged, I think my profession does understand a little better implications for human health that are arising out of the changes occurring in the man/environment relationships which ensue.

The ecologists have a saying: "You cannot do just one thing." But too often developers and practitioners and physicians have yet to understand that axiom. Many of our actions motivated by a desire to improve the quality of life have, to our detriment, caused unexpected consequences because we fail to recognize or to admit to ourselves the essential, inter-relatedness of all things.

My portrayal of man as a passive entity in an evolutionary drama totally dominated by the environment is only one side of the evolutionary process, for evolution is more than the molding of entities by their surroundings. In the case of man, it also involves the ability of these entities to interact with, to adapt to and to change environments in creative, intelligent and novel ways, and many of you are engaged in that task. Yet, it seems to me as I travel around the world that for the billions of the poverty stricken, they see their environments being changed and shaped in ways that are inimicable to their hopes and aspirations, and they may soon provide clear evidence to what Teilhard de Chardin saw years ago as a possibility when he said, "Mankind is suddenly falling out of love with its own destiny." To the extent that development fails to transform the possibilities into realities, mankind sees more this image of the future as an illusion and not an element in the chain of causality.

The environmental crisis, of which you hear much, and of which you will hear more this week, of which my colleague from UNEP will shortly be speaking, the environmental crisis it seems to me is fundamentally a crisis in human evolution. Modern man stands at the crossroads. Continued geometric growth in human numbers, unbridled consumption of resources, pollution and death of ecological systems, morbidity and mortality evidencing global and staggering dimensions -- these have propelled mankind down a road of diminishing options. Alternatives suddenly will revolve around extinction or Orwellian regimentation, for we are witnesses to, it seems to me, a process of evolutionary retrogression wherein higher human values are destroyed in behalf of the fundamental value of biological survival.

Can this process be stopped and reversed? Yes. Will it? I am personally very doubtful, for it entails a reordering of presently held values and acceptance of man's true dependency on his environment and a new anthropocentric view that sees an individual's well being as dependent on the well being of both his social group and ecological support systems. As Professor Birch was wont to say, "Man left only with his self-interest, however enlightened, will not provide sufficient motivation for ecological survival." Yet, having said that, it is in the striving that we must persevere. And that is why we are gathered here. In the hope that singularly and collectively the very small incremental improvements that we can make in this direction will do two things. It will bring us time, much needed time. And hopefully by our small examples we can stimulate thinking that will be translated into larger and globally meaningful, more practical works.

As you've gathered, the bottom line of my remarks this morning is this: In a very few short years, certainly within all of your lifetimes, world population will number around six billion (barring a cataclysm of horrific dimensions) of which over three quarters will live in the still developing countries, and something in excess of fifty percent of those will live in an urban setting. If these peoples are not to have a view of the world as essentially meaningless in terms of their own individual situations, one abundantly clear factor in their resolve to strive and suffer for it will reside in their capacity to form a bond of identity with future generations. Sick and debilitated people existing in an environment that contributes to and reinforces that state cannot make that affirmation. And, moreover, they cannot make effective use of whatever development tools you place in their hands. The horizons of the poverty stricken are necessarily limited. Development in the absence of health is inconceivable and health without development is unattainable.

See to it, then, that when you leave this seminar and you go back to your countries or back to your institutions, see to it if you can that your development efforts recognize this reciprocity between man and his environment -- this reciprocal relationship, and make possible an improvement in health and not an added threat to the already afflicted.

19

CONSERVATION: A MANAGEMENT CHALLENGE FOR THE EIGHTIES

Dr. Noel J. Brown
Director
New York Liaison Office
United Nations Environment Program

June 1980

International Environmental Management Institute
ENVIRONMENTAL RESEARCH & TECHNOLOGY, INC.
Concord, Massachusetts USA

20

Thank you Mr. Chairman.

Distinguished colleagues, ladies and gentlemen.

Once again, the Executive Director of the United Nations Environment Programme has asked me to convey to you the greetings of the Programme and our best wishes for a successful seminar. We would also like to offer a word of commendation to the organizers for their initiatives and continuing commitment to training at a level which not only complements our programme, but also reinforces our work in a very significant way.

Mr. Chairman, as this is your first International Management Seminar in a relatively new decade, it might be appropriate to introduce my remarks this morning with a few observations that might tighten the context within which we will discuss the main theme, namely, conservation as a management option for the eighties. Such an approach, I believe, is necessary because of certain very disturbing trends and commentaries suggesting that with the passing of the seventies, environmentalism may have come to the end of its golden era. And that the world must now address the more dramatic, if more sectoral issues as energy, inflation, monetary stability and even the changing strategic equation of Western Asia -- in a word -- pending global emergence.

In a very thoughtful essay recently, U.S. News and World Report summarized the situation this way:

> The environmental movement, an important political force during the 1970's, is faltering -- with little prospect for an early resurgence.
>
> Boxed in by inflation, recession and the energy shortage, environmentalism actually could lose ground. Things are likely to get worse before they get better in the 1980's. Steady pressure in the name of energy development and inflation control will continue in the early 1980's to roll back some standards protecting the environment. Environmental causes and environmentalist candidates are faring poorly in elections. The once potent environmental lobby is losing much of its influence on Congress.

I suppose the underlying reasons for such conclusions may be the continued lack of understanding of man's changing relationship to his life support system and his modification of the environment in ways that will ultimately affect all his activities and social processes. It may also be due, in part, to a backlash to the apocalyptic environmentalism of those unable to distinguish between billboard pollution and ozone depletion; or the tendency to blame

21

environmentalists if not for the sins of the world, then at least for the ills of the economy. For example, in a recent editorial, the Wall Street Journal expressed its criticism this way: "the next time you wonder why economic growth is suffering because of the fanaticism of a few environmentalists then you know who to blame." What is more disturbing, however, is the fact that this kind of environmental illiteracy is likely to become all too fashionable. It is one thing, however, to question the "environmental extremism" of a few "fanatics" and quite another to ignore the fact that the central environmental imperative of the 1980's remains what it was in the 1970's -- namely, WHETHER THE NATURAL ORDER CAN LONG SUSTAIN THE HUMAN ENTERPRISE AND WHETHER THE CUMULATIVE POWER AT OUR COMMAND AND OUR IRREPRESSIBLE DRIVE FOR PROGRESS WILL SOMEHOW IMPEL US TO TRANSGRESS THOSE OUTER LIMITS ON WHICH THE CONTINUED STABILITY OF THE BIOSPHERE DEPENDS.

All available evidence points to the fact that there are unprecedented strains in the earth's natural systems and resource capacities and there is some question as to whether the critical tolerances around which these operate can be maintained without fundamental changes in our behavior styles of life and patterns on production and consumption as well as in our land and space use: hence the importance of seminars such as these.

What seems clear is that whereas we have the power to radically alter the biosphere, we lack the knowledge, and one might add -- the wisdom -- to control it. And therein lies one of our dilemmas.

It is in the face of such dilemmas environmentalists are likely to find that the challenges of the eighties are more subtle than the seventies, demanding a better understanding of the large natural systems of the earth -- many of which transcend national boundaries and, therefore, require broad international cooperative strategies for their management and protection.

It is to this more subtle agenda that UNEP is currently adjusting its own programme and refocussing its attention. Our agenda of concern includes:

I. UNDERSTANDING THE GREAT INTERLOCKING SYSTEMS OF AIR, WATER AND MINERALS OF THIS BIOGEOCHEMICAL CYCLE THAT NOURISH THE EARTH.

Such understanding is essential for any reliable assessment of the opportunities for enhancing the productive capacities of the planet and optimizing the use of its rapidly declining resources.

In a joint statement issued with the President of the Scientific Committee on Problems of the Environment (SCOPE), the Executive Director of UNEP, Dr. Mostafa K. Tolba, some months ago, was to warn that if, in the next few years, we can achieve a better comprehension of these biogeochemical cycles, then we shall have forged a powerful tool for identifying ways in which mankind can beneficially influence and utilize the resources of soil, vegetation, water and atmosphere. We shall also possess a means of assessing many of the potentially serious risks to the global environment which, so far, have been studied without an adequate general frame of references.

22

To do so, however, will demand expanded cooperation and greater commitment to basic studies involving many individual scientists, and will call for an integrated effort of many disciplines, including scientists from all the regions of the world. Continuation of efforts at the present level will be too little -- too late.

Perhaps the clearest example of this concern is to be found in one of these great cycles on which world attention has finally begun to focus; and here I refer to the carbon cycle, or more popularly, the CO^2 problem.

A number of recent reports have concluded that if present trends and projections continue in fossil fuels use, deforestation and the acceleration of the industrialization process, especially in the developing countries, then there is likely to be a doubling of carbon dioxide in the atmosphere early in the next century and that if a doubling does indeed occur then the so-called greenhouse effect, that is, the trapping of solar heat, and the warming of the atmosphere by several degrees, would result. World temperature would increase by an average of two to three degrees, and at higher altitudes in the polar regions, "the shift would be as much as 9 to 12 degrees," thereby causing a melting of the polar caps and the raising of sea-level by 15 feet or more, with devastating social and economic implications, particularly in terms of agricultural production and global food security.

What is significant here, however, is that, while there is broad agreement that the carbon dioxide problem is potentially serious and that governments should start dealing with it NOW - no one seems quite sure what is to be done or how to go about doing it -- and this issue remains fraught with uncertainty.

One dimension which is of particular relevance to the Third World is the implications of the carbon dioxide problem to their own development plans, which will undoubtedly involve an increase in fossil fuels use, particularly if the Lima target is to be realized, and the developing countries are to achieve a 25 percent share of the world's industrial capacity by the year 2000 -- their current share being 7 percent.

The question must eventually be asked -- on what energy base is this industrialization to proceed? In his Environment Day message of 1980, the Executive Director of UNEP suggested a policy of prudence and the acceleration of efforts that would reverse deforestation and promote alternative energy strategies together with environmental conservation measures.

While one may speculate on any number of reasonable alternative energy systems, it is doubtful that the developing countries can move too far away from a fossil-fuelled economy during the next two decades, and as most projections suggest, the growth of energy consumption in the Third World will be steeper than that of the developed countries during the same period. In the light of such a

prospect, the question undoubtedly will be asked -- what will be the impact of this increase of energy consumption, i.e. both fossil fuel and fuelwood, by developing countries on the carbon dioxide problem, and what realistic alternative will be available to the developing countries during the next two decades? Perhaps the United Nations Conference on New and Renewable Sources of Energy will provide some answers although one is not overly optimistic, given the immense difficulties in any kind of innovation in the energy field.

One perhaps naive option, if the carbon problem is as severe as projections show, would be the slowing down of energy consumption by developed countries thereby permitting corresponding increases on the part of the developing countries without increasing the net consumption by too large a percentage. But this kind of scenario, despite the dramatic upsurge in conservation thinking in the United States, may not be tenable and politically it would seem very questionable. For one thing, it would require at the very minimum some kind of global system for energy planning and budgeting and some mechanism for both assessing the state of the CO_2 situation and allocating energy resources accordingly. But the world seems some distance, even in the consideration of such an option. In any event, in relation to the CO_2 problem, there are serious environmental issues that must be factored -- properly costed and effectively managed -- and there are serious questions whether we now possess the capacity, mechanisms or policy to do this.

II. CONTROLLING THE CHEMICAL ENVIRONMENT: THE PESTICIDE AND HAZARDOUS WASTES ISSUES

It is generally agreed that world agricultural production must increase if a key goal of the New International Economic Order (NIEO) is to be realized. Implied in this is a need to expand dramatically world food production and reduce post harvest losses due to improper storage, mishandling and pests. It is here, I believe, that we might see certain trends in world pest management that hold serious implications for both environment and development.

In the 1979 State of the Environment Report, the Executive Director of UNEP focused on the issue of resistance to pesticides, and here again the implications are as disturbing as the dimension frightening. The report did not focus on the toxicity of pesticides, which is a major problem, as is well known; approximately 500,000 people a year are victims of pesticide poisoning -- especially among developing country populations, which, although not the largest consumers, tend to use these substances more intensely. Nor did the report address the current anarchy in the export trade and the fact that large quantities of pesticides on the world market are made for "Export Only"--the exporting government banning their use in the home country for any number of reasons. This state of affairs, as you know, has moved a number of developing countries to express alarm over the prospect that their regions may become dumping grounds for

chemicals known to be harmful and their populations used as guinea pigs. In this connection they have urged governments to take steps to ensure that potentially harmful chemicals, in whatever form or commodity, which are unsuitable for domestic purposes in the exporting countries, are not permitted to be exported without the knowledge and consent of appropriate authorities in the importing countries. And, in this connection, they requested the Executive Director to assist developing countries in developing and strengthening their capabilities for evaluating chemicals, foods, drugs and cosmetics being distributed in their countries. I know that at least the United States has responded in part, by requiring, under the Federal Pesticide Act of 1978, that foreign purchasers must be informed of any pesticide that cannot be sold or used in the United States, and such purchasers are required to sign an acknowledgment of their understanding of that fact.

While these dimensions are significant and undoubtedly have been treated in depth elsewhere, the Executive Director of UNEP chose to focus on the resistance to pesticides and the spectre of a pest resistant world. According to our report, some four billion pounds of pesticides are produced each year involving a trade representing $5 billion. In the United States alone the Pest Control Budget amounts to some $2.25 billion.

Now since World War II, the extensive use of chemicals for pest and vector control has been a principal factor in boosting agricultural production in many parts of the world and has enabled food and fibre production to stay roughly abreast of population growth -- or at least not to lag too far behind.

One of the unwanted effects of the repeated application of pesticides to pest populations has been the development of resistant strains and ultimately resistant populations.

An almost automatic response to resistance has been increasing the dosage, but this, in turn, has led to multiple resistance. In some cases, the evolution of double, triple and quadruple resistant strains are able to resist a wide range of compounds. Today, for example, some 400 species of insects and mites are resistant to pesticides -- more than twice as many as in 1965. This has led a number of scientists to fear that, in time, all pests are likely to develop a resistance to all types of pesticides. This, in turn, could adversely affect the efficiency and economy of pest control on a global scale with increasing deleterious effects on world health and world agricultural production.

Already we have seen symptoms of such a development with recurring epidemics of certain pests in various parts of the world. With the resurgence of malaria, for example, and the very sobering conclusions that despite our best technology, man has yet to eliminate a single pest; and everywhere the bugs are on the march again reclaiming ground lost in earlier pesticide battles, but now holding their own, and confident on winning the war or at least impairing man's ability to dominate the planet by himself.

But the obverse side of the coin is equally challenging; and there I refer to:

THE MANAGEMENT OF TOXIC WASTE AND HAZARDOUS MATERIALS AND THE DISPOSAL DILEMMA INHERENT THEREIN -- part of the expanding chemical environment's unwanted legacy.

Many of us will recall Dupont's offer some years ago of "better things for better living through chemistry". That offer, I believe, was universally accepted. Now the bills are being rendered in such examples as "Love Canal" in the State of New York and the many other "dump sites" that are only now beginning to attract political attention and action.

Compounding the disposal problem is the fact that there appear to be no records of where the dump sites are and if found, whether they can be effectively controlled. In turn, the costs may be as high as the effects unmanageable and there are international implications. For example, as the pressures for safe disposal mount in the industrialized countries and the standards become tighter--as is the case of the United States -- there will be the temptation to export these substances to developing countries, many of which lack either the waste disposal standards or the technical sophistication necessary to fully assess which might be in the chemical Pandora's Box. This is a risk to which developing countries have drawn the attention of UNEP, as mentioned above. And in a recent decision, the Governing Council or UNEP did indeed:

> Urge member states, in order to protect health and the environment, to ensure the institution of adequate protection measures for the handling and disposal of hazardous chemical wastes, to exchange information on such measures and the procedures used in their implementation, and to develop notification procedures and controls for international transfers of such wastes between countries involved; and

Request the Executive Director, in co-operation with competent organizations in the United Nations system and other international organizations, to develop, after consultation, guidelines for the safe and appropriate disposal of hazardous chemical wastes and pertinent measures concerning their trans-boundary transport, and to report on progress in this respect to the Governing Council at its ninth session.

.... PROTECTING OUR DIMINISHING RESOURCE BASE

As world population increases the man-to-resource ratio will undoubtedly change negatively. And this is likely to have serious political implications as more and more societies are obliged to come to terms with scarcity. And as the competition for scarce resources intensifies, new and dangerous pressures for control are likely to be generated in the international system. In a very thoughtful series in the New Yorker[1] a few weeks ago, Richard Barnett of the Institute for Policy Studies in Washington, ventured some very sobering projections:

- Whoever controls the world's resources systems, he says, will control the world in a way that mere occupation of territory cannot match.

a) Even the illusion of scarcity creates power

b) As materials becomes scarcer and more expensive, estimating their future becomes a political act

c) A world of scarcity is a world of inevitable struggle.

Already such symptoms exist in the Middle East where a declining resource -- OIL -- is at stake. But this is only the beginning since, according to recent estimates, many of the earth's resources which enabled the human race to feed, shelter, clothe and transport itself have now passed their peak of production.

- And that the principal biological crops, such as cattle, fish, grain and wood -- renewable though they are -- have begun to decline largely because the support bases have been undermined or destroyed. (New York Times - B. Webster, 5 February, 1980).

---

[1]The article has since been published in a book The Lean Years.

- Using data from the United Nations and the Department of Agriculture, the Worldwatch Institute in Washington[2]--in a survey of six principal biologically produced commodities--fish, beef, mutton, wool, cereal and wood found the following:

1. Wood production peaked in 1967...from a total of 2.2 cubic feet per capita to 2;

2. Fish peaked at about 1970 from 43 lbs. per capita to 36 at present;

3. Beef production reached its high point in 1970 declining thereafter from 26 lbs. per capita to 24 lbs.;

4. Mutton declined from 4.2 lbs. in 1972 to 4 lbs. at present;

5. Wool production peaked in the sixties declining from 2 lbs. per capita to 1.4 lbs; and

6. Cereal peaked in 1976 when it was 754 lbs. to 739 in 1971 and 701 lbs. in 1979.

It was in response to data such as these that the United Nations Environment Programme commissioned a study to deal systematically with the status of the world's living resources and their supporting ecosystems, and the policies and strategies that would be required for their effective management. A World Conservation Strategy, jointly developed with the International Union for the Conservation of Nature and Natural Resources (IUCN) and the World Wildlife Fund (WWF) was the result.

The Strategy, as you know, was launched in approximately 40 countries on 5 March 1980 as a way of dramatizing the global resource issues and dilemmas and alerting policy-makers and relevant publics everywhere to the fact that national and international capacities to conserve are ill-organized and fragmented -- even split up -- among various economic sectors with consequent duplication of efforts, competition for money and things, and even conflicts. As a result, their ability to shape the development process is often impaired and in many instances they add to the problems of development by degrading the living resource base of human welfare. The launch also sought to generate changes in the popular perception of conservation as merely a preservationist activity of a highly abstentionist character, and as such, inimical to the development aspirations of much of the world -- especially the Third World.

The Strategy defines conservation as a dynamic and positive activity designed to:

[2]Resource Trends and Population Policy: A Time for Reassessment - Worldwatch Paper No. 29.

28

a. maintain essential ecological processes and life-support systems -- such as soil regeneration and protection, the recycling of nutrients, and the cleansing of waters -- on which human survival and development depends;

b. preserve genetic diversity -- the range of genetic material found in the world's organisms -- on which depend the functioning of many of the above processes and life-support systems, the breeding programme necessary for the protection and improvement of cultivated plants, domesticated animals and microorganisms, as well as much scientific and medical advance, technical innovation, and the security of the many industries that use living resources; and

c. ensure the sustainable utilization of species and ecosystems -- notably fish and other wildlife, forests and grazing lands -- which support millions of rural communities as well as major industries.

These objectives are expected to reinforce UNEP's programme priorities in the management of terrestrial ecosystems and natural resources and will facilitate the development of cooperative and sustained action, in especially the following areas vital to human survival and sustainable development:

(i) Securing the World's agricultural base:

According to the Strategy, if current rates of land degradation continue, close to one-third of the world's arable land will be destroyed in the next twenty years. These losses are not confined to developing countries as would normally be expected, but represent a serious global phenomenon. In developed countries, for example, some 3,000 square kilometres of prime farmland disappear every year under buildings and highways. In the United States, where the loss of cropland of nonagricultural use is estimated at three million acres a year, the implication for the world food supply is even more ominous, given the importance of agriculture to the world's food system. If this loss rate were to continue then by the year 2000 the United States is likely to be a marginal food exporter. But even if these projections are not realized, population pressures would merely intensify the demand for increasing food supplies and the expansion of cultivable areas. But at the present loss rate from all causes the prospect for such expansion would seem bleak indeed.

In a statement issued recently by the Executive Director of UNEP, it was reported that:

> Loss of arable land is an escalating environmental problem. Nearly 44 per cent of the land resources of Africa, and 43 per cent of those in South Asia, are subject to drought. Moreover, 47 per cent of the soil resources in South America and 59 per cent in South East Asia are subject to nutritional deficiencies or the impact of toxic substances.
>
> Barely 15 to 18 per cent of the soils in South America, Africa and Asia may be described as having no serious limitations for agricultural use. As much as 95 per cent of the total land area in the arid and semi-arid zones is subject to the risk of desertification. And desertification is not confined to the dry areas. Its hazard can reach large proportions even in the sub-humid zones. Nearly 35 per cent of the world land is subject to moderate-to-very high desertification hazard: 55 per cent in Africa, 34 per cent in Asia and 20 per cent in South America.

A call by UNEP at its Seventh Session of its Governing Council for an integrated soils policy is expected to provide a more coherent framework for international action in this vital area and it is hoped that this Strategy would give added impetus to these efforts.

(ii) Protection of the World's Forest Resources:

In a timely volume - World Without Trees - Robert Lamb states even more dramatically a central concern of the Strategy, namely, that over-exploitation and neglect have destroyed the world's forests capacity to serve essential ecological funtions, as the guardians of the air and water quality, the soils production ability and climatic stability. To this end, Lamb asks, "What future is there for trees and how will the world be for human beings if the forests, which made both our evolution and civilization viable, continue to vanish at today's extraordinary rate?" Then, as if to underscore the point, Lamb demonstrates that over millions of years, trees sheltered more than three-quarters of the earth's dry land - their fortunes interrupted only by the severest climatic upheavals; now, just twenty-five thousand years since the invention of the axe, they cover less than one-third of it.

Human effect on the forests, "especially during the last 200 years, has outdone even the worst ice age in its thoroughness. Moreover, it may already be too late to save most of these forests in their original forms."

And Lamb's conclusions are borne out by considerable data. Recently, the Executive Director of UNEP warned that:

> The rates at which tropical forests are being depleted are so much accelerating with far-reaching consequences. Forty per cent of the world's tropical rain forests and tropical deciduous forests have disappeared already, and the remainder is being felled at the rate of 110,000 square kilometres a year or 20 hectares a minute. The effects of clear felling in mountain areas are equally severe, especially in the Himalayas, the Andes and the East African Highlands.
>
> By 1975, closed forest area was only 0.2 hectares per person in Asia and 0.5 hectares per person in Africa, as compared to 2.0 hectares per person in North America and 2.7 hectares per person in the USSR. In South Asia, South-East Asia and the South Pacific, the area under forests is being depleted at a rate of 2 per cent per annum. In certain areas, for example, Malaysia, Nepal and Thailand, there are some indications that if the present logging, farming and other practices continue, there could be a virtual disappearance of closed forests within the next 25 years.
>
> The environmental consequences of such large-scale destruction of tropical forests range from unpredictable and unfavourable changes in local micro-climatic patterns to the more predictable erosion, salinization, desertification, flooding, waterlogging, silting up of reservoirs and streams, and clogging up of irrigation networks.

Perhaps the most dramatic case to date is to be found in the Indian Ocean where a large island, about 50,000 square kilometres, is reportedly being formed as a result of soils washed away from the Himalayas and approximate watershed. Haiti, somewhat closer to home, provides some equally disturbing data. Twenty years ago, 80 per cent of Haiti was forested; today, that figure is about nine per cent -- approximately half of which is secondary growth. Without forests, the land mass becomes over-heated and less water-retentive; with resulting lower rainfalls, the water table is lower, the soil now dryer is more easily washed away. So that today, Haiti, repeatedly loses 14 million cubic metres of soil a year at a cost of some $14M and even higher agricultural and environmental costs.

In spite of such dramatic, if somehow bleak examples, the central ecological role of the forests seems neither fully understood nor appreciated, at least as far as national policies are concerned. That is why environmentalists must continue to reiterate the fact that forests are, among other things, moisture conservators and their canopy intercepts rainfall and protects soils from direct impact, thereby preventing run-off.

Moreover, not only are they important in maintaining soil fertility, but they represent some 69% of the earth's biological productivity.

But perhaps most important is their role in stabilizing the carbon/oxygen balance. These trees absorb carbon dioxide and store it in the form of organic compounds and give oxygen. Moreover, their replacement by any other form of vegetation with a smaller biomass per unit area would probably add significant amounts of carbon dioxide to the atmosphere. Because of their sheer height and mass, trees are, by far, the most protective fortress for photosynthesis operations.

For example, replacement of the entire Amazon forest by grass would probably release an amount of carbon dioxide equal to about 20% of that in the whole world's atmosphere. Even assuming that about half of this would be dissolved by buffers, namely the oceans, rivers, lakes, etc. -- there would still be a net increase of about 10%. That, coupled with the release by the burning of coal, means our atmospheric and climatological future would seem very cloudy indeed.

It was concerns such as these that led UNEP, in cooperation with FAO, UNESCO and other interested organizations, to convene an international expert meeting in Nairobi, to examine, in depth, the urgent question of conservation and wise utilization of tropical forests. That conference was to recommend a series of measures including: programs to educate citizens in the value of forests, training of forests personnel to prevent waste and damage and to seek assistance from international bodies to help the collection and analysis of land capability data. The conference also stressed the need for regular surveys to be carried out with the most up-to-date equipment, including satellites and ground and air surveillance technologies, in order to monitor the status of the forests. Most importantly, however, the conference emphasized the fact that the forests are a renewable resource and part of an integrated environment in which not only trees are at stake but ultimately man himself. Again, it is hoped that the Strategy will assist various publics to appreciate the implications of forests destruction for their future well-being and will provide standards as well as a framework for sound management policies.

(iii) Averting a Coastal Crisis:

Acre for acre, coastal areas are reportedly among the most productive places on earth. Often called "ocean nurseries," they provide food and shelter for water fowl, fish, crustaceans and mollusks; utilized by an estimated two-thirds of the world's fisheries, some of which, like the shrimp, are among the most lucrative in the industry. Efficiently self-renewing and resilient, these coastal shallows, wetlands and estuaries form an intricate interlocking system with the oceans and together perform vital life-supporting functions. Unfortunately, however, the harmonious relationship seems jeopardized as human pressures on coastal ecosystems are beginning to assume dangerous proportions. Wetlands,

38

flood plains, sea-grass beds and even coral reefs are being destroyed the world over. The off-shore search for energy, the construction of dams -- blocking the passage of migratory fish, destroying their habitats -- and dredging to create or deepen harbours are among the most visible and perhaps most obvious, evidence of human impact. Not so visible, but equally dangerous, are the problems of pollution caused by agricultural run-off and other land-based abuses.

The residues of toxic weed and insect killers that are used in our agricultural systems are washing out into our waterways as are the nutrients in the chemical fertilizers -- which in turn feed algae that clog and deaden these waters.

So far there are no reliable estimates on the damage caused to the world's water budget by these chemicals, nor have we discussed effective means for combatting such agricultural pollution without inhibiting production.

These land-based sources are fairly well-documented in the case of the Mediterranean:

At a meeting in Monaco in January 1977, convened to review efforts for the protection and development of the Mediterranean basin, the Executive Director of the United Nations Environment Programme, underscored the urgency of the risks to be faced when he reported that, as a result of man's activities, 120 tons of mineral oils, 60 tons of detergents, 100 tons of mercury, 3,800 tons of lead, 2,400 tons of chromium, 21,000 tons of zinc, 90 tons of pesticides, 1,120 tons of nitrogen and phosphorous, and 2,500 curies of radio-nuclides enter the Mediterranean annually. A price of some five billion dollars has been estimated as the cost of putting into effect a protocol that would limit the annual discharge of these substances from land-based sources. And, naturally, a number of governments are reluctant, at this stage, to commit themselves to any such programme. Nevertheless, a start has been made. In mid-February, a Convention came into effect among the eighteen states of this region, which established, among other things, a legal framework for action, and a basis for sustained cooperation. This achievement can hardly be over-estimated, since the Mediterranean represents, in microcosm, the same patterns of tension and conflicts that characterize much of international activity. It is our hope that this Convention will serve as a model for cooperation in the development and management of the resource and, more especially, the development of effective machinery for the abatement of pollution in major waterways. Because the Mediterranean is not alone; the Caribbean represents an even more pertinent example for Americans. The Caribbean, after all, is larger than the Mediterranean and involves a larger number of States. Like the Mediterranean, however, it too stands threatened.

According to Earthscan, "it is probably the Sea most damaged by pesticides in the world. The Mississippi Basin drains 41 percent of the U.S. land area, including much of its agricultural headland, and a considerable amount of pesticides used there drain in the Gulf of

Mexico. Moreover, large quantities of pesticides are used in Caribbean agriculture which eventually wash out into the Caribbean Sea. Like the Mediterranean, UNEP has accorded high priority to the protection of the Caribbean as part of its Regional Seas Programme."

And again, it is hoped that the recommendations outlined in the Strategy will assist policy-makers in adopting the measures necessary to avert a coastal crisis.

IV. GENETIC DIVERSITY: MINIMIZING RISKS, MAXIMIZING BENEFITS

The earth's genetic resources is reported to include anywhere from 5 to 10 million species of animals and plants, but by the end of the century, many might be extinct if the rate of one a day loss is maintained. This was the conclusion reached by the World Conservation Strategy -- a conclusion shared with even more dramatic detail by Edward O. Wilson, a Harvard entomologist. According to one report:[3]

> Man is wiping out species at a rate that threatens the environmental stability of the earth. He notes that the current extinction rate is estimated at 1,000 plant and animal species a year. By the late 1980's, the figure could rise to 10,000 species a year and during the next 30 years fully one million species could be erased. He noted that the effects of so many predicted exterminations of species would be worse than economic collapse, limited nuclear war or conquest by a totalitarian government.

While threats to the earth's genetic resources are many and varied, there are some which seem more directly within the human capacity to control or at least to alleviate. The preservation of genetic diversity would seem to be one such area and, as the Strategy reminds us, such preservation is both a matter of investment and insurance necessary to sustain and improve agricultural, forestry and fisheries production, to keep open future options as a buffer against harmful environmental change and as raw material for much scientific and industrial innovation.

Yet, in spite of innumerable examples which conclusively demonstrate that plants and animal species -- once thought to be insignificant -- can suddenly become useful and important, the threat persists and the genetic base continues to shrink, often under pressure for the creation of super strains or genetic uniformity. Nowhere is this more systematically advanced than in regard to the seed industry and this should be a matter of concern to the Third World since the genetic strength of most of the world's crops is drawn from the regions of Africa, Asia and Latin America -- traditional centers of genetic diversity.

---

[3]New York Times - 19 February 1980

The risks for food production inherent in the narrowing of the genetic base are amply documented in the Strategy which notes for example that:

> Only four varieties of wheat produce 75% of the crops grown on the Canadian Prairies and more than half of the Prairie wheat lands are devoted to a single variety;
>
> 72% of U.S. potato production depends on only four varieties and just two varieties supply U.S. pea production;
>
> Most of Brazil's coffee production descends from a single plant, and
>
> The U.S. soybean industry is entirely derived from six plants from Asia.

It is clear, therefore, that developments such as these place a number of the world's food crops in a position of extreme vulnerability to outbreaks of pests and diseases and changes in growing conditions. Compounding the problem, however, is the fact that corrective possibilities are, themselves, being undermined as the diversity of crop populations are being destroyed. This situation becomes even more ominous when, as the Strategy warns, that many wild and domesticated varieties of crop plants such as wheat, rice, millet, beans, yams, tomatoes, potatoes, bananas, limes and oranges are already extinct and many more are in danger of following them. These dangers are further compounded by the fact that commercial seed companies are now actively involved in the collection of exotic and rare varieties with a view to developing new strains expected to be "high yielding" but only in response to high inputs of fertilizers and chemicals. And it is very problematic just how sturdy and enduring these strains will be in the future.

Even more ironic is the fact that the Third World, long the genetic home of many of these crops, will find these developments to be very costly as commercial plant breeders and seed suppliers patent the new variety and demand royalties for them. As a result, many developing countries find themselves having to pay twice for genetic material -- once for the new variety and once for protecting the material from which it is derived. Again, UNEP is deeply concerned with this issue and is actively involved in the development of programmes designed to train developing country personnel in collecting and storing indigenous seed varieties. It is our hope that the strategy will generate momentum for these efforts, as well as provide at least some of the tools that will enable developing countries to assess the potentialities of their genetic resources and to develop the policies necessary for the effective management of genetic diversity.

Ladies and gentlemen,

Within the time allotted, one was hardly able to do more than to introduce the World Conservation Strategy and to commend it to your attention. I believe once this document is studied, you will agree with me that while it is by no means a panacea, it does present perhaps the most focused approach to date of the management of living resources and provides policy guidelines on how these can be carried out by government policy-makers and their advisers, development practitioners, corporate planners, conservationists and others concerned with living resources. As managers and developers, I believe the Strategy offers a number of resource management options which you would do well to ponder.

Thank you very much.

36

DEFINITION OF ENVIRONMENTAL ISSUES

James Mahoney

Senior Vice President
Environmental Research & Technology, Inc.

June 1980

International Environmental Management Institute
ENVIRONMENTAL RESEARCH & TECHNOLOGY, INC.
Concord. Massachusetts. USA

PRINCIPLES OF ENVIRONMENTAL MANAGEMENT - OVERVIEW

1. DEFINITION OF ENVIRONMENTAL ISSUES
2. GOALS OF ENVIRONMENTAL MANAGEMENT
3. STRATEGIES FOR ENVIRONMENTAL MANAGEMENT
4. ENVIRONMENTAL MEASUREMENTS
5. ENVIRONMENTAL STANDARDS
6. NATIONAL GOVERNANCE FOR ENVIRONMENTAL MANAGEMENT
7. ORGANIZATION FUNCTIONS FOR ENVIRONMENTAL AGENCIES
8. ANALYSIS MODELS
9. ENVIRONMENTAL IMPACT ANALYSIS METHODS
10. EDUCATION AND TRAINING

38

DEFINITION OF ENVIRONMENTAL ISSUES

MEDIA

- AIR
- WATER
- LAND

LOCATIONS

- HUMAN HABITATS
- WORKPLACES
- AGRICULTURAL LANDS
- OPEN SPACE

HOW TO LIMIT THE SCOPE OF ENVIRONMENTAL MANAGEMENT?

GOALS OF ENVIRONMENTAL MANAGEMENT

- PROTECT PUBLIC HEALTH
- OPTIMIZE USE AND PRESERVATION OF NATURAL RESOURCES
- MAINTAIN PRODUCTIVE CAPACITY OF LAND/WATER/AIR SYSTEM
- PRESERVE AMENITIES

40

STRATEGIES FOR ENVIRONMENTAL MANAGEMENT

TECHNOLOGICAL CONTROLS ON POLLUTION SOURCES

- ESTABLISH STANDARDS AND GUIDELINES
- REQUIRE COMPLIANCE
- NEW FACILITIES VS EXISTING FACILITIES

PLANNING TECHNIQUES

- DIRECTED USE OF LAND
- INCENTIVES FOR FAVORED DEVELOPMENT

PUBLIC EDUCATION FOR ENVIRONMENTAL AWARENESS

- GENERAL SCHOOLING
- SPECIALIST TRAINING
- PUBLIC INFORMATION

41

ENVIRONMENTAL MEASUREMENTS

- DEFINITION OF REPRESENTATIVE DATA AND APPROXIMATE SAMPLING SITES
- IMPORTANCE OF TREND ANALYSIS
- RELIABILITY OF MEASUREMENTS
- ANALYSIS METHODS TO EXTEND THE MEASUREMENT DATA
- DATA ARCHIVES

ENVIRONMENTAL STANDARDS

1. AMBIENT STANDARDS - ENVIRONMENTAL MANAGEMENT APPROACH

   - QUANTITATIVE (NUMERICAL LIMITS)
   - QUALITATIVE (MINIMIZE CHANGE FROM NATURAL CONDITIONS)

2. SOURCE STANDARDS

   - EFFLUENT LIMITS
   - EQUIPMENT STANDARDS
   - OPERATIONAL PRACTICE STANDARDS

43

NATIONAL GOVERNANCE FOR ENVIRONMENTAL MANAGEMENT

- CENTRAL PLANNING VS LOCAL CONTROL
- SINGLE ENVIRONMENTAL AGENCY VS DISTRIBUTED RESPONSIBILITY IN GOVERNMENT
- LEVEL OF AUTHORITY FOR ENVIRONMENTAL MANAGEMENT
- ROLE OF INDUSTRY
- ROLE OF UNIVERSITIES AND PROFESSIONAL ORGANIZATIONS

ORGANIZATIONAL FUNCTIONS FOR ENVIRONMENTAL AGENCIES

- GENERAL MANAGEMENT
- ENVIRONMENTAL MONITORING
- RESEARCH AND DEVELOPMENT (INCLUDING STANDARD SETTING)
- ENGINEERING AND PLAN REVIEW
- INSPECTION AND ENFORCEMENT
- PUBLIC INFORMATION

ANALYSIS MODELS

(AIR AND WATER POLLUTION MODELS)

USES

- ENVIRONMENTAL CONTROL PLANNING
- EXTENSION OF MEASUREMENT DATA
- IMPACT ASSESSMENT

LIMITATIONS

- LIMITS OF MODEL ACCURACY
- IMPERFECT INPUT DATA

ENVIRONMENTAL IMPACT ANALYSIS METHODS

DEFINITION OF CASES FOR COMPARISON

- PROPOSED ACTIVITY
- ALTERNATE ACTIVITIES
- NO ACTION ALTERNATE

FRAMEWORK FOR COMPARISONS

- QUANTITATIVE
- QUALITATIVE
- GENERAL PROFESSIONAL JUDGMENT

EDUCATION AND TRAINING

- GENERAL EDUCATION
- COLLEGE LEVEL EDUCATION
- SPECIALIST TRAINING
- INTERNATIONAL TRAINING PROGRAMS
- PUBLIC INFORMATION

BENEFIT/COST ANALYSIS OF ENVIRONMENTAL PROGRAMS

Robert Dorfman

David A. Wells Professor of Political Economy
Faculty of Arts and Sciences
Harvard University

June 1980

International Environmental Management Institute
ENVIRONMENTAL RESEARCH & TECHNOLOGY, INC.
Concord, Massachusetts, USA

49

EXECUTIVE SUMMARY

Benefit-cost analysis applied to an environmental program consists in estimating the economic cost of the program and comparing that cost with the beneficial effects on public health and environmental conditions. As a general rule, the economic costs are expressed in monetary units, but the beneficial effects cannot be; they are measures of the degrees of attainment of some of the social goals of the community. Therefore, benefit-cost analysis is not a method for reaching decisions about environmental programs or policies, but rather a tool for organizing and presenting the information that is needed for effective decision-making.

Benefit-cost analysis is easier to define than to execute. In the first place, the economic costs entailed by a program are always projections subject to a margin of uncertainty. The estimation of the beneficial results presents much more serious difficulties. Our understanding of the way in which human activities affect environmental conditions and also of the way in which changes in environmental conditions affect public health and welfare are both too limited to permit forecasting with much precision or assurance. Furthermore, both the costs and the benefits of an environmental program typically extend over long periods of time so that some method is required for comparative evaluation of consequences that occur many years apart. Often environmental decisions are irreversible and therefore affect the welfares of generations still unborn. In such cases difficult ethical problems arise. Frequently also the costs of environmental programs fall on segments of the population that are different from the ones that enjoy the benefits; then both political and ethical problems arise. All these complications reinforce the conclusion that benefit-cost analysis can present the facts and inferences scientifically derived from them but cannot determine environmental policies, which ultimately must depend on the judgments of responsible officials.

The methods used in benefit-cost analysis have been developed primarily in the more advanced countries for use in guiding their environmental policies. The environmental problems of the less developed countries are significantly different so that the conventional methods cannot be applied without substantial modification. The environmental problems of the more developed countries result from the disposal of industrial waste products--gaseous, liquid, and solid--from the emissions created by automobiles, electricity generation, and heating plants in modern cities, and from the runoffs of chemicals used in modernised market agriculture. In the less developed countries, the principal environmental problems result from the practices of traditional agriculture and from the inadequacies of water supply and sewerage in their cities, towns, and villages. These problems are much more severe and urgent than those of the more developed countries. Traditional agriculture practices accelerate soil erosion, depletion, and salinization and induce excessive deforestation and overuse of grazing land. The evil consequences are not a threat for the future, they are at work right now; thousands of tons of irreplacable topsoil

are being washed away every day. The costs of inadequate water supply and sewerage are equally immediate: in many cases of the less developed countries such debilitating diseases as schistosomiasis and gastro-intestinal worms are endemic, sap the strength of the population, and shorten its life spans.

Not only are the environmental problems of the less developed countries different from those of the more developed countries and more urgent, the cost of dealing with them are also different. In the more developed countries, environmental programs and restrictions typically increase the costs of producing marketable goods and services and reduce the quantities available for consumption. Benefit-cost analyses in those countries therefore compare the improvements in environmental conditions with the decreases in the consumption of marketable goods and services. In the less developed countries the level of consumption of much of the population is already too low to be pushed down any further and, typically, is supported by a variety of subsidization programs. Environmental protection programs therefore increase the burden of subsistence maintenance and compete with economic development programs for already scanty resources.

This means that the major cost of an environmental protection measure in a less developed country is the resources that it drains away from economic development. The costs of an environmental protection measure should therefore be estimated by exactly the same methods and conventions that are used in appraising development projects--in this way comparability will be attained. In fact, environmental protection programs should be considered an integral part of the country's economic development program. To a considerable extent this is already the case: urban water supply and sewerage and rural soil protection programs are already incorporated in many development budgets. At the same time the environmental burdens created by development projects should be taken into account before irreversible damages are inflicted. The less developed countries have the advantage that there is still time for them to avoid the serious mistakes that their predecessors committed before the consequences were understood. To take advantage of this time requires the close coordination of development and environmental policy.

51

BENEFIT-COST ANALYSIS OF ENVIRONMENTAL PROTECTION PROGRAMS IN LESS DEVELOPED COUNTRIES

Robert Dorfman

1. Introduction

The purpose of this lecture is to present the economist's view of environmental problems in the less developed countries. The first thing to mention is that economists regard the use and protection of the environment as fundamentally economic problems, for two reasons. First, because economics is the study of social arrangements for making use of scarce resources, and second, because the principal instrument of this study is the analysis of the behavior of markets, and our current difficulties in managing the environment arise chiefly from aberrations in market behavior. These two economic aspects of environmental problems are clearly closely linked.

The first aspect depends on realizing that the environment cannot satisfy all the demands that we should like to place on it. This is a fairly recent state of affairs. Twenty or thirty years ago students of civil engineering in this country were taught the dictum, "Flowing water cleanses itself every ten miles." That was in the good old days, when the water supply per capita was so great that one could dump all the wastes one chose into rivers without deteriorating them or giving any thought to the matter. In many of the less developed countries, "slash-and-burn agriculture" is still practiced; one after the other those countries are attaining populations that preclude such lavish use of agricultural land. Those two illustrations indicate what we all know, namely that we are now experiencing a change of circumstances in which resources that were formerly plentiful have abruptly become scarce. Social institutions naturally lag behind. Since time immemorial scarce commodities have been allocated by means of market exchanges, even in socialist countries. But until recently there was no need for market exchange or other control of the use of environmental resources. Clean air, clean water, open space, and so on were so plentiful that everyone could use them as he chose without diminishing their availability to other people. Now this is no longer so. As a result we have not inherited from our past the social instruments we need today to control and preserve the use of those resources. Today's environmental problem is essentially the problem of developing those social instruments.

2. Benefit-Cost Analysis

It is at this stage that benefit-cost analysis enters the picture. Benefit-cost analysis, which I shall define shortly, is not a method of social control but rather a set of procedures for appraising the consequences of any particular set of social controls over the use of environmental resources. It is therefore an essential instrument for judging whether a proposed set of controls is an improvement over the present situation, and for selecting the most advantageous of a number of proposed controls.

52

Definitions of benefit-cost analysis differ and I shall make use of a very broad one, to wit: benefit-cost analysis is a systematic accounting of the favorable effects or benefits and the unfavorable effects or costs of proposed programs, from a social point of view. It is a variant of ordinary business accounting but differs in two significant respects. First, it values consequences from a social rather than a business point of view. We shall see the consequences of this shift in viewpoint later on. Second, it pays more attention than ordinary methods of accounting to consequences that do not have market prices. Business accountants also pay attention to nonprice consequences, as when they have to estimate the value of patents or the depreciated value of plant and equipment. But, whereas those are subsidiary problems to the business accountant, they are in the forefront of concern for the benefit-cost analyst because, as we have already noted, the environmental resources and social consequences with which he is predominantly concerned do not exchange in markets and do not have well established market prices. The lack of prices complicates the task enormously and leads into difficulties that cannot always be solved, as we shall see. But it is inevitable, and a great share of the task of performing a benefit-cost analysis consists in various methods of circumventing this difficulty.

The techniques of benefit-cost analysis were developed primarily in the more developed countries and are adapted to the conditions of those countries. Therefore we should be warned that those techniques cannot be applied without substantial amendment and adaptation to the circumstances of less developed countries. There are two quite separate reasons for this.

In the first place the less developed countries confront very differenc environmental problems from the more developed ones. Problems in the more developed countries result largely from the stresses that modern technology places on the environment. They result from the problems of disposing of the waste products of industrial processes, from the discharges of pesticides and fertilizers used in modern market agriculture, and from the concentrated loads of pollutants generated in cities by their transportation systems, their power plants, and their heating requirements.

By contrast, in the less developed countries the critical environmental problems are the consequence of traditional agricultural methods and the inadequate sewerage and water supply systems of traditional types of villages and cities. Traditional agriculture methods typically accelerate soil erosion, deplete soil nutrients, permit salts to accumulate in irrigated land, overgraze pastures, and denude forests. These are not threats for the distant future. Today and every day traditional agricultural practices are imposing irreparable damage on tens of thousands of acres in one or another of these ways.

53

The problems of village and urban pollution in the less developed countries are equally severe and pressing. They are the source of the widespread prevalence of acute and chronic infectious disease, gastric infections, intestinal worms, schistosomiasis, and many other plagues that sap the strength and shorten the lives of the populations of the less developed countries. In short, the environmental problems of the less developed countries are different from those of the more developed ones and even more severe.

Of course there is some overlap between the problems encountered in the two kinds of countries. Pesticides cause significant damage to the ecological systems in both of them. There is mining and smelting in both, and a mine or smelter can disrupt its environment for miles around. Increasingly, enterprises that generate pollution that is unacceptable in the more developed countries are seeking locations in less developed countries where the environment is less heavily burdened. This tendency presents difficult problems to the less developed countries, which would like the benefits of modern technological enterprises and the highly paid employment that it affords, but have very reasonable misgivings about accepting the environmental burdens. And finally there are, of course, some thoroughly modern cities with all their burdens of congestion and pollution in many of the less developed countries. In spite of these common problems however, the critical and environmental problems encountered in the more and the less developed countries are substantially different.

The foregoing differences relate to the benefits of environmental protection measures. The costs of those measures to the less developed countries are also very different from those to the more developed countries. In the more developed countries the major impact of environmental protection measures on the economy is to transfer productive resources from the production of goods and services to environmental protection activities. The real cost, then, is some reduction in the quantities of goods and services available for consumption. In the less developed countries, consumption levels for the bulk of the population are already uncomfortably close to socially tolerable minima. Any resources devoted to environmental protection, therefore, have to be taken from the resources available for investment, that is to say, from the economic development plan. It has to be faced that environmental protection is in direct competition with economic development for essential resources, of which the most critical, usually, is foreign exchange. It is, then, a very good approximation to say that the real cost of an environmental measure to a less developed country is the amount by which it reduces the availability of foreign exchange for economic development. This has two implications. First, that the economic costs of environmental protection measures should be calculated in terms of the reduction that they impose on the resources available for generating foreign exchange or for economizing on it. Second, that the environmental protection program in a less developed country should be coordinated very closely with the economic development program.

3. Applying Benefit-Cost Analysis

With this background we can look more closely at the way in which benefit-cost analyses of environmental programs are performed. For this purpose we view the generation of harmful effects on the environment in the way shown schematically in Figure 1. The figure begins in the box labelled "A Human Activity." From any human activity there will flow two kinds of effect: the beneficial results for which it is undertaken, and its inadvertent side effects on the environment. For example, if the activity is protecting a crop by use of a chemical pesticide, the beneficial result is the increase in the yield of the crop and the side effects consist primarily of deposits of residues on the crop, the field, and neighboring fields, plus a suspension of droplets of the pesticide in the air. These residues then alter ambient conditions in and near the protected field for a greater or lesser length of time, depending on the persistence of the pesticide. Some of the pesticide may run off into nearby streams or filter down to the aquifer, altering the conditions of those aquatic environments. All such effects are indicated by the third box. Finally, all forms of plant and animal life, including man, that come in contact with the altered environment may experience adverse effects. Those consequences are indicated by the last box in the row. The purpose of laying out this chain of consequences is to display the sequence of studies and analyses that have to be performed in order to estimate the environmental effects of human activities that have impacts on the environment.

The three stages of work that have to be performed are indicated by the three arrows on the diagram. Table 1 suggests in more detail the nature of the work that has to be performed. It indicates the fields of knowledge that have to be applied in order to estimate first, the direct impact of a given activity on the environment in which it occurs, second, the changes in ambient conditions that result from those impacts, and third, the effects of those ambient conditions on public health, on ecological conditions, and on buildings and materials. All this work leads up to the dangling arrows at the right edge of the diagram that point down to the lower panel. The estimated effects of the activity on public health, ecological conditions, and artifacts of all sorts, as well as the degree of attainment of the beneficial purpose for which the activity is undertaken all have to be evaluated from a social point of view in order to assess the social contribution of that activity. The task of evaluation, to be discussed below, is the final stage of a benefit-cost analysis.

In fact, the task of benefit-cost analysis is quite a bit more complicated, even, than Figure 1 indicates. The first essential complication is indicated in Figure 2. Benefit-cost analyses are rarely made just for fun or curiosity. They are undertaken when some policies or governmental programs are contemplated that will change the human activity that generates all those effects, so that what really has to be evaluated are the changes that will be induced by the

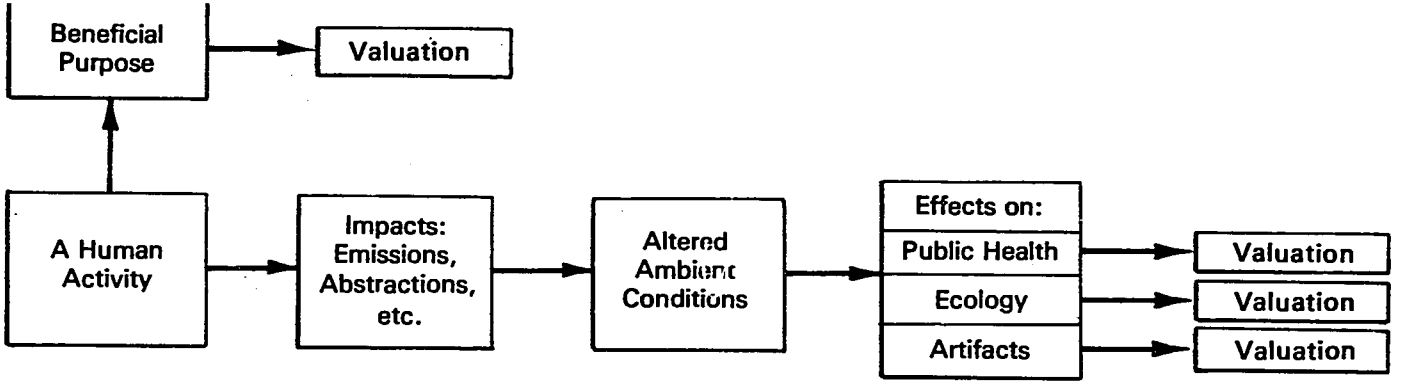


Figure 1 Conceptual Framework

TABLE 1

TASKS OF A BENEFIT-COST ANALYSIS
AND SPECIALISTS RESPONSIBLE

1.	Activity → Impacts		Engineers Agronomists
2.	Impacts → Ambient Conditions		Meteorologists Hydrologists Chemists Soil Scientists
3a.	Ambient Conditions	→ Public Health	Epidemiologists Toxicologists Oncologists
3b.		→ Ecology	Zoologists Biologists Foresters
3c.		→ Structures and materials	Engineers Chemists Hydrologists Geologists
4.	Public Health Ecology Structures and materials	→ Valuation	Economists Social Scientists ↓ Responsible Officials

57

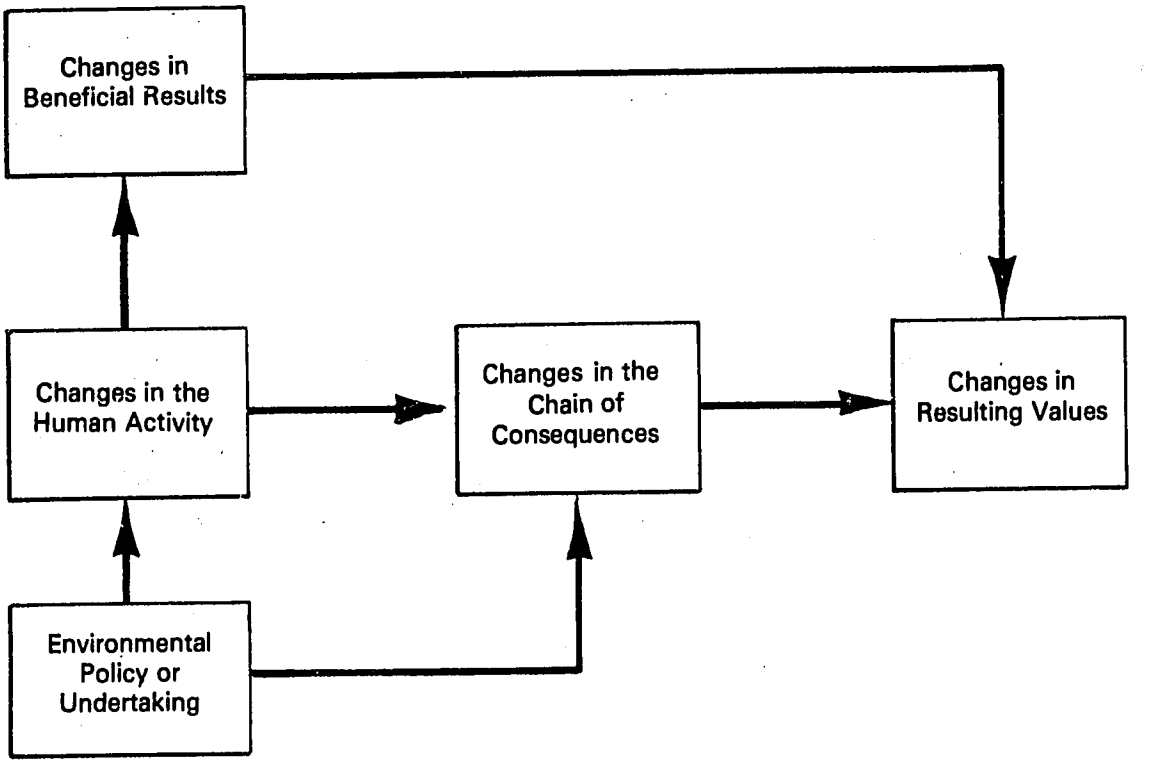


Figure 2 Environmental Policy

contemplated program. This adds a new box to Figure 1 and two new arrows. It is necessary, in addition to everything else, to estimate the effect that the contemplated program will have on the activity that generates the environmental damage, because it can never be taken for granted that the program will have precisely the intended effect. For example, if a regulation is passed requiring that all wastes be treated in a specified way before being discharged into waterways, it cannot be assumed that all discharges will forthwith meet the quality standards that were intended by the regulation. Estimates have to be made of the degree of compliance and the effectiveness of the responses that will be made in compliance with such a regulation. The changes in beneficial results also have to be estimated, since those are the costs of the environmental improvement that is attained. Finally, as shown in the figure, the policy may have direct impacts on the environment in addition to those mediated through the human activity at which it is directed.

A number of other complications also are hidden in Figure 1 but have to be dealt with in any benefit-cost analysis. One of these is that the effects of any environmental policy will extend over a substantial period of time and may even affect several generations. This circumstance complicates the task of estimation somewhat. More fundamentally it introduces the problem of evaluating consequences, both beneficial and adverse, that occur at different dates. In ordinary business accounting this problem of dating is handled by discounting all consequences to a common point in time. The solution applied in benefit-cost analysis is the same. Comparative values have to be established among consequences that occur immediately, those that occur ten years into the future, and those that accrue to future generations. The key operational question is the discount rate to be used in making such comparisons. This question has generated a large and controversial literature which I shall not review, principally because the arguments and counterarguments do not apply to benefit-cost analysis in less developed countries. In those countries, as we noted, environmental policy has to be coordinated very closely with economic development. As a result, the discount rate to be used in the evaluation of environmental programs should be identical with the one used in formulating the development plan. This principle resolves all questions about what discount rate to use.

Another complication that cannot be ignored in practice results from the fact that the benefits and costs of an environmental policy are generally distributed very unequally among segments of the population. On whom the burdens fall and to whom the benefits accrue are matters of great consequence. A regulation that increases the cost of producing luxuries is likely to be considered preferable to one that costs the same in total and has the same environmental effects but increases the cost of food production. Estimates of the distribution of benefits and costs are generally obtained automatically in the course of the analyses indicated in Figure 1. For some purposes they can be combined or aggregated in the overall evaluation. But for other purposes they cannot be. Thus a benefit-cost analysis must be designed to disclose the differential effects of environmental policies on different population groups.

59

One final complication has to be mentioned. It should be amply clear from Figure 1 and Table 1 that estimating the environmental effects of changes in human activities is a very difficult job and requires a variety of data that are difficult to obtain, if obtainable at all. The results of this work can never be precise or reliable. This implies that when comparisons are made of the benefits and costs of alternative policies, the estimates that have to be compared are not hard data, but rather indications of the ranges in which the two values are expected to lie. The benefit-cost analysis, therefore, has to estimate and indicate these ranges of uncertainty. I shall develop this thought further below.

Let us assume that we have now reached the right-hand box of Figure 1. Estimates are at hand of a wide variety of social consequences of alternative programs for meeting an environmental problem. With respect to public health, there may be estimates of the proportion of babies who survive to age five under different programs, and of the proportion of the population afflicted with intestinal worms. With respect to ecology, there may be estimates of the fish populations of lakes and rivers under the various alternatives. With respect to the beneficial purpose the analysis may have produced estimates of the costs of rice production under the different alternatives. And so forth. All of these estimates may and should be dated; they should indicate when the estimated results will occur and how long they will endure. The task of evaluation is to bring all these estimates, expressed in their diverse units of measurement, together and to derive from them an appreciation of the comparative overall social value of the different programs being contemplated. This is the task to which we now turn.

4. Comparative Values

I have to preface my discussion by pointing out that there are two contending schools of thought with respect to this task. One school, probably the predominant one, holds that all these diverse consequences should be reduced to monetary values in order to facilitate comparisons. The authority of that school appears to be fading, and in my opinion quite properly. The decisive difficulty is suggested by some of the illustrative information that I just mentioned. For example, who is to place a monetary value on a change in the proportion of babies expected to survive to age five, and how can he do it? The other school, which is where I place myself, holds that some of the social consequences of environmental change can be reduced readily to monetary values, and some stubbornly resist such a reduction. We admit that this complicates the task of comparing alternatives and reaching environmental decisions. But there is no help for it. Decisions about environmental policy inherently require tragic choices in which some important social values have to be sacrificed in favor of others. A benefit-cost analysis cannot make those choices; it can only present to responsible decision-makers the social consequences of the alternatives among which they must choose. I shall discuss the task of evaluation from this point of view.

4.1 Costs

The cost of programs for protecting or improving the environment are predominantly monetary, and I shall discuss them first. In many instances these costs take the form of requiring producers to do something that increases their monetary production costs or else to refrain from some activities (such as using toxic pesticides) that reduce production costs. The producers affected can themselves estimate the monetary costs that such a regulation will impose on them; the benefit-cost analyst must reevaluate those costs from a social point of view.

To see what is involved we have to consider the value to a society of producing a particular commodity and how that value changes when the costs of production change. The fundamental concepts are illustrated in Figure 3. In the interest of concreteness the figure presumes that the commodity in question is rice. The various possible quantities of rice production per year are shown horizontally; prices or monetary values are shown vertically. There is a demand curve and a supply curve. The demand curve shows for each possible price the amount of rice that consumers would like to purchase if that were the price on the market. For example, if the market price were p_1 then consumers would want to purchase the quantity corresponding to the right-hand edge of the narrow column drawn on the graph. The supply curve is analogous. It shows for each possible price the quantity of the commodity that producers would be willing to produce and offer if that were the market price. For example, if the market price were p_2 then producers would want to offer the same quantity that consumers would like to buy at the higher price, p_1. The demand curve slopes downward because the higher the price the lower the amount that consumers would want to buy. The supply curve slopes upward for an analogous reason that we should look at more closely. Suppose that the market price is p_2. Then, as we have seen, producers would be willing to provide the quantity q on the diagram. Why would they not want to produce more? Presumably because when they are producing q tons of rice the next small quantity of output, say the next hundred tons, would cost more to produce than they could bring on the market, which is p_2 per ton. Thus p_2 is not only the price that will call forth a production of q tons, it is also the cost per ton of additional production when q tons are being produced. Technically this is called the marginal cost. We shall make use of this fact below, but now turn to the relation between the supply and demand curves.

Because the curves have opposing slopes, they cross, and cross only once. The intersection, at price p^* and quantity q^*, is called the equilibrium position of the market because p^* is the only price at which consumers want to buy the same quantity that producers want to provide.

61

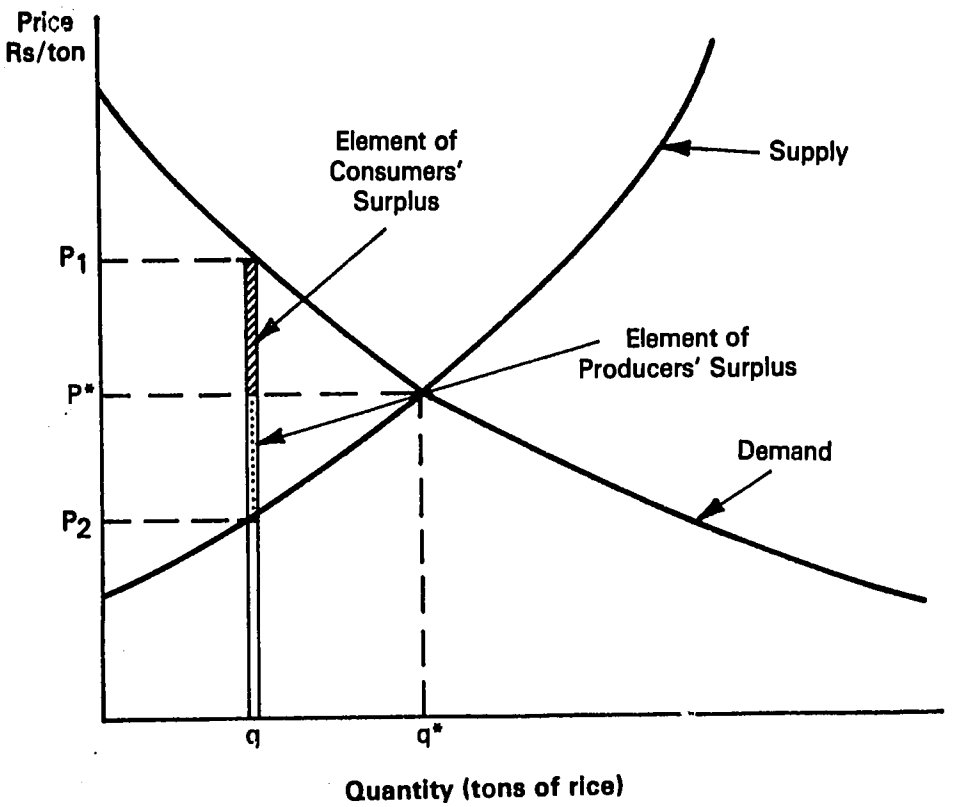


Figure 3 Supply/Demand

We should now notice several things. First, the diagram shows the total cost of producing q* tons of rice. This total is the cost of producing the first hundred tons plus the cost of the second hundred tons and so on all the way up until q* tons are produced. We have seen that when q tons are produced the cost of the next hundred tons is the area of the narrow unshaded column drawn on the diagram, if we imagine the width of that column to be 100 tons. Then the total cost of producing q* tons is the sum of all such columns from zero up to q*, or, in effect, the area under the supply curve from the origin up to q*. When q* tons are produced, however, the price is p* so that rice producers receive a total payment represented by the rectangle bounded by the dashed horizontal line at p* the dashed vertical line at q*, and the two axes. This shows that the producers' gross receipts exceed their total production costs. The excess is called the producers' surplus, and is represented in the diagram by the warped triangle bounded by the price axis, the horizontal line at p*, and the supply curve. The dotted part of the column on the diagram represents the contribution to total producers' surplus of the qth to q + 100th tons produced when a total of q* tons are being produced.

Now turn to the demand curve. If only q tons were being produced the consumers would be willing to pay approximately p_1 per ton for each of the next hundred tons. Actually, when the equilibrium amount is being produced they have to pay only p* per ton so that they are obtaining, in a sense, more than their money's worth for those tons. The excess, $p_1 - p^*$, is called the consumers' surplus per ton. The contribution to total consumers' surplus of the qth to q + 100th tons is represented in the diagram by the cross-hatched section of the column, and the total consumers' surplus is the sum of all such columns, or the area of the warped triangle bounded by the price axis, the demand curve, and the horizontal line at p*.

The contribution of this commodity or market to total economic welfare is the sum of the producers' and consumers' surpluses. On the graph this sum is the area of the large triangle under the demand curve and above the supply curve up to their crossing point. Conceptually it is the total amount that consumers would be willing to pay for the equilibrium output, if they had to, in excess of the total cost of producing that output. The division of the total surplus into consumers' surplus and producers' surplus is significant because it shows how the total economic gain is divided between the farmers who grow the crop, or other producers, and the households that consume it.

These concepts enable us to estimate the economic cost of an environmental protection measure. Turn to Figure 4. The demand and supply curves from the last figure have been copied onto this one. In addition a new supply curve is shown which lies to the left of the old one to reflect an increase in production costs resulting from an environmental protection policy. The new supply curve intersects the old demand curve at a higher price, indicated by p^n, and a lower quantity, indicated by q^n, than in the previous equilibrium. The economic surplus has shrunk; it is now represented by the triangle

63

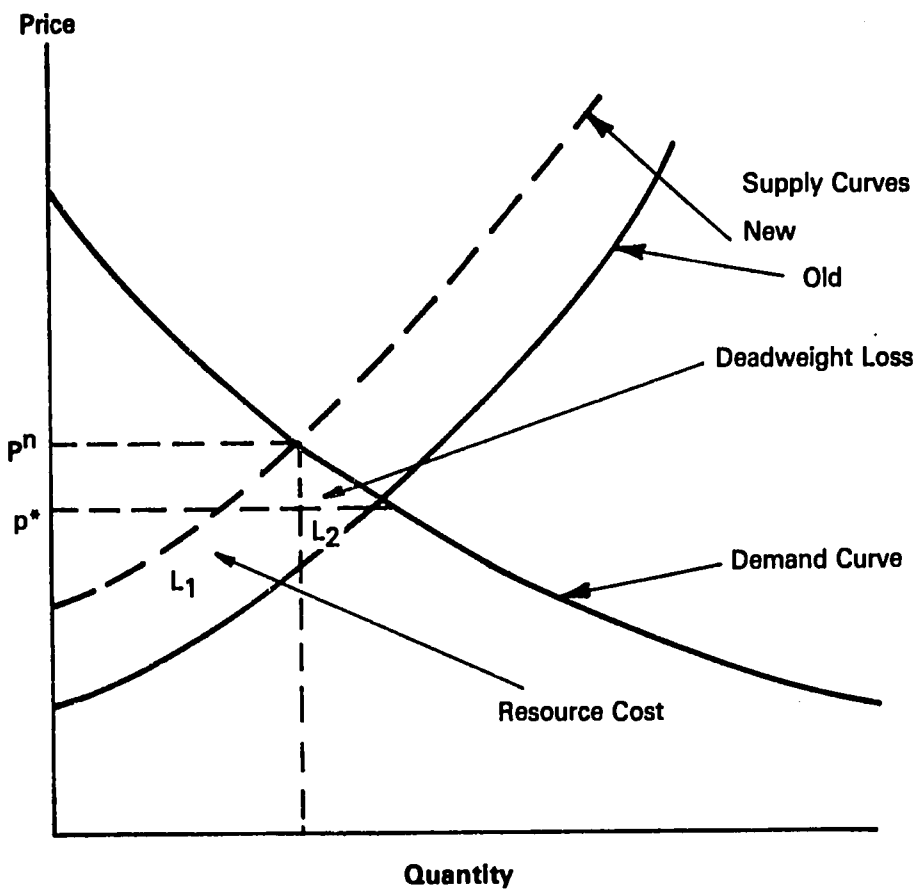


Figure 4 Effects of Environmental Protection on Supply/Demand

64

below the demand curve, above the new supply curve, and to the left of the new equilibrium quantity, q^n. The amount of the loss is shown by two areas on the diagram: the curved parallelogram indicated by L_1 and the triangle labelled L_2, of which the first is by far the larger. L_1 is called the resource cost of the measure. It is clearly just the new equilibrium quantity, q^n, multiplied by the increase in average production cost that has resulted from the environmental protection measure. L_2 is called the deadweight loss of the measure because it is the economic surplus that was yielded by the amount of product that was produced under the pre-existing conditions but is no longer produced because of the increase in production costs and prices resulting from the measure. Geometrically its amount is closely approximated by one half the reduction in quantity, $q^* - q^n$, multiplied by the average increase in production costs. Altogether, then, the economic cost of the protection measure is given by:

$$\begin{aligned}\text{Economic Cost} &= L_1 + L_2 \\ &= (\text{average of old and new equilibrium quantities}) \\ &\quad \times (\text{increase in average production cost}).\end{aligned}$$

All of these data are comparatively easy to estimate. In practice, L_2 is frequently so small that it can be neglected entirely. In estimating the increase in average production costs for insertion into this formula, however, it is important to remember that the costs as they appear to the farmer or other producer are not necessarily equal to the social costs that the benefit-cost analyst has to take into account. It is necessary therefore to estimate the changes in all the resources used in production--farm labor, use of draft animals, fertilizer, and all the rest--and to assign to each of them its social value, which may be considerably different from the cash value as it appears to the farmer or other producer. The relevant social values, as we noted, are the amounts by which these changes in resource use reduce the amount of resources, particularly foreign exchange, available for the economic development plan.

For example, suppose that, among other things, the environmental measure increases the number of hours of farm labor required to produce a ton of rice. Each hour of this farm labor should be valued at the amount of foreign exchange that it would be used to earn or conserve if not devoted to producing rice in the more expensive way required by the environmental protection measure. When there is substantial rural underemployment, this value may be nil or very small, even though it appears significant to the farmer who must engage the labor or sacrifice the income that his family labor could earn if additional effort were not required as a result of the protection measure.

It should not be difficult to obtain estimates of the social values of the resources involved, since those values are required for formulating the economic development plan. The values used in the plan should also be used in estimating the economic costs of environmental protecton measures, even if the benefit-cost analyst

feels that they are inadequate or inaccurate. If the analyst believes that the values used in the plan are wrong, he or she should endeavor to have them changed, but should use them nonetheless in order to maintain comparability between the estimates of environmental protection costs and the estimates used in other aspects of economic planning.

Most of the costs of an environmental protection measure are monetary. A large proportion, generally, take the form of increased costs of production; these can be estimated by the methods just illustrated. Another portion is likely to be the capital costs of structures and equipment needed to implement the protection measure, and the subsequent maintenance and operating cost. These can be derived from the usual engineering estimates of construction and operating costs by revaluing the resources used at their social prices to the extent that these differ from their cash prices. There are generally, also, administrative and enforcement costs which should not be forgotten.

4.2 Benefits

Estimating the benefits is substantially more complicated. There are often some monetary benefits but, as I pointed out before, benefits that take the form of improvements in public health or in environmental conditions frequently cannot be converted persuasively into monetary equivalents.

The monetary benefits can be estimated by the same methods that were indicated for estimating monetary costs. For example, if an environmental protection measure reduces coastal pollution and thereby increases the productivity of commercial fisheries, the analysis follows the lines in Figure 4. In this case the effect of the environmental protection measure is to shift the supply curve of fish to the right, increase the equilibrium output, reduce the equilibrium price, and increase the social surplus. Figure 4 still applies except that the dashed supply curve should now be regarded as the old one and the solid supply curve as the new one. All beneficial effects that have market values should be reduced to monetary equivalents, using social values, rather than the actual cash values when these diverge.

4.3 Analytical Complications

There remain the beneficial effects for which reasonable monetary equivalents are not available. The problem that arises is illustrated schematically in Figure 5. The situation envisaged is an environmental threat to public health. Four measures for dealing with it are contemplated, labelled A, B, C, and D. The least ambitious is A whose annual cost is estimated to be $2.5 million and so on up to D with an annual cost of $10 million. The only socially important effect is assumed to be an improvement in public health that is measured by the proportion of babies surviving to age 5. The estimated increase in this indicator corresponding to each of the four measures is shown vertically.

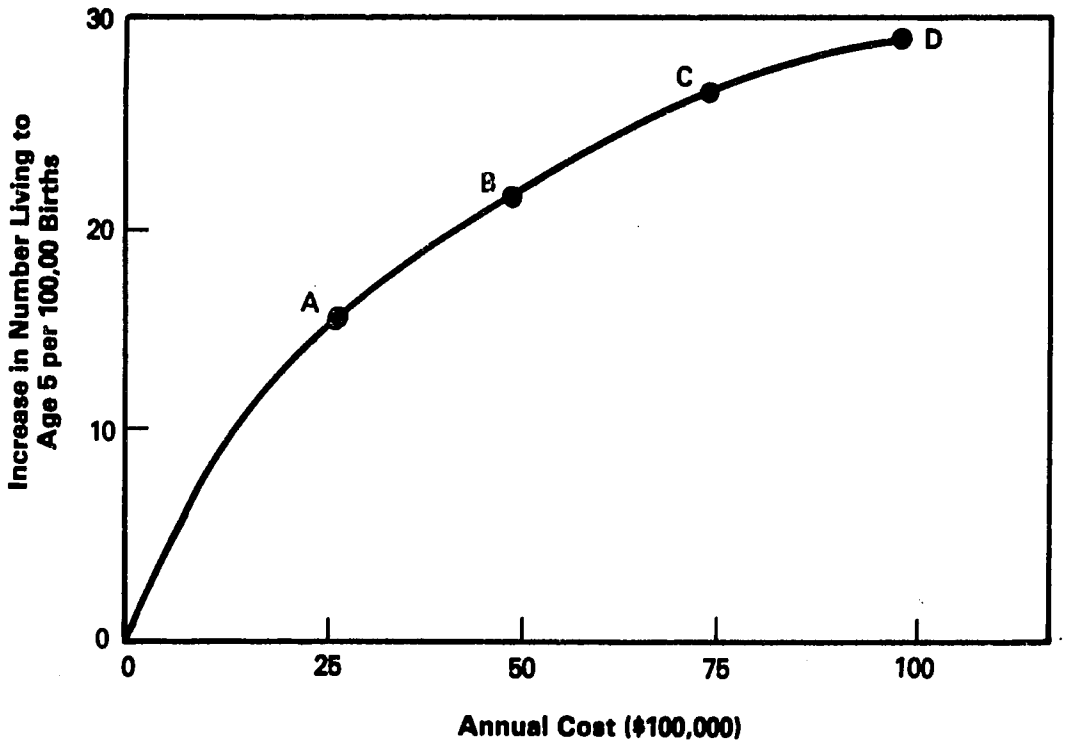


Figure 5 Benefit-Cost Comparison - Idealized Case

67

This sample graph contains all the relevant information about both the costs and benefits of the four alternative measures, on the basis of which the decision has to be made as to which of them, if any, to implement. It should be noted that in this case, as typically, each additional $2.5 million buys a smaller improvement in public health than the preceding one. N formula can make the judgement of how far it pays to go along ıe curve. Occasionally the judgement can be nearly mechanical. For instance, if limited funds are available to be allocated among a number of projects all of which have improvements in infant mortality as their primary benefits, then clearly the funds should be divided so as to obtain the largest total increase in infant survivorship. Decisions are rarely that easy. Funds are typically limited, but the undertakings that compete for those funds frequently yield benefits of different and noncomparable kinds. Then the decision has the effect of sacrificing some amount of one kind of benefit to gain an increase in the attainment of some dissimilar social goal. Such decisions are always subjective and difficult. The data yielded by benefit-cost analyses are essential to making judicious decisions of this sort, but still the decisions remain very hard.

Furthermore, the results of benefit-cost analyses are never as clear-cut as those shown in Figure 5. Figure 6 is more typical. Figure 6 portrays the same actual situation as Figure 5 but recognizes that neither the costs nor the beneficial effects of any of the alternatives can be foretold with precision. Accordingly the results of each alternative are indicated by a box, rather than by a point. Horizontally each box extends from the lowest cost that the analysis indicates to be likely to the highest cost. Vertically the height of the box indicat the range of beneficial effects that is deemed likely. Confronting such a portrayal the decision-maker has to arrive at this judgement as to which of the alternatives is preferable in the light of these indications of the uncertainty of the results. There are no mechanical rules for making such a choice, and the analyst cannot relieve the responsible officials of their responsibility.

Nor is that all. In Figures 5 and 6, I have vastly oversimplified the time-dimension. All of the alternatives considered have benefits and costs extending over several years, perhaps many, into the future. The costs will vary from year-to-year--and usually in different ways for the different alternatives--and usually cannot be represented adequately by a single annual cost. Similarly the beneficial effect will not be the same in every year, and the fluctuations or growth over time will be different for the different alternatives. It is therefore necessary to estimate the benefits and costs of the different alternatives year by year as far as they may extend or until some remote horizon date. When this has been done the costs can be reduced to a single representative number for ease of comprehension and comparison by computing the sum of the costs in the individual years discounted at the applicable social rate of discount, as discussed earlier. A total present value of the benefits of each alternative can be calculated similarly, using the same rate of discount.

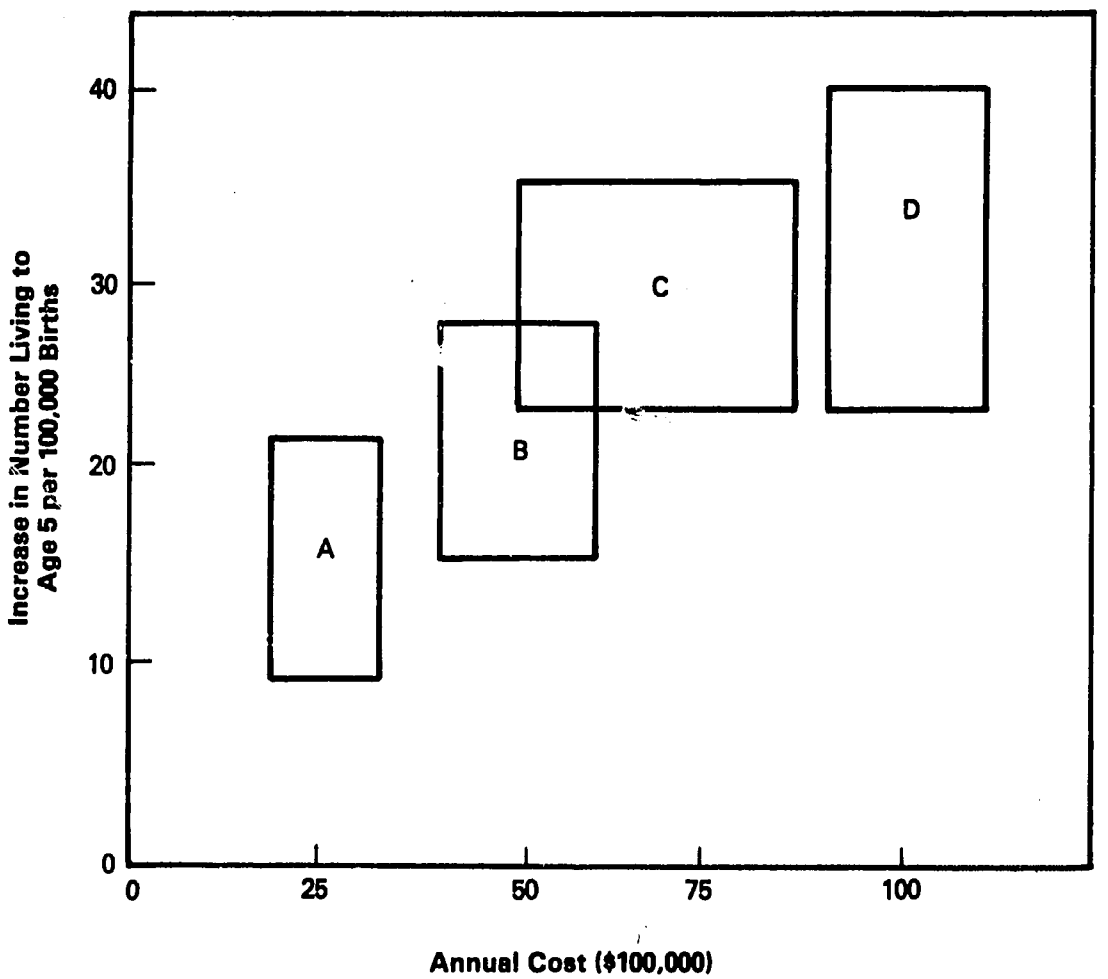


Figure 6 Benefit-Cost Comparison - Less Idealized Case

69

Parenthetically, many people resist the idea of discounting future benefits such as improvements in mortality rates, feeling that this implies a lower social evaluation of the welfare of future people than of people alive at present. That would be objectionable, but it is not really the reason for discounting benefits. The real reason is, rather, that a smaller quantity of current resources has to be committed to produce a benefit five or ten years from now than to yield the same benefit in the immediate future.

In addition, Figures 5 and 6 suppress the distributional aspects of the programs. That complication is really a special case of another one which I shall discuss immediately, so that separate treatment is unnecessary.

The final complication I want to call attention to is that diagrams such as Figure 5 and 6 have room for indicating the degree of attainment of only a single social goal. Environmental measures frequently are designed to achieve single goals, but that is not always the case. When several goals are involved more complicated means of summarization and portrayal are required. Since those methods introduce more by way of analytic technicalities than fundamental new concepts, I shall not go into them. The distributional aspects of a program can be regarded as a special case of multiple goals, since the effect of the program on each population group considered amounts to a distinguishable social goal.

5. Summary Illustrations

I think that by now I have conveyed the essential flavor of benefit-cost analyses of environmental problems. By way of summary I should like to present a couple of illustrative applications which, though simplified will show more concretely how this approach can help reach wise decisions about environmental programs in less developed countries.

The first example is addressed to the problem of preserving a less developed country's agricultural resource base. Suppose that population pressures are pushing farmland onto hillsides that have been protected by natural vegetation previously but now are being exposed increasingly to erosion. It is proposed to terrace the hillsides in order to arrest the erosion and preserve their fertility. The analytic task is to assess the benefits and the costs of the terracing. In this case both the benefits and the costs are essentially monetary, since the principal beneficial effect will be to prolong the productive life of the hillside farms. In terms of Figure 1, the human activity at issue is cultivating an unprotected hillside, the impact is the erosion of topsoil, the altered ambient condition is the reduction in fertility developing progressively over the years, and the social effect is the gradual reduction of a desirable crop and means of livelihood. In terms of Table 1, the initial analytic task, which falls to soil scientists and agronomists, is to estimate the rate of erosion in the circumstances of this

10

particular terrain and climate and to translate that rate into the effect on crop yields. Figure 7 shows the result of their studies. Years into the future are plotted horizontally. The vertical scale shows net yields in tons per hectare, meaning the additional yield per hectare that can be obtained in each year by cultivating the hillside fields, over and above the yield that the same resources could produce if devoted to cultivating the overcrowded valley. Two curves are shown: one for the estimated yields, if the hills are not terraced, and one for the yields if they are. The curve for net yields without terracing begins at two tons per hectare and falls, first very gradually and then increasingly steeply as the effects of erosion accumulate, until by the tenth year the net yields have fallen to zero and the fields are abandoned. The yields anticipated if the fields are terraced remain at two tons per hectare for thirty years, at which time the works require replacement. The analysis stops at year 30. The benefits of terracing are the excesses of the net yields with terracing over the net yields without, year by year over the economic life of the project, the area indicated as "Gain" in the figure. The gain is only a small fraction of a ton per acre in the early years, but grows gradually until it amounts to two tons per acre in the tenth year and thereafter. Since most of the gains occur well into the future they have to be discounted. If a discount rate of 10% per year is used, it is easy to calculate that as the diagram is drawn the present value of the gains over the thirty years amounts to approximately five times the initial net yield.

Costs are not shown in this diagram. They are, of course, the value of the resources required to construct the terraces and associated drainage works needed to prevent erosion. If the construction is undertaken as part of a rural works program, as is often the case, these resources will comprise rural labor for the most part, local construction material, a small component of skilled and supervisory labor, and some use of construction machinery. The requisite quantities of all these resources are estimated in the course of the standard preparatory engineering studies. The economic costs can then be computed by valuing the resources as usual, at their social values. If the costs per acre so calculated are less than five times the value of a single year's crop, there is a net economic gain to be had by terracing the hillsides. Even if the costs are somewhat greater than that, terracing might be advisable since the erosion, if once permitted, is irreparable. In this case a judgement would have to be made about the social value of preserving the fertility of the hillside even though on strict economic grounds it is not worthwhile under current conditions.

My second illustrative application concerns the other pressing environmental problem of the less developed countries, namely water supply and sanitation. Consider a program intended to reduce the pollution of village water supplies by moving the wells to higher ground where they will not be so subject to contamination, and protecting them with parapets. The beneficial effect intended is a reduction in the prevalence of intestinal infusoria. The costs are very similar to the costs of the terracing in the first example.

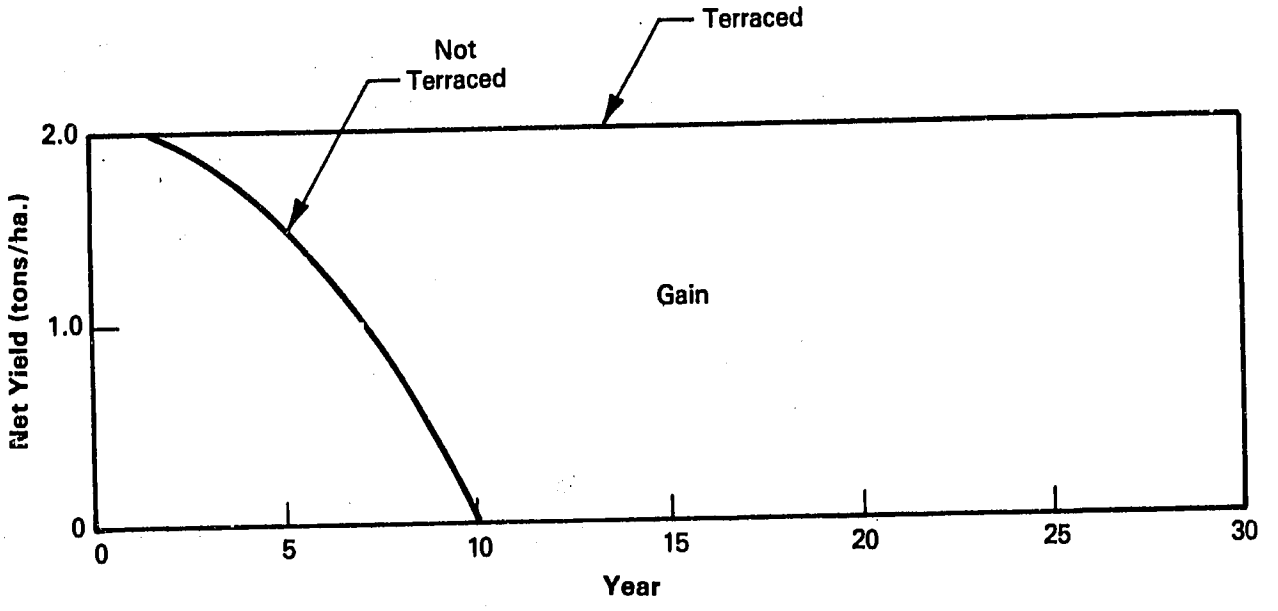


Figure 7 Gain from Terracing

17

To analyze the environmental and social benefits of this kind of undertaking it is helpful to use the framework of Figure 2, which emphasizes the changes that are induced by an environmental undertaking. The human activity that is involved is simply obtaining water from the village water supply. The change intended is to reduce or even eliminate the use of contaminated sources in favor of new and clean ones. But the change that will actually result is a different matter. It depends on how readily villagers can be enticed away from their familiar sources of water to new and generally less convenient ones, and also on the vulnerability of the new supplies to contamination. The first of these considerations calls upon the skills of the sociologist. The second consideration depends on social behavior also and in addition on the details of the design of the new wells. If they are open and are used by dipping buckets or jars into the reservoir they will become contaminated in short order. If they are covered and if the discharge point is at some distance from the well proper they are virtually invulnerable. They are also much more expensive to construct and may be more difficult to use, so that the villagers may avoid them. Clearly the effects of such a program depend on a complex of considerations going far beyond the usual analyses of sanitary engineers and specialists in infectious diseases, though these specialists too have essential contributions to make.

In short, the first and critical stage of analyzing a project whose results depend on altering behavior patterns is to estimate the extent to which behavior will in fact be changed. From these estimates the infectious disease specialists can infer the resulting reduction in the incidence of gastro-intestinal infection. The result can be depicted in a diagram similar to Figure 6. Now we may think of A, B, C, and D as four different designs of less vulnerable wells, design A being the cheapest and most subject to contamination, design D the most expensive and least vulnerable. The choice of design then depends largely on how this diagram compares with diagrams for alternative programs designed to reduce the same kind of infection, as well as on the adequacy of the budget available for this purpose.

6. Closing Remarks

A few final words. It has not been my intent in this exposition to initiate you into the professional mysteries of benefit-cost analysis. I have tried, rather, to help you, as responsible officials, appreciate what benefit-cost analysis can do to help you with your very difficult tasks. You should know what benefit-cost analysis does, what difficulties the analyst confronts, and what the limitations of the procedure are. You should know, and I hope that this discussion has alerted you, what questions to ask of the analyst--what assumptions to ask about, what complications should be taken into account, and what information you have a right to demand of the analyst. You should also appreciate what resources the analyst has a right to demand if his work is to deserve credence.

13

I hope that I have also made clear two points of substance. First that the environmental problems of the less developed countries are different from those of the more developed countries and at least as severe. This difference accounts, in my opinion, for the divergence of views at the Stockholm conference on world environmental problems. There, you will recall, the representatives of the more developed countries called for world-wide abstention from the use of DDT as an agricultural pesticide; the representatives of the less developed countries did not go along. Each group was correct from its own point of view.

Second, I hope that I have conveyed the importance of integrating environmental decisions with decisions relating to economic development, and have made some practical suggestions as to how this can be done.

And, really finally, I hope that I have persuaded you that prudent and effective decisions about environmental problems require the information that only benefit-cost analyses can provide. The information will always be far less than the decision-maker would like to have, but still he or she will find it indispensable.

July 5, 1979

14

BIOGRAPHICAL SKETCH

Robert Dorfman

Professor of Political Economy
Harvard University
Cambridge, Massachusetts

Education: B.A. Columbia University 1936
M.A. Columbia Univeristy 1937
Ph.D. University of California (Berkeley) 1950

Professional Career

1939-1943. Economic statistician at Bureau of Labor Statistics and Office of Price Administration. Worked on Consumer Price Index at BLS and on price control policies at OPA.

1943-1946. Operations research work for U.S. Air Force. Was a member of the first American organization to develop and apply operations research methods.

1950-1955. Professor of Economics, University of California (Berkeley).

1955-Present. Professor of Economics, Harvard University. His present position is David A. Wells Professor of Political Economy.

Dr. Dorfman's research interests after becoming an economist were in applying the theory of linear programming to economic analysis and business decisions. In 1958 he published Linear Programming and Economic Analysis (with Paul A. Samuelson and Robert Solow), which for many years was the leading treatise in the field. (Now out of date.)

Around 1955 Dr. Dorfman's interests turned to natural resource problems. In 1962 he published Design of Water Resource Systems (with Arthur Maass, Maynard Hufschmidt, Harold A. Thomas, Jr. and others). This became the leading treatise on the economic analysis of water resource development. Many of its recommendations have since become standard practice, and it is still consulted.

In 1961 Dr. Dorfman was appointed a member of a committee sent by President Kennedy to Pakistan to make recommendations about the very severe water resource problems in the Punjab. This led to other work in less developed countries faced with water-related problems, including Ghana and Bangladesh, and to a general interest in the planning of development programs.

Most recently, Dr. Dorfman's interests have centered on environmental problems. He has been a member of the Environmental Studies Board of the National Research Council and is currently a member of the Science Advisory Board of EPA. In 1972, he published Economics of the Environment, Selected Readings (with Nancy S. Dorfman), now in its second edition.

15

Along the way Dr. Dorfman published The Price System (1964) and Prices and Markets (1967, third edition, 1978) and the usual assortment of papers on various aspects of economic theory, particularly capital theory. Also, in 1965 he edited Measuring Benefits of Government Investments, an early collection of papers dealing with those difficult problems.

Dr. Dorfman has served as President of The Institute of Management Sciences (1965), member of the councils of the Econometric Society and the American Economic Association and the Operations Research Society of America. He consulted for the Agency for International Development, the World Bank, the U.S. Department of Energy, and others.

THE ROLE OF
ENVIRONMENTAL STANDARDS AND REGULATIONS
IN THE MANAGEMENT OF INDUSTRIAL DEVELOPMENT

Barbara J. Goldsmith
Manager, Program Development
Policy Analysis Division, Washington, D.C.
ENVIRONMENTAL RESEARCH & TECHNOLOGY, INC.

June 1980

International Environmental Management Institute
ENVIRONMENTAL RESEARCH & TECHNOLOGY, INC.
Concord, Massachusetts, USA

77

THE ROLE OF ENVIRONMENTAL STANDARDS AND REGULATIONS IN THE MANAGEMENT OF INDUSTRIAL DEVELOPMENT

EXECUTIVE SUMMARY

The discussion of environmental standards and regulations is presented in two parts. The first part, beginning on page 1, describes the purposes served by governmental standards for pollution control and the points to be considered in their formulation and implementation. This material included discussion of the separate, but interrelated roles served by ambient standards and source standards. This discussion was prepared by Mr. Roger Strelow, former Assistant Administrator for Air Pollution Programs of the U.S. Environmental Protection Agency and presently with the Washington, D.C. law firm of Leva, Hawes, Symington, Martin and Oppenheimer.

The second part of the environmental standards and regulations chapter, beginning on page 7, discusses options for the management of long-term industrial growth consistent with the protection of environmental amenities. This discussion illustrates, by case example, a U.S. program which regulates the location, type and amount of industrial growth on the basis of air quality considerations.

<u>The Need for Governmental Standards</u>

- "The Tragedy of the Commons"
- Failure of economic systems to "internalize" environmental damage costs
- Limitations on private legal remedies
- The clearest means to articulate society's values relating to environment
- Should permit orderly, reliable planning

<u>Relevant Considerations</u>

- State of the environment
  - -Present problems
  - -Potential threats
  - -Accuracy of information

18

Important Values

-Health

-Visibility/aesthetics

-Others

- The economy
- Complementary and conflicting objectives
- Realities of the political system

The Role of Environmental Quality Standards

- Distinguish ambient/receptor standards from source/discharge standards
- These define the ultimate goals and the justification for source controls.
- Based on health and welfare criteria and possible non-degradation objectives
- Must be preceded by monitoring
- May be goals or requirements

  -Depends partly on status of ambient monitoring and discharge inventory

The Role of Source Standards

- The ideal--source standards based on environmental objectives and conditions
- Practical limitations--incomplete ambient monitoring information, inaccurate discharge inventory, limited dispersion modeling tools, complex (not always proportional) relationship between discharges and ambient conditions (e.g., secondary pollutant formation), economic and technological limitations
- Sometimes used as surrogate for environmental quality standards (simple but inefficient)
- Normal approach--A mixture of ambient-related and technology-based source standards

19

-Relate to ambient conditions where possible

-Technology-based standards for new plants and some existing plants

-Some technology-based standards must specify equipment or management practices (normally avoid if possible)

-Extensive use to protect groundwater surface water runoff

Components of Standards

- Environmental quality standards

  -Concentration limit

  -Averaging time

  -Measurement locations

  -Permissible frequency of exceedences

  -Measurement criteria and methods ("reference" and equivalent methods, quality assurance, calibration)

- Source standards

  -Quantity per unit of time, production, or input

  -Schedule for compliance

  -Measurement techniques (discharge measurement, determination of fuel quality, checking conditions of equipment and use of "emission factors")

Two Basic Strategies--Cleanup or Prevention

- Relevant conditions

- Relationships between the two strategies--e.g., regulating new plants in dirty areas

- Cleanup strategy

  -Equitable allocation of the burden

  -Need for deadlines, periodic reassessment of progress

  -Accurate discharge inventory is essential

80

- Preventive Strategy

  -Focus on technology and siting

  -Must relate controls to land use planning

  -Limiting degradation

U.S. Case Example (Implementation of a Preventative Strategy)

- U.S. goal to preserve good air quality in less developed regions

  -Called Prevention of Significant Deterioration (PSD) of Air Quality

  -Includes detailed preconstruction review of all major new and expanded industrial plants

- Control levels are greater than that needed to protect public health

Background of PSD Policy

- Courts decreed that U.S. air pollution program purpose is "to protect and enhance..quality of..nation's air resources"

- No legal definition of "significant deterioration of air quality" given

- Regulations developed to implement PSD policy

  -Air quality increment approach ($\mu g/m^3$)

  -Three types of clean air areas

Requirements of PSD Policy

- Stringent emission control and siting rules

- Allowed emissions increases are small fraction of related ambient standards

Effects of PSD Policy

- Can limit size of industrial plants

- Can limit total number of sites suitable for development

- Has created technical and administrative uncertainty regarding new industrial plant construction

- Has in some cases foreclosed planned construction

81

Questions Raised by PSD Policy

- How can long term growth be managed consistent with environmental goals?
- Should countries allow development up to maximum allowable standards or "allocate" growth in some other manner?
- What is the appropriate statement of such guidelines?

THE ROLE OF ENVIRONMENTAL STANDARDS AND REGULATIONS IN THE MANAGEMENT OF INDUSTRIAL DEVELOPMENT

The Need for Governmental Standards

A proper starting point is to consider why we need governmental standards for pollution control in the first place. Fundamentally, this need arises in any society or nation when the level of polluting activities relative to the natural resources that they use up--basically, air and water--threatens to consume those resources--that is, when those resources begin to become scarce. In the absence of governmental standards and restrictions, normal economic incentives do not adequately protect air and water resources or their ultimate owner, the general public, since these resources are free goods, i.e., they have no market price. This phenomenon is true in both capitalistic or free market economies and in socialist economies. In neither case, absent regulations, must those who use air and water as a dumping ground for their waste products "internalize" or account for the costs to the society of doing so. Absent regulations, the costs of impaired health, reduced visibility, damage to crops, and other consequences of pollution are borne by the affected public and not by the responsible enterprises and their customers. One result is that polluting goods and services are underpriced and therefore produce a distorted allocation of society's total economic resources.

This phenomenon is sometimes called "the tragedy of the commons," a reference to a very simple example. It involves a community that makes a piece of public land available for grazing by livestock. When the demand for the grass exceeded the capacity of the commons, allocations had to be made (i.e., regulation) or the entire community would suffer.

In the U.S., the legal system heavily favors and encourages individual citizen actions in court to restrain and obtain compensation for harm inflicted by a neighbor, including neighboring plants that create pollution. Even in such a legal system, it is obvious that leaving pollution control to such case-by-case attention is highly inefficient and inequitable. Just one of many important limitations on such an approach is the fact that individual citizens who object to a particular pollution problem rarely have the financial and scientific resources to demonstrate that they are entitled to relief.

More importantly, there are affirmative benefits to many affected interests when pollution is regulated by the government through comprehensive standard-setting and enforcement. First, such a system allows a society, through its normal political decisionmaking processes, to articulate and define on a regional or national basis just what balance it wishes to achieve among competing economic, health, aesthetic and other interests. Second, it allows scientific and other pertinent data to be gathered and analyzed in a way that is more efficient and meaningful than any alternative would allow. Third, so long as the governmental decisionmaking process attaches reasonable

83

weight to industry's need for certainty and stability, the standard-setting process facilitates the long-range industrial and/or governmental planning that is critical to healthy economic development in modern times. With standards and timetables to guide them, economic planners can (and must) factor environmental constraints into their work, thereby minimizing future conflicts. Fourth, standard-setting in an economy that allows or promotes competition tends to maximize equity among competitors.

The U.S. has been through several phases of environmental standard-setting and regulation. First, there was a very generalized and decentralized process which left many key decisions to individual states and communities. Then, at the turn of the last decade, we shifted to a more rigid and ambitious assertion of centralized national authority in response to public dissatisfaction with the results of earlier efforts. Now, we are moving inevitably into an era of greater recognition of the economic and social limitations on how much environmental improvement we can achieve and how fast. The enormous costs of regulations are now receiving considerable attention as well as the benefits.

Relevant Considerations in Standard-Setting

Once the decision has been made to regulate pollutant discharges into the air or water, or onto the ground, the government must define the basis on which standards are to be set and implementation strategies devised. (Throughout these remarks, please bear in mind that only one small part of "standard-setting" is the selection of numerical or other limits. Equally important are the allocation of pollution reduction responsibilities among different plants and industries, the schedules selected for their achievement, and the means chosen for enforcement.)

In any situation, there are both technical and non-technical factors that should be considered in setting standards. The relative weight given to each, and the way in which each is considered will vary considerably according to the basic political system, the prevailing political climate, and the accuracy of the information available.

The technical or scientific factors to be considered include, most prominently, the state of the environment and the state of control technology. Assessment of the state of the environment must include both present conditions, and their effects on public health and welfare, and potential future conditions together with their likely consequences. This latter consideration may have overriding importance in a rapidly developing economy and should be a major factor in deciding when to institute a serious regulatory program. Experience in the U.S. and elsewhere will demonstrate that waiting until problems are severe, and then instituting corrective action, is inefficient and invites harmful overreaction.

Defining the present state of the environment involves two parts. First, determining ambient levels and trends can be accomplished only by a well-conceived program of monitoring, supplemented by modeling

84

simulations. Studies of comparable experience elsewhere cannot substitute for such a program in your own nation. Design of a cost-effective monitoring program, targeted on the pollutants most likely to be prevalent and in representative locations, is critically important. Experience to date in the U.S. and other nations with environmental programs should be reviewed carefully--for both successes and failures. Even the most advanced governmental programs are still learning some fundamentals, as you will see from a recent U.S. EPA regulation substantially changing the approach to nationwide ambient air monitoring and reporting. (Basically, it replaces a large network of poorly maintained monitors with fewer and better-maintained key trend-monitoring stations and correspondingly less data reporting.)

The second part of defining environmental conditions is a determination, or, more accurately, an estimate, of the health and welfare effects associated with present or projected ambient pollution levels. This tends to be more difficult and time-consuming. However, there is less scientific necessity for assembling nation-specific or region-specific data than is the case with ambient monitoring. Absent unusual circumstances, reliable data from other nations that can be correlated to your conditions should be very useful. The pressure to have your own, site-specific health effects studies may well be more political than scientific. Unfortunately, data on the most critical subject, human health effects, is still quite sparse for most pollutants.

The other major technical consideration is that of control technology and its capability. Many of these technologies are relatively well documented. Here too, basic information can and should be gathered from abroad as well as domestically. In the U.S. air pollution control program, one of the most important technological developments used to tighten U.S. emission standards for power plants has been the SO_2 "scrubber", largely a Japanese innovation. It appears that Japanese NO_x control technology may be an important influence in the U.S. as well. Of course, "availability" of control technology must consider realistic operating and maintenance capabilities as well as the hardware itself.

One potentially important factor in assessing control capabilities is fuel availability and national fuel policy. Consider the contrast, for example, between the U.S. and Mexico. In this country, natural gas supplies appear to be dwindling over the next several decades despite the present temporary upturn in supplies tied at least in part to new government pricing policies. This fact, combined with undeniable shortages of domestic petroleum and a dangerous degree of dependency on foreign sources dictates that the U.S. do all it can to use coal for fossil fuel needs. Hence the great pressure for developing and using technology for cleaning up this inherently dirty fuel. In Mexico, on the other hand, the domestic fuel supply situation is quite different, allowing that government to turn from high sulfur oil to natural gas as a means of reducing pollution in the highly polluted Mexico City area.

85

Besides technological factors, of course, the standard-setter must consider other very important factors such as the present and projected state of the economy and governmental or social objectives that may require tradeoffs with the objective of environmental improvement. Current developments in the U.S. well illustrate how the fortunes of costly environmental protection efforts are inevitably tied to the state of the economy. Persistent and substantial inflationary conditions in our economy have forced a very pro-environmental Administration to get quite serious about holding down regulatory costs. Such costs are largely inflationary regardless of the offsetting economic benefits of a cleaner environment. It is essential, for the long-term viability of an environmental improvement program, that it be structured in a way that ensures adequate consideration of economic and political factors in the standard-setting process. Without this, the program may run amok, perhaps producing greater short-term environmental gains but very likely building up a dangerous resistance of "backlash" over the longer term.

The U.S. clean air program presents a curious example of how economic factors may be considered. Almost unique among other environmental and health-protection legislation, our Clean Air Act sharply limits the consideration that may be given to economics by the federal EPA and by the State air pollution agencies. This approach resulted from Congressional frustration in 1970 with the poor performance of state agencies and skepticism that federal administrators, if given flexibility, succumb too readily to economic pressures for weak regulation. The consequence is that to a large degree, relief based on economic grounds must be obtained periodically from the Congress itself rather than from administrative officials. In addition, however, these officials use great ingenuity to grant quite a bit of economic relief, not strictly authorized under the law, without admitting they are doing so. One can seriously question whether there isn't a more sensible and straightforward way for Congress to ensure that economic realities are considered while ensuring at the same time that narrow economic pressures are not given undue weight.

The Role of Environmental Quality Standards

Since the ultimate justification for expenditures to reduce discharges into the environment is prevention of some environmental harm or providing an environmental benefit, the only logical starting-point for an environmental quality program is the specification of environmental quality standards. Controls on individual sources of pollution should be related to these governing targets. These targets may be numerical limits on ambient pollutant concentrations above which it is believed there will be an unacceptable amount of harm. As illustrated in recent U.S. experience, these may include somewhat arbitrary limits on the extent to which further degradation is to be allowed in relatively clean areas. Preservation of cleanliness may be important not only for aesthetic reasons but also for economic reasons, e.g., to preserve recreational values.

86

Having accepted environmental quality standards as the starting point, however, it is essential to recognize the many uncertainties and pitfalls that exist in relating both individual source regulations and overall strategies for source regulations, to these ultimate goals in any precise way. If we have an ambient air quality standard for pollutant X, for example, we can be reasonably confident that ambient levels of that pollutant will be roughly proportionate to the allowed discharges of that pollutant or its precursors into the air or water. Often, however, we cannot proceed beyond such a conclusion with any degree of reliability.

Ambient levels of pollutant X often depend not only upon the emissions of that pollutant or precursor pollutants but also upon atmospheric levels of other pollutants and upon meteorological conditions such as humidity and temperature. Moreover, it is essential to determine the relevant area within which discharges may be related to ambient conditions. Over the last decade, for example, we have confirmed that both sulfate and ozone levels in the atmosphere result from emissions over very broad geographic areas. Thus, atmospheric levels of these pollutants in any single area or even in an entire state may be only minimally related to emissions within that area or state. This phenomenon, of course, has profound political as well as technical implications. It means that neighboring nations, including those that are not adjacent to one another, must develop cooperative strategies for solving a shared problem to which each contributes. This fact is well illustrated in a recent study which ERT conducted for the U.S. Department of State on the issue of long-range transport of pollutants. Within the U.S. itself, we are grappling more intensively each year with the transport of sulfates and their precursors from the industrial Midwest to the Eastern U.S. The same is true for ozone.

The Role of Source Standards

Ambient standards by themselves accomplish nothing. To have any effect on pollution levels there must be discharge or emission limitations for all significant individual sources and for categories of sources that are individually minor but collectively significant in impact. To the extent reasonably possible, these source standards should be based on estimates of how much control is needed to meet the ambient environmental quality standards or targets. This is the ideal. But a combination of technical and economic realities, and the uncertainties of relating emission and ambient levels, dictate that some compromises be made. Even if the relationship between emission and ambient levels could be clearly defined, limitations in the state-of-the-art in control technology and on the amount of economic resources that can be devoted to pollution control in particular plants and industries will constrain what can and should be done. It seems logical, of course, that the extent of uncertainty regarding emission and ambient relationships and regarding the adverse effects occurring at the level of the ambient standards should play a significant part in determining how much technology-forcing and economic hardship it is reasonable to demand for particular sources.

87

It should be obvious that the impacts of economic, social and political considerations will be felt more heavily at this secondary stage of environmental standard-setting -- that is, in determining controls for individual sources -- than at the more abstract initial stage of setting environmental quality standards. It is essential throughout both of these stages that regulators and those who are regulated be totally candid with each other and the public. Economic and other constraints should be handled openly and identified as such. Too often there is a tendency to confuse technical and economic considerations, for example by arguing that a particular environmental quality standard is unduly stringent for health protection purposes when in fact the problem is that its attainment is not economically feasible. Confusing such considerations leads to loss of credibility with the public and with legislative and executive leaders in the government. Such a loss of credibility, as we have seen in the U.S., hurts both the regulators and the regulated.

As a practical matter, when there is substantial uncertainty as to how much control of particular sources is needed to meet ambient objectives, it is often a prudent course to set source standards primarily on the basis of technological and economic feasibility, insisting on more stringent measures only where this appears clearly needed. This approach, followed in the Clean Water Act in the U.S., has proved far less contentious and troublesome in general than the contrasting Clean Air Act strategy. The Clean Air Act focuses much more heavily on estimated ambient/emission relationships and gives far less weight to technical and economic constraints.

Two Basic Strategies -- Cleanup and Prevention

Where the environment is already fouled, the basic strategy must be to achieve a cleanup, a "rollback" of emissions from existing levels at existing sources. This involves far different measures than does a preventative strategy for keeping a clean area clean. These differences illustrate the wisdom of imposing a regulatory program before environmental conditions deteriorate, if possible.

Where cleanup is required, there must be an accurate emissions inventory -- basically a technical task. Then there must be an appropriate allocation among various existing sources of the total emissions reduction that must be achieved -- a potentially difficult task from a political point of view. Unless most of the major existing sources in the area are relatively new and located at sites with available land, retrofitting of necessary controls may be very costly both in absolute terms and relative to the remaining value of the facilities. Plant operators will have considerable incentive to delay or totally avoid the applicable requirements, and therefore a major, sustained enforcement effort may be needed. In addition, assuming industrial growth is continuing in the area, there may be substantial difficulties in accommodating such growth while existing sources alone are exceeding environmental standards.

88

If this is the situation in your country, you must simply face up to the difficult tasks involved and prepare for a long clean up campaign. However, if you can avoid such a predicament by instituting controls before environmental impacts get out of hand, you are far better off, and so are those being regulated. In the first place, a preventative strategy can and should accommodate land use planning as an integral element, a subject discussed below. Intelligent planning can channel growth into areas where natural conditions tolerate pollution better than other areas (e.g., well-ventilated smooth terrain) and avoid sensitive areas (e.g., areas with significant recreational value). Decisions may be made to allow normal standards to be exceeded in designated "industrial parks" just as other areas can be protected by standards more stringent than the normal.

Secondly, controls on new facilities, regardless of their location, will be better able to minimize the long-distance pollutant transport problem discussed earlier. This is because new plants almost always can be designed from the outset to incorporate more effective controls at less cost than is possible with retrofits.

In the U.S., attention has turned increasingly to the preventative approach at the same time that we continue the demanding process of cleaning up dirty areas. Public concern over preserving the pristine air found in much of the scenic Western U.S., where development pressures are building, provided the trigger for a new U.S. program called "prevention of significant deterioration of air quality", described below.

Land Use Planning Aspects of Air Pollution Control

While control of air pollution is not the central issue for most countries in the formulation of development plans for regions, many potential air pollution problems (in particular those associated with the operation of heavy industrial facilities) can be minimized by a careful choice of location for such facilities. In regions where substantial development has not yet occurred, but will occur in the next several years, careful locational planning can improve air quality for residents and for the work force within these regions. These benefits of good air quality can often be achieved with little additional cost if air pollution is considered early in the planning process.

The planning decisions which most directly influence air quality for the population include:

1. location of heavy industry and principal transportation routes,
2. location of residential areas relative to the industrial zones,
3. location of sensitive facilities, such as hospitals and schools, and
4. specification of maximum industrialization in the development areas.

89

Early consideration of these decisions will generally result in better air quality (both present and future) in the major development regions of countries. Where environmental standards or guidelines are established in a country, such standards will in some cases impose limitations on industrial development. Standards can provide definite limits which can be considered by planners, architects, and engineers in the design of major industrial and transportation facilities. The issue is whether countries should allow development to occur up to the maximum allowable standards or whether countries should seek to "allocate" growth in some other manner.

A Case Example: The U.S. "PSD" Policy

In the United States, a goal to preserve good air quality in less developed regions was codified into the Federal Clean Air Act in August 1977. To implement this goal, detailed rules for preconstruction review of major new and expanded industrial plants in clean air areas have been established in order to minimize the amount of air pollution emitted from sources in these areas. These areas of the country where air quality is better than the National Ambient Air Quality Standards (NAAQS) are called Prevention of Significant Deterioration or "PSD" areas.

The PSD policy in the U.S. is intended to preserve the special characteristics of the national parks and other sensitive areas, and to allow moderate growth of well-controlled facilities at suitable locations in other clean air areas. To meet this goal, the PSD rules establish stringent emission control and siting requirements on all new and expanded major emitting facilities in clean air areas. Therefore, these rules can limit the size of individual plants as well as the total number of sites potentially suitable for industrial development. Three classes of clean air areas have been established and maximum increases of SO_2 and TSP concentrations have been specified. These increment values (expressed in micrograms per cubic meter) are small percentages of the related national ambient standards for each pollutant. Control of air pollution through the PSD policy, therefore, goes well beyond the control levels needed to protect public health. PSD has created substantial technical and administrative uncertainties and delays in major plant construction in the country, and has in some cases, foreclosed planned construction. The following material describes the United States experience in developing and implementing its PSD policy in order to illustrate how one country has sought to regulate the location, type and amount of industrial growth on the basis of air quality factors.

90

Background of the PSD Policy

The basis for PSD policy grew out of a citizen group law suit filed against the United States Environmental Protection Agency (EPA) in 1972. The courts interpreted that the preamble to the United States Clean Air Act, which states that one of the purposes of the Act is "to protect and enhance the quality of the nation's air resources", was sufficient basis to compel the EPA to establish a policy to "prevent significant deterioration of air quality" in regions of the country having cleaner air than the national standards. However, the lower courts (and ultimately the Supreme Court) did not define the meaning of "significant deterioration of air quality". In 1974, after considering several alternative definitions, the EPA adopted an air quality concentration "increment" approach, which specifies a maximum allowable increase in pollutant concentrations above "baseline" air quality. In 1977, after considerable debate, the United States Congress extended and made more stringent the EPA increment approach to PSD and incorporated the PSD policy into the nation's law.

To provide an appropriate context for the discussion of the PSD rules, three air pollution control objectives which are embodied in the U.S. Clean Air Act are summarized in Table 1. The 1970 Amendments to the Clean Air Act established the requirement that the ambient air quality (designed to protect public health and welfare) for regulated pollutants be attained at all locations in the country. The 1970 Amendments further protect existing air quality by requiring the use of best available controls at all new facilities. The PSD policy assumes that all the ambient standards will be attained and that best controls will be employed at all new facilities in addition to preventing air quality deterioration.

The Clean Air Act, as amended in 1970, divided the country into air quality control regions (AQCRs) for regulatory purposes. By December 6, 1977, each state was required to submit to EPA a listing of the attainment status of its AQCRs for each of the criteria pollutants. An area with air quality better than the National Ambient Air Quality Standards (NAAQS) (based on the most recent air pollution monitoring or modeling data available) is designated as a prevention of significant deterioration (PSD) or attainment area for these pollutants. An area with air quality measured (through monitoring) or estimated (through modeling) to be worse than the NAAQS is designated as a nonattainment area for the applicable pollutant. Areas for which there is insufficient information on attainment status are initially classified as PSD areas. Entire AQCRs may be designated as attainment or nonattainment areas, or the state may apply such designations to subdivisions of AQCRs.

The attainment status of AQCRs throughout the country was originally published on 3 March 1978 for each of the criteria pollutants: sulfur dioxide, particulates, nitrogen oxides, carbon monoxide, hydrocarbons, and oxidants. Numerous changes to the March 1978 designations have since been made. New and expanded industrial facilities proposed in a PSD area are subject to preconstruction review according to the PSD rules described below.

91

TABLE 1

GOALS OF THE U.S. AIR POLLUTION CONTROL LEGISLATION

1. Attainment and Maintenance of Air Quality Standards	Promulgation of standards for maximum permissible concentrations of pollutants which may endanger public health and welfare. Compliance mandatory regardless of limitations on industrial and commercial activity.
2. Use of Best Available Controls	Represents a commitment to include the best available controls in terms of economics and technology, on all new facilities even if controls are not necessary to assure compliance with air quality standards.
3. Prevention of Significant Deterioration of Air Quality	Represents an aim to preserve good air quality in regions having ambient air quality levels better than any national primary (health) or secondary (welfare) standard.

92

Clean Air Act Requirements

Part C of the Clean Air Act as amended in 1977 contains provisions to protect areas of the country which are in compliance with the NAAQS. These PSD provisions are generally extensions of similar regulations promulgated by the U.S. Environmental Protection Agency (EPA) in December 1974. Three classes of clean air (PSD) areas are established and maximum allowable increases in sulfur dioxide (SO_2) and total suspended particulate (TSP) pollution levels over baseline measurements of air quality are specified. By August 1979, EPA was to have promulgated PSD regulations for the remaining criteria pollutants (carbon monoxide, photochemical oxidants and nitrogen oxide). The Act does not require increments to be developed for these pollutants, but mandates "specific numerical measures against which permit applications may be evaluated". If a national standard is promulgated for any additional pollutant species in the future, EPA must promulgate PSD regulations for that pollutant within two years following promulgation of the standard.

Immediately upon passage of the 1977 Amendments the following areas were designated as Class I areas: all international parks, national wilderness areas and national memorial parks greater than 6,000 acres in size (158 areas). All other PSD areas of the country were initially classified as Class II. A state may redesignate any area to Class I. The Act requires federal land managers to review all national monuments, primitive areas, and national preserves (Class II areas) and recommend those areas where air quality related values are important attributes for redesignation to Class I. States are also permitted to redesignate certain areas to Class III, <u>except</u> the following areas greater than 10,000 acres in size: present national monuments, primitive areas, recreation areas, wild and scenic rivers, wildlife refuges, lakeshores and seashores, and future national parks and wilderness areas. Redesignation of an area to Class III is a complicated process requiring approval by the governor, detailed analysis of the health, environmental, economic, social and energy impacts of the proposal, public notices and hearings, consultation with the state legislature, and approval by a majority of the potentially affected local residents.

Table 2 summarizes the increment limitations for SO_2 and TSP concentrations in each of the three area classifications. The Class I increments are approximately 2% of the related ambient standard in the case of SO_2 and 7% for TSP. The Class II increment limits are approximately 25% of the related ambient standards for both pollutants (with the exception of the 3-hour SO_2 limit which is larger) and the Class III increments are 50% of the related standards. It is very important to note that the increment limits must be attained for all future times; therefore individual new facilities generally will not be permitted to "use up" the increment. Instead, they will be required to limit emissions so as to use only a part of the increment.

93

TABLE 2

PSD PERMITTED INCREMENTS ($\mu g/m^3$)*

		Class I	Class II	Class III	NAAQS
SO_2					
	Annual	2	20	40	80
	24-Hour	5	91	182	365
	3-Hour	25	512	700	1300(s)
TSP					
	Annual	5	19	37	75 60(s)
	24-Hour	10	37	75	260 150(s)

*All 24-hour and 3-hour values may be exceeded once per year.
(s) indicates a secondary standard.

94

Major emitting facilities commencing construction after 7 August 1977 must comply with the PSD numerical increment limitations. A "major emitting facility" is defined as one of 28 specifically named industrial categories having emissions in excess of 100 tons/year of any pollutant, and any other source with emissions exceeding 250 tons/year of any pollutant. A listing of the 28 designated industries appears in Table 3.

The short-term (3- and 24-hour) SO_2 and TSP increments in any Class I, II or III area may be exceeded once per year. The maximum allowable concentration of any air pollutant in any PSD area cannot exceed 90% of the national primary or secondary standard (whichever is lower) for each pollutant for each period of exposure. Under special conditions, a facility proposed for location in or near a Class I area may be granted a permit which allows less stringent Class I increments 18 days a year if it can be demonstrated that no adverse impact on the air quality related values (including visibility) of the Class I area would occur. No similar variance is allowed for the increment limits in Class II or Class III areas.

General Requirements

The final PSD regulations, promulgated by the U.S. Environmental Protection Agency on 19 June 1978, detail procedures governing preconstruction permit review and approval of major stationary sources (new construction or facility modification) in a PSD area. The PSD review process includes the following:

- Review of Best Available Control Technology (BACT) for each applicable pollutant. BACT determination is "made on a case-by-case basis by the reviewing authority taking into account several factors including cost, energy, and technical feasibility".

- Air quality review demonstrating that a source would not violate the NAAQS or the maximum allowable increase over the baseline concentration (increment) in an area.

- Additional analysis of the impacts associated with the new source or modification on air quality related values such as visibility, soils, and vegetation.

After an application is submitted to EPA, the Administrator must notify the applicant of any deficiencies in the application within 30 days. Within one year of receipt of a completed application, the Administrator must allow for public review and hearing and make a final determination on the application. Generally, if the PSD review process indicates that the source will not violate the PSD increments, then a construction permit may be issued.

95

TABLE 3

MAJOR EMITTING FACILITIES SUBJECT TO PSD REVIEW

1. Power Plants (250 million Btu/hr)

Specific Sources (100 tons/year any pollutant)

2. power plants
3. coal cleaning plants
4. kraft pulp mills
5. portland cement plants
6. primary zone smelters
7. iron and steel mill plants
8. primary aluminum ore reduction plants
9. primary copper smelters
10. municipal incinerators (250 tons/day)
11. hydrofluoric acid plants
12. sulfuric acid plants
13. petroleum refineries
14. lime plants
15. phosphate rock processing plants
16. coke oven batteries
17. sulfur recover plants
18. carbon black plants (furnace process)
19. primary lead smelters
20. fuel conversion plants
21. sintering plants
22. secondary metal production facilities
23. chemical process plants
24. fossil-fuel boilers (250 million Btu/hr)
25. petroleum storage and transfer facilities (300,000 bbls)
26. taconite ore processing facilities
27. glass fiber processing plants
28. charcoal production facilities

Any Other Source (250 tons/year any pollutant)

96

Source Applicability

The PSD regulations apply to major sources beginning construction on or after 1 March 1978, and sources which received permits prior to 1 March 1978 and commence construction before 19 March 1979. In addition, the regulations require that construction not be discontinued for more than 18 months. The 1 March 1978 deadline does not apply if that date was not met exclusively because of an extension of the public comment period.

As set out in the Act, a permit to construct will be required of "major" sources of any criteria pollutant, defined as:

- twenty-eight specific source categories with potential to emit an increase in pollutants of 100 tons/year (Table 2); and
- all other sources with potential to emit an increase in pollutants of 250 tons/year.

"Potential to emit" was defined under the final regulations as "maximum capacity to emit a pollutant in the absence of control equipment." This is in the process of being changed from sources with uncontrolled emissions to controlled emissions.

Under the final PSD regulations, full PSD impact analysis (including BACT review, screening test, and other air quality analyses) is required of all sources or modifications causing an increase in allowable emissions greater than or equal to 50 tons/year, 1,000 lb/day, or 100 lb/hour or having an impact on a Class I area or on an area where the increment is known to be violated. "Allowable emissions" is defined in the regulations as actual emissions after all required controls; specifically, the "emission rate calculated using the maximum rated capacity of the source and the most stringent of the following: (i) applicable New Source Performance Standards (NSPS), (ii) applicable SIP emission limitations, or (iii) the emission rate specified as a permit condition". Major sources whose allowable emissions are less than the amounts cited need only undergo some of the review procedures, although they still will require a permit to construct.

It is important to note that "allowable" rather than "potential" emissions trigger full PSD review. There may be isolated instances where a source with "potential" emissions less than 100 (250) tons/year has "allowable" emissions greater than 50 tons/year. If such a source will have an impact on a Class I area or an area where the increment is known to be exceeded, it will be subject to impact analysis regardless of the level of potential emissions. EPA's review of major sources whose allowable emissions are less than the cited rates is only to ensure that the source will meet any applicable emission limitations and has undergone adequate public scrutiny.

91

The increase in emissions which may occur at an existing source proposing a "major modification" is determined cumulatively from a baseline date of 7 August 1977. This determination may in some cases consider reductions achieved elsewhere at the source.

BACT Review

Best available control technology (BACT) will be required of all new sources (1) whose allowable emissions equal or exceed 50 tons/year, 1,000 lb/day, or 100 lb/hour, or (2) having an impact on the air quality in a Class I area or an area where the increment is known to be violated. BACT is defined as:

> ....an emission limitation based on the maximum degree of reduction of each pollutant subject to regulation under... the Clean Air Act ...emitted from or which results from any major emitting facility, which the permitting authority, on a case-by-case basis, taking into account energy, environmental, and economic impacts and other costs, determines is achievable for such facility through application of production processes and available methods, systems, and techniques.

BACT may not be less stringent than applicable new source performance standards (NSPS) or national emission standards for hazardous air pollutants (NESHAPS).

A source owner or operator subject to BACT review in the PSD permit review process must supply the following: (1) a description of the chosen control technology: (2) a description of alternate control systems with greater control levels; and (3) a demonstration that the chosen system is the best control technology among the alternative systems, including an assessment of energy, environmental, and economic impacts of the chosen and alternative systems.

Baseline Determination

The focus of the PSD new source review permit process is to determine whether the new or modified source would violate or exceed the allowed increment. The amount of increment available for consumption is determined from an emissions "baseline" (the total emissions within the PSD area).

The regulations establish a constant emissions baseline date of 7 August 1977. Included in the baseline concentration are:

- all actual emissions as of 7 August 1977. "Actual emissions" includes "any future increase in hours of operation or capacity utilization as they occur if such are allowed to the sources as of 7 August, and if the source could have been reasonably expected to make these increased on this date";

98

- allowable emissions from sources commencing construction prior to 6 January 1975 but not in operation as of 7 August 1977; and

- allowable emissions from sources to be regulated by a State's air quality plan revision pending as of 7 August 1977.

Increment Consumption

The increment available for consumption by new source construction or modification is determined by tracking emissions increases and reductions since the baseline date. Reductions, which would increase the available increment, are obtained through renegotiated emissions limits or through emission offsets (e.g., emissions "traded off" with emissions of a retiring plant). Actual emissions must be used to offset baseline actual emissions. Allowable emissions used in determining baseline concentration, can be offset by allowable emissions. After determining the size of the increment, sources whose construction began on or after 6 January 1975 and SIP relaxations received by EPA after 7 August 1977 consume increment on the basis of "allowable" (i.e., controlled) emissions.

A state governor may temporarily exempt certain emission increases from consuming the increment such as emissions from fuel switches, gas curtailments, and temporary sources. To retain this exemption, the state must submit the exemption in an approvable PSD plan revision within 9 months of promulgation. No permanent relaxations of the PSD increments can be approved.

EPA has not provided explicit guidance to the states concerning allocation of the available PSD increment among sources. The agency has, however, suggested several possible economic-based schemes of allocating increments to sources. They include: a marketable permit program (a permitted source could sell part of its permit to other sources); emission fees (fees would be charged to a source according to the quantity of pollutants it emits); and emission density zoning (a certain quantity of pollutants could be allowed for a land area and a source would then purchase "air rights" to enough land to cover their emissions). These economic incentive approaches would give states discretion in controlling the pace of development of certain regions. In addition, a state can stipulate that a single facility may consume only a fixed portion of the increment (e.g., half the available increment).

99

Modeling to Determine Increment Allocation

Under PSD rules, modeling and monitoring of ambient concentration and emission rates may be required to support a construction permit application to demonstrate that emissions from the new source will not cause ambient air quality to exceed either the increment concentration or the NAAQS for the pollutant. The consumption and allocation of the increments is to be calculated with modeling, not monitoring data. This is done because increment consumption is based on worst-case emissions and meteorological conditions, not on normal or average conditions that would be measured by monitoring.

EPA has established a "screening analysis" of allowable emissions whereby a proposed source can be exempted from the requirement to use extensive modeling techniques to show compliance with the increments and NAAQS. The screening analysis uses very conservative, worst-case emissions and meteorological parameters in a simple mathematical test. If this analysis demonstrates that the new source will use up at most one half of the remaining increment, or at most one half of the available allowance to NAAQS, whichever is less, then no additional modeling is required.

If more extensive modeling is required, all new sources permitted and/or constructed since the baseline date will be modeled together with the proposed new source. The cumulative impact on ambient air quality will be compared to the increments. If the combined impact of the new source and other sources is less than the level of the increment, then the new source could be granted a permit. The amount of remaining increment that a source will be allowed to consume is at the discretion of the EPA region or state air quality control agency. The agencies could deny issuance of a permit to the source or require further control equipment, even though the increment limit would not be exhausted, on the grounds that a new source will consume more than its "share" of the remaining increment.

Similar modeling is required to demonstrate that a new source would not cause exceedance of the applicable NAAQS. The new source must be modeled together with a background pollutant concentration of emissions from all sources operating or permitted, to determine if the total pollutant concentration will exceed the NAAQS.

Use of Monitoring to Ensure Compliance

If the preliminary modeling indicates that a new source may affect NAAQS attainment in a PSD area, representative monitoring data will be required to show actual baseline air quality concentrations. The regulations specifically require any necessary monitoring to take place during the year preceding the application, unless the applicant demonstrates that data from a portion of that year or other representative years are adequate. Only completed applications submitted before 7 August 1978 are exempt from these requirements. The interpretive material preceding the regulations stated that monitoring

100

will not be required of a source which does not "pose a threat to a NAAQS". Based on this wording, it appears that in most cases some monitoring will be required unless representative data are already available. In addition, EPA may require both preconstruction and postconstruction monitoring.

Effects of the PSD Policy

The PSD requirements significantly influence the strategies for the development and siting of industrial and energy-related facilities in clean air areas of the United States:

- These requirements can have the effect of substantially limiting the size of individual facilities and the total number of sites potentially suitable for development.

- Small-scale facilities are generally favored, because of the small emission limits required at any individual site.

- Substantially more stringent source emission limits will generally be required for plants located in regions of rough terrain, because the effluent can occasionally impact on the elevated terrain.

- Uncertainties and delays in the development of major new facilities may occur as a result of the requirements for use and interpretation of air pollution models and monitoring data in the permit application and review process.

The PSD policy has special relevance for countries which are currently planning industrial, commercial and residential complexes in previously undeveloped regions and wish to be able to accomodate additional growth in the future.

- Where should major industrial facilities and their related residential areas be located relative to one another, so as to minimize the impact of the industrial emissions upon the nearby residential areas as the population expands?

- Will the total loading of pollutants cause unacceptable effects in the major population centers of the country?

- Will the ultimate industrial growth in developing regions be limited by the maximum concentrations of pollutions which will be caused in nearby residential areas or in more distant population centers?

- Will continued growth of these regions require very large costs to control pollution?

101

The implementation of the PSD policy in the United States raises the question as to how nations can effectively manage long-term growth consistent with environmental goals, and what the appropriate statement of such guidelines should be. In general, the essential goals of PSD (i.e. protection of special areas, minimization of pollution in previously undeveloped regions) could probably be achieved in other countries through a less complex procedure. Specifically, the application of sound land use and environmental planning principles can provide the basis for an effective statement of these goals. The optimum growth of a region can be considered early in the development process. Clearly, if a region experiences substantial industrial and residential growth over a 10-20 year (or longer) timeframe, some of the originally developed sites may suffer deteriorating air quality. Therefore, the expected ultimate industrialization of a region should be considered in order to develop guidelines for land use allocations which permit a nation's air quality goals to be efficiently achieved.

102

Bibliography

- U.S. Agency for International Development. 1979. Environmental and Natural Resource Management in Developing Countries: A Report to Congress. Department of State, Washington, D.C. 2 Vols.

  This document consists of overviews of the environmental and natural resource problems of developing countries and of the institutional capabilities of those countries to deal with such problems. The overviews are organized along regional lines: there are separate discussions of the developing countries of Africa, Asia, Latin America and the Near East.

- Kneese, A. V. and C. L. Schultze. 1975. Pollution, Prices and Public Policy. Brookings Institution, Washington, D.C.

  The book presents a number of economic incentives as alternate strategies for developing a comprehensive pollution control plan.

- U.S. Environmental Protection Agency. 1976. Quality Criteria for Water. Washington, D.C.

  This report recommends water quality criteria levels to provide protection for fish and other aquatic life, for recreation, and domestic water supply use, which reflect the latest scientific knowledge on health and welfare effects of basic water constituents. A rationale supporting the recommended criterion is presented for each basic water constituent or pollutant.

- Johnson, Hope. 1977. Environmental Policies in Developing Countries. Beiträge zur Unweltgestaltung, Heft A 27, Berlin.

  The book summarizes the status of environmental policy and regulation in 63 countries focusing on the following areas: environmental policy in general; use of natural resources and environmental conservation; environmental planning; and environmental science, education and technology.

- Campbell, T. H. and R. O. Sylvester. 1968. Water Resources Management and Public Policy. University of Washington Press, Seattle and London.

  This book addresses issues of water rights, quality, quantity, and pricing associated with development of surface and groundwater resources. Chapter VIII presents a methodology for establishing water quality standards based on water quality goals, toward which control efforts are directed.

103

- Kneese, A. V., and B. T. Bower. 1968. Managing Water Quality: Economics, Technology, Institutions. Resources for the Future. John Hopkins Press, Baltimore, Md.

  This book recommends the use of effluent charges and other economic strategies to achieve water quality goals.

- Dales, J. H. 1968. Pollution, Property, and Prices: An Essay in Policy-Making and Economics. University of Toronto Press, Toronto.

  This essay proposes the use of economic and market incentives to control water pollution.

- Ferris, Benjamin. 1978. "Health Effects of Exposure to Low Levels of Regulated Air Pollutants: A Critical Review". Journal APCA Vol. 28; 5: 482-494.

  This paper provides a thorough review of the acute and chronic data available on health effects of the criteria pollutants and examines the present U.S. air quality standards in light of the evidence.

- World Health Organization. 1979. Environmental Health Criteria #8: Sulfur Oxides and Suspended Particulate Matter. WHO, Geneva.

  This document, prepared by a WHO task group reviews the available information on the biological effects of sulfur oxides and suspended particulate matter, including suspended sulfates and sulfuric acid aerosols. Guidelines for the protection of human health are recommended.

- U.S. Environmental Protection Agency. 1974. The Worlds' Air Quality Management Standards Document EPA-650/9-75-0012, EPA, Washington D.C.

  This document presents U.S. and world air quality standards in a tabular format.

- Goldsmith, B. J. and Mahoney, J. R., "Implications of the 1977 Clean Air Act Amendments for Stationary Sources", Environmental Science and Technology, Vol. 12, No. 2, February 1978.*

  This article discusses the principal air pollution analysis requirements for stationary source operators wishing to expand or modify existing facilities or construct new facilities in the United States. Particular attention is given to the requirements for data modeling and monitoring necessary to obtain a permit to construct.

---

*Reprints can be obtained from Environmental Research & Technology, Inc., Marketing Department, 696 Virginia Road, Concord, MA 01742, U.S.A.

- Environmental Research & Technology, Inc., Technical Evaluation of the Significant Deterioration Portions of Proposed Clean Air Act Amendments, prepared for the Electric Utility Industry for submission to the U.S. Senate, February 1977.

  This report describes the results of air quality model calculations performed for 74 coal-fired power plants scheduled for capacity additions between 1975-83 in order to assess the effect of PSD requirements upon future development of these facilities.

- Mahoney, J. R. and Goldsmith, B. J., "Air Pollution Control Requirements for Industrial, Commercial and Public Facilities" in Dangerous Properties of Industrial Materials, fifth edition, N. Irving Sax, editor, Van Nostrand Reinhold Company: 1979.

  This chapter discusses the manner in which air pollution control requirements in the United States influence strategies for the development and siting of industrial and energy-related facilities in the country.

- Organization for Economic Cooperation and Development, Report on the Use of Techniques to Provide Air Quality Information for Land Use Planning, Paris, France, 1976.

  This report of the Air Management Sector Group describes the techniques used to incorporate air pollution considerations into the planning process. Information assembled in national case histories from Canada, Finland, France, Germany and Japan provided the basis for this report and the applications of various techniques and their limitations are discussed.

- Quarles, John, Federal Regulation of New Industrial Plants, 1979.+

  This report surveys the environmental regulations in the United States which affect the siting and construction of new industrial plants and expansions.

+This report can be obtained by writing to: New Plants Reports, P.O. Box 998, Ben Franklin Station, Washington, DC, 20044, U.S.A.

105

BIOGRAPHICAL SKETCH

Ms. Barbara J. Goldsmith, Manager, Program Development
Policy Analysis Division
Environmental Research &
Technology, Inc.,
Washington, D.C.

Barbara J. Goldsmith has been associated with Environmental Research & Technology, Inc. (ERT) since 1973. She is responsible for directing projects on national and international environmental and energy policy issues undertaken for government and industry.

Ms. Goldsmith is technical project manager for ongoing programs relating to the effects of the Clean Air Act on industrial and energy development in the United States for the U.S. Department of Energy, The Business Roundtable, the Utility Air Regulatory Group and other national business and industry groups.

Other project responsibilities have included the development of recommendations for the organization of the national environment program of Saudi Arabia, a study for the U.S. Department of State to investigate the international aspects of long range transport of air pollutants, and environmental assessment of proposed nuclear power stations and oil refineries.

During 1974-1975 Ms. Goldsmith served as a consultant to the Environment Directorate of the Organization for Economic Co-operation and Development (OECD) in Paris, France. She is the author of a number of reports relating to energy and air quality planning in the United States and other countries.

ENVIRONMENTAL MONITORING

Principles of Environmental Monitoring

David Chang

Vice President
ERT International Group
ENVIRONMENTAL RESEARCH & TECHNOLOGY, INC.

June 1980

International Environmental Management Institute
ENVIRONMENTAL RESEARCH & TECHNOLOGY, INC.
Concord, Massachusetts, USA

107

1. INTRODUCTION

Management of environmental resources presupposes that the manager understands what is the proper use of those resources. Proper use of a resource is defined by the society which controls the resource. The complexities of this issue have been dealt with by other speakers at this seminar and will not be addressed here. However, to whatever end man's management of his environmental resources is directed, his effective management is predicated on the timely delivery of information about that resource to him as the decision maker. This information of the state of the environment and its changes, together with the management objectives, are basic to the formation of sound management actions.

In this present discussion, the process of information gathering--from the acquisition of data to its transformation to intelligent information, and to the delivery of this information to the user--is reviewed as a prelude to the discussions presented by subsequent papers.

For want of a better term, we have chosen to call the mechanism by which all of the elements of information gathering are joined together a "monitoring system." The choice of the term "system" is deliberate because it provides the proper technological connotation that the various elements are selected, from a number of alternatives, to fit logically into a whole in order to satisfy some predefined need. For, indeed, modern technology has provided us many approaches to the acquisition and delivery of environmental information, and the trick is to select the right technical approach that best satisfies the need, at a cost which is commensurate with the problem at hand.

We will start our discussion with a brief review of the various elements which make up a monitoring system, followed by an examination of the general technology available for the design of systems and the specific considerations which must be given to the design to satisfy user needs.

108

2. ELEMENTS OF A MONITORING SYSTEM

An environmental monitoring system may simply be a trained observer, or a team of observers, in the field making manual entries into notebooks, the contents of which are subsequently collated, organized, interpreted, and presented as information to a user. This kind of elemental monitoring system has provided us with much of the information we currently have on the environment, especially that on the ecosystem. Indeed, simple as it may be from a technology point of view, it is still used extensively; and in certain technical fields, it is still the most effective method for the gathering of information of phenomena which do not change rapidly.

Environmental phenomena which undergo rapid changes, and which have dramatic impact on man or on other elements of the environment, place more severe requirements on an information gathering system. Severe weather parameters are a case in point. Tornadoes form, increase in intensity, and dissipate in the time span of hours, extending their damaging influence over only a very limited area. If there is to be "management" through forecasting and warning, an appropriate environmental monitoring system must be responsive to the time and space framework of the phenomenon involved. In this instance, trained observers taking notes do not constitute an appropriate monitoring system. Fortunately modern technology has provided us with the means for a system which is capable of monitoring events such as severe weather phenomena.

Regardless of the degree of technical sophistication, there are certain elements which are common to all monitoring systems. An effective system must have at least the following:

- a sensing element;
- a communications element; and
- a processing element.

In the accompanying schematic, the sensing element--or sensor--is in "contact" with the environment sensing <u>data</u>, i.e., a measurement of some very limited property of the environment in time and space. These data, of themselves, have limited intrinsic value. To be useful, it must be "processed" with other data points and perhaps other knowledge to create <u>information</u>. (Information here is broadly defined to mean the organized collection of data points, in time and space, organized in a logical arrangement and perhaps combined with other knowledge which enables the user to draw conclusions regarding the state of a limited aspect of the environment and/or its changes in space and time.) The conversion of data into information is the function of the processing element. The third element in a monitoring system is that which links the user and the environmental phenomenon-communications. In many parts of the world, monitoring on a routine basis has become possible only because of advances in communications.

109

7906080

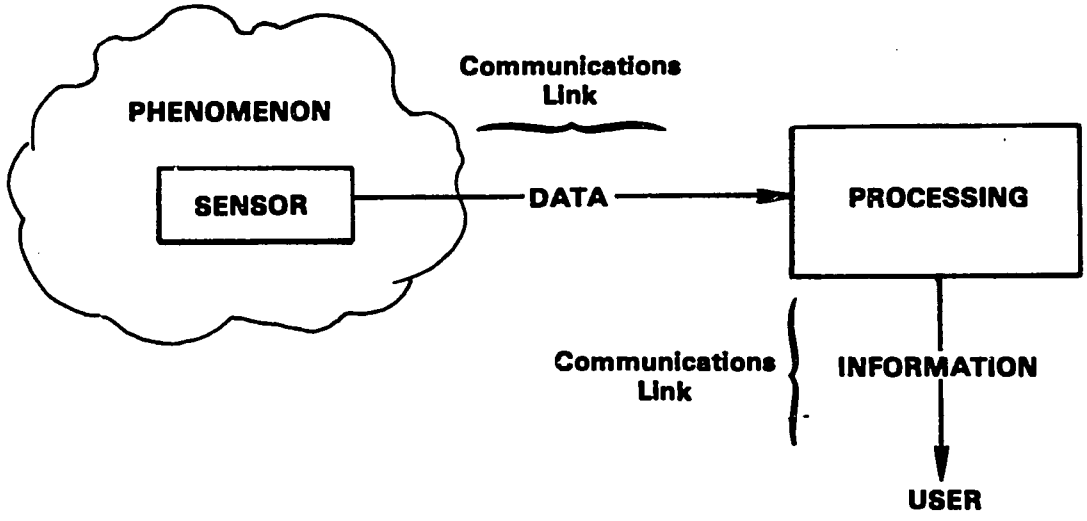


Figure 1 Schematic of a Generalized Monitoring System

110

Before proceeding to a more detailed discussion of the various possibilities in the design of each of the three elements, it is important to develop an overall philosophy in the design of systems as a whole. It is often the case that monitoring systems are designed by electronics, communications, or computer engineers with only a minimum participation in the design by the end user. This is a mistake which often leads to a system designed to generate volumes of data and not information. There is a natural tendency to overdesign the data collection portion of the system, i.e., sensing element and underdesign the data processing element. The proper approach to the design of an environmental monitoring system is to begin with the user requirements for information. These requirements should then form the basis of trade-off studies of the various combinations of data acquisition, processing, and communication systems which best meet these requirements. In other words, the system should be designed as a whole instead of forcing the processing and communication elements to meet some favored sensing approach. This methodology to system design is time-consuming. In the long run, however, the approach will provide a system which meets the user's need and not the designer's bias for a particular approach to sensor technology.

3. SENSING ELEMENT

There are two basic types of sensing: contact sensing and remote sensing (see Figure 2). While the advent to infrared technology and satellite sensing platforms have given recent popular recognition to remote sensing as a new technology, one of the oldest forms of sensing, that of the human eye, is in fact remote sensing. Basically, in remote sensing the sensing element is remotely located from the physical phenomenon being measured. Radiometry, radar technology, and optical devices are examples of remote sensors, the most familiar being the photographic camera. Recently, acoustic sensors have been developed for environmental monitoring. All of these devices are dependent on the propagation of energy, electro-magnetic and acoustic, from the phenomenon to the sensor. This sensing technology is ideal for measurements of phenomena which are not readily accessible. Despite this advantage, there is a drawback. The measurements are not specific, often requiring sophisticated interpretation.

Contact, or in-situ measurements have the transducer or sensor in direct contact with the phenomenon being measured. This is the more traditional method of sensing. The sensor output, if properly designed and calibrated, can be made specific to the parameter being measured, at least over a reasonable range of values. In environmental monitoring it is often difficult, if not impossible, to place the sensors in difficult terrain or in inaccessible locations. This is one of the drawbacks of contact sensor. Another drawback in contact sensing is in the area of spatial coverage. Remote sensing from spacecraft or aircraft, and even from ground-based instruments, is ideally suited to provide spatial coverage. The motion of the platform, together with the scanning motion of the sensor, provide continuous coverage of the spatial variability of a phenomenon. For contact or in-situ sensors, spatial coverage is achieved by placing sensors at a number of locations in the form of a network. The spatial distribution of the sensors is a critical element of system design. Allied with the problem of spatial coverage is the question of spatial resolution. In the case of a network of contact sensors, spatial resolution is determined by the spacing between adjacent sensor elements. For remote sensors, spatial resolution is determined by elements within the sensor itself such as antenna configuration or optical design.

Spatial coverage and resolution of a system should be based on the enduse of the information, i.e., user requirements. However, often times it is not possible to meet the most stringent requirements of the user because of economics, terrain problems, or other factors. When this is the case, it is vitally important that the limitations of the system be fully appreciated by the user such that he does not apply the information beyond the limits of its validity.

112

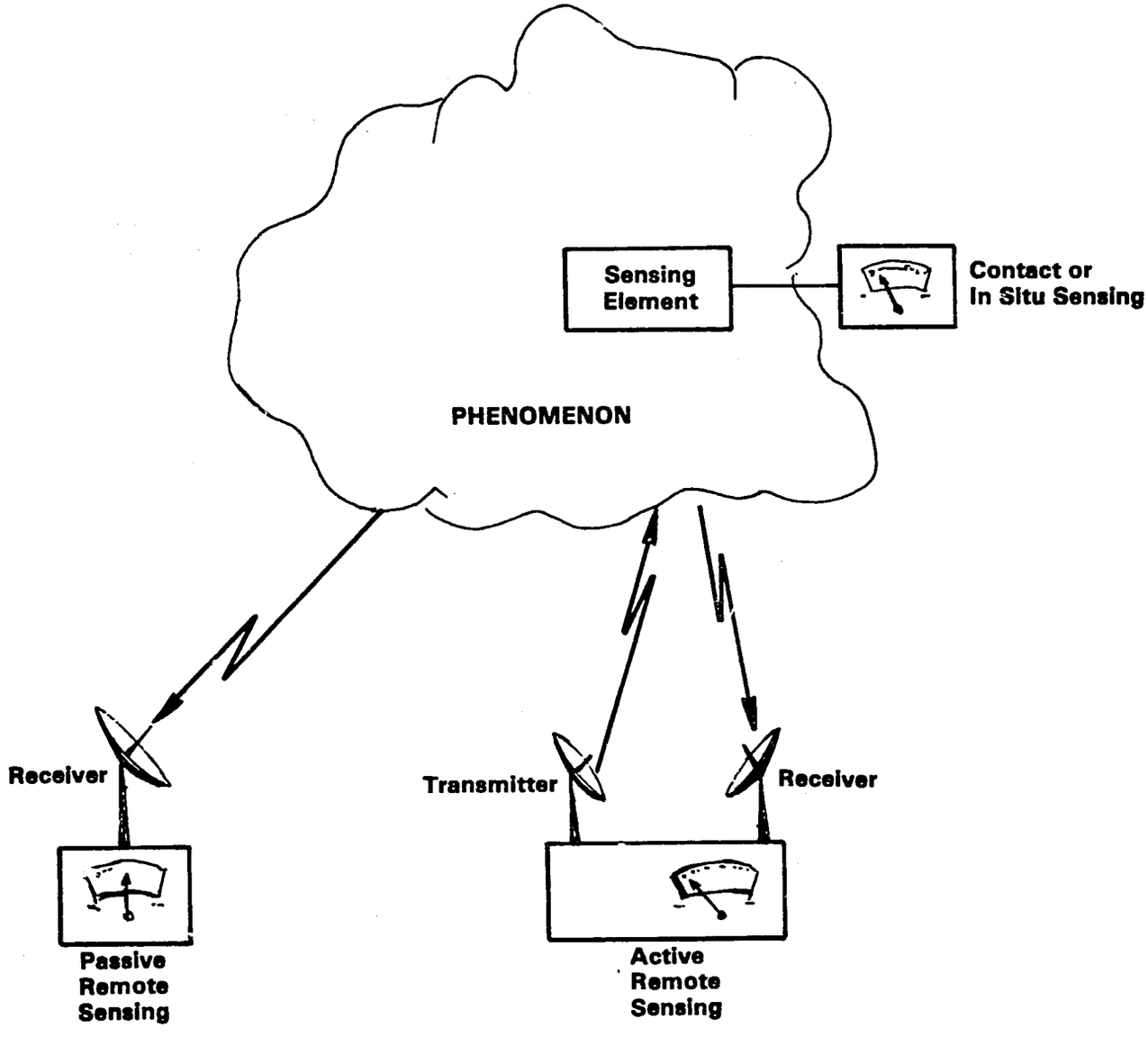


Figure 2 Schematic of Sensing Systems

In the design of monitoring systems, there is available then the choice between contact sensors and remote sensors. Each has its merits and its drawbacks. In subsequent papers, the application of both remote sensors and contact sensors in specific system configuration will be discussed. What needs to be emphasized here, however, is that from a system point of view, the sensing element can be made up of both contact and remote sensora hybrid system. This is possible if the communication and processing elements in the system are properly designed to handle both types of data. In the discussion on Advanced Systems, an example of such a hybrid system will be discussed in detail.

In the past few years, while there have been advances in contact sensor technology, the most dramatic developments have taken place in remote sensors. This can be attributed in part to the impetus given by the space program and by military surveillance requirements. Both active and passive systems have been developed. The use of lasers operating in a spectral selective mode, and as ranging devices are now commonplace. Microwave radiometry has been developed to the point where rain over land and oceans and soil moisture can be mapped globally from space platforms. Particulate pollutants can now be mapped, and their movement over long distances traced. Measurements of trace gases in the stratosphere, their concentration and their buildup, are now possible. The same spectral selection techniques are also being used to map the spatial distribution of selected pollutants--particulates and gases-with ground-based systems. The potentials of remote sensing are just beginning to be exploited.

114

4. PROCESSING ELEMENT

The output of the sensing element is data. For both contact and remote sensors, the data are often in the form of electrical voltages which have not immediately reconizable relationships to the phenomenon being measured. The conversion of these data to information requires processing--calibration, collation, organization and possibly combining with other knowledge (see Figure 3).

The processing element in a system can be very simple, consisting of a team of technicians recording and organizing readings from calibrated meters in tabular form to provide the user with information on the spatial or temporal distribution of a limited aspect of a phenomenon. If, however, the phenomenon is complex or the sensor data is not specific, than the level of technology in the processing element of the system must be increased. Very soon one is led inevitably to the requirements for computation machines and other marvels of the electronic age.

It is very important to stress that a computing machine of itself is useful only in a limited way. Many times the most important part of the processing procedure, that is the conversion of data to information, requires the use of models. The computing machine may prepare the data for the model and actually "run" the model, but the resulting information is only as good as the model itself. The design of models is then a very critical element of a monitoring system.

Models are of two basic types--diagnostic and prognostic. In diagnostic models the collated data are organized by the model in a "best" approximation of the current state of the phenomenon of interest. Even here a model is needed because no measurement system is perfect, and when the phenomenon is a complex one with different sets of attributes, a model must be used to "integrate" the data and fill in the missing elements. In a prognostic model, the collated data from different intervals of time past are organized by the model to project the state of the phenomena into future time. Often these models are more complex than diagnostic models requiring more sophisticated computing systems. However, in the design of monitoring systems, one should not forget that the user himself may be part of the processing element. With proper training and experience, the user has a set of mental models which he can exercise on the collated data.

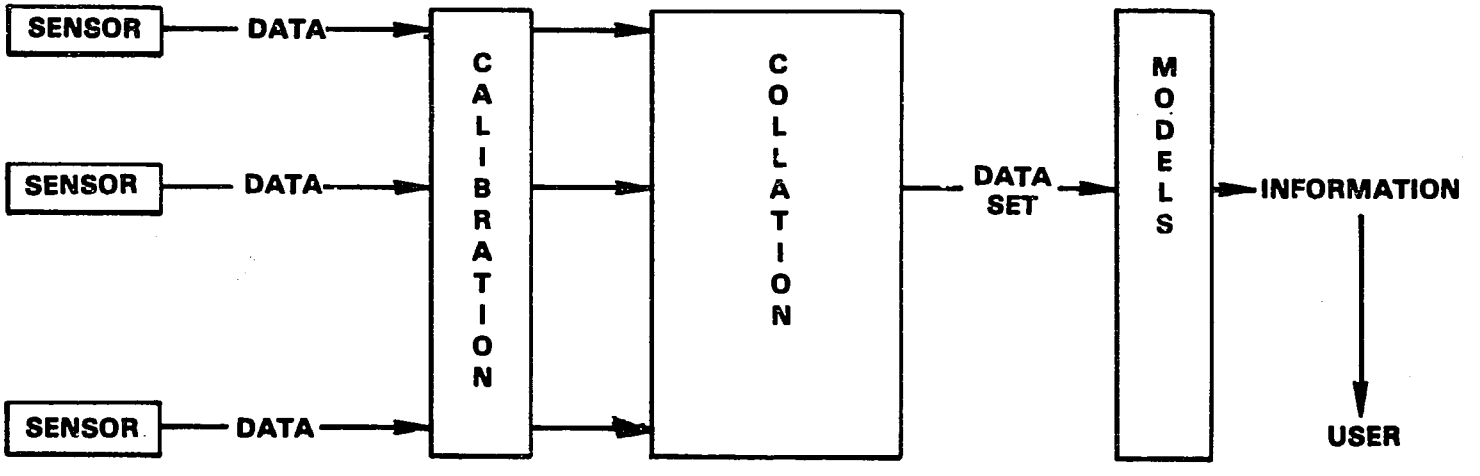


Figure 3 Elements in Data Processing

116

5. COMMUNICATION

Data from the sensors must get to the processing unit, and the processed information must get to the user. The moving of data and information is the function of the communication element of the system. There are a large number of choices of the type of communications link to be used (see Fig. 4). For contact sensors located in urbanized areas, telephone cables may be a logical choice. For locations which are difficult to get to, radio telemetry may be the answer. With the advent of satellite technology, the choice of satellite communications might be the logical one for developing countries. The cost of data collection platforms and transmitting and receiving equipment is being reduced at a rapid rate, and as more and more people use the system, the cost will come down all the more.

The use of satellites as a communication mechanism for environmental data has been fully demonstrated by NASA, NOAA, and by COMSAT. Other papers in this volume will be addressing this technology in greater detail.

117

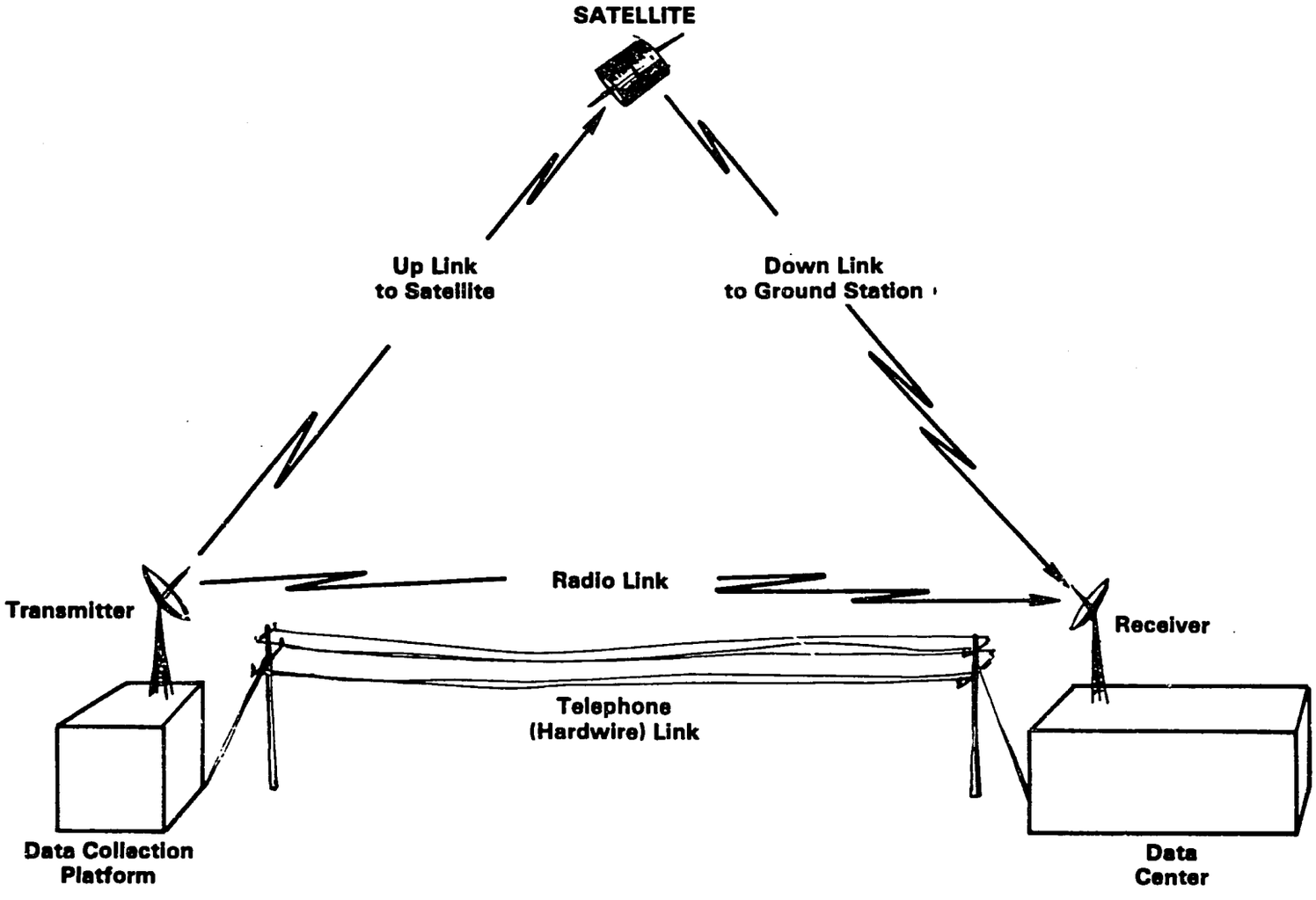


Figure 4 Modes of Data Communication

18

6. SUMMARY

Environmental monitoring systems should be designed to satisfy user requirements. There are a number of choices in the technology to be used in the implementation of a system. Each has its potential and limitations. It is important that the limitations are recognized at the outset by the user to mitigate the danger of having the information applied to situations which are not appropriate.

ENVIRONMENTAL MONITORING

Remote Sensing

James Barnes

Manager, Earth Resources Section

and

Michael Smallwood

Environmental Scientist
Earth Resources Studies Section
Environmental Research & Technology, Inc.

June 1980

International Environmental Management Institute
ENVIRONMENTAL RESEARCH & TECHNOLOGY, INC.
Concord, Massachusetts, USA

120

During the past few decades, man has not been deeply committed to environmentally sound human and natural resources development plans. We have seen the earth stripped of its forest, permanently scarred by strip mining operations, its air and water polluted, and its once productive agricultural lands stripped of their essential nutrients. This senseless exploitation of our finite earth has occurred mainly as a result of ignorance of the fundamental laws of nature in combination with an inadequate data base from which to design environmentally sound development policies.

As we rapidly approach the 21st century, we must take a retrospective look at the work of our predecessors and assimilate the requisite knowledge to build upon their successes and avoid their failures. Even as the decade of the 1970's approaches its end, we have learned many important lessons. We know that the earth's resources are fragile; that we must properly manage these resources, and that man's interaction with his environment, if not planned and monitored, can result in irrevocable damage to the earth.

Paralleling man's increased awareness of his impact on the environment is the increasing need for more reliable earth resources information. This need is most acute in developing countries where often little or no information exists. This informational gap can be bridged using the techniques of remote sensing.

Remote sensing, defined as the collection of data by systems that are not in direct contact with the medium or target being investigated, had its true beginning in the days of manned balloon flights during which crude, handheld photographs of the earth were taken. Since that time, technology has created remote sensing systems that probe into nearly all portions of the electromagnetic spectrum and produce black-and-white photographs, false-color multispectral scanner images, and even computer generated digitized maps displaying temperature variations on the earth's surface. In the last decade, the advent of satellite platforms such as Landsat, Skylab, and the numerous meteorological satellites has greatly expanded the applications of remote sensing.

Remote sensing techniques can be separated into two main types: satellite imagery and aircraft photography. In the 1960's, the advent of meteorological satellites heralded a new realm of remote sensing. Many studies were performed utilizing this new data source to extract information relating to earth and physical science disciplines. The natural outcome of these early investigations was a need and demand for higher resolution satellite images. In July 1972, the Landsat satellite was launched to meet these new requirements. Landsat is equipped with a Multi-Spectral Scanner (MSS) capable of imaging in four distinct wavelength bands. Bands 4 (0.5 - 0.6 micrometers (μm) and 5 (0.6-0.7 micrometers (μm) are in the visible portion of the spectrum and Bands 6 (0.7 - 0.8 μm) and 7 (0.8 - 1.1 μm) are in the near-infrared.

121

Data from these four bands can be analyzed separately or manipulated to produce false-color composite images utilizing three or even all four bands. The MSS has a ground resolution of 80 meters, and each frame covers a surface area of approximately 185 km x 185 km. Landsat is therefore capable of producing relatively high spatial resolution images of large areas. Because of the limited area viewed by Landsat, repeat coverage by the same satellite occurs only once every 18 days; nevertheless, this repeat coverage is sufficient for monitoring many aspects of land use.

Photography acquired from aircraft is the most frequently used remote sensing technique presently available. The user may choose from a wide range of flying altitudes, cameras, lenses, film types, and time or season of the photography, in order to obtain a product specifically suited to his particular data needs. Table 1 illustrates the application of large, medium, and small-scale photography to the interpretation of various resource features at the regional, local, and minute levels of investigation.

Black-and-white is normally the most economical film type and is well suited to many resource interpretation needs. Black-and-white infrared, color, and color-infrared films are also available (higher cost for color products) and may be better suited to particular data requirements. Multispectral photography allows the interpreter to distinguish specific features by virtue of their varying spectral "signatures" in different portions of the electromagnetic spectrum.

A partial list of remote sensing applicatons might include:

- forestry
- geology
- agriculture
- land use
- urbanization
- desertification
- water pollution
- wildlife studies
- environmental impact studies
- transportation planning
- engineering

For each of these applications as well as many others, there are a variety of film types, sensing platforms, scales, cameras and interpretation techniques from which a specific remote sensing program can be defined that will meet the specific requirements of the user.

In summary, remote sensing exists as a valuable tool to aid the resource planner. Its value lies in its ability to discern the nature of the environment in a cost-effective manner. The methodology is available to all and can be used to supplement other environmental data collection techniques.

122

TABLE 1

THE EFFECTS OF SCALE ON THE ABILITY TO INTERPRET VARIOUS RESOURCE CATEGORIES[1]

Resource Category \ Scale	1:2,500 to 1:10,000	1:10,000 to 1:20,000	Smaller than 1:20,000
Natural Features			
Regional	Poor	Good	Excellent
Local	Excellent	Good to Fair	Poor
Minute	Excellent	Poor	Very Poor
Cultural Features			
Regional	Poor	Good	Fair
Local	Excellent	Fair	Poor
Minute	Excellent	Poor	Very Poor
Soils			
Regional	Poor	Excellent	Good
Local	Good	Good	Poor
Minute	Excellent	Good	Very Poor

[1]Source: American Society of Photogrammetry, Manual of Photographic Interpretation, Washington, D.C., 1960, p. 344.

123

Introduction to Remote Sensing Techniques

Remote sensing may be defined as the collection of data by systems that are not in direct contact with the medium or target being investigated. Remote sensing has evolved from, and still includes, aerial photographic techniques and methods of interpretation. Today use is made of a variety of wavelength or frequency intervals (i.e., spectral regions) beyond the visible region of the electromagnetic spectrum (see Figure 1.1). The more practical operational methods make use of radiation in the five spectral regions listed below in Table 2.

Remote sensing can be applied to a wide variety of topics including land use, geology, soils mapping, hydrology, the definition of ecosystems, and air and water quality studies. The necessary instrumentation may be mounted or carried on a ground vehicle, a satellite, or on an aircraft. For mapping surface characteristics, aircraft are used most frequently, although in recent years, satellites have become an important vehicle for studies of the earth's atmosphere and surface. Output produced by the various systems includes familiar black and white or color photographs, "picture-like" scanner imagery in color or black and white, strip charts, and magnetic tapes. Many of the techniques involving the use of non-visible spectral regions have become readily available only recently for civilian use on an operational basis.

The various systems, types of output, platforms, and uses are discussed in the following sections. For those who wish to pursue a particular technique in greater depth than is possible in this review, a bibliography of generalized literature on remote sensing has been included.

Aerial Photography

One of the most commonly used techniques of remote sensing is photography. Generally the photographs are taken from various types of aircraft flying at altitudes ranging from 150 to 20,000 meters (500 to 65,000 feet) above the surface. Aerial photography methods vary from the simple use of handheld camers to sophisticated techniques such as multiband stereo vertical photography. Within the past several years, photographic data have been acquired from satellites and from the manned Skylab, and in many cases, information of high quality have been obtained at a small scale. Depending on the needs of the study, any one or all of these aerial survey methods might prove useful. The required information as well as the time and money constraints are all factors in deciding what type of photographs are adequate.

124

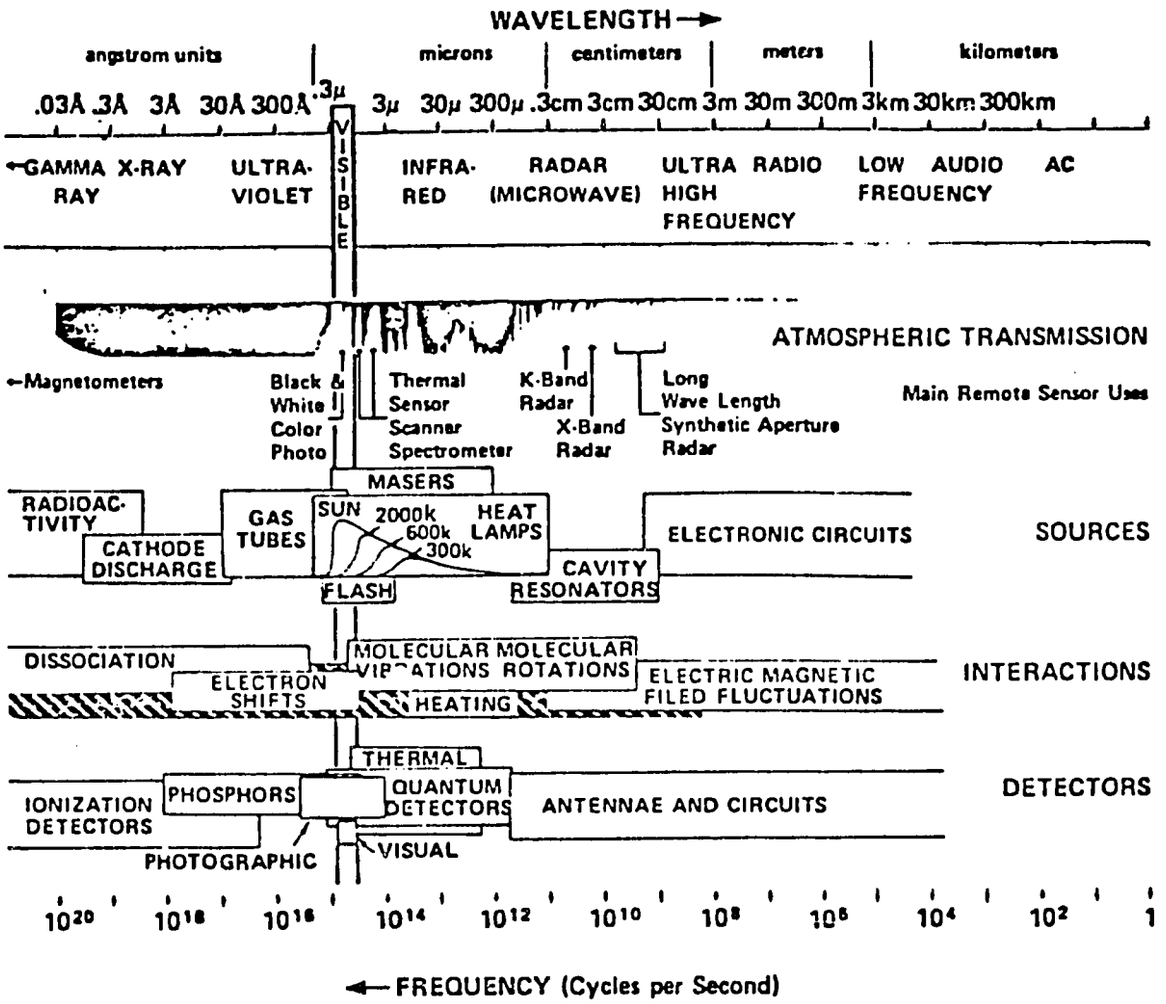


Figure 1.1 Characteristics of the Electromagnetic Spectrum Which Are of Significance in Remote Reconnaissance. Note that the spectrum spans a range of wavelengths from less than 10^{-11} (0.00000000001) to more than 10^6 meters (= 1,000,000) and that the visible region is a very narrow segment of the spectrum.

Source: Subcommittee 1, Photo Interpretation Committee, American Society of Photogrammetry, "Basic Matter and Energy Relationships Involved in Remote Reconnaissance", Photogrammetric Engineering, Vol. XXOX, No. 5, September 1963, p. 763.

125

TABLE 2

Wavelength intervals of five useful spectral regions. The units of this table are the meter (m), the centimeter (cm) = 10^2m, and the micrometer (μm) or micron (μ) = 10^6m.

Region	Wavelength Interval (approximate)
Visible	0.35 to 0.75 μm
Near Infrared	0.75 to 3 μm
Thermal or Emitted Infrared	8 to 14 μm
Microwave	0.1 to 30 cm
Low Frequency Radio	500 to 100,000 m

126

Acquisition Methods

There are generally two types of aerial photographs: oblique photographs and vertical photographs. Vertical photography is taken with the camera pointed down vertically and obliques are taken with the camera pointed intentionally between vertical and horizontal. Vertical photography yields a map-like appearance and may be used in mapping with a minimum of correction. Details remain sharp over the entire photograph. Oblique photography has the advantage of covering a larger amount of ground in one exposure than vertical photography. However, mapping from the photography is difficult, because the detail becomes considerably less clear in the background as a result of the distortions created by the angle of the camera. On the other hand, oblique views can provide valuable information not obtainable from vertical photography. For example, some trees are more easily identifiable from the side views.

Cameras may be mounted rigidly in an aircraft or they may be handheld. Mounted cameras generally take vertical photographs, handheld cameras are often used to take oblique photographs, although in some cases, the camera is pointed downward.

Photogrammetic photography (photography to be used for highly accurate measurements) is obtained by utilizing large cameras located in the floor of appropriate aircraft. These cameras require specialized suspension mounts which minimize vibration and adjust for tilt of the aircraft platform. Leveling devices and controls are continually adjusted by the photographer to compensate for variations in the orientation of the platform. Other specialized equipment is needed to take exposures at regular intervals so as to provide the desired amount of overlap for stereo coverage. Experienced professionals with an aircraft properly outfitted for accurate navigation are also required.

Handheld oblique photography is best taken out an aircraft window or door. Gyroscope devices are available to minimize vibrations and stabilize the camera when shooting this type of photography. Although vertical or nearly vertical photography can be taken by handheld cameras, it is not as precise as if taken with a mounted camera. Handheld vertical photography is taken out of a hatch door in the floor of the aircraft or out of a side door or window with the airplane rolled up on its side.

Though it is possible to obtain overlap between each photograph when taking handheld photography, it is difficult to take continuous strips of photography with enough overlap to obtain stereo coverage. Stereo coverage which consists of two photographs of the same area taken from slightly different angles permits one to view and analyze features in three dimensions. To provide stereo coverage the photographs are taken in a line so that each succeeding picture covers 60% of the area covered by the preceding photograph. When flying at

127

low altitudes, which is often the case in taking handheld photography, a large number of photographs have to be taken rapidly in order to maintain 60% overlap. The higher the altitude or the wider the area covered by one exposure (wide angle photography) the less pictures have to be taken.

Various types of aircraft are used for platforms when taking aerial photography. Typically, a single engine light airplane is used. This is the least expensive and most readily available type, and it will provide photographs of adequate quality for many purposes. Larger twin engine aircraft are needed when taking photographs of sites farther away from the base airport. Larger planes are also employed to fly at higher altitudes, for longer distances, or when additional equipment is needed. Besides the wide variety of propeller planes in use today, several sizes of jet airplanes including the Lear and the Caravelle are commercially flown. Jets have the ability to fly at very high altitudes, such as 12 to 18 km (40,000 to 60,000 feet).

Helicopters are often appropriate platforms for aerial photography. They have the ability to fly at low altitudes where fixed wing planes are not allowed. They are more maneuverable and can hover over one spot if desired. Helicopters are considerably more expensive than airplanes to use and to operate, particularly the jet helicopters. Helicopters also have considerably less fuel capacity (often only several hours), thus their ability for photographing large areas at long distance from the base airport is limited.

Cameras

Photogrammetric Cameras

Vertical aerial photographs to be used for accurate measurements and mapping (photogrammetric mapping) must be taken with high quality aerial cameras. There are several makes of aerial cameras such as Zeiss, Wild, and Fairchild which are commonly used today. Each of these companies make several different types of aerial cameras, but items such as focal length of various lenses, size of negative exposed, and specifications of accuracy have become nearly standardized. Most cameras used in North America have a 23 cm (9 inch) square negative size. In Europe, cameras which have a 18 cm (7 inch) square negative size are commonly employed.

The modern photogrammetric lens is an extremely precise piece of optical equipment which costs many thousands of dollars. The high quality of the lens is crucial if one is to obtain the detailed resolution which is often required. In addition to its high quality, a characteristic of a camera lens which is of prime interest to a photointerpreter is the focal length. Common focal lengths used are 3-1/4 inch (82 mm), 6 inch (152 mm), 8-1/4 inch (210 mm) and 12 inch (300 mm). The shorter focal lengths or wide angle lenses permit wider

area coverage and exaggerate the stereoscopic effect. This exaggeration is helpful for many kinds of interpretation, particuarly those which involve elevation or height measurements. However, in hilly or mountainous terrain the exaggeration which is obtained through image displacement means that horizontal measurements will be inaccurate; thus, wide-angle photography is often inappropriate for precise mapping. The long focal-length or "telephoto" lenses are preferable in mountainous terrain in order to reduce the excessive exaggeration. The medium focal-length lenses are often the best compromise for average conditions. The 6-inch focal length lens is most commonly used and is considered the standard mapping lens, since it permits enough stereo exaggeration for producing topographic maps without extreme horizontal displacement. The 8-1/4 inch focal lengths lens is also used a great deal, especially for reconnaissance projects where height is not a prime factor.

Handheld Cameras

Handheld aerial photography can be taken by most any kind of camera, but the quality of the photographs and therefore their effectiveness for interpretation is dependent largely on the quality and negative size of the camera. The image quality also depends on other factors such as the skill of the photographer, the stability of the aircraft and the type of film used. The larger the negative size, the better the image quality will be. Cameras with a 35 mm negative size are the smallest size cameras that should be used and photography taken with these cameras has to be taken at a low altitude (1000' or less) to produce usable data. A negative size of 60 mm to 70 mm is commonly used for handheld photography. Appropriate cameras which are easily available utilizing this size negative roll form include: (1) a Hasseblad with a 60 mm or 70 mm square back, (2) a Pentax 6 cm x 7 cm, or (3) less expensive cameras such as a 4" x 5" (10 cm x 12.5 cm) Speed Graphic with a 2-1/4" x 3-1/4" (approximately 6 cm x 8 cm) roll film. Cameras which take roll film at sizes larger than 2-1/4 x 3-1/4" are expensive as well as hard to obtain. Although aerial film is made in a 5-inch wide size, no camera is commercially available in this country that uses this size film. The Lindhoff camera which exposes a 4" x 5" negative can be obtained if ordered from Germany. Cameras using film over 5" wide are generally too heavy and bulky to hold by hand easily.

Film

Black and White

Black and white panchromatic aerial film is one of the oldest and most widely used films for aerial photography. It is the least expensive aerial film and is capable of registering the entire visible spectrum in black and white with fine resolution. Most photogrammetric work (i.e., making topographic maps) is done using this film because it provides finer detail at less cost than any other aerial film. It is usually exposed using a yellow filter to cut haze.

Though black and white is a very versatile film for many uses, interpretation capabilities using this film are limited when compared to color films. The human eye can separate more than 100 times more color combinations than black and white tones (grey-scale values). More training is required for an interpreter to recognize objects by grey-scale tone than by color, since color provides two additional dimensions, hue (color) and chroma (strength of color).

Black and White Infrared

Infrared film is sensitive in the reflective portion of the infrared, though it is less sensitive to the blue-green part of the visible spectrum. When red filters are used to cut out the blue and blue-green wavelengths, broad-leaved vegetation appears in light tones, water and moist soil or rocks appear dark. A loss of vigor in broad-leaf vegetation shows up darker than the healthy vegetation. Because the blue end of the spectrum is effectively cut out, infrared film has superior haze-cutting capabilities.

The disadvantages of black and white infrared film include its poorer resolution quality compared with that of panchromatic film, its poor shadow penetration, and it lack of tonal gradation.

Color

In the past decade, vast improvements in color film have been made increasing its resolution, stability, fidelity, sensitivity and processing ease as well as reducing its cost. These factors have brought color aerial film into wider use. There are two types of normal color film that can be used, color positives, which are generally viewed as positive transparencies, and color negatives, which are usually viewed as positive paper prints. Both types are more expensive than black and white photography. Color positive transparencies are cheaper to obtain than color prints when acquiring new photography, however, when acquiring copies of existing color film, color prints made from original negatives are somewhat less expensive than obtaining reproductions from color positive transparencies, because an internegative is required.

Though the costs are more and the resolution is not as fine as when using black and white film, especially when using color negative film, color provides more information for many kinds of interpretation. One advantage of color film for interpretation is that the image is in natural color which is more easily interpreted especially by inexperienced interpreters. As mentioned above, color film allows for much finer discrimination between color tones and brightness than is possible with black and white, thus for example, it is possible to identify vegetation species from color, but not from black and white in many cases.

130

Because color film is sensitive in the blue region of the spectrum, it readily detects haze. This inability to penetrate haze makes it difficult to obtain high resolution color photography in many areas throughout much of the year, and particuarly at high altitudes (small scale). This, in addition to the increased costs, is a major disadvantage.

Color Infrared (CIR)

Color infrared film, also referred to as false-color film, camouflage-detection film, or infrared color film, is generally Kodak Ektachrome Infrared Aero film. Though there are other CIR films, this is the most common CIR film in the United States. A yellow filter is always used to block out the blue wavelengths, thus only the reflected green, red and infrared portions of the spectrum are recored on this film. As with black and white infrared, this infrared film has special advantages for detecting water and moisture, in vegetation discrimination, and in haze penetration.

The reflectance of healthy broad-leaf vegetation is higher in the infrared than in the green and red portions of the spectrum, and therefore, the CIR film presents healthy vegetation as bright red. When vegetation begins to die, it loses its strong infrared reflectance, and thus, it no longer appears bright red on CIR film. Conifer or needle-leaved trees display somewhat different color characteristics, thus making vegetation identification easier than using this film. Water bodies are easily detected due to their dark tones, and often an indication of soil moisture can also be deduced. Finally, CIR film allows one to obtain very high altitude photography (i.e., 1:80,000) while still maintaining fine resolution and not losing the films' wide color tone and hue variations.

Multiband Photography

Multiband photography is designed to obtain simultaneous exposures of one scene at a variety of visible and/or infrared wavelengths. This type of photography can provide more information than is obtainable from any one spectral region alone. Multiband camera systems are designed to record variations that exist in the spectral reflectivity of natural objects. Analysis of these variations helps to identify the objects and their condition.

A number of camera systems which provide imagery of scenes within various spectral bands are commercially available. Some systems use separate cameras mounted together; many use multiple lenses on one camera, and the U.S. Army Topographic Labs use a camera with internal prisms to obtain the different bands. By using different film and filter combinations these camera systems can photograph the entire range of reflected light. However, it does not record as much of the entire spectrum as is possible with multispectral scanners, which can produce imagery in the non-reflective wavelengths, such as thermal infrared. If the target has, in fact, a unique spectral signature

against its background, the multiband camera can be "designed" to optimize the detection by selecting the appropriate filter/film combination to accentuate the spectral differences. Careful control must be exercised to assure consistency throughout the system in order to get comparable and repeatable results.

Some disadvantages to using multiband photography for environmental analysis are as follows: (1) the image coverage is generally smaller than with conventional aerial photography and thus more exposures are needed to cover the area at the same scale; (2) often the information needed for some parts of environmental impacts analyses can be acquired more economically through the use of a single, broad band film; (3) the specialized equipment, calibration, and control needed to obtain high quality multiband photography require systems which are quite expensive, and (4) the tremendous amount of information acquired may overload the interpreters with too much information to use or even comprehend.

Equipment for Interpretation and Costs

Equipment used to interpret aerial photography, like the equipment used to acquire aerial photography discussed in previous sections, range from simple to sophisticated. The first requirement is to provide equipment which aids in viewing the photography. Generally, the equipment is used to facilitate stereo viewing and/or to magnify the image. If the photography has stereo coverage, stereoscopes of various types are commonly used to aid the interpreter in seeing in three dimensions by forcing each eye to look straight down at each photograph and thus the three dimensional image is seen. However, stereo vision with the unaided eye can be attained with some practice. Many stereoscopes also magnify the photograph which is useful for interpretation. There are two types of stereoscopes used for photo analysis; these are lens stereoscopes and reflecting stereoscopes. Lens stereoscopes combine the advantages of magnification (usually two times, sometimes four times) with portability, and low cost. A disadvantage with lens stereoscopes is that the entire overlap area of standard photographs cannot be viewed at one time. Reflecting or mirror stereoscopes use mirrors and sometimes prisms to separate the line of sight of the eyes and this helps the viewer see stereoscopically. With mirror stereoscopes, the entire stereoscopic overlap can be examined at one time. Some mirror stereoscopes have scanning capabilities, such as the Old Delft scanning stereoscope. With this stereoscope photographs up to 9" x 18" in size can be viewed stereoscopically without moving the photographs or the stereoscope. The Old Delft has a range of magnifications from 1-5x (1 to 5 times) to 9x depending on the lens used.

132

If stereo coverage is not acquired, then enlargement or magnification of the photograph is often used to aid the interpretation process. The photograph can be enlarged photographically or viewed under magnification. Anything from a simple magnifying glass to a large complicated and expensive automated viewer such as a Variscan can be used.

The approximate costs of equipment which is required or will aid in the interpretation of the aerial photographs is as follows:

Stereoscopes

• pocket lens stereoscope (2x*)	$12.00-$15.00
• Abrams CB-1 (2x & 4x)	$50.00-$60.00
• Small mirror stereoscope (1.5x)	$70.00
• Mirror stereoscope (no magnification	$200.00-$300.00
Eyepiece (3x)	$150.00-$200.00
• Old delft scanning stereoscope (1.5 & 4.5)	$4,900.00

Viewing Equipment

• Magnifying glass	$2.00-$50.00
• Opaque projector	$200.00-$400.00

*2x means 2 power magnification

Satellite Data

A number of satellite programs have provided useful observations of the earth's surface. These programs include the operational National Oceanic and Atmospheric Administration (NOAA) satellites with their relatively "high resolution" visible and infrared sensors (resolution of about 0.9 km or 0.5 mi). Although these satellites are designed primarily for meteorological purposes, the data have been used successfully by scientists to map certain geologic and hydrologic features such as fault areas, the changing extent of snowcover in mountainous areas, and the extent of river flooding. However, the most appropriate form of satellite imagery for the task of providing synoptic coverage for tasks such as monitoring land use changes over large areas is that from the Landsat Satellite, previously called the Earth Resources Technology Satellite (ERTS).

The first of the satellites specifically designed to make earth resource surveys, Landsat-1, was successfully launched into a sun-synchronous orbit of about 900 km (560 mi) on 23 July 1972. Except for a brief period in early August of 1972, one of its primary sensor systems, the MSS or Multispectral Scanner, has operated continuously. The MSS has a ground resolution of 80 meters and views a swath 185 km wide, with each frame of the imagery covering an area about 185 km x 185 km (115 mi x 115 mi). The total number of frames required to cover the entire surface of the conterminous United States is approximately 800. The configuration of the orbit is such that repeated coverage of the same area occurs every 18 days. A second satellite, Landsat-2, was launched on 22 January 1975 and is currently providing useful data of the same type as from Landsat-1. A third Landsat was launched in March, 1978. The locations and coverage of Landsat Receiving Stations is shown in Appendix A.

Skylab is another spacecraft observation system that may be of some interest to resource planners. Photographs from the Skylab S190A Multispectral camera and the S190B Earth Terrain camera have better resolutions than imagery from the Landsat MSS (about 20 m for the S190B and 30-80 m for the S190A). The resolution varies somewhat for each camera depending on film type. Unfortunately, these systems were operated for only about six months during 1973-1974 and cover only a relatively limited area compared with the coverage provided by Landsat. Nevertheless, it is possible that for some applications (e.g., geography) over certain areas Skylab cameras can provide useful photography at a scale comparable with that from high altitude aircraft, 1:125,000 for a 34.4 inch paper print of an S190A photograph compared with 1:120,000 for a small scale photograph from a high altitude aircraft. Further information on satellite data can be found in Table 3.

While the standard satellite products are available at a maximum scale of 1:250,000 (Landsat and S190A) and 1:125,000 (S190B), the scales may be increased by either special processing of the standard products or by use of a zoom transfer scope or similar device. However, the resultant products still will not have the resolution obtained in aerial photography; for example, Landsat images may be enlarged by the user to a maximum of about 1:120,000, but the ground resolution of about 80 m remains the same while the quality of the image diminishes considerably. The major advantage of satellite imagery and photographs is the large coverage of each frame, thereby permitting a rapid, relatively inexpensive, survey of an extensive area where the necessary resolution is 20 or 30 m (Skylab) or 80 m (Landsat).

134

TABLE 3

SPACECRAFT DATA FACT SHEET
(Available on request from the EROS Data Center, U.S. Department of the Interior, located in Sioux Falls, South Dakota)

ERTS/LANDSAT

On July 23, 1972, the first Earth Resources Technology Satellite (ERTS/LANDSAT-1) was launched into a sun synchronous polar orbit around the Earth. On January 22, 1975, the second Earth Resources Technology Satellite (ERTS/LANDSAT-2) was launched into a similar orbit. Each satellite has the capability for receiving coverage of most of the Earth on an 18-day repetitive cycle. The sensors on board the spacecraft transmit data to NASA receiving stations in Fairbanks, Alaska; Goldstone, California; and Greenbelt, Maryland. The Data received at the NASA receiving stations are forwarded to Goddard Space Flight Center in Greenbelt, Maryland where they are converted to 70mm photographic film positives. Copies of the imagery are immediately flown to the EROS Data Center in Sioux Falls, South Dakota where they are placed in the public domain and where requests for reproductions of the images can be filled for the scientific community and the public at large.

THE ERTS/LANDSAT SENSORS

The ERTS/LANDSAT Spacecraft carry two types of imaging sensors: The Multi-Spectral Scanner Subsystem (MSS) and the Return Beam Vidicon (RBV) cameras.

The Multi-Spectral Scanner (MSS) is a line-scanning device which uses an oscillating mirror to simultaneously scan the terrain passing beneath the spacecraft. The scanner produces four synchronous images, each at a different wave band. The wave length ranges of each band are:

Band 4 (green)	0.5 to 0.6 micrometers
Band 5 (lower red)	0.6 to 0.7 micrometers
Band 6 (upper red-lower infrared)	0.7 to 0.8 micrometers
Band 7 (near infrared)	0.8 to 1.1 micrometers

Band 4 sometimes discriminates, qualitatively, the depth and/or turbidity of standing bodies of water. Band 5 is best for showing topographic and cultural features, such as drainage patterns, roads, and cities. Band 6 shows the best tonal contrasts that reflect various land use practices; it also gives maximum land-water contrast. Band 7 is the best for land-water discrimination.

Thus, for general display purposes, a scene is best presented by four photos. If only one photo is desired, however, band 5 will usually be the best selection.

The Return Beam Vidicon cameras are television cameras mounted side by side in the spacecraft and bore-sighted to simultaneously photograph the earth beneath the spacecraft.

Because of functional problems, the RBV sensors on ERTS/LANDSAT-1 were rendered inoperative on approximately August 15, 1972. Therefore, we have received no RBV images since that time. Some RBV images, acquired prior to its malfunction, are in our film holdings. Some RBV images from ERTS/LANDSAT 2 will be available in limited quantity. The wave length ranges of each band are:

Band 1 (green)	.460 to .600 micrometers
Band 2 (red)	.569 to .680 micrometers
Band 3 (near infrared)	.660 to .820 micrometers

The individual frames of MSS and RBV images cover approximately 115 x 115 miles and overlap by 10 percent along the spacecraft track. They are converted from electronic signals to black and white photographic positives on 70mm film by an Electron Beam Recorder (EBR). These original images have a scale of approximately 1:3,369,000. Master reproducible copies are all System Corrected Images, processed by Goddard Space Flight Center and forwarded to the EROS Data Center as 70mm photographic film negatives.

COLOR COMPOSITES

Only selected scenes of the RBV and MSS images are reproduced as color composites. Therefore, color composites do not exist for all ERTS/LANDSAT scenes. Scenes reproduced as color composites are selected and compiled by NASA and the EROS Data Center as a result of customer requests. Three black and white spectral bands from either the RBV or MSS images are registered and sequentially exposed through appropriate color filters onto color film at a scale of 1:1,000,000.

Inquiry should be made as to the availability of a color composite over a specific area before submitting payment.

135

TABLE 3 (cont)

ERTS/LANDSAT (continued)

COMPUTER COMPATIBLE TAPES

Computer compatible digital tapes of ERTS/LANDSAT images may be ordered from the Data Center. However, all scenes requested must be prepared in computer compatible tape (CCT) form by NASA/Goddard and forwarded to the EROS Data Center for reproduction.

MICROFILM

After every 30 days, the Goddard Space Flight Center prepares a complete listing of photography and a 16mm "browse" microfilm of images processed. The microfilm are not intended for analysis purposes, but are instead intended to provide visual index to the coverage and a capability for cloud cover assessment by the user. The band 2 RBV and band 5 image from each scene will appear on the microfilm. The microfilm are available for purchase from the Data Center on open reels.

NASA ERTS/LANDSAT DATA CATALOGS

The listing of the imagery shown on the microfilm previously mentioned is published in NASA ERTS/LANDSAT Standard Catalogs. Photographs are not included in the catalogs. Information contained in the catalogs is not always compatible with revisions made of film holdings. It is suggested that inquiry be made to the Data Center for ordering information.

SKYLAB

The NASA Skylab Program consisted of one unmanned and three manned missions. Limited Skylab photos from the three manned missions were acquired from May 22, 1973 through February 8, 1974.

The spacecraft traveled in an equatorial orbit 270 miles above the Earth, and acquired limited data between latitudes 50° north and 50° south. The data cover a number of scattered test sites selected to support Earth Resources Experiments, but do not provide complete and cloud free coverage of these areas.

The Skylab Earth Resources Experiment Package (EREP) used two basic photographic remote sensing systems and was designed as a spaceborne facility to be used by the scientific community. The two basic systems used were:

S190A – Multispectral Photographic Camera – A six camera array designed for a wide range of user oriented subjects. Each camera used 70mm film and a six inch focal length lens. The films utilized ranged in the spectrum from narrow band black and white to broad band color and color infrared.

S190B – Earth Terrain Camera – A single, high resolution, Earth Terrain Camera selected to support the S190A system. It utilized five inch film and an 18 inch focal length lens. Various films were periodically used in the camera and basically consisted of black and white, color and color infrared.

Skylab imagery is indexed and listed at the Data Center by individual scene. Each Skylab image, viewed from an altitude of approximately 270 miles, covers the following general areas depending on the camera system: the S190A system covers approximately 100 miles by 100 miles. The resolution of S190A photos is such that an object of about 150 feet by 150 feet can be identified. The S190B system covers approximately 68 miles by 68 miles. The resolution of S190B photos is such that an object of about 75 feet by 75 feet can be identified. The resolution of any scene depends on the contrast of the cultural and geological features as well as the atmospheric conditions.

The Skylab flights have been completed and all photographic data from missions 2, 3, and 4 are available from the Data Center.

APOLLO/GEMINI PHOTOGRAPHY

Early photographic coverage over limited geographic areas of the Earth acquired by the Gemini and Apollo missions is available from the Data Center. The majority of this coverage is color photography, acquired by handheld 70mm cameras.

Costs for obtaining satellite data of various types are shown in Table 4. The cost per square mile can be quite low, several cents per square mile for a large area of several thousand square miles entirely covered by one frame. For large areas not requring details less than about 80 m (somewhat less for linear features such as highways) use of Landsat imagery provides the cheapest means of obtaining information compared with aerial imagery or photographs. A constraint on the use of Landsat data is the time needed to acquire imagery from the EROS Data Center, about two to six weeks depending on the amount and type of data needed.

Requests for Landsat and Skylab Data products should be addressed to:

EROS Data Center
U.S. Department of the Interior
Sioux Falls, South Dakota 57198

For additional information on meteorological satellite data, contact:

Coordinator, Direct Readout Services
United States Department of Commerce
National Oceanic and Atmospheric Administration
National Environmental Satellite Service
Washington, DC 20233
U.S.A.

Other Imaging Remote Sensors

Scanners

Scanners, or scanning radiometers, are sophisticated instruments usually mounted on aircraft or satellites and are generally pointed downward. The radiometer (any device that passively measures radiation) is scanned to either side of the vertical direction as the vehicle travels along its flight path. The scanning of the sensor and the forward movement of the vehicle, provides a "mapped" image for each channel, or spectral interval (see Figure 1.2). Commercially available units generally provide a number of channels in the visible and near infrared regions, and perhaps, a single channel in the thermal infrared. With such a unit, target "signatures"* can be detected which make use of the visible and near infrared reflective properties of an object, and its emission in the thermal infrared.

*A target signature may be described by the pattern of the various responses in the several channels of the system. For example, in a two channel system a signature may consist of a very high reading from one channel and a very low one from the other.

137

TABLE 4

PRICE LIST

STANDARD REMOTE SENSING DATA

U. S. DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

JANUARY 1, 1979

SATELLITE DATA

STANDARD LANDSAT

NOMINAL IMAGE SIZE	PRODUCT MATERIAL	BLACK & WHITE UNIT PRICE	BLACK & WHITE PRODUCT CODE	COLOR UNIT PRICE	COLOR PRODUCT CODE
55.8mm (2.2 in.)	Film Positive	$ 8.00	11	NA	NA
55.8mm (2.2 in.)	Film Negative	10.00	01	NA	NA
18.5cm (7.3 in.)	Paper	8.00	23	$12.00	63
18.5cm (7.3 in.)	Film Positive	10.00	13	15.00	53
18.5cm (7.3 in.)	Film Negative	10.00	03	NA	NA
37.1cm (14.6 in.)	Paper	12.00	24	25.00	64
74.2cm (29.2 in.)	Paper	20.00	26	50.00	66
COLOR COMPOSITE GENERATION				$50.00	59

NOTE:
1) Portrayed in false color (infrared) and not true color.
2) Cost of product from this composite must be added to total costs
3) Not applicable for MSS Band 8 or RBV Subscenes
4) Master composite retained at EDC

CCT

TRACKS	BPI	FORMAT	MSS All Bands Available PRODUCT CODE	MSS All Bands Available PRICE	RBV Single Subscene PRODUCT CODE	RBV Single Subscene PRICE	Set of Four RBV Subscenes PRODUCT CODE	Set of Four RBV Subscenes PRICE
9	800	TAPE SET	183-D	$200.00	183-C	$200.00	183-D	$400.00
9	1600	TAPE SET	184-D	200.00	184-C	200.00	184-D	400.00

138

TABLE 4 (cont)

MANNED SPACECRAFT DATA

	IMAGE SIZE	NOMINAL SCALE	PRODUCT MATERIAL	BLACK & WHITE UNIT PRICE	BLACK & WHITE PRODUCT CODE	COLOR UNIT PRICE	COLOR PRODUCT CODE
SKYLAB S190A	55.8mm (2.2 in.)	1:285000	Film Positive	$ 8.00	11	$10.00	51
	55.8mm (2.2 in.)	1:285000	Film Negative	10.00	01	NA	NA
	16.3cm (6.4 in.)	1:1000000	Paper	8.00	23	12.00	63
	32.5cm (12.8 in.)	1:500000	Paper	12.00	24	25.00	64
	65.0cm (25.6 in.)	1:250000	Paper	20.00	26	50.00	66
SKYLAB S190B	11.4cm (4.5 in.)	1:950000	Paper	$ 8.00	22	$ 8.00	62
	11.4cm (4.5 in.)	1:950000	Film Positive	8.00	12	12.00	52
	11.4cm (4.5 in.)	1:950000	Film Negative	10.00	02	NA	NA
	21.8cm (8.6 in.)	1:500000	Paper	8.00	23	12.00	63
	43.4cm (17.1 in.)	1:250000	Paper	12.00	24	25.00	64
	86.9cm (34.2 in.)	1:125000	Paper	20.00	26	50.00	66
APOLLO/GEMINI	55.8mm (2.2 in.)	Variable	Film Positive	$ 8.00	11	$10.00	51
	55.8mm (2.2 in.)	Variable	Film Negative	10.00	01	NA	NA
	22.6cm (8.9 in.)	Variable	Paper	8.00	23	12.00	63
	45.5cm (17.9 in.)	Variable	Paper	12.00	24	25.00	64

AIRCRAFT DATA

	IMAGE SIZE	PRODUCT MATERIAL	BLACK & WHITE UNIT PRICE	BLACK & WHITE PRODUCT CODE	FILM SOURCE
INDEXES	25.4x30.5cm (10x12 in.)	Paper	$ 5.00	36	B & W — Size A
	OTHER	Paper	5.00	37	B & W — Size B

139

TABLE 4 (cont)

AIRCRAFT DATA Continued

	IMAGE SIZE	PRODUCT MATERIAL	BLACK & WHITE UNIT PRICE	BLACK & WHITE PRODUCT CODE	COLOR UNIT PRICE	COLOR PRODUCT CODE
AERIAL MAPPING	22.9cm (9.0 in.)	Paper	$ 3.00	23	$ 7.00	63
	22.9cm (9.0 in.)	Film Positive	5.00	13	15.00	53
	22.9cm (9.0 in.)	Film Negative	6.00	03	NA	NA
	45.7cm (18.0 in.)	Paper	10.00	24	25.00	64
	68.6cm (27.0 in.)	Paper	15.00	25	30.00	65
	91.4cm (36.0 in.)	Paper	20.00	26	50.00	66
NASA RESEARCH	55.8mm (2.2 in.)	Film Positive	$ 3.00	11	$10.00	51
	55.8mm (2.2 in.)	Film Negative	4.00	01	NA	NA
	11.4cm (4.5 in.)	Paper	3.00	22	7.00	62
	11.4cm (4.5 in.)	Film Positive	4.00	12	12.00	52
	11.4cm (4.5 in.)	Film Negative	5.00	02	NA	NA
	22.9cm (9.0 in.)	Paper	3.00	23	7.00	63
	22.9cm (9.0 in.)	Film Positive	5.00	13	15.00	53
	22.9cm (9.0 in.)	Film Negative	6.00	03	NA	NA
	22.9x45.7cm (9x18 in.)	Paper	6.00	31	20.00	69
	22.9x45.7cm (9x18 in.)	Film Positive	10.00	14	30.00	56
	22.9x45.7cm (9x18 in.)	Film Negative	12.00	04	NA	NA
	45.7cm (18.0 in.)	Paper	10.00	24	25.00	64
	68.6cm (27.0 in.)	Paper	15.00	25	30.00	65
	91.4cm (36.0 in.)	Paper	20.00	26	50.00	66

140

TABLE 4 (cont)

MISCELLANEOUS

MICROFILM

FORMAT	BLACK & WHITE UNIT PRICE	BLACK & WHITE PRODUCT CODE	COLOR UNIT PRICE	COLOR PRODUCT CODE
16mm (30.5m/100 ft.)	$15.00	72	$40.00	73

DIAPOSITIVES

MATERIAL	BLACK & WHITE UNIT PRICE	BLACK & WHITE PRODUCT CODE
Contact Glass Prints	$12.00	70
Contact Film Prints	5.00	78
NOTE: Specify method of printing (emulsion to emulsion or through film base) and thickness of glass (0.25 or 0.06 inch).		

TRANSFORMED PRINTS

SOURCE	BLACK & WHITE UNIT PRICE	BLACK & WHITE PRODUCT CODE
From convergent or transverse low oblique photographs.	$ 8.00	71

35mm MOUNTED SLIDES

COLOR UNIT PRICE	COLOR PRODUCT CODE
$1.00	50

AVAILABILITY

(1) Selected Landsat coverage of the 48 conterminous United States.

(2) Major United States Metropolitan Areas (Landsat / Skylab / NASA Aircraft)

NOTE:

35mm mounted slides are only available from existing master slides residing at the Data Center.

Complete roll reproduction delivered in roll format carries a 50% reduction in frame pricing.

Custom processing is available at three times the standard product price. If a non-standard size is desired, the cost is three times the next larger standard product price.

Priority service with guaranteed five working days shipment is offered for standard products only, at three times the standard product price.

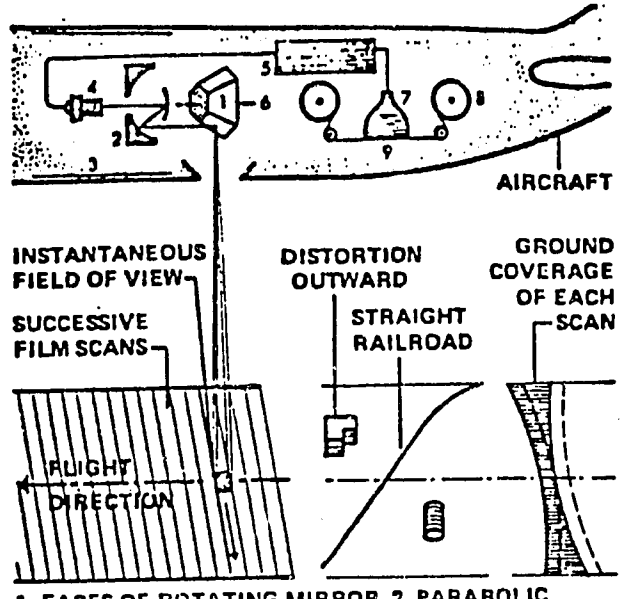
Extra care should be taken to insure that monies and related order forms are forwarded to the same facility.

Landsat microfiche subscriptions are available for catalogs and imagery.

Accession Aids in microform are available for Skylab, Mapping and NASA photography.

Please contact the User Services Section at the EROS Data Center for further assistance.
Comm: (605) 594-6511
FTS: 784-7151

141



1. FACES OF ROTATING MIRROR 2. PARABOLIC MIRROR 3. COOLING JACKET 4. DETECTOR 5. AMPLIFIER-MODULATOR 6. ROTATION AXIS 7. CATHODE-RAY TUBE 8. FILM SPOOL 9. RECORDING OF OPTICAL SCAN ON PHOTO FILM

Figure 1.2 Schematic of the operation of an optical mechanical scanner (from City Planning and Aerial Information by M.C. Branch, Harvard Univ. Press, Cambridge, Mass., 283 pp., 1971)

142

As illustrated in Figure 1.2 corrections must be made for distortion of the viewed area as the radiometer scans away from the vertical. This distortion becomes especially important at lower altitudes, unless only a very narrow area along the flight path is to be imaged. Such a restraint would require a relatively large number of flights to cover a given area. Compensation for image distortion may be performed optically by a step-wise contraction of the image parallel and perpendicular to the flight path as the scan angle increases, or electronically by a computer. The image should be corrected if an accurate map of the area is needed; if only a general overview is required image compensation may not be necessary, but it should be understood that the image does not provide a true-to-scale picture.

Thermal Infrared Scanners

Thermal infrared scanners generally are sensitive to radiation at wavelengths from about 8 to 14 m, or some smaller interval within that range. They measure radiation emitted by the top few tens of micrometers (μm) of the target, and therefore, only supply surface values. The radiation measured may be converted readily into an equivalent black body temperature, the temperature of the equivalent perfect absorber and emitter (i.e., black body). If the observed surface is not a black body (no natural surface is), then the equivalent temperature will be lower than the measured value. Water closely approximates a perfect absorber, while land surfaces generally do not. Thus, a thermal scanner can provide accurate estimates of the temperature of a water surface (within 0.2 or 0.3° celsius, or about 0.5° Fahrenheit, from low altitudes under clear conditions), but temperature estimates may be ambiguous over a land surface.

A correction for atmospheric attenuation is necessary for measurements from satellites or high altitude aircraft. The atmosphere between the sensor and the ground must be free of clouds to obtain useful data, since clouds strongly absorb infrared radiation. Under the best conditions for satellite measurements the accuracy of the estimated water surface temperature usually will not be better than about 1° Celsius (1.8° Fahrenheit). The ground resolution ranges from about 0.9 to 4 km (about 0.5 to 2.5 mi) for satellite imagery to as good as 30 cm (1 ft.) for imagery taken from an aircraft at an altitude of about 330 m (about 1,000 ft.).

An infrared scanner can supply a mapped image of the surface temperature pattern of a body of water. "Contours" of temperature (isotherms) may be constructed through the use of suitable processing techniques, including density slicing of the thermal infrared image or analysis of digitized data, usually by computer. The location of a specific isotherm or pattern of isotherms on the "map" can be placed with a high positional accuracy if the infrared image is combined with aerial photographs of the same area, assuming landmarks are visible on both.

143

Microwave Scanners

Microwave scanners have been tested experimentally, although they are not as readily available as infrared scanners. Microwave scanners are in use at various commercial and government laboratories dedicated primariy to research programs, and their applications as earth viewing sensors on board aircraft or satellites have been demonstrated on a number of cases. A great advantage of microwave sensors is their ability to sense radiation from under the surface, to a depth of perhaps 20 or 30 centimeters (about 8 to 12 inches), thereby permitting the detection of wet or moist soil under a dry crust several centimeters (1 or 2 inches) thick. Unfortunately, the use of microwave scanners for this and similar purposes has not yet gone beyond the experimental stage. A significant disadvantage of microwave scanners is their relatively poor spatial resolution which amounts to about 30 or 40 kilometers (20 or 25 miles) from satellites and to several hundred meters from high flying aircraft.

Multispectral Scanners

Multispectral scanners provide information similar to that from multispectral photography. However, scanners can have a much finer spectral (wavelength) resolution, thus permitting a better definition of spectral signatures. Output from these scanners, as opposed to photography, may be digitized readily, and therefore is more amenable to real-time processing and interpretation by computer. The main disadvantage is the relatively poor spatial resolution compared with that of photographic systems.

An example of a good quality system is the Multi-Spectral Scanner (MSS) carried on Landsat satellites. The MSS is a four-channel scanner operating in four spectral bands as follows: MSS-4 (0.5-0.6 μm), MSS-5 (0.6-0.7 μm), MSS-6 (0.7-0.8 μm), and MSS-7 (0.8-1.1 μm). Table 2 provides additional information on the MSS. Selection of these specific wavelength intervals was based on extensive evaluation of the data required for mapping natural resources on a national and global basis. MSS-7, for example, may be used for the depiction and mapping of plant growth and health, and MSS-4 may be utilized to map coastal and near shore phenomena. Use of all four channels may allow the extraction of spectral signatures which can be used to identify specific target types, such as a particular crop or land use.

The spatial resolution of MSS imagery is about 80 meters,* which is poor relative to aerial systems. However, even at this resolution the geometric shapes of many types of individual target elements are

*Spatial resolution, size of the smallest element on the ground that can be resolved unambiguously, should not be confused with scale, the ratio of a representative length on the image to the actual distance on the ground. For example, MSS imagery has a spatial resolution of about 80 meters (87 yards), but can be obtained at scales from 1:3,369,000 to 1:250,000.

144

clearly discerned and serve as additional signature keys. The orderly patterns of cultivated fields, for example; are recognizable, making it possible to distinguish agricultural from forested areas, even though both types of terrain may have nearly identical spectral signatures.

Side Looking Airborne Radar (SLAR)

SLAR transmits a short pulse at right angles to the flight path of the aircraft and detects the backscattered radiation from the "illuminated" target, with the signal from the inner edge received first. The intensity of the returned signal and recorded spot on the cathode-ray tube depends on the nature of the surface (composition and geometry). Signals scattered from further objects arrive sequentially and are recorded as the electron beam sweeps across the face of the cathode-ray tube (CRT). The time delay of a returned signal is transformed to ground range, and, therefore, the position of the spot on the CRT may be regarded as an indicator of distance along the ground. A moving picture is taken of the display to give a two-dimensional "photograph" (see Figure 1.3).

If the loss (absorption plus scattering) of the "ground" material is low, such as with dry snow and freshwater ice, significant portions of the return will be contributed by subsurface features. Thus, the possibility exists of viewing the terrain even when it's covered by snow or thin ice. No return will be received if the surface is a perfect absorber; also there will be no return from a specular reflector (reflection in one direction only, as by a mirror at visible wavelengths) except when the radar beam is normal to the specular surface. Standard altitudes flown with a commercially available K-band (i.e., wavelength about 1.0 cm) system are 20,000, 12,500 and 9,000 feet (about 6.1, 3.8, and 2.8 km) above ground level, with three ground range distances of 21, 13, and 9 km (about 13, 8.1, and 5.6 mi) respectively. The equivalent film scales range from 1:225,000 to 1:98,000. Resolution across track may be as small as 12 m at 16 km slant range* (about 40 ft. at 10 mi); along the track the resolution is about 21 m at 16 km slant range (about 70 ft. at 10 mi). Resolution varies with slant range, with a smaller range giving a better resolution.

The SLAR system has several important advantages:

1) It's an all-weather system that permits mapping of areas previously not mapped because of adverse weather conditions.
2) It's independent of natural illumination; therefore, it is a 24-hour system.
3) The broad coverage per image reduces the number of flights needed to cover a specific area.
4) Although the system is relatively heavy, it can be employed in both aircraft and spacecraft.

*Slant range is the distance along the line of sight from the radar to the target.

145

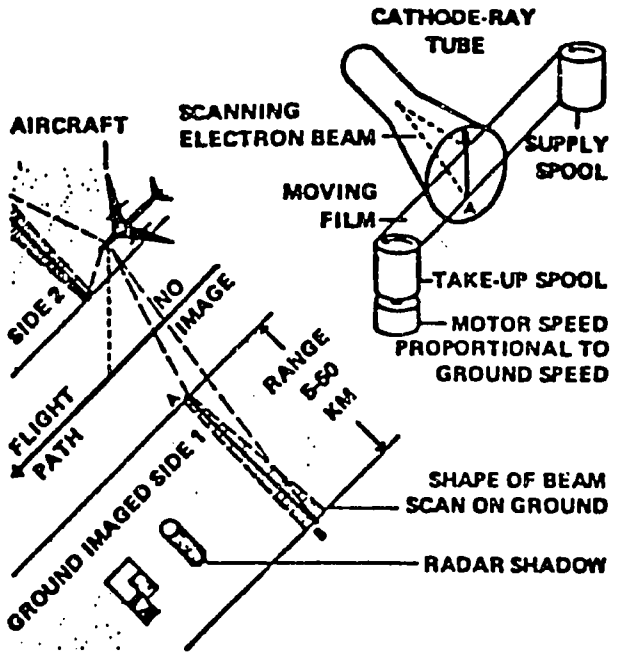


Figure 1.3 Schematic of important facets of side looking airborne radar (SLAR) (from City Planning and Aerial Information by M.C. Branch, Harvard Univ. Press, Cambridge, Mass., 283 pp., 1971).

146

The disadvantages of a SLAR system are:

1) The inherent difficulty in obtaining good stereoscopic coverage, fine resolution relative to aerial scanner imagery and photography, and accurate relative position of all terrain and cultural features.
2) A large antenna is required (partly alleviated by the use of snythetic aperture radars).
3) The system is expensive to operate and is feasible only for very large scale problems.
4) The equipment is heavy and requires special handling.

A good SLAR system is perhaps the most expensive of all those discussed in this report. The cost of such a system (radar plus peripheral equipment) would be on the order of several hundred thousand dollars, not including the cost of buying or leasing an aircraft to carry it. The aircraft would be large (e.g., DC-6, Caravelle, or Lear Jet) because of the weight and bulk of the equipment, aside from its large power requirements. In the past the main users of SLAR have been the military, various government agencies and research groups, and a few major corporations or groups of several companies. The alternative to purchasing a SLAR system is contracting for the work, still an expensive option because of the contractor's need to recover investment and maintenance costs. Typical costs for obtaining SLAR imagery run in the order of tens of thousands of dollars.

Application of Remote Sensing Techniques to Earth Resouces Monitoring

Remote sensing techniques are used to inventory or to monitor various types of resources for many purposes. To inventory, one analyzes remotely sensed data with the intention of producing one inventory or data set, often in the form of a map. To monitor, one completes a number of inventories of a certain area over a period of time in order to detect change. Inventories or monitoring can be generalized or detailed; they can try to analyze everything systematically or narrow the analysis to a certain theme, such as an analysis of factors influencing construction. Whether for a generalized or specific purpose, most of the basic interpretation techniques are the same, it is simply a matter of degree of detail.

Monitoring usually begins with the preparation of a thorough inventory and follows with inventories and analyses that detect and map areas which have changed since the original inventory. This type of monitoring is particularly useful when drastic changes due to construction are involved. Remote sensing provides an economical way to monitor large areas quickly and easily before the construction begins, as the project progresses, and after the construction project is complete. Subtle changes, such as increased water turbidity or vegetation stress can be recorded as well as the major obvious changes brought on by development.

The applicability of remote sensing techniques to various types of earth resources studies is summarized in Table 5. Several regions of applicability are represented ranging from "very useful" to "little or no operational use." The classification of usefulness is, in many cases, somewhat subjective; although objectivity was stressed, undoubtedly rational arguments could be raised for changing some of the classificatons. The usefulness of any particular technique may increase as the technology improves, and new techniques of practical use may be considered in the future. Furthermore, the placing of several techniques in one "region" in no way implies that all are equally useful. For example, both black and white and color photography are "very useful" for determining agricultural land use patterns, but color photography provides the better information. Satellite sensors are listed under separate headings because of their distinct characteristics such as far greater ground coverage per image and poorer resolution relative to similar sensors carried on aircraft. The satellite sensors of interest are the Multispectral Scanner (MSS) of Landsat and the S190A and S190B cameras of Skylab.

148

TABLE 5

USEFULNESS OF REMOTE SENSING TECHNIQUES FOR APPLICATION TO EARTH RESOURCES SURVEYS

The meanings of the symbols are as follows:

● - very useful, ✦ - somewhat useful
o - little or no operational use, x - not applicable.

CRITERIA \ TECHNIQUE	PHOTOGRAPHY					SCANNERS									SATELLITES	
	Black and White	Black and White Infrared	Color	Color Infrared	Multi-Band	(Thermal) Infrared	Micro-wave	Multi-Spectral	Side Looking Airborne Radar	Laser Profiler	Laser Detector	Electro-Magnetic Sensor	Acoustic Sounder	Correlation Spectrometer	LANDSAT	Skylab
1. LAND FEATURES & USES																
Land Use Patterns																
Agriculture	●	●	●	●	●	o	o	●	✦	o	x	x	x	x	●	●
Range/Recreation	●	●	●	●	●	o	o	●	o	o	x	x	x	x	●	✦
Urban Development	●	●	●	●	●	o	o	●	✦	o	x	x	x	x	●	✦
Transportation Corridors	●	●	●	●	●	o	o	●	✦	o	x	x	x	x	✦	✦
Utility Facilities & Right of Way	o	●	●	●	●	o	o	●	o	o	x	o	x	x	o	✦
Topography/Physiography	●	●	●	●	●	o	o	●	●	●	x	x	x	x	●	●
Geology																
Subsurface	●	●	●	●	●	✦	o	●	✦	o	x	●	x	x	✦	✦
Seismic Hazards	●	●	●	●	●	✦	o	●	✦	o	x	✦	x	x	●	●
Other Geological Hazards	●	●	●	●	●	✦	o	●	✦	o	x	o	x	x	✦	✦
Soils																
Type	✦	✦	●	●	●	o	✦	✦	o	o	x	o	x	x	o	o
Depth	✦	✦	✦	✦	✦	o	o	o	o	o	x	o	x	x	o	o
Moisture Content	✦	●	✦	●	●	✦	✦	o	o	o	x	o	x	x	o	o
Slope Stability	✦	✦	✦	✦	✦	o	o	✦	✦	o	x	o	x	x	o	o
2. SPECIES & ECOSYSTEMS																
Dominant Species (Flora)	o	✦	✦	●	●	o	o	✦	o	o	x	o	x	x	o	o
Description of Floral Communities																
Type	●	●	●	●	✦	o	o	✦	✦	o	x	x	x	x	✦	✦
Height/Density	●	●	●	●	✦	o	o	✦	✦	o	x	x	x	x	✦	✦
Health	o	●	✦	●	●	o	o	●	o	o	x	x	x	x	✦	✦
Wetlands	✦	●	●	●	●	✦	o	●	o	o	x	x	x	x	●	●
Description of Unique Natural Areas	✦	✦	●	●	o	o	o	●	✦	o	x	o	x	x	✦	✦
Economic Value (Flora & Fauna)	✦	✦	✦	✦	✦	o	o	✦	o	o	x	x	x	x	o	o
Revegetation Potential	o	o	✦	✦	✦	o	o	✦	o	o	x	x	x	x	o	o
Wildlife Habitat	✦	✦	✦	✦	✦	o	o	✦	o	o	x	x	x	x	o	o

149

TABLE 5 (cont)

USEFULNESS OF REMOTE SENSING TECHNIQUES FOR APPLICATION TO EARTH RESOURCES SURVEYS

The meanings of the symbols are as follows:

● - very useful, ✦ - somewhat useful
o - little or no operational use, x - not applicable

CRITERIA \ TECHNIQUE	PHOTOGRAPHY					SCANNERS									SATELLITES	
	Black and White	Black and White Infrared	Color	Color Infrared	Multi-Band	(Thermal) Infrared	Microwave	Multi-Spectral	Side-Looking Airborne Radar	Laser Profiler	Laser Detector	Electro-Magnetic Sensor	Acoustic Sounder	Correlation Spectrometer	LANDSAT	SKYLAB
3. SOCIO-ECONOMIC																
Population Characteristics	✦	✦	✦	✦	✦	o	o	✦	o	x	x	x	x	x	o	o
Patterns of Social Interrelation	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Housing	✦	✦	✦	✦	✦	o	o	✦	o	o	x	x	x	x	o	o
Economic Base	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Planning	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Community Facilities	✦	✦	✦	✦	✦	o	o	✦	o	o	x	x	x	x	o	o
Community Infrastructure																
Sewage/Water/Power	o	o	o	o	o	o	o	o	o	o	x	x	x	x	o	o
Transportation Networks	●	✦	●	✦	●	o	o	●	✦	o	x	x	x	x	o	o
Municipal Finance	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Relocation/Displacement	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
4. AIR																
Micro-climate																
Temperature	o	o	o	o	o	o	o	o	o	o	o	o	✦	o	o	o
Temperature Extremes	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Inversions/Mixing Depth	o	o	o	o	o	o	o	o	o	o	●	o	●	o	o	o
Fog/Icing	✦	✦	✦	✦	✦	✦	o	✦	o	o	o	o	o	o	✦	✦
Storm Exposure	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Precipitation Patterns	✦	✦	✦	✦	✦	✦	✦	✦	o	o	o	o	o	o	✦	✦
Wind Patterns	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Surface Pressure	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Air Quality																
Gaseous Pollutants	o	o	o	o	o	o	o	o	o	o	o	o	o	●	o	o
Particulate Pollutants	o	o	o	o	o	o	o	o	o	o	●	o	o	o	o	o
Applicable Standards	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Major Point/Mobil Sources	●	●	●	●	●	✦	o	●	o	o	o	o	o	o	✦	✦
5. WATER																
Hydrology																
Flow Rates	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Evapotranspiration	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Surface Runoff	✦	✦	✦	✦	✦	o	o	✦	o	o	o	o	o	o	o	o
Flood Plains	o	●	✦	●	●	✦	o	●	o	o	x	o	x	x	●	●
Watersheds	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Surface Drainage	✦	●	●	●	●	●	o	●	✦	o	x	o	x	x	●	●
Water Bodies	●	●	●	●	●	●	o	●	✦	o	o	o	o	o	●	●
Groundwater	o	✦	✦	✦	✦	o	o	✦	o	o	x	o	x	x	✦	✦

Best Available Document

130

TABLE 5 (cont)

USEFULNESS OF REMOTE SENSING TECHNIQUES FOR APPLICATION TO EARTH RESOURCES SURVEYS

The meanings of the symbols are as follows:

● - very useful, ✦ - somewhat useful,
o - little or no operational use, x - not applicable

CRITERIA \ TECHNIQUE	PHOTOGRAPHY					SCANNERS									SATELLITES	
	Black and White	Black and White Infrared	Color	Color Infrared	Multi-Band	(Thermal) Infrared	Microwave	Multi-Spectral	Side-Looking Airborne Radar	Laser Profiler	Laser Detector	Electro-Magnetic Sensor	Acoustic Sounder	Correlation Spectrometer	LANDSAT	SKYLAB
Water Quality																
Water Surface Temperature	o	o	o	o	o	●	o	o	o	o	x	x	x	x	o	o
Biochemical Oxygen Demand	o	✦	✦	✦	✦	o	o	✦	o	o	x	x	x	x	o	o
Color	o	o	●	o	✦	o		✦	o	o	x	x	x	x	●	●
Turbidity	✦	✦	●	✦	●	✦		●	✦	✦	x	x	x	x	●	●
Hardness/Salinity	o	o	o	o	o	o	o	o	o	o	x	x	x	x	o	o
Acid/Alkali Balance	o	o	o	o	o	o	o	o	o	o	x	x	x	x	o	o
Nutrients	o	o	o	o	o	o	o	o	o	o	x	x	x	x	o	o
Organic Compounds	o	o	o	o	o	o	o	o	o	o	x	x	x	x	o	o
Dissolved Salts	o	o	o	o	o	o	o	o	o	o	x	x	x	x	o	o
Sulfates/Sulphides/Bicarbonates	o	o	o	o	o	o	o	o	o	o	x	x	x	x	o	o
6. NOISE																
Ambient Noise Level	o	o	o	o	o	o	o	o	o	x	x	x	x	x	o	o
Major Point/Mobil Sources	✦	o	✦	o	✦	o	o	✦	o	o	x	x	x	x	o	o
Sensitive Receptors	o	o	o	o	o	o	o	o	o	o	x	x	x	x	o	o
7. UNIQUE FEATURES																
Historic Sites	✦	✦	●	✦	●	o	o	●	o	o	x	x	x	x	o	o
Archeological Sites	✦	✦	●	●	●	o	o	●	o	o	x	x	x	x	o	o
Culturally Significant Sites	✦	✦	✦	✦	✦	o	o	✦	o	o	x	x	x	x	o	o
Scenic Features	✦	✦	●	✦	●	o	o	●	o	o	x	x	x	x	o	o

Best Available Document

151

BIBLIOGRAPHY

Anson, A., (Ed), 1973. Management and Utilization of Remote Sensing Data, Symposium on Remote Sensing, American Society of Photogrammetry, Falls Church, VA., 677 pp.

Branch, M. C. 1971. City Planning and Aerial Information, Harvard University Press, Cambridge, MA, 283. pp.

Estes, J. E. and Senger, L. W., (Eds). 1974. Remote Sensing Techniques for Environmental Analysis, John Wiley and Sons, Inc., Santa Barbara, CA. 340. pp.

National Academy of sciences 1970. Remote Sensing with Special Reference to Agriculture and Forestry, National Academy of Sciences, Washington, DC, 424 pp.

Reeves, R. G. (Ed) 1975. Manual of Remote Sensing, Vols. I& II, American Society of Photogrammetry, Falls Church, VA. 2000 pp (approx.).

Sabins, Floyd F. 1978. Remote Sensing: Principles and Interpretation, W. H. Freeman and Company, San Francisco, CA.

Skylab Explores the Earth, NASA SP-380. NASA Scientific and Technical Information Office, Washington, DC, 1977.

Smith, John T., Jr. 1968. Manual of Color Aerial Photography, American Society of Photogrammetry, Falls Church, VA, 550 pp.

Way, D. S. 1973. Terrain Analysis, A. Guide to Site Selection Using Aerial Photographic Interpretation, Dowden, Hutchinson and Ross, Inc. Stroudsburg, PA, 392 pp.

Williams, Richard S. and Carter, W. D. (eds). ERTS-1. A New window on Our Planet, U.S. Geological Survey Professional Pater 929. U.S. Government Printing Office, Washington, DC.

152

APPENDIX A

INTERNATIONAL LANDSAT STATIONS

The Landsat Ground Station Operations Working Group, an organization of representatives of existing and proposed Landsat ground receiving stations, met in Ottawa, Canada in November 1978. Discussions concerned recent developments involving several international Landsat centers.

The group meets every 6 months at member station locations. Active Landsat receiving stations are located in Brazil, Canada, Italy, Sweden, and the United States. Additional Landsat stations are proposed for Argentina, Australia, Japan, and India.

The receiving facility at Mar Chiquita, Argentina, is tentatively scheduled to be operational by April 1980. The contract for the facility was awarded in October 1978. It is expected that installation will take 12 months, and testing, an additional 4 months.

The Data Acquisition Facility at Alice Springs, Australia, is scheduled for operation by December 1979, and the Data Processing Facility is scheduled for operation by March 1980.

The Landsat receiving station at Ohashi, Japan, near Tokyo, was scheduled for completion by January 1, 1979, and for operation by February 1, 1979, with a "quick-look" capability to be operational by March 1979. The receiving center is part of a large complex known as the Earth Observation Center.

The Landsat receiving station in Hyderbad, India, is scheduled to be operational by the latter half of 1979.

Two active international stations, at Fucino, Italy, and Kiruna, Sweden, have been included in the operations of Earthnet, a new program created by the European Space Agency for acquisition, preprocessing, archiving and distribution of remote sensing data. Its purpose is "to promote a strong, well structured user community in Europe." Participating countries include Belgium, France, Germany, Ireland, Italy, Spain, Sweden, and the United Kingdom. Although the central distributing facility is at Frascati, Italy, near Rome, all participating countries have their own National Point of Contact.

Information about foregin Landsat holdings is now available from the EROS Data Center. Nearly 14,000 records from Brazil and 70,000 records from Italy have been or are being added to the EDC data base. Information from Canada will be available soon. Similar information is being entered in EDC's microfiche reference systems wherever applicable. The integrated data base will provide an indication of what Landsat data are available from the various receiving stations. Orders for data must be directed to the appropriate sites.

The following list of addresses, telephone numbers, and TWX numbers may be used to order data from active international Landsat stations. It should be noted that if you are within a member country of Earthnet, you should order European data from the National Point of Contact; however, if you are anywhere outside the area, you must order from the Earthnet central distributing facility at Frascati, Italy.

Brazil:	Instituto de Pesquisas Espaciais (INPE) KM 210, Radovia Presidente Dutra Departamento de Producao de Imagens Caixa Postal 01 12.630-Cachaeira Paulista-Sao Paulo Tel: (0125) 61.1377 TWX (011)21534
Canada:	Integrated Satellite Information Service, Ltd. P.O. Box 1630 Prince Albert, Saskatchewan S6V 5T2 Te. (306) 764-3602 TWX (074)29242
Italy: (Fucino)	Telespazio Corso d'Italia 43, 00198 Roma, Italy Tel. 06-8497 TWX61654 Telediro
Italy: (Frascati)	European Space Agency (ESA) ESRIN, VIA Galileo Galilei, C.P. 64.00044 Frascati, Italy Tel. 06-9424116 TWX 61637
Sweden:	Swedish Space Corporation Tritonvaegen 27, 171 54 Saina, Sweden Tel. 08-98 02 00 TWX 17128 Spaceco
Japan	Remote Sensing Technology Center of Japan (RESTEC) Uni-Roppongi Bldg. 7-15-17, Roppongi, Minatoku Tokyo 106 Japan Tel: Tokyo (403)1761

154

The 9th meeting of the Landsat Ground Station Operations Working Group was held in Tokyo, Japan, November 12-14, 1979. Discussions centered around current and planned Landsat 3 data acquisition and processing capabilities and on plans for upgrading facilities to receive and process Landsat D data. Briefings on data sales, statistics, and applications were also given. The current status of each of the ground stations is as follows:

Argentina: Installation of the receiving station at Mar Chiquita was completed in December 1979; the processing equipment was installed in Buenos Aires in January 1980. Several symposia and training courses have been held to stimulate interest in remote sensing techniques both in Argentina and in neighboring countries.

Austrialia: The receiving station in Alice Springs began initial reception in November 1979. The processing facility equipment will be installed in Canberra in March. A preliminary document listing products, cataloging, and data distribution procedures was made available in February.

Brazil: The number of users and the amount of data produced and sold by the Brazilian station in Cuiaba continue to increase. An additional user facility is being established in Brasilia.

Canada: The Canada Centre for Remote Sensing has recently helped to develop a low cost data analysis system and a CCT-to-film color imagery recorder system. It is hoped that the recorder system can be used to produce color products beginning in early 1980.

European Space Agency: The Kiruna and Fucino ground stations continue to receive data regularly. The processing facility at Kiruna, Sweden, is processing "quick-look" data as well as MSS images and CCT's. The processing facility in Fucino, Italy, returned to operation in November 1979 after installation and integration of a new imagery recorder and other hardware.

India: The receiving station in Hyderabad began taking test data from Landsat in August 1979. The station should be operational in Early 1980. A large number of applications projects are currently in progress in India including a natural resources survey, a water resources survey, and various soil studies.

Japan: The Japanese ground station in Ohashi became fully operational in July 1979. Radio frequency interference has limited the acquisition of some RBV data to a hexagonal-shaped coverage area, which is less than the potential full coverage zone of the antenna. It is hoped that the problem can be resolved soon.

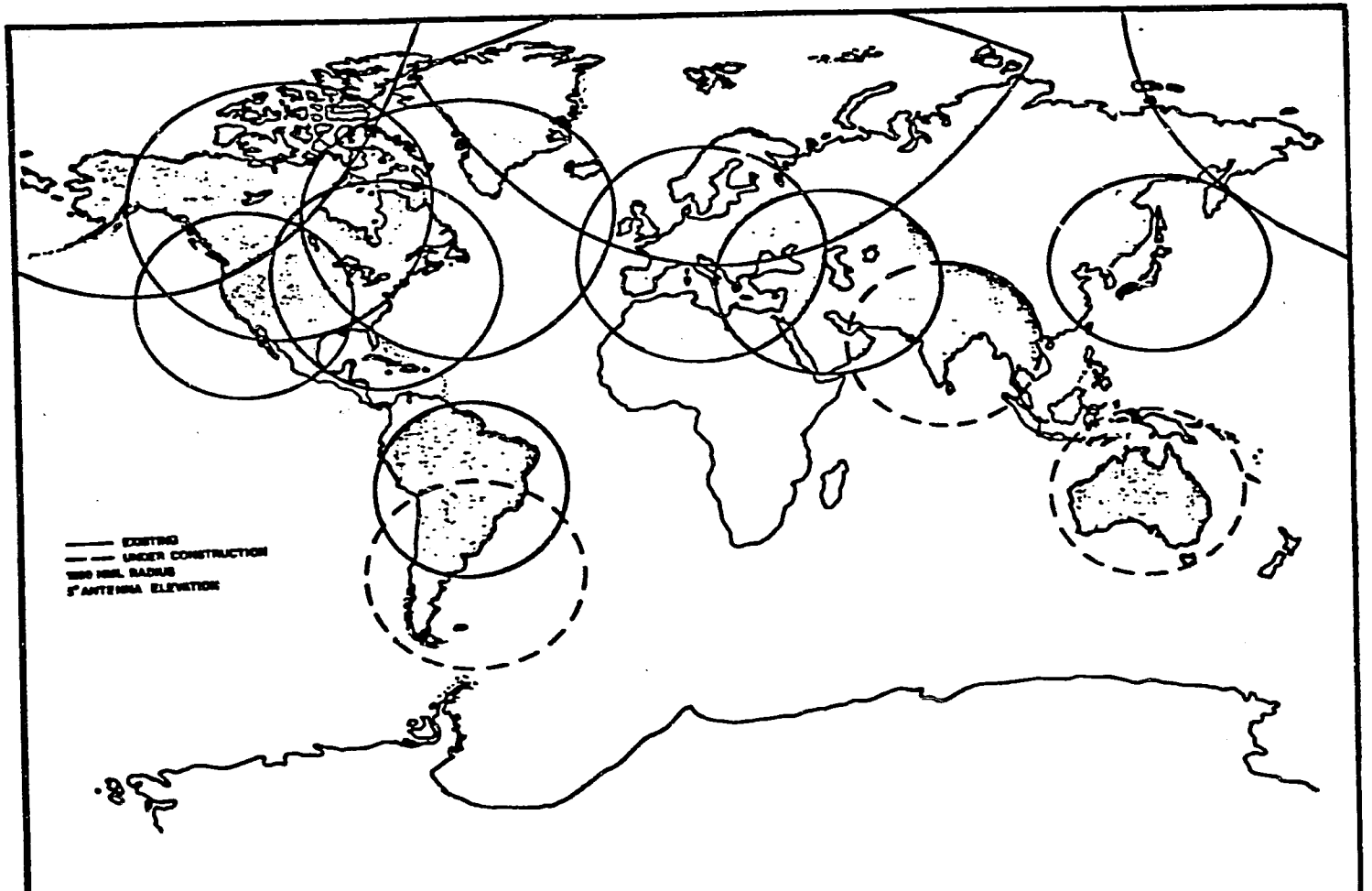
155

Thailand: The National Research Council of Thailand hopes to begin construction of the Thai receiving station in early 1980.

Additional information on Landsat Receiving Stations and Landsat data products may be obtained by contacting:

U.S. Geological Survey
EROS Data Center
Sioux Falls, South Dakota 57198
U.S.A.
Tel: (605) 594-6511

156



Approximate Receiving Ranges of Worldwide Landsat Ground Stations

157

ENVIRONMENTAL MONITORING

Air Monitoring

Anthony Sacco

Manager, Calibration Services
Systems Engineering Group
Environmental Research & Technology, Inc.

June 1980

International Environmental Management Institute
ENVIRONMENTAL RESEARCH & TECHNOLOGY, INC.
Concord, Massachusetts, USA

158

EXECUTIVE SUMMARY

Ever since man discovered the wonders of fire, air pollution has existed to affect the atmosphere. The major pollutants include:

- particulates;
- sulfur dioxide;
- oxides of nitrogen;
- carbon monoxide;
- oxidants; and
- reactive hydrocarbons.

Once the need for air monitoring has been established, it is important to develop a plan which will make the best use of available resources. The number and kind of monitors are important factors, but the proper location of the system is also critical. The worth of an operating air monitoring network depends upon the calibration of its individual components and quality control checks which are designed to assure that data taken will withstand challenge.

Reasons for monitoring will influence choice of samples and their location. Monitoring may be performed to:

- assess existing air quality;
- study pollutant interactions;
- determine the effects of air pollution on man and his environment;
- evaluate compliance with standards;
- develop abatement tactics;
- enforce control regulation;
- activate emergency procedures; and
- guide future planning.

Once the reason for monitoring has been established, the system can be chosen which will best accomplish the task. The system must fit the needs of the program, but it is also critical that it fit the financial and manpower resources of the area. It is better to make a few good measurements than make many measurements of questionable value.

The siting of the samplers and the design of the air delivery system must also be considered so that the data taken will reflect an accurate assessment of the ambient condition and will not be biased by local meteorology or the use of inappropriate materials.

The use of air quality models is a useful method to extend monitoring data and evaluate control strategies. It is important to recognize the different available approaches and to adopt the techniques most suited to the task.

The choice of monitoring methods should begin with consideration of three types of monitors:

- static samplers;
- manual devices; and
- automatic instruments.

Static samplers are relatively low in cost and require minimum servicing. Manual samplers are substantially higher in cost than static samplers, but are much less than automatic samplers. Operation of manual samplers usually requires daily technician visits and adequate laboratory support. Automatic samplers are most expensive and require highly trained technicians for operation and maintenance and good laboratory facilities.

The monitoring program design should be based on an appropriate mix of static, manual, and automatic samples with the understanding of the specific advantages and disadvantages of each type. A well organized support laboratory will be required.

The implementation of a network should take advantage of past programs where they exist.

AMBIENT AIR MEASUREMENT

1. OVERVIEW
2. TYPES OF AIR POLLUTION
   2.1 Particulates
   2.2 Sulfur Dioxide
   2.3 Nitrogen Oxides
   2.4 Carbon Monoxide
   2.5 Photochemical Oxidants (Ozone)
   2.6 Reactive Hydrocarbons
3. PRINCIPLES OF MONITORING
   3.1 Reasons for Monitoring
   3.2 Systems Concept
   3.3 Sampling
   3.4 Calibration (use of standards, quality control, and quality assurance)
   3.5 Data Interpretation and Modeling
   3.6 Ambient Monitoring Methods
   3.7 Case Histories
4. BIBLIOGRAPHY
APPENDIX: Instrument Manufacturers and Types

1. OVERVIEW

Ever since man discovered the wonders of fire, air pollution has existed to affect the atmosphere. The major pollutants include particulates, sulfur dioxide, oxides of nitrogen, carbon monoxide, oxidants, and reactive hydrocarbons.

Once the need for air monitoring has been established, it is important to develop a plan which will make the best use of available resources. The number and kind of monitors are important factors, but the proper location of the system is also critical. The worth of an operating air monitoring network depends upon the calibration of its individual components and quality control checks which are designed to assure that data taken will withstand challenge.

Reasons for monitoring will influence choice of samples and their location. Monitoring may be performed to: assess existing air quality, study pollutant interactions, determine the effects of air pollution on man and his environment, evaluate compliance with standards, develop abatement tactics, enforce control regulation, activate emergency procedures, guide future planning.

Once the reason for monitoring has been established, the system can be chosen which will best accomplish the task. The system must fit the needs of the program, but it is also critical that it fit the financial and manpower resources of the area. It is better to make a few good measurements than make many measurements of questionable value.

The siting of the samplers and the design of the air delivery system must also be considered so that the data taken will reflect an accurate assessment of the ambient condition and will not be biased by local meteorology or the use of inappropriate materials.

The use of air quality models is a useful method to extend monitoring data and evaluate control strategies. It is important to recognize the different available approaches and to adopt the techniques most suited to the task.

The choice of monitoring methods should begin with consideration to three types of monitors: static samplers, manual devices and automatic instruments. Static samplers are relatively low in cost and require minimum servicing. Manual samplers are substantially higher in cost than static samplers, but are much less than automatic samplers. Operation of manual samplers usually requires daily technician visits and adequate laboratory support. Automatic samplers are most expensive and require highly trained technicians for operation and maintenance and good laboratory facilities.

The monitoring program design should be based on an appropriate mix of static, manual and automatic samples with the understanding of

162

the specific advantages and disadvantages of each type. A well organized support laboratory will be required.

The implementation of a network should take advantage of past programs where they exist.

163

2. TYPES OF AIR POLLUTION

The thin layer of air which envelopes us is a most valuable and fragile resource. Man's activities have tended to add pollution to the air ever since his use of fire. Harmful effects of air pollution have been observed for centuries, but it has been just since the 20th century that we have verified scientifically the serious implications of air pollution.

Air pollution can be seen to have effects on both health and comfort. Economic effects result from reduced productivity, increased cleaning requirements and decreased lifetime of materials. These are all measurable ways that we can assess the impact of pollution, but it is difficult to quantify the damage caused to the natural beauty of certain areas due to air pollution.

The Earth's atmosphere is a mixture of gases, water and organic vapors, and particulate matter held in suspension. The typical gaseous composition of unpolluted air contains about 18 different gaseous constituents. Among the particulate matter there are salt particles, mold, yeasts, soil, rock, etc. All of these belong in the air. Most of what man puts there does not, and although there are scores of individual compounds which have an impact upon the quality of our air, we will only discuss here the measurement of the primary pollutants.

2.1 Particulates

Suspended particulate matter includes a wide variety of substances. The mix is related to the kinds of sources in any given area, but may be broken down into several general categories:

- extremely small particles which can be classed as having a diameter of less than 1 micron (millionth of a meter). These are generated from motor vehicles and fuel combustion stationary sources.
- large particles which have been suspended by the wind from roadway, construction, vehicle motion and erosion;
- both large and small particles resulting from industrial processes such as grinding and crushing;
- particles which are the result of reactions of gaseous constituents in the atmosphere. These are usually quite small in diameter.

2.2 Sulfur Dioxide (SO_2)

SO_2 is a non-flammable, colorless gas which can be tasted in concentrations as low as 300 parts per billion (ppb). The most common source of ambient SO_2 is through ordinary combustion of fossil fuels in power plants. Other important sources of SO_2 include refinery operations, smelting, coke processing, sulfuric acid manufacturing and home heating.

164

2.3 Nitrogen Oxides (NO_x)

Nitrogen oxides usually include the two most prevalent constituents, nitrogen dioxide (NO_2) and nitric oxide (NO). Emissions of NO_x from man-made sources are almost exclusively from fuel combustion in stationary and mobile sources.

On a world wide basis, man-made sources of NO_x produce about one-tenth of that produced naturally, arising mainly from biological bacterial processes. But the distribution of man-made NO_x is closely related to population distribution.

2.4 Carbon Monoxide (CO)

Carbon monoxide is the largest single pollutant found in urban atmospheres. It is a product of incomplete combustion of all types of carbonaceous fuels. The largest man-made source results from the combustion of gasoline by motor vehicles. The next largest sources in order of importance are: forest fires, industrial processes, disposal of solid wastes and stationary fuel combustion.

The largest natural source of carbon monoxide results from the oxidation of methane emitted by decaying organic matter.

2.5 Photochemical Oxidants

Photochemical oxidants are a class of atmospheric pollutants which arise from a series of atmospheric photochemical reaction between hydrocarbons and oxides of nitrogen in the presence of sunlight. The three recognized photochemical oxidants include ozone (O_3), PAN, and hydrogen peroxide. Various terms are used to describe these compounds including "oxidant" and "total oxidant". The emphasis in measurement instrumentation is usually ozone (O_3) which is considered to be the major photochemical oxidant.

Seasonal and diurnal variations in oxidant concentration result largely from (1) variations in emissions of oxidant-forming pollutants, (2) variations in the atmospheric transport and diluation, and (3) variations in other atmospheric variables involved in the photochemical formation of oxidants (i.e., sunlight, rain, fog, etc.).

2.6 Reactive Hydrocarbons

A characteristic of hydrocarbons that should be emphasized is the large amount of methane compared to other molecules, which is contained in this group of compounds. Methane is not an important pollutant because it is not very reactive, but it does make hydrocarbon monitoring more difficult because its concentration is usually five times greater than all other hydrocarbons combined in urban atmospheres and are even in higher proportions in non-urban atmospheres. In addition, methane is produced by different sources than that of other hydrocarbons and does not react to form irritating compounds. For these reasons, standards are usually set for non-methane hydrocarbons rather than total hydrocarbons.

165

Atmospheric hydrocarbons arise almost totally from one of four separate sources: biological, petroleum, coal and natural gas. At the present time, the most important single source of non-methane hydrocarbons is from all transportation sources which employ combustion of fuels.

3. PRINCIPLES OF MONITORING

One of the unfortunate outgrowths of increased industrialization is the generation of air pollution. Since most societies see industrial growth as a positive factor, it is wise to plan for the deleterious effects of industrial growth by including strategies for pollution monitoring and control along with industrial planning.

The plans for monitoring need to be implemented no matter how elaborate or modest the requirement. But a primary consideration must be a determination as to why monitoring is to be performed. The reason for making measurements defines what pollutants must be measured and by what techniques. It should be emphasized that often the configuration of the system can also be influenced by other factors such as cost and availability of local technology.

The amount and sophistication of equipment in any monitoring system are important factors, but the placement of samplers and the frequency of their operation (where no continuous methods are employed) is equally important. The assurance of proper operation of any monitoring system must be based upon the calibration of the individual components of the system. Appropriate checks must be included in any program so that systematic errors can be eliminated and so that there is procedural consistency in operation.

Compilation and processing of data into usable format must also be considered an important part of any plan to make environmental measurements.

It is usually helpful to build a monitoring system upon the basics which have been learned by others who have performed a similar task in the past. Although each situation is unique, there are usually similarities among systems which can be used to good advantage for planning.

3.1 Reasons for Monitoring

Air monitoring is a requisite for the control and prevention of air pollution. The data base derived from air monitoring is required for a number of reasons which may be interrelated.

- Assess existing air quality. If standards are to be established, it is important to have a clear picture of the seriousness of the ambient pollution concentrations.
- Study pollution interactions, patterns, and tasks.
- Determine the effects of air pollution on man and his environment. Although the data for the effects of pollution indicate a clear trend, it is important to document this with good measurements.
- Evaluate compliance with, or progress made toward, meeting existing air quality standards. The ultimate success of a program to control ambient air emissions can be dramatized by the results of an effective monitoring program. Conversely, an abatement plan which is not working is graphically demonstrated by measurements.

167

- Develop abatement tactics and control regulations. Monitoring on a local level is a sure way to evaluate the need for controls, and it can often identify the source(s) to be controlled.
- Enforce control regulations.
- Activate emergency procedures to prevent pollution episodes.
- Guide future land use, energy systems, and transportation planning.

The development of a strategy for monitoring the nation's air is the responsibility of the central government authority. Development of an air quality data base requires decisions regarding the pollutants to be measured and the monitoring facilities, the number and types of monitoring site required, their location, choice of instrumentation, frequency and methods of sampling and calibration.

3.2 System Concept

When designing a system for a specific monitoring problem, several factors must be considered. At the core of such a system is an instrument or technique for analysis of the pollutant(s) of concern.

The use of automatic air monitoring instrumentation is increasing and in many areas, it is replacing analytical techniques. The shift toward automated methods results from:

- the need to record data continuously,
- the availability of data processing equipment to provide more rapid analysis of samples,
- the accuracy provided by well-calibrated equipment,
- the ease of determining results from well-designed instrumentation, and
- the potential for lower manpower requirements.

It would be simplistic to assume that automated techniques are always to be sought over manual or in some cases static techniques. The requirements of each program must be the controlling factor in determining whether automated, manual, static or a combination of any or all three types should be considered.

The primary requirement for the choice of any air monitoring system is that it meet the needs of the program. A very important part of this is that the system should be implementable within the technology which is available locally and that it be within the financial and manpower resources of the area. A system which is overly complex or large can prove to be worse than a modest system which is planned around available resources. When a system is planned, the presence of monitors already in use by local industry or others should not be overlooked as a potential way to control the costs of the program. For instance, most airports maintain certain meteorological monitors (wind speed, wind direction, barometric pressure, surface temperature) which could be used to help control costs.

168

3.3 Sampling

The approach to placement of ambient sampling instruments is based upon obtaining a representative sample of the air. This does not necessarily mean that the more samplers placed in any location the better will be the data. Care must be taken so that a sampler is not biased by some local conditions such as downwash from a dominant source if the intent is to establish the overall ambient condition. Site selection is always a time consuming and often frustrating exercise because it involves a good deal of compromise between the technically best sites and the best available sites. A knowledgeable meteorologist is a necessity for choosing the best site locations.

Choosing sites in the urban and non-urban situations usually offer a different set of challenges. In the urban situation, property for monitoring sites is sometimes difficult to acquire, and vandalism is a great concern. Even where an existing building can be employed, it may prove to present an exposure problem for the sampling probe. Some of the major problems in non-urban siting include the inaccessibility of locations due to terrain and the unavailability of power. Servicing remote sites can also be a special problem due to weather related problems (snow storms, dust storms, etc.). Usually the available technically proficient labor force is much smaller as the distance from metropolitan centers increases.

The design of the sample probe for either manual or continuous samplers will influence the quality of measurement. Most of the pollutants under consideration (SO_2, NO_x, O_3) are highly reactive. In order to obtain a representative sample for analysis, care must be taken so that the constituents of the air do not have the opportunity to react with the probe material. In most cases, the use of inert materials such as glass or teflon (fluorocarbon plastic) are required. It is also important to ensure that proper maintenance procedures are established so that probes are kept clean and free of extraneous matter (bugs, birds, etc.).

- Particulate measurements will inevitably reflect an important contribution from nearby sources, in particular, for large particulate monitors and total particulate mass monitors.
- SO_2 measurements can reasonably reflect urban-scale SO_2 variability as long as the monitoring sites are chosen to avoid impact from large single sources of SO_2.
- CO measurements will be strongly influenced by nearby roadway emissions. This influence can be managed in part by standardized placement of CO monitors in relationship to major roads. (However, it is not possible to avoid monitoring in the vicinity of large roads because information about near-road maximum concentrations is usually sought in the monitoring program.)

169

- NO/NO_2 observations will reflect emissions from both mobile and stationary sources. Further, the relative abundance of these species will depend on their reactivity with O_3, hydrocarbons, and other substances in the local atmosphere. Therefore, NO/NO_2 monitors should generally be located away from heavily travelled roads, and the monitoring sites should include adequate sampling of the entire urban-scale variability.
- O_3 monitors should be placed so as to characterize both the in-city human exposure and the maximum concentrations usually found at distances up to 20 kilometers or more downwind of major urban areas.
- If modeling for urban O_3 patterns is to undertaken, nonmethane hydrocarbon measurements might also be necessary at a few locations.

General considerations for probe siting and other spacing criteria are shown in Table 1.

3.4 Calibration

The ultimate quality of the data reported from any monitoring system is dependent upon the ability to assure that the samplers are measuring the pollutants of interest within the accuracy and precision of the technique(s). Calibration is the only way which can assure this. In general terms, calibration requires the infusion of known quantities of test atmospheres to the sampling system and recording the resultant response of the sampler. In this manner adjustments can be made to the instrument or the data.

Calibration techniques and equipment can vary from simple devices which include cylinders of pressurized gases to extremely sophisticated systems which are capable of remote activation and infusion of multiple concentrations of calibration gases automatically. The use of calibration sources, which are traceable to recognized standards (in the U.S. this is the National Bureau of Standards) where they are available, or to standard practices and techniques, is a necessary part of the calibration process.

It is important that calibration be performed by highly qualified technicians and that independent checks be performed to assure that techniques and procedures are properly applied. This relates to the routine operation of the system as well as the calibration of it and requires the generation of documentation which can be used to prove the quality of the data. The application of quality control checks on the system and routine audits of it is also an important part of a properly operated network.

The importance of quality of data over quantity of data should be stressed. A few good measurements which can be traced to properly calibrated sensors is much better than many measurements taken with questionable traceability.

170

TABLE 1

SUMMARY OF DESIRABLE PROBE SITING CRITERIA FOR A FIXED AIR QUALITY MONITORING STATION

Pollutant	Height Above Ground (meters)	Distance from Supporting Structure (meters) Vertical	Horizontal	Other Spacing Criteria
Particulates	2 - 15	-	2	a. 20 meters from trees. b. Distance from sampler to obstacle, such as buildings, should be at least twice the height the obstacle protrudes above the sampler. c. Unrestricted airflow in 3 or 4 cardinal wind directions. d. No furnace or incineration flues should be nearby to avoid undue influences from minor sources. e. Spacing from roads varies with height of monitor (see text).
SO_2	3 - 15	1	1	a. Probe on roof or intermediate height on a building should be 0.8 of the mean height of the building in the neighborhood. b. 20 meters from groups of trees. c. Distance from sampler to obstacle, such as buildings, should be at least twice the height the obstacle protrudes above the sampler. d. Unrestricted airflow in 3 of 4 cardinal wind directions. e. No furnace or incineration flues should be nearby.
CO	3 ± 1/2	1	1	a. 35 meters from roadway for air mass quality, or lesser realistic distance for exposed populations. b. Unrestricted air flow in 3 of 4 cardinal wind directions.
O_3	3 - 15	1	1	a. 20 meters from trees. b. Distance from sampler to obstacle, such as buildings, should be at least twice the height the obstacle protrudes above the sampler. c. Unrestricted airflow in 3 of 4 cardinal wind directions. d. Spacing from roads varies with roadway traffic in order to minimize scavenging by NO emitted by motor vehicles.
NO_2, NO, NO_x	3 - 15	1	1	a. 20 meters from trees. b. Distance from sampler to obstacle, such as buildings, should be at least twice the height the obstacle protrudes above the sampler. c. Unrestricted airflow in 3 of 4 cardinal wind directions. d. Space from roads varies with roadway traffic and population location to avoid undue bias from this source.

171

3.5 Data Interpretation and Modeling

In many nations, the use of air quality models to extend monitoring data and evaluate control strategies has grown substantially during the past ten years. Many technical papers and surveys on modeling approaches appear each year, providing a wide range of experience for estimating short- and long-term average concentration profiles in urban areas. Appropriate elements of such modeling capabilities should be adopted to facilitate the extension and interpolation of the measurements data obtained.

The models most useful for human exposure assessment are not generally those best suited for air pollution control strategy evaluation. Therefore, it is important to recognize the different available approaches and adopt the techniques most suited to the task.

The following are the principal types of models.

1) Gaussian Plume Models - These models are the most widely used, and they can take many forms; all are developed from the basic assumption that the effluent discharged from a source moves downwind and mixes in the atmosphere so that the edge-on view of the resulting concentration profile is a double bell-shaped curve, with the maximum concentration occurring along the plume centerline. Gaussian methods are based on empirical measurements of plume spread in the atmosphere, and they can be used to evaluate the pollution impact of single sources, line sources (e.g., roadways), and multiple sources in a region (e.g., entire urban areas). These techniques can be used to calculate expected concentration profiles as long as they are supplied with data on the emission rate and geometry, wind conditions, atmospheric stability, and terrain conditions. The calculations are frequently inaccurate in their estimates of absolute concentration levels, but they are normally reasonable in their evaluation of patterns of concentration variability. Gaussian models can involve very large computational schemes, including simple chemical reaction rates and deposition processes, or they can be extremely simple. For health effects assessments, the simplest forms of model equations are often preferable.
2) Analog Models - These models are estimating techniques for average or maximum concentration levels that are based on comparison with known conditions in other urban areas where more adequate concentration measurements may be available. As the number of cities having adequate air pollution monitoring and emission data increases, the possibility of finding an analog city (with similar emissions, climatology, and terrain conditions) also increases.
3) Statistical Models - These models relate measured concentratons to associated measured quantities, such as wind speed, vehicle use, or industrial output. Extensive statistical model analyses have been conducted for some

177

cities (e.g., Rotterdam, Tokyo, and Chicago) and adequate data for similar analyses are now available for many major urban areas. These methods can be particularly useful for filling in missing data in measurement records and for evaluating the quality of historical data sets that lack adequate documentation of sampling methods.

4) Numerical Models - These methods are analogous to the Gaussian techniques and are developed from quantitative solutions to the equations of motion for a passive tracer (i.e., the pollutant) or for chemically reactive pollutants. They are most suitable for O_3 or other pollutants that are products of a complicated series of reactions. These models have a wide applicability to rough terrain conditions, and to unusual meteorological conditions such as shoreline fumigation. However, they are not normally useful for exposure assessment because they have not been adopted for evaluation of long-term average conditions.

Simplified forms of the Gaussian equation are recommended as the most useful tools for health effects assessments in most cases. Statistical methods are not as well suited to general assessment, but can have important application to evaluation and extension of historical monitoring records.

Analog models and other calculations schemes should be studied carefully. In many urban areas having little or no air quality measurement data, these models may yield substantial benefits in improved assessments with very small costs.

3.6 Ambient Monitoring Methods

Direct monitoring of air quality at a number of well chosen sites is the primary step in assessing air pollution. Various modeling and estimating techniques can extend the measurement data, but none of the modeling methods demonstrate sufficient accuracy to be used independently as the principal means of assessment. Generally, the complementary use of ambient monitoring and modeling is best suited to the preparation of a human exposure assessment: monitoring provides the best measure of the absolute levels of concentration, but is limited to a fixed number of measurement sites; modeling is imprecise in determining absolute levels of concentration, but is well suited to interpolation and extrapolation of the monitoring data.

The choice of monitoring methods should begin with consideration of three general types of monitors: static samplers, manual devices, and automatic instruments. Each class of monitor has specific advantages and disadvantages for urban exposure assessment.

1) Static Samplers - (e.g., sulfation plates and stressed rubber strips for O_3 monitoring) have the advantage of minimum cost and servicing requirements; these advantages permit deployment of a relatively large number of such

173

samplers to aid in interpretation of variability patterns in the study area. Passive devices rely on ambient air flow to support surface reactions, and variability in exposure rates (resulting from microscale differences in the exposure sites as well as seasonal differences in wind, temperature and humidity) can produce significant variability in indicated pollutant concentrations.

2) Manual Volumetric Samplers - have usually been chosen for beginning urban sampling programs. Their initial cost is substantially higher than the cost of static samplers, but much less than that of automatic instruments. Within the constraints imposed by the need to maintain practical, controllable air flow and reaction rates, most manual samplers can be used to measure concentrations averaged over times varying from one hour to one day. Manual sampler operation is also a valuable training exercise for relatively inexperienced local program staffs, but the accuracy of the sampling data can be significantly limited in quality control practices are not aggressively followed. Operation of a manual sampler network usually requires daily technical staff visits to each site and adequate analytical laboratory support.

3) Automatic Samplers - have the disadvantage of the high initial costs, and they require more highly trained technician, maintenance, and laboratory staff for their support. These samples have, however, two principal advantages: they provide continuous indications of short-term concentrations (i.e., a few minutes), permitting analysis of maximum exposures, and they provide the most reliable and respectable monitoring records when they are well maintained. Automatic instruments always require support from a capable maintenance, repair and calibration laboratory facility.

The monitoring program design should be based on an appropriate mix of static, manual and automatic samplers, with an understanding of the specific advantages and disadvantages of each type. A well organized support laboratory will be required and suitable intercomparisons of monitoring methods and results should be undertaken in each case.

The time resolution needed for the air quality measurements is determined by the need to relate the data to health impact considerations. Short-term and long-term exposure periods that are consistent with air quality standards adopted in many countries are identified in Table 2 together with a number of options for measurement techniques. In industrially developed nations, continuous sampling and recording instruments are frequently preferred; however, several types of static and manual devices often provide adequate information for health assessment purposes. When static or manual devices are adopted, at least one complete continuous monitoring site should be operated in the study regions. This site will provide a

174

TABLE 2

AIR QUALITY MEASUREMENT TECHNOLOGY AVAILABLE

Pollutant	Health Effects Periods: Short Term	Health Effects Periods: Long Term	Associated Available Measurement Technology: Short Term	Associated Available Measurement Technology: Long Term
Particulates	24-hour, shorter for very irritating components	multiday, seasonal, and annual	filtration--laboratory chemistry continual tape--light absorption/ reflection/ -ray attenuation--laboratory chemistry nephelometry rotating rod collector--laboratory chemistry	same fallout jars--laboratory chemistry
SO_2	1-hour to 24-hour	multiday, seasonal, and annual	continuous monitors, various principles bubblers--laboratory chemistry impregnated tube or filter sampling--laboratory chemistry	bubbler--laboratory chemistry impregnated filter sampling impregnated plate/diffusion tube exposure--laboratory chemistry
CO	1-hour to 24-hour	none	continuous monitors, various principles bubblers--laboratory chemistry impregnated tube or filter sampling--laboratory chemistry impregnated plate/diffusion tube exposure--laboratory chemistry	none needed
NO_x	1-hour to 24-hour	multiday, seasonal, and annual	continuous monitoring, various principles bubblers--laboratory impregnated filter sampling--laboratory chemistry	impregnated filter sampling--laboratory chemistry impregnated plate/diffusion tube exposure--laboratory chemistry
O_3	1-hour to 3-hour	none	continuous monitoring, various BAKI* continual bubblers--laboratory chemistry rubber strip exposure	none available except vegetation damage

*Boric acid potassium iodide.

175

central reference point within the city, as well as a cross reference to other cities.

For short-term continuous monitoring of the gaseous pollutants, a number of instrument options are available. The detection principles in common use, and the typical ranges and similarities associated with these principles, are summarized in Table 3. In general, an array of instruments for a network should be selected from the same manufacturer for efficiency in subsequent maintenance, repair and supply of parts, while a supply of spare instruments should be maintained by a central support organization. Continuous instruments need to be recalled from the field once every 6 to 12 months for complete overhaul at a central specialized facility.

For moderate-period (1-hour to 24-hour) average monitoring, several cumulative volumetric sampling techniques, summarized in Table 4 are available. All of these techniques involve collecting substances from measured volumes of air and transporting these samples to an analytical laboratory where the concentrations of each substance can be determined. One major advantage in the application of the cumulative sampling techniques over continuous monitoring techniques is the ease with which they can be used to implement intermittent intensive sampling studies. For assessing population exposure, it is not always necessary to sample every day for an entire year or longer. The gravimetric high volume sampling method is the technique most extensively used for particle measurements. It suffers from a number of limitations, including a dependence of collection efficiency on wind direction.

Static sampling methods are available for all the gaseous pollutants; these methods are summarized in Table 5. The dependence of the static measurements on ambient air flow over a reactive surface introduces a substantial measurement bias risk. However, the static samplers can produce useful indicators of geographic concentration patterns with a minimum of skilled staff and with short mobilization time. The usefulness of static sampler data will be enhanced when adequate volumetric sampling is also available.

3.7 Case Histories

The first multi-network ambient air monitoring system established by ERT was for the American Electric Power Company. These networks were installed in the early 1970s in the mid-western portion of the United States. The parameters being measured include continuous SO_2, NO_2/NO_x, various meteorological parameters and manual suspended particulates. Several lessons were learned early in the operation of this network which is still in operation.

- The value of support facilities close to the network for quick response to maintenance/ repair/calibration.
- The importance of properly trained individuals for all technical tasks.

176

TABLE 3

AVAILABLE AIR QUALITY MONITORING TECHNIQUES FOR SHORT-TERM RESOLUTION

Pollutants	Principles of Detection	Typical Range(s) (ppm)	Limits of Quantitation (ppm)	Response Time to 90% or Greater (seconds)
SO_2	Flame photometric	0 - 0.05 0 - 0.5 0 - 0.1	0.005 0.01 0.02	60
	Pulsed Fluorescence	0 - 0.1 0 - 1.0	0.005 0.01	
	Potentiometric	0 - 0.5	0.005	
CO	Nondispersive infrared with flowing ref. cell	0 - 50	1.00	2.5
NO, NO_2, NO_x	Chemiluminescent with O_3	0 - 0.5 0 - 0.1 0 - 2.0 0 - 5.0	0.005 0.01 0.02 0.02	100
O_3	Chemiluminescence of Rhodamine b	0 - 0.5	0.01	
	Chemiluminescent with ethylene	0 - 0.5	0.005	15

TABLE 4

AVAILABLE MEASUREMENT TECHNOLOGY
(Cumulative Volumetric Sampling)

Pollutant	Method	Applicability and Comments
Particles	Gravimetric high volume	This method has been widely applied using glass fiber filters. The rectangular shape of the filter housing makes large particle collection efficiency highly dependent on wind speed and direction. Collection on glass fiber creates a positive bias from adsorption of SO_2, NO_x, HNO_3, and NH_3.
	Gravimetric lower volume with size classification (dichotomous sampling)	This method is being tested for routine application using Teflon (FALP) filters. The sampler housing is cylindrical, particles greater than about 15 μm AMMD do not penetrate the aerosol inlet, and sampling efficiency is relatively independent of wind velocity. A second size separation can be achieved at about 3 μm by virtual impaction, i.e., it separates the two particle size modes shown in Figure 1.
	Gravimetric lower volume with size classification (cyclone sampling)	Various higher and lower volume versions are being used for outdoor and personal sampling. Two sampling units are involved, one in which the aerosol enters the inlet and flows to a filter and one in which the aerosol is processed with a cyclone before flow to a filter. Any filter medium may be used; Teflon (FALP) is preferred. For personal sampling, a number of combinations of commercially available devices can be assembled (Lippmann 1978). The Harvard personal sampling appears to be the best available completely engineered device.
SO_2	Pararosaniline	This method has been widely applied for 24-hour bubbler sampling, but during and after collection, the sample should be kept isothermal--below 22°C.
	Acidimetric	Suitable for application similar to the pararosaniline method, more simple to handle, but not as specific for SO_2. Other acids, salts, and ammonia are major interferents.
	K_2CO_3 impregnated filter	Suitable for application similar to the pararosaniline method. The impregnated filter could be placed in series with a particulate filter. Careful design is required to achieve low blanks to avoid exposure during shipment and storage, and to stay within the adsorption capacity of the filter. It is free from interferences and relatively simple to implement.
CO	Colored silver sol	This method involves contacting air samples in a cylinder or bag with silver p-sulfamoylbenzoate to form a colored silver sol. Interferences may be removed by processing the inlet air sample with mercuric sulfate impregnated on silica gel. This method has not been applied widely and requires further evaluation. A colorimetric method would be a good alternative where the NDIR method is not feasible.
NO_x	Arsenite	This method has been widely applied for 24-hour bubbler sampling in the USA for NO_2. It suffers from a positive NO and a negative CO_2 bias. The NO interference could be eliminated by adding a chromium trioxide on Firebrick tube to the inlet to convert incoming NO to NO_2 and thereby determining NO_x. The CO_2 bias may be important variability within the urban area and/or between indoors and outdoors when CO_2 is large.
	TG-S-ANSA*	This method was developed for 24-hour bubbler sampling for NO_2. It could be used for NO_x if an oxidizer is used as described above. No bias is created by changes in CO_2. For NO_2, NO does not seem to interfere.

*Triethanolamine - O-methoxyphenol - sodium metabisulfite - 8-anilino-1-napthalene-sulfonic acid.

Best Available Document

18

TABLE 5

AVAILABLE MEASUREMENT TECHNOLOGY FOR OBTAINING DATA FOR MULTI-DAY STATIC SAMPLING

Pollutant	Method	Measurement	Applicability
Particles	Fall-out	$mg/m^2/day$	Requires 1 to 30 days of sampling. Indicates population levels from large particles. Provides some correlation with 24-hour filter sampling and population exposure in places where particulate emission controls are poor. Difficult to relate to health effects.
SO_2	Diffusion plate or tube with reactive surface such as K_2CO_3	$mg/m^2/day$	Requires 1 to 30 days of exposure followed by laboratory analysis for sulfates. May respond to other compounds of sulfur. Very cost effective method. Correlative to volumetric methods.
CO	Diffusion plate or tube with a palladosulfite reactive surface	optical density	Requires 1 to 24 hours of exposure followed by light transmission or reflectance measurement at a laboratory. The method is correlative to volumetric measurements for CO.
O_3	Diffusion surface, neoprene rubber strip	crack length	Requires 1 to 24 hours of exposure followed by observation under a large magnifier. Correlative with volumetric measurements for O_3. The only available noncontinuous method for O_3 that does not require on-site servicing.
NO_x	Diffusion plate or tube with reactive surface such as K_2CO_3	$mg/m^2/day$	Same as for SO_2. Laboratory analysis is for nitrates. Amount of NO adsorbed may depend on NO_2 to NO ratio and is not known. HNO_3 will also be adsorbed. Output will therefore be some function of total NO_x and HNO_3 which may be correlative to volumetric methods.
NO_2	Diffusion plate or tube with arsenite reactive surface		Same as for SO_2. Laboratory analysis is for nitrate. Some NO may also be observed. Output should be a predictable function of specific volumetric measurement for NO_2.
HNO_3	Diffusion plate or tube with reactive surface such as nylon or NaCl		Same as for SO_2. Laboratory analysis is for nitrate. NO_2 are not a serious interference and output should be a function of volumetric measurements for HNO_3.

- The need for spare sensors and parts to assure consistently high up-time.
- Quality assurance performance audits to establish conformity to operating procedures.
- A workable communications system so that problems can be identified quickly.

The more recently implemented system installed for the Electric Power Research Institute (EPRI) was performed with a lesser degree of strain because of the lessons learned from the earlier systems. The EPRI system included more parameters and included both automatic and manual techniques. The system employed some of the equipment previously used by the Environmental Protection Agency (EPA) sponsored Regional Air Monitoring System (RAMS) program.

The EPRI program has performed well through the lessons of close support learned from the AEP program and with equipment modified from the RAMS program.

180

4. BIBLIOGRAPHY

1. "Air Sampling Instruments", 4th Edition, American Conference of Governmental Industrial Hygienist, Cincinnati, OH. 1972.

   This volume describes many of the instruments employed to measure ambient pollutants. Although the source is not comprehensive, it gives a good selection of both manual and automatic instruments. It includes good descriptions and some cost data.

2. "Instrumentation for Environmental Monitoring", Vol. 1, 2, 2a, and 3, 2nd Edition, Lawrence Berkeley Laboratory, University of California, Berkeley, CA, 1973.

   This is a multi-volume compendium of most available monitoring instruments. It includes source, vehicle and ambient measuring instruments and includes manual as well as automatic analyzers.

3. "Air Pollution", Stern, A. C., Volume I, II, III, Academic Press, New York, NY, 1968.

   These volumes have been written by many of the recognized experts in various disciplines which comprise the air pollution technical community. The volumes include discussions on the transformation and transport of pollutants, the effects of air pollution, and the measurement, monitoring and surveillance of air pollution.

4. "Compilation of Air Pollutant Emission Factors", 2nd Edition, U.S. EPA, Research Triangle Park, NC, 1973.

   This volume is a useful tool for determination of order of magnitude emission output loadings of various standard types of point sources.

5. "Quantitative Analysis of Gaseous Pollutants", Ruch, W. E., Ann-Arbor Humphrey Science, Ann Arbor, MI, 1970.

   This is a conveniently arranged collection of the various manual chemical techniques for measurement and analysis of the important gaseous air pollutants.

181

APPENDIX

Instrument Manufacturers and Types

Manufacturer	Instrument Type
Beckman Instruments, Inc. Process Instruments Division 2500 Harbor Boulevard Fullerton, California 92634 PH: (714) 871-4848	SO_2, NO/NO_x, HC, Respirable Particles, CO
Bendix Corporation 1400 Taylor Avenue Baltimore, Maryland 21204 PH: (516) 427-2994	SO_2, NO/NO_x, O_3, HC, Calibrators
Byron Instruments, Inc. 520-1/2 South Harrington Street Raleigh, North Carolina 27601 PH: (919) 832-7501	HC
Cambridge Scientific Research Appliance Company P.O. Box 265 Moose Lodge Road Cambridge, Maryland 21613 PH: (301) 228-9505	Manual and Static Samplers
Climatronics Corporation 1324 Motor Parkway Hauppauge, New York 11787 PH: (516) 567-7300	Meteorological Sensors
Climet Instrument Company P.O. Box 1165 1620 West Colton Avenue Redlands, California 92373 PH: (714) 793-2788	Meteorological Sensors
Columbia Scientific Industries Corp. P.O. Box 9908 11950 Jollyville Road Austin, Texas 78766 PH: (512) 258-5191	O_3, NO/NO_x, Calibrators
Dasibi Environmental Corporation 616 East Colorado Street Glendale, California 91205 PH: (213) 247-7601	O_3, Calibrators
Esterline Angus Instrument Corporation P.O. Box 24000 Indianapolis, Indiana 46224 PH: (317) 244-7611	Strip Chart Recorders

183

Manufacturer	Instrument Type
General Metal Works, Inc. 8368 Bridgetown Road Cleves, Ohio 45002 PH: (513) 941-2229	High Volume Samplers and other Particulate Samplers
HNU Systems, Inc. 30 Ossipee Road Newton, Massachusetts 02164 PH: (617) 964-6690	HC
Lear Siegler, Inc. 74 Inverness Drive East Englewood, Colorado 80112 PH: (303) 770-3300	SO_2, NO_2
Meloy Laboratories, Inc. 6715 Electronic Drive Springfield, Virginia 22151 PH: (704) 354-2600	SO_2, NO/NO_x, O_3, HC, Calibrators
Metronics Associates, Inc. 2991 Corvin Drive Santa Clara, California 95051 PH: (408) 737-0550	Calibrators/Permeation Tubes
Meteorology Research, Inc. P.O. Box 637 464 West Woodbury Road Altadena, California 91101 PH: (213) 791-1901	Meteorological Sensors
Monitor Labs, Inc. 10180 Scripps Ranch Boulevard San Diego, California 92131 PH: (714) 578-5060	SO_2, NO/NO_x, O_3, CO, Calibrators
Rosemount, Inc. 12001 West 78th Street Eden Prarie, Minnesota 55344 PH: (612) 941-5560	Meteorological Sensors
Sierra Instruments, Inc. P.O. Box 909 Carmel Valley, California 93924 PH: (408) 659-3177	Particulate Measurement

Manufacturer	Instrument Type
Teledyne Geotech 3401 Shiloh Road Garland, Texas 75041 PH: (214) 271-2561	Meteorological Sensors
Thermo Electron Corporation 108 South Street Hopkinton, Massachusetts 01748 PH: (617) 435-5321	SO_2, NO/NO_x, CO, Calibrators
R. M. Young Company 2801 Aero-Park Drive Traverse City, Michigan 49684 PH: (616) 946-3980	Meteorological Sensors

185

ENVIRONMENTAL MONITORING

Water Monitoring

Francis Clay McMichael

Senior Technical Advisor
Environmental Engineering Group
Environmental Research & Technology, Inc.

June 1980

International Environmental Management Institute
ENVIRONMENTAL RESEARCH & TECHNOLOGY, INC.
Concord, Massachusetts USA

186

I. Man, Water, and Wastewater

A. The Hydrologic Cycle

1. Water is a plentiful resource - but not all of it is freshwater.
2. Transport properties of the hydrologic cycle

   a. Dissolved materials (conservative and non-conservative chemicals)
   b. Suspended materials

3. Principal water bodies

   a. Coastal waters (saline)
   b. Estuaries
   c. Rivers
   d. Lakes
   e. Groundwater (shallow and deep aquifers)

4. Engineering concepts - material balances

   a. Volumetric flows
   b. Mass flow of chemical tracers
   c. Residence times
   d. Rates of chemical and biochemical reaction

B. Beneficial Uses of Water - Planning

1. Per capita requirements
2. Quality of water needed for use, re-use, recycle
3. Concepts - a hierarchy of water quality

   a. Maintain quality of freshwaters (surface and groundwater)
   b. Maintain quality of estuarine salt waters
   c. Oceans may be used as ultimate sinks

4. Specific beneficial uses of surface freshwaters

   a. Public water supply
   b. Industrial water supply (process and cooling water use)
   c. Agricultural water supply and livestock watering
   d. Fish and wildlife propagation and habitat

187

e. Recreation - swimming, boating, esthetics
f. Navigation and water power and flood control
g. Municipal and industrial wastewater transport and waste assimilation

II. Typical Water Supply and Wastewater Planning Scenarios

A. Conventional - Inland City Water Use

1. Supply - freshwater
2. Disposal - treatment with discharge to same freshwater supply
3. Sludge - to landfill

B. Conventional - Coastal City Water Use

1. Supply - freshwater
2. Disposal - treatment with discharge to ocean via long outfall
3. Sludge - to ocean

C. Conventional - Irrigation Water

1. Supply - freshwater
2. Disposal

   a. Evaporation of water leaves salts in soil. Irrigation has limited lifetime unless drainage for salts is provided.

D. Irrigation Water - Return Drainage Provided

1. Supply - freshwater
2. Disposal

   a. Drainage - demineralization of drainage to rid soil of salt buildup, or continual flushing of high salt content waters to drain
   b. Brine - pipeline to ocean or deep saline aquifer.

E. Wastewater Reclamation

1. Segregation and separation of wastewaters by quality
2. Treatment for next use
3. Concentrated waste streams discharged to deep ocean via long outfalls

188

III. Water Quality Criteria or Standards

A. Receiving Water Quality Standards

1. Categories

a. Dilution requirements
b. Beneficial use of receiving water standards - zones of use classifications
c. Threshold effects

2. Indirect indicators

a. Dissolved oxygen demand
b. Pathogens
c. Toxic chemicals

B. Effluent Water Standards

1. Mass discharge limits

a. Specific chemicals
b. Surrogates or indicators for effects (BOD, suspended solids)

2. Zero discharge concept

a. Forces pollutant discharge to air or land rather than to water

3. Best available control technology limits

a. Uniform source control vs. modeling of source on the receiving water
b. Waste load allocation depending on impact

IV. Water Quality Monitoring - Qualities to Consider in Setting Criteria

A. Definitions and Units of Measurement (Concentrations; Mass)

B. Parameters

1. Major mineral substances (inorganics)

a. Total dissolved solids (TDS)
b. Hardness and sodium
c. Sulfate and chloride
d. Bicarbonate
e. Nitrate

184

2. Minor mineral substances

   a. Ammonia and organic nitrogen
   b. Boron
   c. Carbon dioxide
   d. Chromate
   e. Fluoride
   f. Iron and manganese
   g. Phosphate
   h. Potassium
   i. Selenium
   j. Sulfide

3. Dissolved oxygen and organic chemical indicators

   a. Dissolved oxygen
   b. Biochemical oxygen demand (BOD)
   c. Total organic carbon (TOC)
   d. Chemical oxygen demand (COD)
   e. Phenolics
   f. Methylene blue extractables (synthetic detergents)

4. Suspended solids, turbidity, oil and grease, color

5. Toxics

   a. Heavy metals
   b. Pesticides
   c. PCB
   d. Multiringed aromatic hydrocarbons (PAH)
   e. Bioassay

6. Radioactivity

V. <u>Water Quality Surveillance Programs</u>

A. Purposes

   1. Baseline data for characterization - background levels
   2. Trend identification
   3. Monitoring for enforcement of regulations

B. Characterization

   1. Spatial variations - acre, square mile, or larger
   2. Temporal variations - hourly, weekly, monthly, yearly, decade, or century changes

140

3. Types of constituents in water

   a. Dissolved minerals
   b. Dissolved organics
   c. Suspended particulates
   d. Dissolved gases

C. Lakes, Reservoirs, and Impoundments

1. Spatial variation

   a. Water volume - capacity to resist quality changes
   b. Surface area - oxygen transfer
   c. Surface area/water depth ratio: relative mixing
   d. Sources of supply (flow) to impoundment
   e. Heights of input and withdrawal

2. Temporal Variation

   a. Inflow - outflow vs. volume (hydraulic residence time)
   b. Seasonal changes - temperature stratification

3. Quality constituents

   a. Temperature - thermal variations dictate principal behavior. Monitor vertical profile
   b. Dissolved minerals - distribution depends mainly on degree of density stratification. Monitor flow
   c. Dissolved organics - may be a large vertical variation. Check epilimnion in summer and the bottom of the hypolimnion adjacent to benthos.
   d. Suspended particulates - deposition rates depend on particle size. Plankton blooms expected to occur in epilimnion.
   e. Dissolved gases - oxygen will vary in the vertical profile. Largest temporal variations in the epilimnion.

4. Minimum surveillance requirements

   a. Physical parameters - lake area, lake depth, inflow per unit volume of lake
   b. Number of stations
   c. Number of observations per year
   d. Suggested plan (see Figure 1)

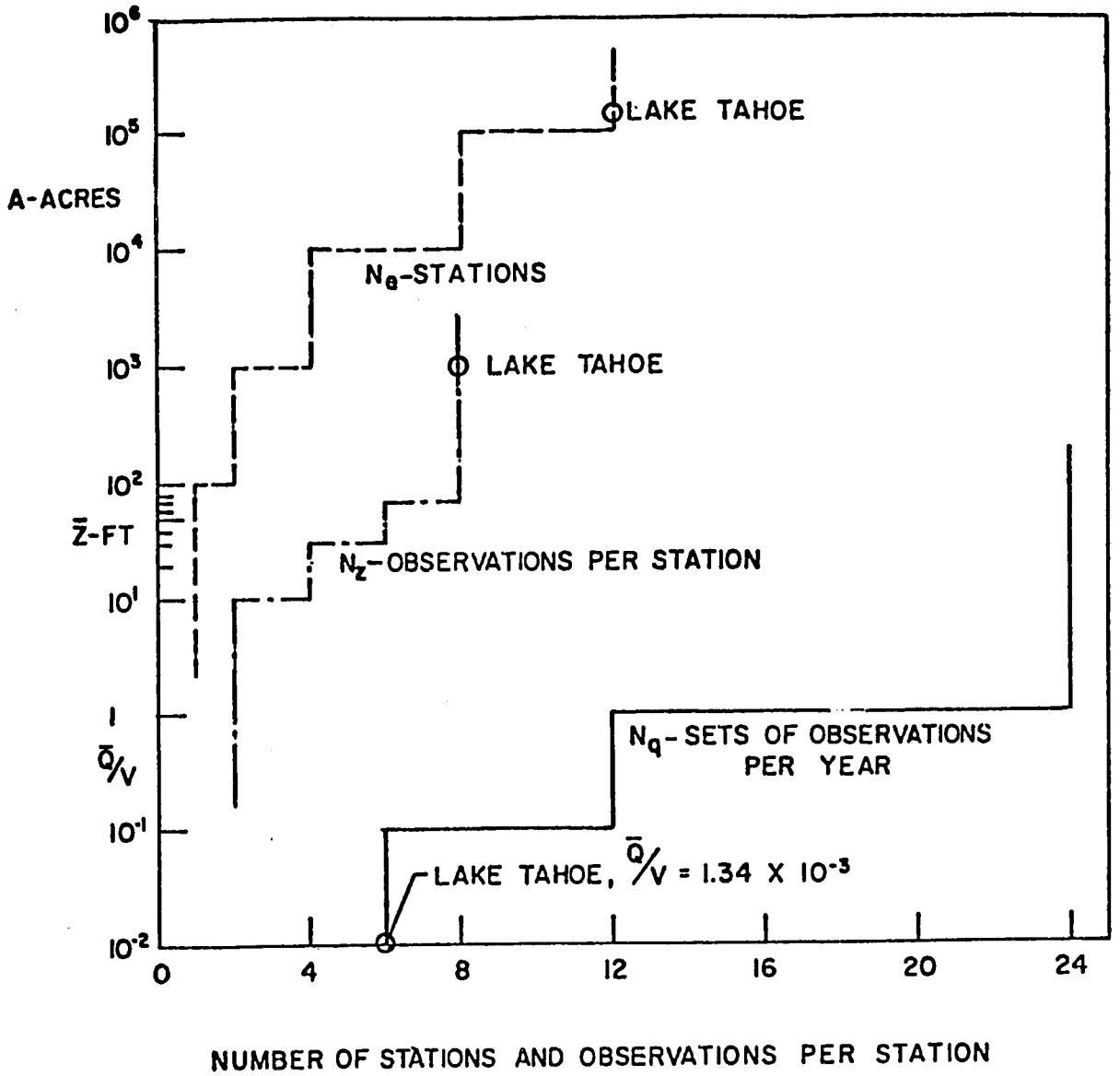


Figure 1 Minimum Requirements for Temperature Characterization of Impoundments after Pomeroy and Orlob (Reference 1)

192

D. Streams and Rivers

1. Spatial variation

   a. Quality varies along length of stream
   b. Flow, width, and depth tend to increase in the downstream direction
   c. Hydraulic variability is most pronounced at points of lowest annual discharge

2. Temporal variation

   a. Annual and diurnal cycles
   b. Low flows (summer months - northern hemisphere)
   c. Relationship between rainfall-runoff
   d. Relationship between flow and sediment load in alluvial streams

3. Quality constituents

   a. Dissolved minerals - concentration tends to follow pattern of diluting flows
   b. Dissolved organics - response of the dissolved oxygen given by Streeter-Phelps model. A minimum dissolved oxygen point occurs.
   c. Suspended particulates - show a large variation in vertical profile in alluvial rivers.

4. Minimum surveillance requirements

   a. Physical parameters: drainage area, length of water course, slope of channel, ratio of annual maximum flow to minimum flow
   b. Number of stations
   c. Number of observations per cycle
   d. Suggested plan (see Figure 2)

E. Estuaries

1. Spatial variation

   a. Large changes in cross-section
   b. Tidal flow and freshwater flow patterns
   c. Stratification by density (saline wedge)

193

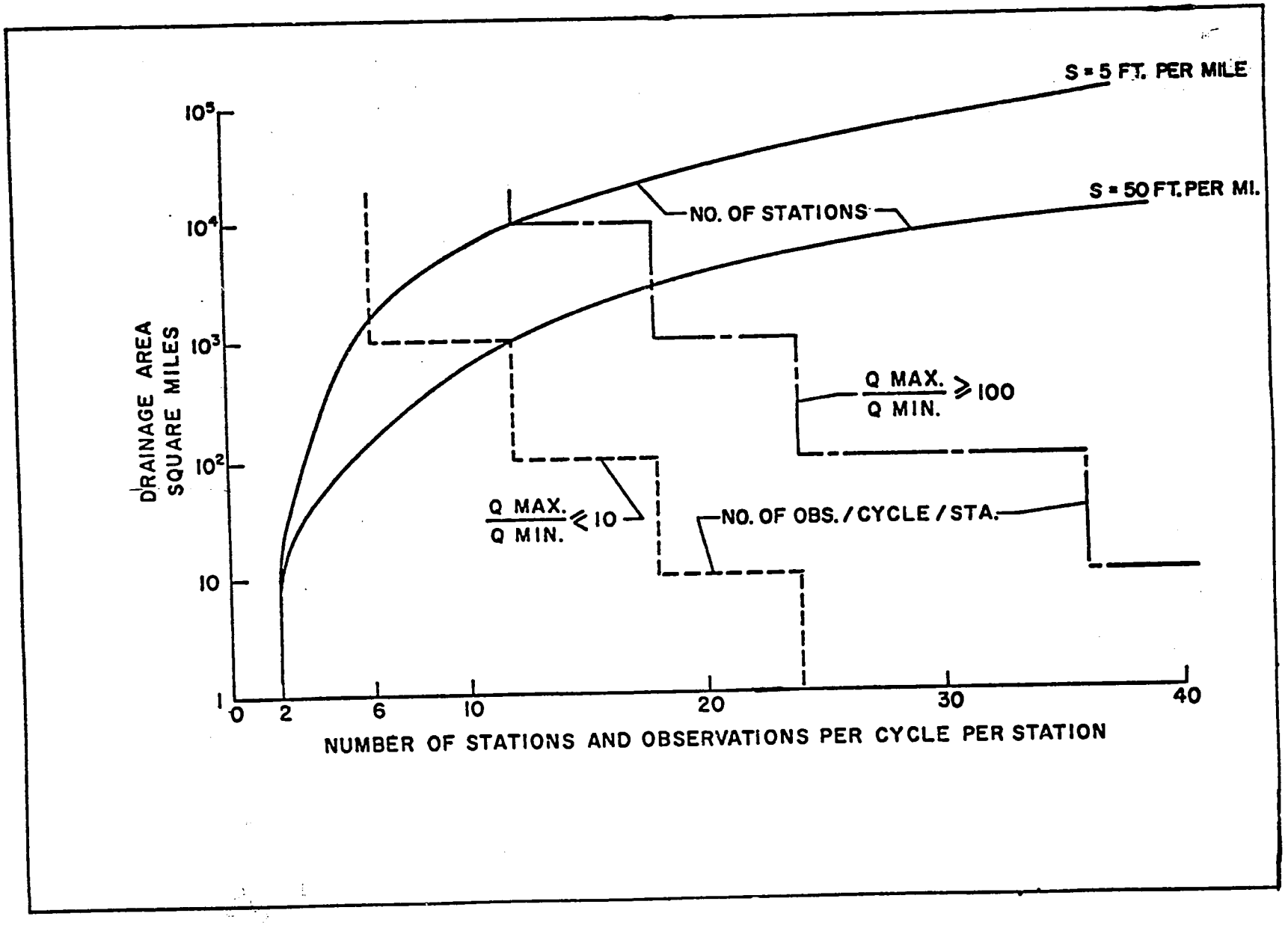


Figure 2 Minimum Requirements for Quality Characterization in Streams and Rivers after Pomeroy and Orlob (Reference 1)

2. Temporal variation

   a. Tidal cycles - transport occurs upstream and downstream
   b. Freshwater tributary rainfall-runoff
   c. Time constants are longer than for rivers

3. Quality constituents

   a. Dissolves minerals - saline profile determines density stratification and mixing
   b. Dissolved organics - dissolved oxygen profiles are more complicated than for rivers. Minimum dissolved oxygen point occurs.
   c. Suspended solids - mixing of fresh and salt waters changes physical-chemical properties of solids and effects flocculation which changes settling rates, turbidity, and photosynthetic activity.

4. Minimum surveillance requirements

   a. Type of quality constituent
   b. Size of estuary
   c. Shape of estuary
   d. Relation between runoff, tidal action, and mixing
   e. Degree of vertical stratification
   f. Cycles - periodic and random
   g. Suggested plan (see Table 1)

195

TABLE 1

RECOMMENDED MINIMUM DATA REQUIREMENTS FOR A SINGLE QUALITY CHARACTERIZATION OF AN ESTUARY OR EMBAYMENT - SALINITY

After Pomeroy and Orlob (Reference 1)

Class of Estuary	Degree Of Stratification	Q_{max}/Q_{min}	Number of Stations[1,2,3]	Samples Per Sta[4]	Frequency Per Cycle[5]	Observations Per Estuary[6]
One-dimensional	Fully mixed	< 10	$\geqslant 4$	2	6-12	48-96
		> 100	$\leqslant 8$	2	6-12	96-192
Two-dimensional	Fully mixed	< 10	$\geqslant 4+2$	2-4	6-12	60-120
		> 100	$\leqslant 8+4$	2-4	6-12	132-264
	Stratified	< 10	$\geqslant 4$	2-4	6-12	66-132
		> 100	$\leqslant 8$	2-4	6-12	144-288
Three-dimensional	Stratified	< 10	$\geqslant 4$	2-10	6-12	108-216
		> 100	$\leqslant 8$	2-10	6-12	288-576

[1] At least one for each reach = distance between annual mean positions of 30 and 70 percent seawater salinity.

[2] For two-dimensional estuaries add two supplementary stations when Width/depth $\geqslant 100$.

[3] Locate supplementary stations at near-bank one-quarter points, sample at mid depth.

[4] Collect 4 samples at stations in seaward one-third of estuary, 3 samples in central one-third of estuary, and 2 samples in landward one-third.

[5] Six samples per tidal cycle (12 per diurnal cycle).

[6] This is for a one-day characterization. For an annual characterization, not less than six such one-day sets are needed.

VI. References

1. Pomeroy, R. D. and G. T. Orlob, "Problems of Setting Standards and of Surveillance for Water Quality Control," Resources Agency of California, State Water Quality Control Board, Publication No. 36 (1967).

2. McKee, J. E. and H. W. Wolf, "Water Quality Criteria, Second Edition," Resources Agency of California, State Water Quality Control Board," Publication No. 3-A (1963).

3. Brooks, N., "Man, Water, and Waste," in The Next Ninety Years, Industrial Associates Conference Proceedings, California Institute of Technology (1967).

4. Council on Environmental Quality, "Environmental Quality," Annual Reports since 1970, U.S. Government Printing Office.

5. National Academy of Sciences, "Drinking Water and Health," A Report of the Safe Drinking Water Committee, Washington, D.C. (1977).

197

FRANCIS CLAY McMICHAEL

Senior Staff Engineer

Professional Experience

Dr. McMichael, a nationally recognized expert in industrial wastewater characterization and treatment, serves Environmental Research & Technology, Inc. (ERT) in several areas, including water supply, wastewater treatment and disposal, and hydraulics, hydrology, and water quality.

Dr. McMichael has worked as a Professor of Civil Engineering and Head, Department of Civil Engineering, Carnegie-Mellon University, Pittsburgh, PA. Previous to holding that position, he had been Senior Fellow, American Iron and Steel Institute Water Resources Fellowship, Mellon Institute, Pittsburgh, PA (1967-1972); Assistant Professor of Civil Engineering, Princeton University, Princeton, NJ (1965-1967); Research Faculty Fellow in Civil Engineering, California Institute of Technology, Pasadena, CA (1963-1965).

Dr. McMichael has consulted for numerous industries and corporations regarding environmental problems, including Jones and Laughlin Steel Corp., Wheeling-Pittsburgh Steel Corp., National Steel Corp., Interlake Steel Corp., Inland Steel Corp., Bethlehem Steel Corp., Algoma Steel Corp., Shenango Inc., Westinghouse Electric Corp., Pittsburgh and Midway Coal Mining Co., Conoco Coal Development Co., and the Institute of Gas Technology. He has also had governmental consulting roles with the U.S. Environmental Protection Agency, the U.S. Public Health Service, Los Angeles County Sanitation and Flood Control Districts, and the Allegheny County (PA) Health Department.

In governmental committee work, Dr. McMichael has been active at federal, state, and local levels. He is currently a member of the Technology Assessment and Pollution Control Advisory Committee of the Science Advisory Board, U.S. Environmental Protection Agency. He has previously served as a consultant to the National Commission on Water Quality, and with the U.S. Department of Commerce Technical Advisory Committee, as well as with numerous state and local environmental committees and task forces.

Education

Ph.D. (Civil Engineering) California Institute of Technology, Pasadena
M.S. (Geophysics) California Institute of Technology, Pasadena
B.S. (Mining Engineering) Lehigh University, Bethlehem, PA

Memberships

American Geophysical Union
American Institute of Chemical Engineers
American Society for Engineering Education
American Society of Civil Engineers
International Association for Hydraulic Research
Sigma Xi
Water Pollution Control Federation

GF-5/78

198

WATER MONITORING CASE STUDY

Industrial Zone Water Monitoring System in Kuwait

Robert Bartlett

Vice President, Engineering
Technology World, Inc.

June 1980

International Environmental Management Institute
ENVIRONMENTAL RESEARCH & TECHNOLOGY, INC.
Concord, Massachusetts, USA

199

EXECUTIVE SUMMARY

This case study addresses the design considerations and constraints attached to a water monitoring system installed as part of an effort to provide a hydrological model for the water immediately adjacent to a large industrial area on the shore of the Arabian Gulf. A real time data collection system was installed to maximize data capture and the instruments selected were resistant to the severe marine fouling resulting from the high temperatures and salinity of the Gulf. The data collection system was highly automated to minimize the need for skilled manpower.

Instruments are tower mounted to avoid the water current and wind measurement errors associated with moving instrument platforms.

Data from the system will be used to calibrate models of thermal diffusion which will take into consideration effluent heat and rate of discharge, wind and waves, current flows and tide, and density stratification of the water. The model will be a tool for planning the future expansion of the industrial area and its harbor. Use of the model will permit calculations of cooling efficiencies as a function of weather conditions and as a function of the location of intake and outfall structures, breakwaters and jetties.

The availability of the data acquisition allows real time measurement of certain water pollution indicators such as pH and dissolved oxygen. However, at present continuous in-situ measurement of water quality is difficult to achieve since sensors for most parameters of interest are subject to interferences and marine fouling.

The measurement techniques of the system to be described are useful for any major industrial activity requiring proximity to a large water source for cooling purposes or removal of industrial byproducts.

200

WATER MONITORING CASE STUDY

Industrial Zone Water Monitoring in Kuwait

Robert P. Bartlett
Technology World, Inc.

This case study will attempt to illustrate how modern communications technology can be applied to the general case of water measurement programs to provide high data capture and reduce the cost of data gathering.

Characteristics of the Case Study Industrial Area

The Shuaiba Industrial area is a highly concentrated complex of power generation and water desalination plants, petrochemical industries including a refinery and a fertilizer plant, support industries and a fishery. It occupies 8.4 million square meters of land located on the coast of Kuwait approximately twenty-five miles south of the City of Kuwait. The industrial area contains a modern harbr and both on-shore and off-shore oil loading facilities. The harbor is currenty undergoing expansion and plans exist to accomodate new industries.

The mass rate of introduction of waste materials and products into the environment by the various emissions of the industries has increased continuously over the last decade. An environmental pollution problem has developed because an acceptable balance has not been preserved between the "loads" imposed by "man-made" activities and the capacity of the ecosystem to absorb and to recycle wastes harmlessly.

The quality of the coastal waters of the Gulf are of critical importance. In other parts of the world, extreme pollution of sea water can cause interruptions of electrical supplies, but nowhere else is there the same dependence on sea water and its quality as the major fresh water source for consumption by both the industrial and domestic sectors. Further, it must be remembered that the Gulf is virtually a land-locked lake with little through flow to flush out contaminants.

The probable major pollutants in the marine environment of the coastal waters of Kuwait may be classified as--

a) compounds of nitrogen;
b) compounds of sulfur;
c) compounds of carbon including hydrocarbons (oils); and
d) heavy metals.

201

Specific problems encountered in the industrial area are---

- Contamination of sea water by ammonia causing: attack on cupro-nickel tubes of the cooling water heat exchangers; an increased chlorine demand to prevent marine growth; carryover or "spewking" of salts producing unstable operation of the power stations; and increased pH of the water.

- Contamination of sea water by oil causing: reduced efficiency of heat transfer surfaces of condensers and evaporators in the power stations; adverse effects on the marine life in the vicinity of the Shuaiba area by a reduction in the amount of oxygen available.

- Reduction in cooling efficiencies due to recycling of cooling water under adverse weather conditions. It was found that certain weather conditions could produce intake waters only 1.2° below the critical maximum design temperature of the cooling water heat exchanger.

The Need for Data

To mitigate the effects of pollution in the waters adjacent to the industrial zone, the bulk transport and mixing of the pollutants in the marine environment must be known as a function of instantaneous weather conditions and the general variations in climatology through the seasons. Dispersion of pollutants in the Gulf is a much slower process compared with atmospheric mixing and is restricted by the formation of thermoclines which act as physic[illegible]rriers to free vertical movements and dilution of pollutants [illegible] the surface to the depths of the Gulf.

Data on the movement of water in the vicinity of Shuaiba as a function of tide, wind and waves is very limited as is data on temperatures and salinities as a function of depth. In addition, the Pollution Control Center established in Shuaiba in 1970 is desirous of obtaining continuous readings of pollutant concentrations and water quality in an effort to better understand and control the ongoing pollution processes.

In 1976, the Shuaiba Area Authority launched a multiphase program to gain more information on the dynamical processes of the offshore water. Phase 1, which is now complete, involved water sampling and bathymetric measurements. Phase 2 which is now in process calls for an extensive hydrographic and water quality monitoring program to be conducted for a period of one year, and Phase 3 will be the construction of mathematical and physical models of the offshore water which will provide an important tool for design of pollution mitigation strategies.

202

The Hydrological Monitor

Phase 2, the Hydrological and Water Quality Monitoring Program, is being carried out by the Kuwait Institute for Scientific Research (KISR). KISR's approach to the monitoring program is to use fixed continuous in-situ monitors for data gathering for as many of the desired measurements as is practical. In-situ monitors, where the monitor sits in the medium whose characteristics are to be measured, are very practical for measurements of the hydrological parameters--water current speed and direction, and wave height and period. In-situ monitors are much less satisfactory for water quality or pollutant measurements. Measurements of pH and dissolved oxygen can be accomplished as long as service personnel are routinely available for servicing (cleaning) of the probes. Measurements of most pollutants in water such as hydrogen sulfide, ammonia and oil are much more difficult due to interference between pollutants, probe drift and power requirements of the sensors (no land power is available at the monitors in the water). These latter measurements are satisfactorily handled at present by periodically gathering water samples from different locations and depths and analyzing the samples in the laboratory.

Fixed location point measurements of water current flow can often be misleading due to eddies or local anomalies of the flow. KISR will supplement the data derived from the hydrological monitors with fluorescent dye tracer studies allowing them to gain a complete picture of circulation patterns and how they are influenced by tides, wind and waves, and salinity.

Approach to the Design of the Hydrological Monitor System

A. Measurement Platform

Three approaches to the design of a platform to hold the instruments were considered: a moored surface buoy, a subsurface buoy and a fixed structure or tower. Moored surface riding buoys were rejected because of the desire to obtain accurate current measurements. The Gulf is generally shallow and the maximum depth for monitoring is twenty meters. In the wave zone, severe current measurement errors are induced if the current meter is in motion.

Subsurface buoys allow the current meters to be more stable in position but they require more diver servicing and need an electromechanical cable to an antenna if a radio telemetry system is to be used. The flexing of the cable, caused by waves and tidal variations, often causes electrical failures.

203

The design approach adopted uses a fixed tower whose base sits on the floor of the sea. All sensors are held in a fixed position eliminating any errors arising from movement of the sensor within the medium. The towers extend above the surface of the water by a length of twelve to twenty feet, allowing much of the tower electronics system to be mounted above water for ease of servicing and providing a mount for aids to navigation (fog horn, navigation light) to reduce the hazard of collisions with vessels. The tower also provides a stable mount for a wave staff and anemometer and a solar panel which provides the electrical power for the monitoring equipment. This latter consideration is important since the availability of manpower in Kuwait is limited and routine visits to the monitors for battery changing are eliminated.

B. Temporal and Spatial Characteristics of the Measurement System

In planning a long-term measurement program, it is important to reduce the quantity of measured values to that number which adequately characterizes the dynamical relationships of the parameters. Modern sensors, communications technology and computer science have given us valuable tools which can be misused and produce data so voluminous as to impose a formidable reduction task on the analytical team.

The number and distribution of monitors should be chosen at least on the basis of a crude model or guess of the spatial variability of the parameters to be measured. For the Shuaiba application, the area of interest was judged to be a 4 x 8 kilometer rectangle encompassing four intakes and several outfalls. One monitor was placed near each intake to allow measurements of temperature profiles, salinities and currents near the point of ingest. Two monitors were placed near the seaward corners of the rectangles, and two monitors were placed in the interior of the rectangle at locations judged necessary to give a complete picture of the circulation pattern. A constraint placed on the tower design was to permit their being moved. With the arrival of data early in the program, KISR analysts will be able to refine their initial guesses as to the general circulation and choose better locations of the monitors to provide data for model calibration. One constraint on monitor location is the necessity to stay out of the shipping lanes and not interfere with harbor operations.

It is possible to operate all of the hydrological monitor sensors continuously in time. However, just as we desire to minimize the number of monitors to be consistent with the spatial variation of the parameters, we also desire to limit the frequency of observations to numbers which are consistent with the temporal variation of the sensed parameters. For all of the parameters measured, observations thirty to sixty minutes apart were deemed sufficient, allowing several observations for each diurnal or tidal cycle. Specific frequencies of observations were ---

One Hour	Water Temperature (Profile) Conductivity (Salinity) pH DO Significant Wave Height and Period
Half Hour	Current Speed and Direction Wind Speed and Direction

Each of the eight towers is fitted with two current meters, one near the surface and one near the bottom allowing an evaluation of wind effects on the surface layer. Conductivity is also measured at two depths and the temperature profile can be determined from as many as ten temperature sensors arrayed in a vertical column. The dissolved oxygen and pH are measured near the bottom. Wind and waves are measured from one offshore tower as the spatial variability of the wind field is not judged to be significant in the measurement area.

C. Sensor Sampling

As noted above, observations are taken once per hour or once per half hour, and are taken simultaneously at all eight towers under local control of the tower sampling electronics. Thus, we have a set of synoptic observations giving us a "snapshot" of the phenomena behavior in the entire measurement area. Some of the parameters of interest require multiple samples to yield the observation. These include wind, waves and water current. In the shallow water of the Gulf bordering the industrial area, the orbital wave motion often produces instantaneous readings significantly higher than the steady state current. Thus, the X and Y components of wind and wave are each averaged for 4-1/4 minutes to produce the desired observations.

Oceanographers generally choose to observe wave motions for periods of approximately 20 minutes to ensure that long period waves are included in their spectral analyses. ERT chose to do no processing of wave data into "observations" at the monitors. Instead 2400 samples of water levels are taken over an interval of twenty minutes each hour and subsequently transmitted to a shore computer for storage in a data base. This permits the oceanographer to employ a variety of wave processing algorithms in his effort to produce meaningful indices of wave characteristics.

205

D. Design of the Data Collection System

Earlier hydrological monitoring studies most often employed local storage of sensor data using data loggers recording on magnetic tape or writing data on photographic film. The storage media would be retrieved from the monitor and transported to a computer site for reduction and analysis. These systems are called "historical" systems.

More recently, an electronic communications capability has been added to some data gathering systems, allowing sensor observations to be viewed by an analyst in a central facility as rapidly as they become available from the monitor sensors. Such systems are known as "real-time" systems. Their advantages include:

(1) An ability to implement a control action if the monitor is part of a real-time control system.

(2) A reduction in operations manpower since data are automatically transmitted to the analysis facility.

(3) An increase in valid data capture since most instrument malfunctions are detected as soon as they occur. This is significant in monitoring programs of fixed duration where no opportunity exists to recapture missing data. When a failure is detected at the central facility, technicians can be immediately dispatched to effect repairs.

For the Shuaiba monitoring application KISR and ERT elected to implement a near-real-time system. The term "near-real-time" means that sensor observations are not available at the central facility as soon as they are produced but arrive with a short time delay. The time delay in the Shuaiba application is a metter of a few hours at most and is not significant since the intent of the Shuaiba monitoring system is data gathering and not real time control. The other advantages of real time systems remain.

KISR and the Shuaiba Area Authority (SAA) elected to build an analysis facility within the Institute. This analysis facility houses a monitor network control computer and is located approximately forty kilometers northeast of the Shuaiba Industrial Area. It was also decided to provide a readout of observations and analyses within the Industrial Area so that personnel of the Shuaiba Pollution Control Center would be continuously aware of the behavior of the phenomena sensed by the monitoring system. To satisfy these requirements and to increase system reliability, ERT has supplied two identical computers and linked them with a telephone line. One of the computers is located in KISR and the second in the Pollution Control Center in Shuaiba. At any one time, only one computer controls the network, and the second functions as a remote readout. The controlling computer is referred to as the "Master" and the remote readout computer is called the "Slave." Either computer can act as Master and control is shifted if the computer which has been designated Master fails.

206

Figure 1 shows the Data Collection System implemented by ERT at Shuaiba. Each monitor is equipped with an electronics package and clock which schedules and stores observations on a fixed schedule. A UHF radio is provided in each monitor and at the Pollution Control Center (PCC). The radio at the PCC is linked, via a leased telephone line, to the network control computer in the Institute for Scientific Research. On a fixed schedule, the network control computer at KISR requests, via the telephone line and radio link, each monitor to transmit its stored data to the control computer. The monitor "answers" the control computer and transmits its data to the computer at KISR. The KISR computer processes the data and sends a summary of the observations back over the telephone line for recording and display at the PCC. This sequence occurs when the KISR computer is in the Master mode. If the PCC computer is in the Master mode, it controls the network and sends data summaries to the KISR computer.

Each remote monitor has enough memory to store the observational data acquired during a twelve-hour period. Normally, the network control computer requests data from monitors every hour. If no data is returned from the monitor, the control computer requests the data again, and if necessary, a third time. If all three tries are unsuccessful, the network control computer will try to retrieve the missing data an hour later when the next polling sequence starts. Thus, missing data can be retrieved up to eleven hours after the observation is taken and the communications and network control is not vulnerable to radio interference, loss of power, computer failures or telephone line failures which exist over periods up to eleven hours long.

E. Data Processing

The prime function of the Hydrological Monitor System computers is to retrieve and store observational data for subsequent analysis and model calibration. As an aid to the system operations, the computer displays observations as soon as they arrive (see figure 2) and at intervals of six and twenty-four hours produces summaries of the data from each sensor including ---

- Average Value
- Maximum Value and Time of Occurrence
- Minimum Value and Time of Occurrence
- Standard Deviation.

207

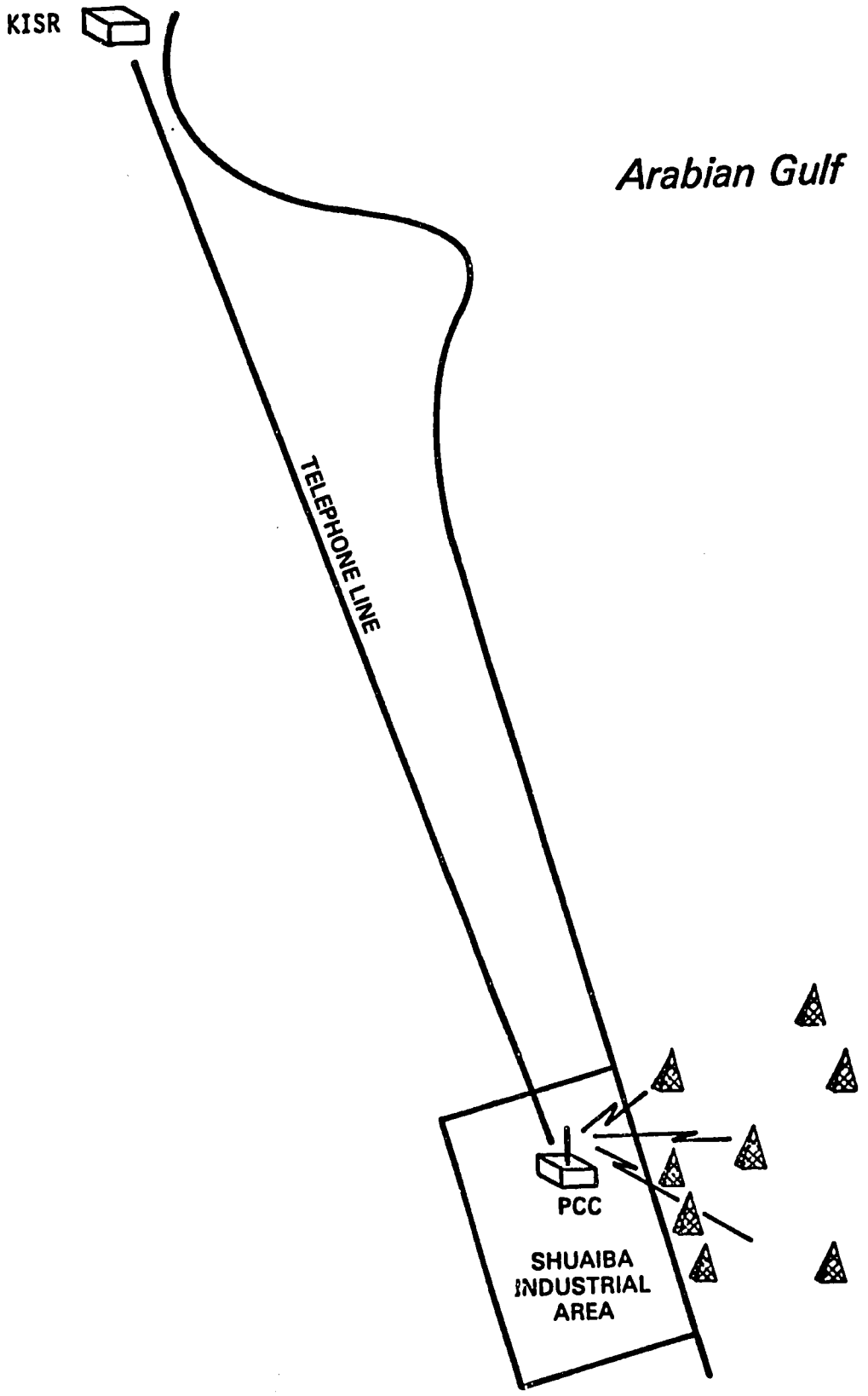


Figure 1 HMS System Configuration

208

SENSOR	UPPER HOURLY	LOWER	UPPER HALF HOURLY	LOWER	UNITS
COND	42.95	41.24			MMHOS/CM
COND REF	4.57	4.81			VOLTS
LCL TEMP	17.50	17.32			DEGREE C
TEMP REF	4.81	4.81			VOLTS
R TEMP 1	17.52	17.36			DEGREE C
R TEMP 2	17.40	17.37			DEGREE C
R TEMP 3	17.51	17.39			DEGREE C
R TEMP 4	17.42	17.39			DEGREE C
A GROUND	0.00	0.00	0.00	0.00	VOLTS
+8 VOLTS	7.97	8.04	7.97	8.04	VOLTS
-8 VOLTS	-7.97	-7.98	-7.97	-7.98	VOLTS
BATTERY	12.63		12.63		VOLTS
BOX TEMP	15.81		15.96		DEGREE C
CURRENTX	1.06	-2.97	1.87	-4.51	CM/SEC
CURRENTY	-1.50	1.36	-1.94	1.36	CM/SEC
WIND X	-9.57		1.23		M/SEC
WIND Y	11.08		-3.71		M/SEC
PH	4.90				UNITS
DO	10.08				PPM
SPARE	0.00		0.00		VOLTS
DAYS	15		15		NUMBER
TIME	7: 0: 2		7:30: 2		HH:MM:SS

Figure 2 Typical Output of Monitor Observations

209

Another computer function of the HMS which is very valuable to those charged with its proper operation is the generation of "alarms". One type of alarm is produced when an observation is outside of the range of expected values. This is a signal to the system operator to investigate further and make a judgement as to data validity. A second type of alarm is generated when the observation departs from its anticipated range by an amount which suggests a sensor failure. This is a signal to the system operator to dispatch maintenance personnel to the offending monitor.

F. Demand Scans

A facility exists to allow the system operator to request data on demand. (The system operation described above is automatic and all observations are taken on a fixed schedule). The operator may request the same set of observations which is taken on the normal schedule, or he may request data from an individual sensor. When a monitor receives a request for data from an individual sensor, the monitor sends a sequence of values from the selected sensor where each value is spaced at one-half or one-second internals. This is a valuable tool for maintenance since the sequence of values will allow determination of erratic or "noisy" operation of the sensor.

G. KISR has written a number of plot programs for graphical data display. Figure 3 shows a 24-hour plot of dissolved oxygen content from an upper sonde probe on an offshore tower.

Summary

The HMS design as described above should produce a data capture significantly higher than that of hydrological monitoring systems used in the past. Its near-real-time communications system is invulnerable to short-term failures and allows rapid detection of system faults so that failed components may be immediately replaced (weather permitting). Tests to date indicate that the expected degree of reliability will be achieved. The design principles of the data gathering system have general applicability to environmental monitoring.

Acknowledgements

The description of the Shuaiba Industrial Area and its environmental hazards was derived from material furnished by the Shuaiba Area Authority. The Authority and its Pollution Control Center are to be commended for having planned an aggressive data gathering program to aid their formulation of pollution control strategies. The author also wishes to acknowledge the contributions of the Kuwait Institute for Scientific Research, which has the lead technical role in the multiphase program designed to gain a better understanding of the natural phenomena of the Shuaiba water as modified by the processes active in the Industrial Area.

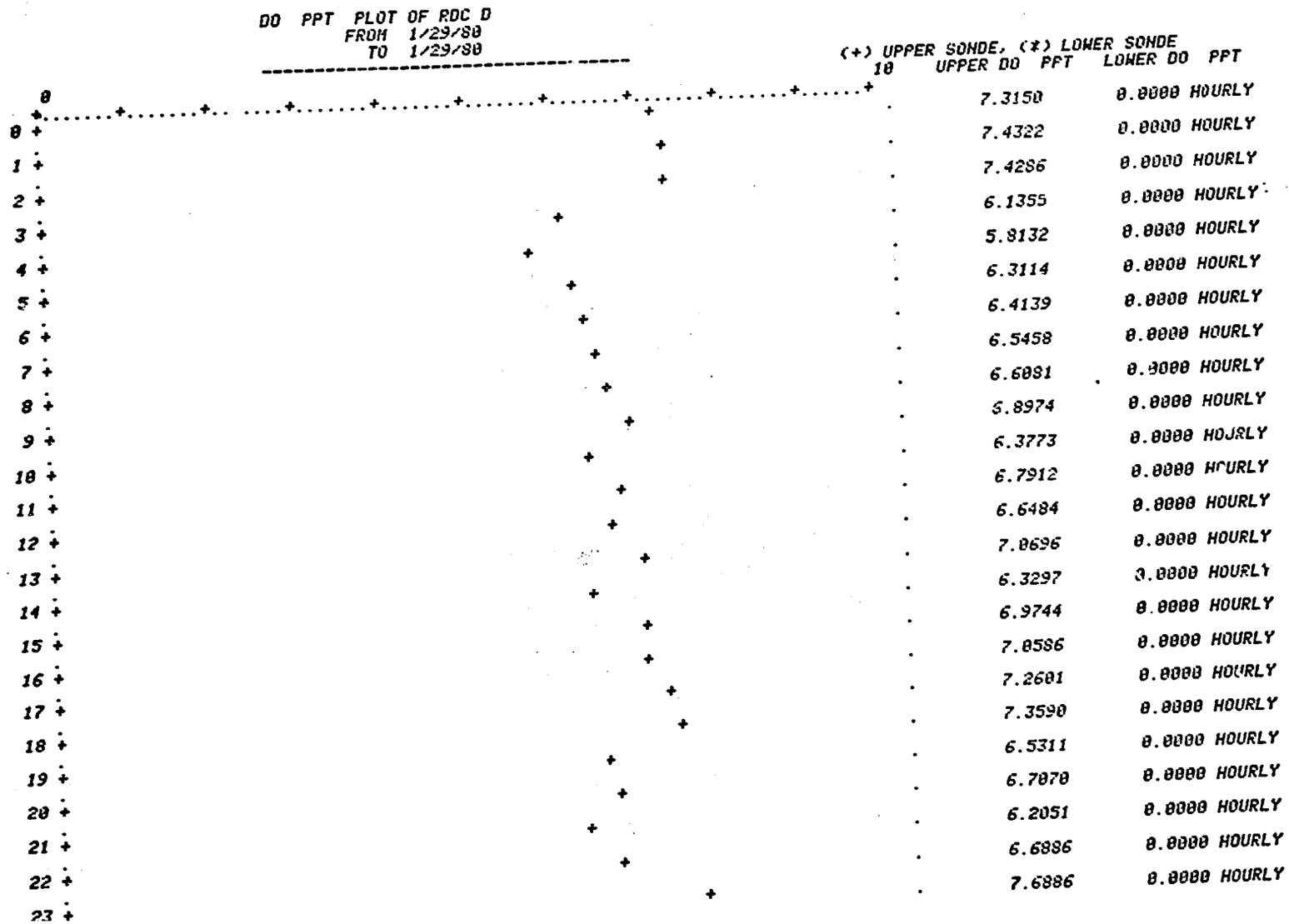


Figure 3 Dissolved Oxygen for a 24-Hour Period

BIOGRAPHICAL SKETCH

Mr. Robert P. Bartlett
Vice President, Engineering
Technology World, Inc.

Mr. Bartlett holds a B.S. degree in electronics engineering from the Massachusetts Institute of Technology. He has been responsible for the design and development of a variety of computer-based electronic systems and is currently managing the deployment of a large water monitoring system in Kuwait.

In 1955, Mr. Bartlett joined the Electronics Corporation of America where he was project engineer for a number of infrared sensing systems including a star-tracker for ship navigation and a portable gun-flash detector. Mr. Bartlett joined Allied Research Associates in 1958 where he designed high speed instrumentation for sorting of industrial products by color. As chief engineer of the Geophysics division, he designed a photogrammetric system for meteorological satellite altitude detrmination and a satellite-borne computer for superposition of latitude/longitude grids on cloud cover pictures.

In 1968, Mr. Bartlett joined EPSCO, Inc. where as Vice President of Engineering he developed a line of marine products including Loran-C and Omega navigation receivers, a microprocessor-based position plotter, and a shipboard radar. At EPSCO he was responsible for all development and engineering activities for products such as pilotless aircraft control systems, analog to digital and digital to analog converter subsystems, navigation simulations, and a line of high power microwave sources and test sets.

In 1976, Mr. Bartlett joined ERT. As Chief Engineer of ERT International, Mr. Bartlett directed the development of a number of computer-based environmental data acquisition systems for air and water quality measurements and oceanographic applications.

At Technology World, Mr. Bartlett is responsible for all technical activities which currently include an upgrading of the meteorological and environmental data gathering, processing and forecasting facilities for the Kingdom of Saudi Arabia.

212

ENVIRONMENTAL IMPACT ASSESSMENT METHODOLOGY

Prepared by

Dr. Janice G. Baker
ERT Senior Program Manager

and

John R. Whitman
Director, ERT International Environmental
Management Institute

June 1980

International Environmental Management Institute
ENVIRONMENTAL RESEARCH & TECHNOLOGY, INC.
Concord, Massachusetts, USA

213

TABLE OF CONTENTS

	Page
1. INTRODUCTION	1
2. DESCRIPTION OF THE EIA	3
2.1 Definition	3
2.2 Necessity	3
2.3 Timing	5
2.4 Who Should Prepare?	5
2.5 Difficulties in Preparation	6
3. GOALS OF AN EIA	9
4. THE EIA PROCESS	11
4.1 Project Siting and Definition	11
4.2 Evaluation of Project Elements	11
4.3 Assessing Project Impacts	18
4.4 The Environmental Report	19
5. METHODOLOGY FOR ASSESSING IMPACTS	23
5.1 Data Collection	23
5.2 Data Analysis	23
5.3 Impact Prediction	25
5.4 Mitigation Measures	29
5.5 Unavoidable Adverse Impacts	29
5.6 Alternatives	29
6. PRODUCTS OF AN EIA	31

214

1. INTRODUCTION

An Environmental Impact Assessment (EIA)* is a systematic consideration of the relationship between a project and the environment; that is, a determination of how a project will impact its environment and how the environment will affect a project. In some countries, EIAs are required for industrial developments by regulatory agencies, however, the EIA can be used by the private sector without the duress of legislation. The EIA process can be an effective planning tool for private enterprise to adopt in order to achieve cost savings, time savings, and overall efficiency in achieving project development objectives.

If an EIA is required by legislation or conducted solely for the benefit of a private company, there are common elements in the EIA process and methodology utilized. A general methdology for conducting EIAs is presented in this paper.

---

*The environmental impact assessment (EIA) and the environmental impact statement (EIS) can be the same. To distinguish the two, generally the EIA is prepared by an applicant who is seeking a permit for a project and must comply with regulations calling for an environmental assessment. The principal agency responsible for granting the permit then undertakes an independent evaluation, which is compared with the submitted EIA. The agency then prepares the EIS, which may or may not be identical to the submitted EIA. The applicant and the agency may contract with a third party (e.g., a university of consulting firm) to undertake the assessment in order to avoid duplication of effort and to ensure an objective assessment.

Although such a distinction may be unique to the United States, it is mentioned here to avoid confusion between the EIA and the EIS. EIA is used in this report to mean any systematic environmental impact assessment.

215

2. DESCRIPTION OF THE EIA

After a project sponsor understands the EIA concept, the need to prepare an EIA for a specific project can be evaluated. If it is determined that an EIA would be beneficial, one must decide when to begin the EIA process and who should prepare the EIA. These topics as well as some inherent difficulties in the EIA process are discussed in this section.

2.1 Definition

An EIA was previously defined as a systematic consideration of the relationship between a project and the environment. Types of projects that may require an EIA are discussed as well as various components of the environment that may need to be considered.

Projects that may require an EIA are those in which the environment is a factor in the project's location, design, engineering, or operations, and those that could have an effect on the environment. The location of natural resources, such as oil or coal, can influence the siting of a project. The local terrain, such as sandy soil or steep slopes, can influence the design and engineering of a project. The operations can be influenced by the distance to urban centers that may supply trained workers or raw materials. A project may affect the environment by altering the terrain through excavation or filling, by air emissions or effluent discharges. Examples of types of projects that could benefit from an EIA are presented in Table 2-1.

The environment may include the natural environment, for example, the hydrologic, geologic, ecologic, and climatic conditions that may be affected by a project. The environment may also include social, cultural, or economic factors that could be affected by a project. The environment can be affected by a project in a beneficial manner, such as by supporting the local economy, or in a detrimental manner, such as by deteriorating water quality.

2.2 Necessity

There is no universal formula for determining if an EIA is needed for a specific project. In some countries, such as the United States, the EIA is required by law under certain circumstances. Government regulations also define a general scope for the EIA. The World Bank requires an environmental assessment for projects receiving its assistance, and provides a set of considerations that serve as guidelines for assessment. In the absence of a specific requirement for an EIA, a project sponsor may elect to perform an EIA if the sponsor wishes to compare the environmental (including social and economic) impacts associated with several project alternatives, to minimize the possible disruption to the environment, or to protect himself against potential future litigations. (Law suits could result from a project if it detrimentally impacts other industries or private parties.) Goals of an EIA are discussed in more detail in Section 3.

216

TABLE 2-1

TYPES OF PROJECTS THAT MAY REQUIRE ENVIRONMENTAL IMPACT ASSESSMENTS*

- Agricultural projects
- Industrial projects, including:
  - fertilizer plants
  - iron and steel mills
  - mining operations
  - petroleum and petrochemical operations
  - pulp and paper mills
  - smelting plants
  - textile mills
  - tourism projects
- Transportation projects, including:
  - airports
  - ports and harbors
  - roads and highways
- Utilities, including:
  - dams
  - power plants
  - sewerage and sewage treatment plants
- Human settlements, including:
  - urbanization
  - rural development
  - recolonization

*Source: Environmental, Health and Human Ecologic Considerations in Economic Development Projects, World Bank, Washington, D.C., May 1974.

217

2.3 Timing

There are generally four phases in a project's life: project planning, implementation, operations, and termination. The EIA should be undertaken as early as possible in the project's planning stage. If, for instance, the location of a port is determined prior to considering the advantages and disadvantages of possible alternative sites, an entire level of control is lost--control that may have selected a more advantageous site if the EIA had been undertaken prior to site selection.

Project sponsors frequently select a project site and complete preliminary engineering before beginning an EIA. In these cases, the EIA emphasizes impacts that could result from the project as designed rather than comparing project alternatives. Any changes in project design or engineering are usually minor, unless very severe environmental impacts are expected to result. Major design changes, or elaborate mitigation measures, may be costly and can be frequently avoided by beginning the EIA at an early stage in project planning.

2.4 Who Should Prepare?

An EIA can be prepared by a project sponsor (either a governmental agency or private industry), a governmental body that has jurisdiction over a project, or a third party (such as a university or a private consulting firm).

In some countries a project sponsor must submit an EIA to a governmental agency for review. The project sponsor has the option of preparing the EIA utilizing his own staff or hiring a third party. In this case, the third party is reponsible only to the project sponsor. A governmental agency and a project sponsor may jointly select a third party to prepare an EIA. In this case, the sponsor is responsible for all costs incurred by the third party, but the third party is supervised and directed by the agency as well as the sponsor. A governmental body may decide to prepare the EIA utilizing their own staff. If they select this option, the agency is frequently supported by consultants (or experts in specific areas) from universities or the private sector.

The size and qualifications of the team that will prepare the EIA depend on the size and complexity of the project, the requirements of governmental regulations, as well as the type of impacts anticipated.

A key difficulty in the EIA process is anticipating impacts. Proposed projects often have impacts on a wide range of environmental, economic, and social sectors. It is beyond the capacity of one individual to possess the range and depth of scientific, economic, and social knowledge needed to anticipate all or most of the impacts. A carefully chosen team of experts representing the various sectors to be affected is needed early in the planning stage.

213

The credentials and experience of members of the team also should not be underestimated. Since much of EIA work is based on value judgments, it is critical to consider in advance the practical experience one brings to bear in making value judgments; academic training alone probably will not suffice.

The team coordinator or environmental project manager especially should be experienced in conducting EIA work in the particular sector for which the work is proposed, for instance petroleum, pulp and paper, or chemical industries. The project manager should also be familiar with any pertinent regulations and methodologies for conducting environmental assessments. The project manager should have prior experience in coordinating various environmental studies to ensure that the necessary information exchange occurs among the discipline areas. For example, if the soil is disturbed, the geologist may need to calculate the sedimentation rate; the water quality scientist may need to evaluate potential changes in water quality; the zoologist should consider the effects of the changes in water quality on the aquatic life; and the botanist should be consulted concerning revegetation methods.

The environmental project manager is supported by experts in the various environmental areas of concern. The project team members should have prior experience in conducting environmental assessments as well as pertinent academic training.

2.5 Difficulties in Preparation

The purpose of an EIA is to consider the relationship between the project and the environment in order to identify significant impacts on the environment by the project and the environment's effects on the project's location, design, engineering, or operations. The project's effects may be benign, or detrimental. This means that determining and measuring the effects must ultimately lead to a value judgment. The value judgment, in turn, allows one to consider changing or terminating the project, depending on the acceptability of its effects and the effects of other available options.

There are four key difficulties inherent in applying the EIA:

1) Anticipating effects. By definition, the EIA is meant to consider a project's effects; however, it proves difficult to predict all the effects a project may have. It is important, therefore, to compose a multidisciplinary team of experts early in the planning stage in order to help anticipate the range of types of effects a project may have.

219

2) Predicting changes. The difficulty in predicting changes as part of the assessment is twofold. First, one must predict changes in the environment (including social and economic changes) that will take place naturally, without the proposed project intervention. Second, one must then predict the effects the project will have on a dynamic environment. In some cases the project may have beneficial effects, for instance providing jobs. In some cases certain effects may combine and create a collective effect more damaging than the sum of the other effects. The critical need in predicting changes is to describe adequately the current or baseline condition of the area and determine how the baseline is changing naturally. This description calls for collecting the data that will serve as a basis from which to determine changes.

3) Measuring effects. The difficulty in measuring effects is in determining how to describe changes and effects, particularly in a way that will be helpful in comparing the effects of alternative ways to implement the project.

4) Judging value. This is the most difficult aspect of environmental assessments. While other difficulties may be resolved by scientific expertise, value judgments often defy scientific analysis. Nevertheless, the relative values of segments of the society that may be affected by the project can be studied by using certain techniques, such as interviews and surveys. Such social assessments have a useful and sometimes critical role in the EIA process. It is worthwhile to involve community leaders and other members of the public in the planning phase of a project in order to consider their thoughts and suggestions early and to avoid later misunderstandings about the project's purpose and design. The acceptance of a particular project will depend on value judgments that can be difficult to predict.

It must be emphasized that the environmental impact assessment is a valuable, but difficult tool to use, principally because many impacts are not easily quantifiable and most evaluations are based on value judgments.

3. GOALS OF AN EIA

Before an EIA can be prepared, one must first determine the goals of the EIA and the audience to whom it is addressed. An EIA is usually designed to satisfy one or more of the goals listed below:

- In cases where established standards for environmental protection exist, such as in the United States, one goal is to ensure that the project's location, design, engineering and operations comply with existing standards.

- A second goal might be to minimize disruption to the environment caused by the project. This disruption could be assessed in terms of the social and economic dimensions of the environment, in addition to the natural features and dynamics of the environment.

- A third goal could be a selection of the most desirable economic and environmental alternatives for the project's location, design, engineering and operations.

- A fourth goal may be the documentation of existing environmental problems in order to protect the project sponsor against future litigation and/or costly project delays.

- A fifth goal may be the protection of sensitive areas or endangered wildlife species.

- A sixth goal could be the anticipation of potential impacts so that mitigation measures can be implemented before project construction and/or operation.

Naturally, the goals of a specific EIA must be determined and understood by the sponsor before execution of the EIA process.

271

4. THE EIA PROCESS

The EIA process begins with the establishment of the goals of the EIA followed by an analysis of the project and ending with preparation of the environmental report. An EIA usually begins as a very broad analysis focusing on the entire project, then focuses more specifically on the project elements and finally examines in detail the project elements and associated impacts and mitigation measures. Sequential steps in the EIA process are summarized in Table 4-1.

4.1 Project Siting and Definition

After the EIA's goals are established, the entire project is examined. This preliminary examination focuses on project definition and siting (or location). A consideration of the project definition could include an evaluation of the environmental consequences (advantages and disadvantages) of constructing a refinery at the same location as an oil storage facility versus shipping the crude oil from the storage facility to existing refineries.

Project siting is frequently a major part of the preliminary studies. A siting study may be a sophisticated study utilizing computer models or a simple comparison of alternative sites.

4.2 Evaluation of Project Elements

After a site has been selected and the project has been defined, the EIA focuses on the major elements of a project. For some projects the project sponsor may have selected a site and defined the project before the EIA process was started. In those cases, the EIA begins with the evaluation of project elements.

The environmental project manager may begin an evaluation of the project elements by asking a series of questions about the project or by reviewing an environmental checklist. An example of the types of questions that might be asked for a project involving the construction of new roads or highways is presented in Table 4-2.

As an alternative approach, in order to identify those environmental areas likely to be affected by a proposed project, a list of environmental parameters may be examined. Each of the parameters on the list is checked to determine the nature or magnitude of the impact. Those parameters for which no effect is likely are discarded. Those parameters where an impact is likely are examined further by an environmental specialist in order to determine the significance of the impacts. A sample checklist is provided in Table 4-3.

222

TABLE 4-1

THE EIA PROCESS

Step 1 Determine Goals of the EIA

1) Consider alternatives
2) Satisfy regulations
3) Reduce disruption of the environment

Step 2 Site and Define Project

1) Perform siting study
2) Consider alternatives

Step 3 Evaluate Project Elements

1) Consider engineering and design alternatives
2) Identify areas of significant impact for futher study

Step 4 Assess Impacts

1) Consider detailed environmental engineering
2) Select questions that impact methodology should answer
3) Select methodology for assessment
4) Perform detailed assessment

Step 5 Prepare Environmental Report

1) Describe proposed action
2) Describe existing conditions
3) Predict impacts
4) Explain mitigation measures
5) Summarize unavoidable impacts
6) Compare alternatives

223

TABLE 4-2

QUESTIONS THAT MAY BE ASKED IN ORDER TO DETERMINE IF SIGNIFICANT IMPACTS WILL RESULT FROM CONSTRUCTION OF A ROAD OR HIGHWAY*

A. Environmental/Resource Linkages

- Will environmental criteria be incorporated into the selection of the road or highway route?
- Are the character, quality and major components of the affected ecosystems known?
- Will access provided by the road open unsettled or previously inaccessible areas to human, animal or plant communities?
- Will the road's impact on agricultural, industrial, commercial, or other urban land-use patterns be considered?
- Does the project complement land-use patterns developed for urban or regional programs?
- Will the road have adverse effects on important domestic livestock, wildlife or vegetation?
- Will wildlife migration routes be disturbed?
- Will squatter settlements along the highway route be controlled?

B. Design and Construction

- Is there a consolidated construction plan for the project that takes into account ecological factors?
- Are forest conservation principles being incorporated into design and construction activities in forested areas?
- Will natural drainage patterns be unnecessarily disturbed?
- Do plans include provisions for preventing despoilment of the landscape and vegetation during construction?

*Source: Environmental Health and Human Ecologic Considerations in Economic Development Projects, World Bank, May 1974.

TABLE 4-2 (Continued)

B. Design and Construction (Continued)

- Will clearing, grubbing and burning be limited to the extent practicable?
- Will the size and number of quarry, borrow and disposal sites be controlled?
- Will topsoil be stored for respreading?
- Will soil stabilization measures be taken during construction to minimize damage, e.g., slope reseeding to prevent erosion by wind or water?
- Do plans include provisions for preventing water pollution by spillage and runoff during construction or during use of roadway?
- Will water impoundments create health hazards?
- Will wastes from machinery, asphalt and concrete plants, construction camps and shops be controlled to prevent water pollution?
- Will air pollution by smoke, fumes and sprays originating from construction operations be a problem?
- Will air pollution by dust from unsurfaced roads or construction operations have a deleterious effect on the environment or on human welfare?
- Does the roadway traverse a scenic area? If so, are steps being taken to protect and/or enhance areas of aesthetic and tourist value?
- If a large work force is to be assembled from various locations, is provision being made for a preemployment medical screening and periodic examination of employees to prevent introduction of new diseases and/or further spreading of endemic diseases?

C. Operations

- Will the road serve purposes other than transportation?
- Will road shoulders and aprons provide space for strip urbanization or vendors?

225

TABLE 4-2 (Continued)

C. Operations (Continued)

- Will heavy traffic produce congestion, pollution or noise with adverse consequences to surrounding human, animal or plant communities?
- Will traffic preempt or disrupt use of agricultural land?
- Will there be an adverse effect on habitat and migration of wildlife?
- Will facilities be available to monitor circulation and impact of traffic and new access upon important elements of ecosystems - population settlements, migration patterns, diseases, surface water, and erosion?
- What will be the environmental effects of herbicides and pesticides if they are used?

D. Sociocultural Factors

- Will the roadway disrupt the existing cultures, or impact on archaeological sites or other unique resources?
- Has provision been made for adequate living conditions for populations that are displaced by construction activity, and those that are attracted to newly opened areas?

E. Health Impacts

- Will the roadway and related construction activity open up new pathways for disease vectors affecting humans, plants or animals (e.g., hoof and mouth disease)?

F. Long-Term Considerations

- Has the project been examined for ecological and environmental effects in the context of local and regional plans for development?
- Have the effects of future highway or transport development on the ecology of the area been considered?

226

TABLE 4-3

SAMPLE CHECKLIST OF ENVIRONMENTAL PARAMETERS THAT COULD BE AFFECTED BY A PROJECT*

PHYSICAL/CHEMICAL

Water

- BOD
- Groundwater Flow
- Dissolved Oxygen
- Fecal Coliforms
- Inorganic Carbon
- Inorganic Nitrogen
- Inorganic Phosphate
- Heavy Metals
- Pesticides
- Petrochemicals
- pH
- Stream Flow
- Temperature
- Total Dissolved Solids
- Toxic Substances
- Turbidity

Noise

- Intensity
- Duration
- Frequency

Land

- Soil Erosion
- Flood Plain Usage
- Buffer Zones
- Soil Suitability for Use
- Compatibility of Land Uses
- Solid Waste Disposal

Air

- Carbon Monoxide
- Hydrocarbons
- Nitrogen Oxides
- Particulate Matter
- Photochemical Oxidants
- Sulfur Oxides
- Methane
- Hydrogen and Organic Sulfates
- Other

ECOLOGICAL

Species and Populations

- Game and Nongame Animals
- Natural Vegetation
- Managed Vegetation
- Resident and Migratory Birds
- Sport and Commercial Fisheries
- Pest Species

Habitats and Communities

- Species Diversity
- Rare and Endangered Species
- Food Chain Index

Ecosystems

- Productivity
- Biogeochemical Cycling
- Energy Flow

*Source: Environmental Assessments for Effective Water Quality Management and Planning, E.P.A., Washington, D.C., April 1972.

227

TABLE 4-3 (Continued)

AESTHETIC

Land

- Geologic Surface Material
- Relief and Topography

Air

- Odor
- Visual
- Sounds

Water

- Flow
- Clarity
- Interface Land and Water
- Floating Materials

Biota

- Animals - Wild and Domestic
- Vegetation Type
- Vegetation Diversity

Man-Made Objects

- Man-Made Objects
- Consonance with Environment

Composition

- Composite Effect
- Unique Composition
- Mood Atmosphere

SOCIAL

Individual Environmental Interest

- Educational/Scientific
- Cultural
- Historical
- Leisure/Recreation

Social Interactions

- Political
- Socialization
- Religious
- Family
- Economic

Individual Well-Being

- Physiological Health
- Psychological Health
- Safety
- Hygenic

Community Well-Being

- Community Well-Being

228

In order to determine if significant impacts will occur in a specific discipline area, a specialist in that discipline who is familiar with the type of project proposed may ask a series of questions. The answers to these questions may lead the specialist to determine (1) that significant impacts are anticipated in that environmental area and therefore more detailed studies should be undertaken in the next stage of the analysis, or (2) that no significant impacts are anticipated, therefore additional studies are unnecessary.

At this stage of the EIA process, environmental areas which are expected to receive major impacts have been identified and environmental and engineering issues are integrated.

4.3 Assessing Project Impacts

The next level of analysis is a detailed assessment of the project engineering and significant environmental impacts identified in the previous stage of analysis. Detailed questions are asked about the project, such as, "Are the storage tank dikes designed to hold the total rainfall from a 25 year storm without discharge?" and, "What is the probability of an oil spill resulting from a tanker collision?" In addition detailed studies are undertaken in the areas of environmental concern. However before these studies can be undertaken a method must be selected for assessing impacts.

The methodology applied for assessing impacts depends first on the resources available. The most important considerations are: money, manpower, time, knowledge and computational facilities. EIAs frequently absorb about 0.1% of the capital cost of a project. By contrast, engineering studies may cost as much as 10%.* As previously mentioned, a team of specialists is needed to complete an EIA. Time must be available to complete the EIA before construction begins in order for the EIA to be most useful. Knowledge of the local environment and the availability of relevant data influence the assessment procedures to be utilized. The need for computational facilities varies with the nature of the proposed project, the environmental areas being assessed, and the assessment approach adopted.

In choosing a suitable method for assessing impacts, one should ask if the method is comprehensive, selective, mutually exclusive, objective, if it predicts interactions, and produces estimates of the confidence limits to be assigned to the predictions.* A comprehensive method will detect the full range of important elements and combinations of elements, revealing unsuspected effects as well as expected ones. A selective method focuses attention on major factors. A mutually exclusive method avoids double counting of

*Environmental Impact Assessment, Principles and Procedures, Scope 5 (2nd ed.), R.E. Munn ed., John Wiley & Sons New York, 1979.

effects that may occur because of the many interrelationships in the environment. An objective method minimizes the possibility that the predictions will automatically support the preconceived ideas of the assessor. Prediction methods should have a capability for identifying environmental interactions and estimating their magnitude. Finally, subjective approaches are common in many methods and can lead to useful impact predictions. However, in some cases statistical models are more appropriate. When statistical models are applied, a measure of uncertainty or confidence limits associated with the prediction are usually determined.

No one assessment method can satisfy all of the questions asked above. However, the assessor should ask the questions to be certain that the method he or she selects meets the EIA goals and to increase the assessor's awareness of the strengths and weaknesses of the selected method. Assessment methodology is discussed in more detail in Section 5.

4.4 The Environmental Report

An EIA is usually presented in an environmental report (ER). The environmental areas to be addressed in an ER depend upon the goals and scope of the EIA. However, there are some basis components of an environmental report that are usually considered regardless of the environmental disciplines included in the assessment or the goals of the EIA. A listing of the major components of an environmental report is found in Figure 4-1 and presented below:

- The proposed action or project is described. This description includes the purpose of the project, identifies the project sponsor, and presents the major elements of the project design.

- The existing conditions are described for the environmental areas expected to be impacted by project construction or operations.

- Changes in the existing conditions (impacts) that are expected to occur as a result of the project are presented.

- Mitigation measures that the project sponsor plans to implement are described. Mitigative measures that could be implemented but are not planned due to prohibitive costs or other factors are also discussed.

- Unavoidable adverse impacts that are expected to result if the project is implemented in spite of the mitigative measures are summarized.

230

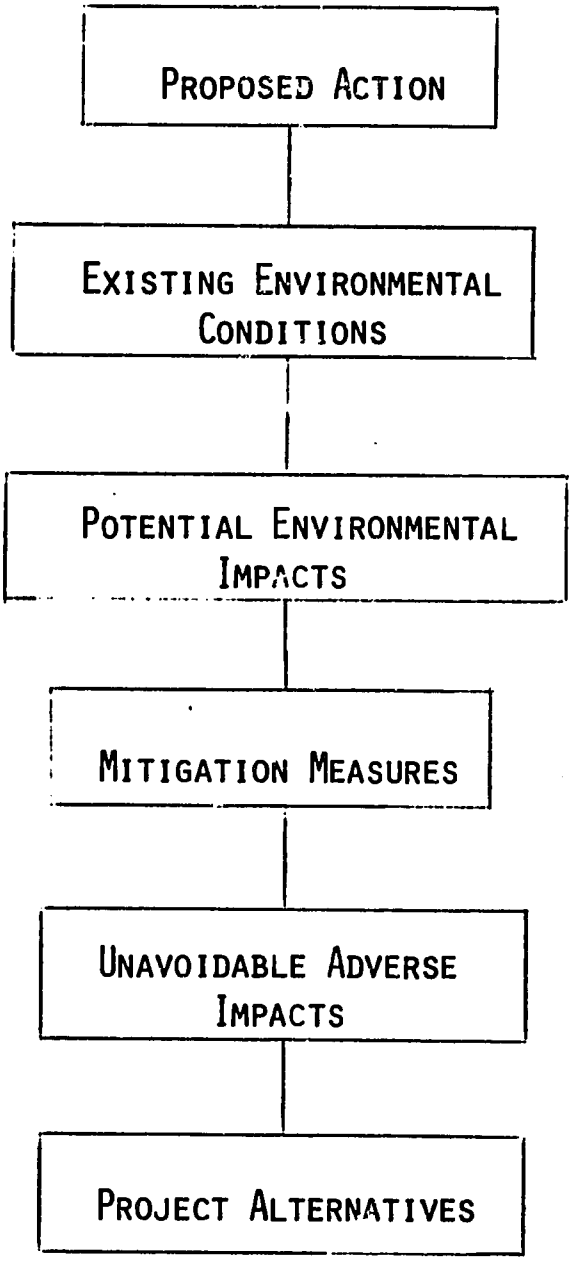


Figure 4-1 Major Components of an Environmental Report

231

Alternative locations and designs are discussed. Impacts associated with the alternatives are assessed and compared to the proposed action. The rationale for the selection of the proposed action is presented. The discussion of alternatives usually includes a "no action" or "no build" alternative.

If the goal of an EIA is primarily to compare project alternatives and select the best alternative, the sequence in which the major components of an ER are considered and presented may be altered as well as the emphasis placed on each major component. An outline for an ER that is designed to meet the primary goal of consideration of alternatives is presented in Figure 4-2.

232

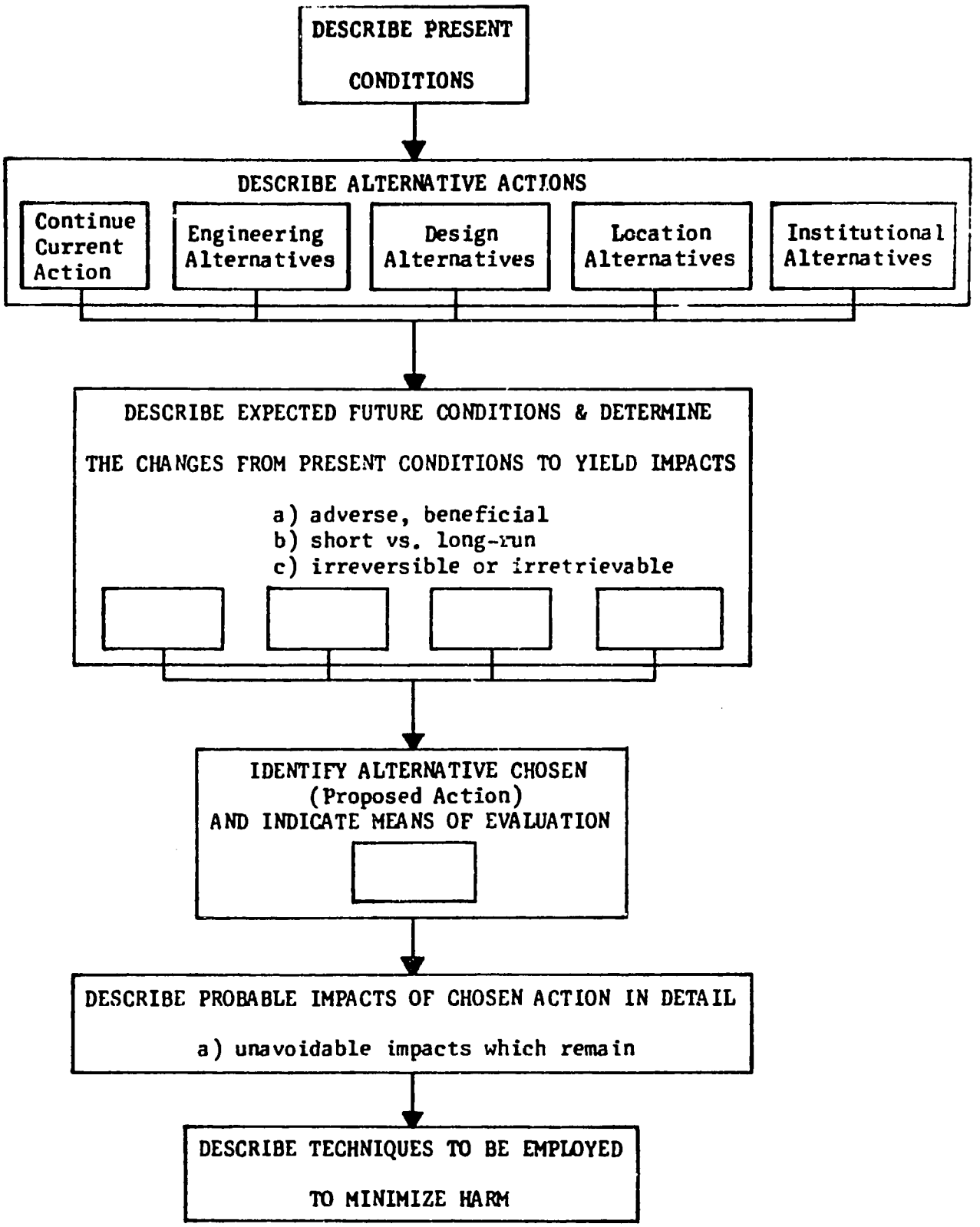


Figure 4-2 Major Components of an Environmental Report Primarily Designed to Assess Alternatives*

*Source: Environmental Impact Statements: Handbook for Writers and Reviewers, Lewis D. Hopkins, et.al., University of Illinois, August 1973

233

5. METHODOLOGY FOR ASSESSING IMPACTS

After the environmental areas to be subject to a detailed assessment have been determined, the environmental specialist selects a methodology for the assessment that is appropriate for his or her study area and that will provide answers to the relevant questions. A general methodology for impact assessment is presented in Figure 5-1.

5.1 Data Collection

The environmental specialist or assessor must collect data in order to describe existing environmental conditions for the region of the proposed project and project data related to his or her environmental specialty (see Figure 5-1). The baseline environmental data are needed in order to identify any existing problems and to provide a data base for impact predictions. It is important to document any existing problems, such as crop disease, to prevent unjust damage claims after operations begin. It is necessary to obtain a detailed description of the existing project and related data in order to identify impact areas and the extent of the impacts. For example, unless one is aware of the effectiveness of an oil-water separator one cannot evaluate the potential impacts of any effluent discharged from the separator.

Baseline environmental data may be collected from published literature, agency files, from others that have completed studies in the area, field surveys and/or monitoring programs. The collection method selected depends on the extent of the data required for subsequent analyses, appropriateness of existing data, and the severity and type of impacts anticipated.

Pertinent project data is usually collected from meetings with and the project files of the project sponsor or their design engineers.

5.2 Data Analysis

It is usually desirable to organize, summarize and manipulate the data collected into a meaningful format for decision making. The selected method for analysis may be verbal, graphic or statistical. For a verbal analysis, the data collected may simply be presented and then conclusions discussed. This analysis method relies almost completely on the expertise of the assessor.

Graphic representations are often useful for summarizing tables and suggesting trends. For example if dissolved oxygen levels in the receiving water are plotted against time in months, it may enable the reviewer to determine in which portion of the year changes in dissolved oxygen levels will be most critical to fish. A color-coded map of surrounding land uses may enable the project sponsor to locate a coal pile and crusher in an area so that the noise will not annoy sensitive land uses, such as schools.

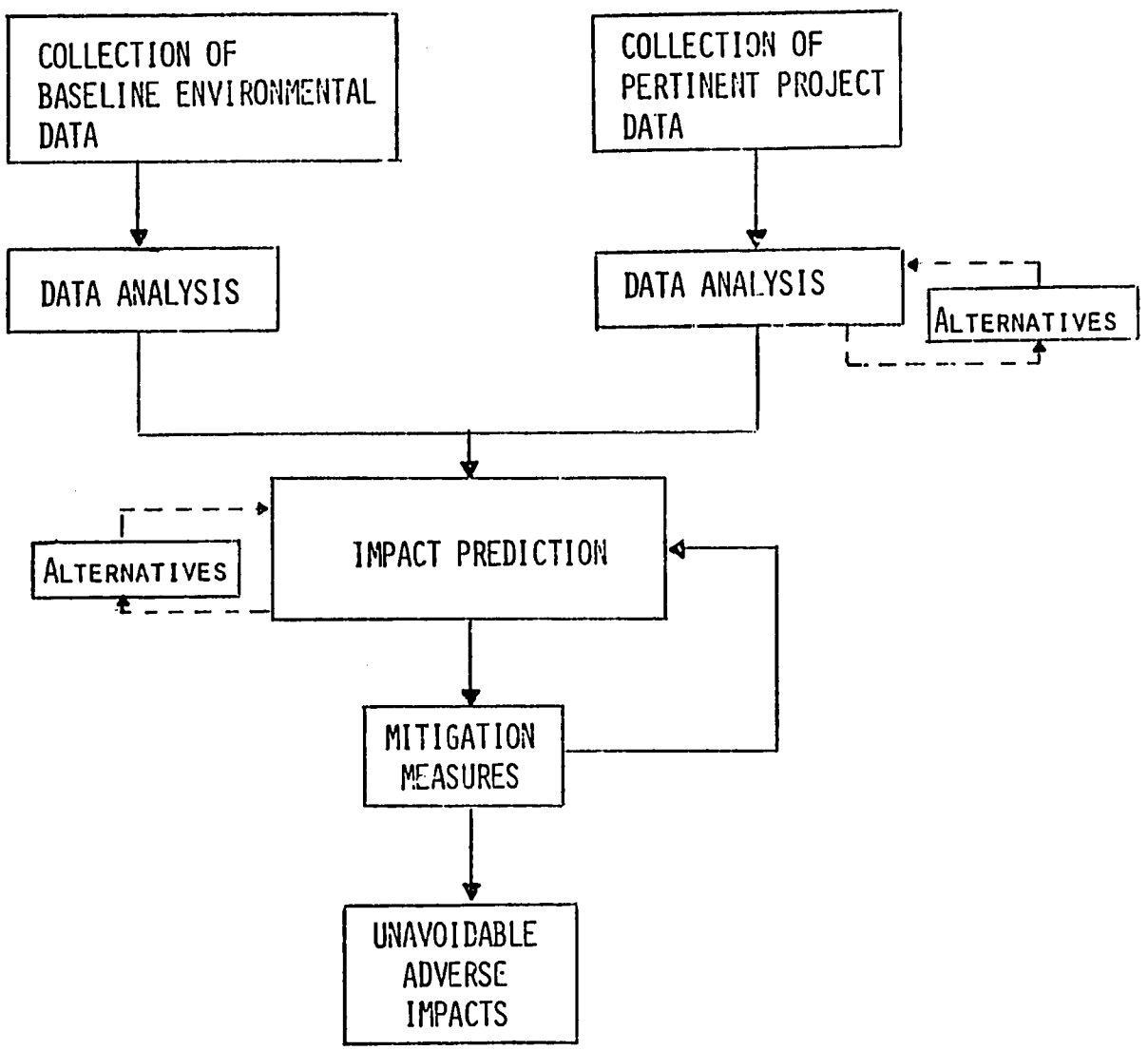


Figure 5-1 General Methodology for Impact Assessment

235

Statistical summaries of data are necessary in order to draw conclusions from large volumes of raw data that may be collected in field surveys or monitoring programs. It may also be necessary to analyze or statistically summarize a data base before it can be used for impact predictions.

5.3 Impact Prediction

Impacts may be identified by using checklists, matrices, flow diagrams, statistical analyses or computer simulation models. Checklists were previously discussed as a means for identifying environmental areas where environmental impacts are likely to occur. Checklists are simply comprehensive lists of environmental effects and impact indicators. The checklist is a more useful tool for initially identifying impact areas and summarizing the results of the data analysis than for actually predicting the impacts. Table 5-1 summarizes the environmental areas where impacts are expected to occur for a transportation project and during which stage of the project (planning, construction or operation) the impacts are expected. (The termination phase is not considered in this example).

A matrix is a more advanced extension of the checklist, but can be relatively simple or complex. The matrix can be two- or three-dimensional. Although there are different types of matrices, the standard format sets the various elements or parameters, hierarchically arranged, along one axis, and the project activities along the other axis. Figure 5-2 illustrates a two-dimensional matrix employed by the U.S. Geological Survey.

Flow diagrams are sometimes useful to identify cause and effect relationships. For example, a decrease in growth rate and size of commercial shellfish could be related to discharge of untreated sewage. The flow diagram permits the reviewer to visualize the relationship between the action and impact. This method is best suited to single-project assessments and is not recommended for large regional actions.

For a statistical analysis, the results of the analysis of the baseline data are compared with the results of the analysis of the project data to determine project impacts. For example, existing excess electric generating capacity in the project region may have been calculated in the baseline data analysis. Power needs for the proposed project may have been calculated in the project data analysis. By comparing the available capacity with the project needs one can determine if industries in surrounding cities will be impacted (due to an electric power shortage) by implementation of the proposed project. This method of analysis is probably the method used most frequently for the assessment of project impacts.

236

TABLE 5-1

AN EXAMPLE OF A CHECKLIST OF ENVIRONMENTAL IMPACTS RESULTING FROM A TRANSPORTATION PROJECT*

Environmental Area	Stage of Project in Which Impacts are Anticipated: Planning and Design	Construction	Operation
1. Noise Impacts		X	X
a. Public Health			
b. Land Use			
2. Air Quality Impacts		X	X
a. Public Health			
b. Land Use			
3. Water Quality Impacts		X	X
a. Ground Water			
(1) Flow and water table alteration			
(2) Interaction with surface drainage			
b. Surface Water			
(1) Shoreline and bottom alteration			
(2) Effects of filling and dredging			
(3) Drainage and flood characteristics			
c. Quality Aspects			
(1) Effect of effluent loadings			
(2) Implications of other actions such as:			
- disturbance of benthic layers			
- alteration of currents			
- changes in flow regime			
- saline intrusion in ground water			
(3) Land Use			
(4) Public Health			
4. Soil Erosion Impacts		X	X
a. Economic and Land Use			
b. Pollution and Siltation			
5. Ecologic Impacts		X	X
a. Flora			
b. Fauna (other than man)			

*Source: Department of Transportation, Synthesis for Action, Washington, D.C., April 1971.

237

TABLE 5-1 (Continued)

Environmental Area	Planning and Design	Construction	Operat
6. Economic Impacts			
a. Land Use	X	X	X
(1) In immediate area of project			
(2) In local jurisdiction served or traversed			
(3) In region			
b. Tax Base	X	X	X
(1) Loss through displacements			
(2) Gain through increased values			
c. Employment	X	X	X
(1) Access to existing opportunities			
(2) Creation of new jobs			
(3) Displacement from jobs			
d. Housing and Public Services	X	X	X
(1) Demand for new services			
(2) Alteration in existing services			
e. Income	X	X	X
f. Damage to economically valuable natural resources		X	X
7. Socio-Political Impacts			
a. Damage to, or use of		X	X
(1) Cultural resources			
(2) Scientific resources			
(3) Historic resources			
(4) Recreation areas			
b. Life styles and activities	X	X	X
(1) Increased mobility			
(2) Disruption of community			
c. Perception of cost/benefit by different cohesive groups	X	X	X
(1) Racial			
(2) Ethnic			
(3) Income class			
d. Personal Safety		X	X
8. Aesthetic and Visual Impacts		X	X
a. Scenic resources			
b. Urban design			
c. Noise			
d. Air Quality			
e. Water Quality			

"X" denotes an impact which could be positive as well as negative, depending on the circumstances.

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.

			II B b Industrial sites and buildings	II B d. Highways and bridges	II B. h. Transmission lines	II C a Blasting and drilling	II C b Surface excavation	II D 1 Mineral processing	II G. c. Trucking	II H c Emplacement of tailings	II I b Spills and leaks
I	A. 2. d.	Water quality					2/2	1/1		2/2	1/4
I	A. 3. a.	Atmospheric quality						2/3			
I	A. 4. b.	Erosion		2/2			1/1			2/2	
I	A. 4. c.	Deposition, Sedimentation		2/2			2/2			2/2	
I	B. 1. b.	Shrubs					1/1				
I	B. 1. c.	Grasses					1/1				
I	B. 1. f.	Aquatic Plants					2/2			2/3	1/4
I	B. 2. c.	Fish					2/2			2/2	1/4
I	C. 2. e.	Camping and hiking					2/4				
I	C. 3. a.	Scenic views and vistas	2/3	2/1	2/3		3/1		2/1	3/3	
I	C. 3. b.	Wilderness qualities	2/4	4/4	2/3	1/1	3/3	2/5	3/5	1/5	
I	C. 3. h.	Rare and unique species		2/5		5/10	2/4	5/10	5/10		
I	C. 4. b.	Health and safety							3/3		

The reduced matrix for a phosphate mining lease.

Figure 5-2 Sample Two-Dimensional Matrix*

* Source: A Procedure for Evaluating Environmental Impact, L. B. Leopold et. al., U.S. Geological Survey, Circular 645, 1971.

Best Available Document

Computer simulation models may be used to predict the extent and geographical areas of impact when a sufficient data base is available. These relatively sophisticated tools are most frequently utilized to predict air and water quality impacts. Using established computer modeling techniques one can predict which geographic areas are likely to receive the heaviest concentrations of an air pollutant. By predicting the concentration at a particular location one can evaluate the probability of effects on human health or crops in the geographic area.

5.4 Mitigation Measures

After potential impacts are identified and the magnitude of the impacts estimated, mitigation measures are considered. Mitigation measures are, of course, specific to the impact that one wishes to reduce. There may be several potential mitigation measures that could be applied to reduce an anticipated impact. The measure selected will usually depend upon a simplified cost/benefit analysis. That is, is the reduction in the anticipated impact (benefit) sufficient to justify the costs associated with the proposed measure? (This, again, involves a value judgment).

After the mitigation measures are selected by the environmental specialist and project sponsor it may be necessary to reassess the project impacts. For example, if a mitigation measure to be implemented reduces the power requirements of the project, it is then necessary to recalculate the impacts on surrounding industries.

Mitigation measures that were considered but not implemented are usually discussed in the environmental report so the reviewer is aware of the rationale for selection of the proposed measures.

5.5 Unavoidable Adverse Impacts

After the project impacts have been reassessed considering the mitigation measures selected, the remaining adverse impacts are traditionally labelled as unavoidable adverse impacts. These remaining impacts are usually summarized in a section of the environmental report for ease of reference by the project sponsor or other reviewer.

5.6 Alternatives

A critical goal of the EIA process that has not been emphasized in this section is the evaluation of project alternatives. Alternatives in project design and engineering are continually assessed and compared with the proposed action throughout the impact

240

assessment process. As shown in Figure 5-1 the consideration of alternatives is a vital part of the project data analysis and impact prediction steps. The details of a project may be continually changing as a result of the impact assessment process.

6. PRODUCTS OF AN EIA

The most tangible product of an environmental assessment is the environmental report. The value of other products of the EIA process depends on how well they satisfy the goals of the EIA.

If a goal of the EIA is to satisfy existing standards, then one product of the EIA is documentation, utilizing established methods, that the standards are satisfied. If a goal is to minimize disruption of the environment, the EIA permits the assessor to identify the environmental disruptions and avoid them or minimize them by implementing mitigative measures.

A goal common to almost all environmental assessments is the selection of the most desirable economic and environmental alternatives for the project's location, design, engineering and operations. If a siting study is performed, one or more recommended sites will be identified. If alternatives are evaluated throughout the EIA process, then at its completion the project sponsor will have a project that is designed in a desirable manner from an environmental as well as economic perspective.

Other products of an EIA might be documentation of existing problems in the project region or an inventory of sensitive areas and habitats of endangered species.

In conclusion, the savings in cost, time and overall efficiency may well justify undertaking an EIA, whether or not legislation requires it.

JANICE BAKER

Senior Program Manager

Professional Experience

Dr. Baker is responsible for the management of multidisciplinary projects at Environmental Research & Technology, Inc. (ERT). She has directed environmental impact assessment studies for major projects such as paper mills, power plants and chemical plants. Dr. Baker is currently managing a multidisciplinary study for a proposed paper mill in Minnesota. Her responsibilities include agency liaison, definition of environmental studies, preparation of the environmental report and permit application support,

Dr. Baker has also directed the preparation of a multidisciplinary environmental report for the expansion of a pulp and paper mill in the southeast; managed a multidisciplinary baseline study for a proposed chemical plant in the midwest; directed the preparation of a seven-volume environmental and engineering report for a pipeline project; Task manager in baseline evaluations for a proposed coal-fired power plant; worked on a site and transmission line route selection study for a proposed generating station; designed and managed ecological siting studies to meet Nuclear Regulatory Commission (NRC) Regulatory Guide 4.2 for a proposed nuclear-fueled power plant; designed and directed studies for a proposed hydroelectric project; prepared descriptions of existing conditions and potential impacts associated with the construction of an open pit copper mine and smelter, and designed field sampling program for two proposed oil refineries in New Jersey, analyzed the resulting data, and formulated descriptions of present conditions and impact assessments. Dr. Baker has also provided technical direction and review for numerous other EIA projects while at ERT. She has appeared at public meetings and public hearings and provided expert testimony.

Before joining ERT, Dr. Baker was a member of the faculty at Boston College. She completed her doctoral program in biology at New Mexico State University. Her research in entomology emphasized statistical techniques such as discriminant and cluster analysis for comparing morphological characteristics of populations, subspecies, and species, and their habitat requirements. Another research project completed by Dr. Baker involved the examination of anatomical changes occurring in irradiated and nonirradiated Sphaeralcea (globemallow) as a result of infestation by a spider mite. Historical and morphological changes were studied in the Sphaeralcea collected from the Nevada Test Site.

Education

Ph.D. (Biology; Minor: Experimental Statistics) New Mexico State University
M.S. (Biology) New Mexico Highlands University
B.A. (Zoology and Anthropology) Eastern New Mexico University

Memberships

American Society of Systematic Zoology
Ecological Society of America
Phi Kappa Phi
Sigma Xi

GF-12/79

JOHN R. WHITMAN

Director - International Environmental Management Institute

Professional Experience

Mr. Whitman is Development Manager and Director of the International Environmental Management Institute of ERT. Mr. Whitman is responsible for developing educational and training programs in management and technical areas to facilitate technology transfer and to strengthen environmental management and operations skills in the developing world. Mr. Whitman has been with ERT since June 1978.

Mr. Whitman conducts an annual two-week international Seminar on Principles of Environmental Management in Developing Countries, which, in 1979, included fifty-five participants from twenty-six countries. The seminar is designed to acquaint top-level decisionmakers in governments, industries, and international organizations with an integrated approach to environmental management. Government ministers, government agency and department heads, and representatives from industry comprise the group of participants.

Prior to joining ERT, Mr. Whitman was a consultant to the School and Society Programs division of Education Development Center, Inc., one of the world's largest non-profit educational research and development corporations with extensive experience in developing innovative programs for developing countries. There, Mr. Whitman designed a variety of educational programs dealing with issues such as reducing the socio-economic effects of earthquakes, reducing the economic hardship of increasing energy costs on the elderly, and involving large networks of volunteers in scientific research.

Mr. Whitman is founder of Strategic Environmental Planning, a private consulting group responsible for developing a major international environmental education program in cooperation with Unesco and United Nations Environment Program, and a worldwide oil spill reporting network for the U.S. Environmental Protection Agency.

Mr. Whitman served for seven years with the Smithsonian Institution National Museum of History and Technology, Museum of Natural History, and Center for Astrophysics, principally developing international environmental programs.

Mr. Whitman has served on a variety of international expert panel workshops dealing with issues such as oil spills, pollution monitoring, and environmental education.

Education

Ed.M.	Harvard University (Administration, Planning, and Social Policy)
A.B.	Boston University (Philosophy)

GF 1/80

244

ENVIRONMENTAL GUIDELINES AND THE POLICIES OF INTERNATIONAL FINANCIAL INSTITUTIONS

Agriculture

J. Clive Collins
Agricultural Advisor, Irrigated Field Crops
The World Bank

June 1980

International Environmental Management Institute
ENVIRONMENTAL RESEARCH & TECHNOLOGY, INC.
Concord, Massachusetts, USA

245

EXECUTIVE SUMMARY

After a brief description of the World Bank, its organization, sources of finance and operating methodology, the Bank's expansion of lending for Agriculture and Rural Development and shift of emphasis from production oriented to poverty alleviation oriented projects is described.

Against this background the growing awareness in the Bank for the importance of environmental aspects of development and the attitudes and constraints it faces in the developing world are discussed. After outlining some of the environmental factors which need to be taken into account in resource management and development planning in the agricultural and rural sector, a more detailed examination is made of typical lowland irrigation, upland area development and catchment protection and forest development projects using illustrations from actual projects to show what the Bank has been doing in this field to protect and improve the environment.

The Bank's demonstrated willingness to experiment with innovative approaches to the environmental problems and the magnitude of its involvement in the rural sector is stressed and its real practical achievements underlined together with its continuing future commitment to its environmental objectives.

246

ENVIRONMENTAL MANAGEMENT IN THE CONTEXT OF THE WORLD BANK'S LENDING FOR AGRICULTURE AND RURAL DEVELOPMENT PROJECTS

About the World Bank

The International Bank for Reconstruction and Development (IBRD), together with the International Monetary Fund, was founded in 1944 at the United Nations Monetary and Financial Conference at Bretton Woods. The development of IBRD and the International Development Association (IDA) and the way the two institutions operate are described in some detail in Annex I. The capital of the IRBD is provided by its member governments, which presently total 134, who contribute in proportion to their economic strength. Its capital subscription on June 30, 1979, was about US$37 billion. Its lending operations are financed in the world capital markets. Its loans are regulated by basic rules laid down in its charter and must be for productive purposes which will stimulate the economic growth of borrowing countries. The interest rate on its loans is related to its cost of borrowing and, at present, is about 8%.

IDA was established in 1960 to provide development assistance to the poorer developing countries, many of whom were unable to meet IBRD's strict credit-worthiness criteria and lending terms. Most of IDA's lending is financed by subscriptions from its more developed and industrialized members. The funds it provides are called credits to distinguish them from IBRD loans, and the terms are 50-year maturities with 10 years grace, free of interest but with an annual 0.75% service charge.

In the financial year ending June 30, 1979, IBRD made 142 loans to 44 countries for a total commitment of US$6,989.0 million, while 116 IDA credits to 43 countries totalled US$3,021.5 million. Of the combined total of US$10,010.5 million, the lending for agriculture and rural development comprised 25.2%.

The Expansion of Lending for Agriculture and Rural Development

The Bank's early lending for agriculture was oriented towards economic growth and took the form of agricultural credit for on-farm development -- generally benefiting larger and more progressive farmers -- and the provision of infrastructure -- roads, irrigation systems. While growth is necessary to generate savings for investment, create jobs and expand social and physical infrastructure to keep pace with expanding populations, there was a gradual realization that growth alone was not sufficient and an increasing concern over poverty alleviation. This problem was brought sharply into focus by a speech given by the Bank's President at the 1973 General Meeting in Nairobi, in which Mr. McNamara discussed the nature of the poverty problem, particularly as it affected rural areas,

247

suggested a strategy for dealing with it and outlined a plan to do so through the Bank's operations. While there has been a massive increase in the Bank's total lending during the past decade, there has been an even more dramatic increase in the proportion of that lending going to the poorest countries and in the proportion of lending for agriculture and rural development. With the change in emphasis towards the problem of helping the rural poor, the Bank set out its pollicy on Rural Development in a sector policy paper which defined Rural Development as a strategy designed to improve the economic and social life of a specific group of people -- the rural poor -- a group including small-scale farmers, tenants and the landless. The objectives of Rural Development included improved productivity, increased employment and thus higher incomes for target groups as well as minimum acceptable levels of food, shelter, education and health.

During the decade 1969-1978, the proportion of the Bank's lending to the 30 poorest countries (with 1977 per capita GNP below $295) plus Indonesia ($300) increased as follows:

	FY 68	FY 78
Combined IBRD/IDA	16%	33%
IBRD	10%	14%
IDA	63%	82%

Average annual lending for Agriculture and Rural Development doubled in terms of numbers of projects and quadrupled in amount between 1969/73 and 1974/78, and the average annual lending for Rural Development Projects quadrupled in terms of number of projects and increased tenfold in amount for the same periods.

	Annual Average FY 69 - 73	Annual Average FY 74 - 78	FY 78
Agriculture and Rural Development Projects			
Number of Projects	35	73	88
Total Amount US$ M	500	2,004	3,270
Rural Development Projects			
Number of Projects	10	42	49
Total Amount US$ M	109	1,062	1,728

248

In identifying, assisting to prepare and appraising Agriculture and Rural Development Projects for investment, the Bank is concerned that they are:

1) technically sound;
2) economically viable; and
3) socially beneficial.

Economic benefits accrue either through increased productivity or through arresting an ongoing decline in productivity as occurs, for example, in irrigated lands subject to increasing waterlogging and salinization. Social benefits accumulate through measures which target a significant proportion of such benefits towards increasing the incomes and improving the living standards of the rural poor. Such factors as traditional social structures and land tenure arrangements often necessitate that measures benefiting the poor (e.g. improved farming practices, better seeds, improved availability of inputs) equally benefit the larger and more affluent farmers too, so that, although the incomes of the poor increase in comparison with national average incomes, the gap between the large and small farmers within a project may remain or even widen. Furthermore, while projects can be designed to ensure a significant share of the benefits to small farmers in the community, it is often extremely difficult to directly benefit the landless -- often the poorest of the poor -- through increases in agricultural productivity. The Bank is acutely aware of this problem but, apart from seeking to generate increased opportunities for employment through the encouragement of adoption of labour-intensive techniques, it is a difficult exercise and we are still seeking solutions.

The Bank's Concern for Environmental Aspects of Development

With the upsurge of conern over the environment world-wide during the 1960s, the Bank appointed an Environmental Advisor in 1970 and, subsequently, established its Office of Environmental Affairs now numbering six professional staff. The office is responsible for reviewing and evaluating all investment projects from the standpoint of their potential effects on the environment, providing support and advice on environmental matters to Bank staff directly involved in the preparation, appraisal and supervision of projects and advising the Bank's management in the development of policy as it may pertain to environmental issues. The early work and lessons of the Bank's environmentalists are described in its publication "Environment and Development."

In the Agriculture and Rural Development field the Bank has concentrated, in the first place, on ensuring as far as possible, that activities under its projects will not adversely affect the environment and, where there is a risk of possible environmental harm, to include either specific remedial measures, or else provide for close monitoring of the situation in order that appropriate measures

249

may be promptly instituted if harmful effects materialize. Secondly, the Bank may include in a project measures aimed at remedying an already existing progressive deterioration in the environment, providing that they will ensure sustained and profitable production in the future. The report prepared by the appraisal mission, which subsequently is included in the documentation provided by the President to the Board for approval of a project, includes a section in which the environmental impact of the project is discussed. Specific assurances may be sought from a Borrower concerning actions to be taken to protect the environment, and these become part of the legal agreement between the Borrower and the Bank.

The costs of environmental protection components of projects generally are small in relation to the total investment, but the Bank encourages Governments of developing countries to assess the cumulative impact of their increasing development on the environment and to examine the need for more stringent standards affecting the design and execution of projects. As development accelerates, the proportional cost of environmental protection will increase. Recognizing a need for measure to protect the environment as a part of project implementation, the Bank seeks to identify the least cost solution consistent with meeting environmental needs.

Attitudes and Constraints in the Developing World

Here in the U.S.A., controversy over issues has led to polarization of attitudes towards, on the one extreme, the preservationists who oppose any development which may degrade the environment from the ecological, health or amenity standpoint and, on the other, the developers who believe economic growth is essential for the continued well-being of humanity and that environmental degradation is a concomitant cost we must be prepared to pay. Of course, there has to be a middle road, but adverse publicity given to, for example, the effects of indiscriminate pesticide use -- remember "Silent Spring?" -- the risks of atomic power generation, following the Three Mile Island power station failure and concern at the dumping of hazardous waste material brought to the forefront of public attention by the furor over the Love Canal, coupled with the public's image of "big business" as being hell-bent on profit regardless of the effects on the future, has progressively widened the gap.

The developing world is presently in a more fortunate position as far as attitudes to environmental management are concerned, but lack of resources, particularly finance and trained personnel to undertake environmental measures and monitor the situation, is often a severe limitation on what can be achieved. Consider, too, that while many or perhaps most governments recognize in principle the need to conserve resources and protect the environment, the political will to conserve for the future is always weaker than political pressure to develop and, thereby, alleviate existing widespread and often growing poverty. With limited resources it is little wonder that environmental management comes low down on the list of priorities.

250

Even given a willingness to address environmental problems and the allocation of resources to that end, other factors further constrain such efforts as they apply to Agriculture and Rural Development. Farmers the world over seek first to ensure that the basic human needs of their family -- food, clothing, shelter -- are provided and, having done so, then respond primarily to financial incentives. Growing legumes in rotation with cereals may be agronomically preferable to continuous cereals in the long term, but if continuous cereals give a greater financial reward in the short and medium-term, farmers will be slow to adopt the more desirable rotation until a significant yield decline through monocropping has become evident.

Agricultural production systems, much more so than industrial ones, are highly location specific. What works in one country or one part of a country may not work elsewhere. You just cannot take a modern western technology and use it in a developing country without an extended period of testing and adaptation under local conditions. This takes time and means that one usually cannot find an instant solution to an agricultural problem. In developing countries the most needy farmers are often found in areas where climatic and soil conditions are marginal. They survive because they have developed traditional farming systems which minimize the risk of a catastrophic crop failure. Such farmers are extremely conservative in their attitude toward new innovations and unwilling to adopt practices which may enable them to increase productivity in a good year, but increase their risk in a bad one. A number of small, scattered fields are much less efficient to cultivate than a single, consolidated holding but, where the rainfall pattern is highly variable, it offers a much better chance of getting a crop off some of the farm when rainfall is below average and some locations get insufficient amounts to carry the plants through to maturity.

In the developing world new measures in environmental management affecting agriculture must:

1) be clearly a worthwhile use of scarce resources and demonstrably so in order to convince those responsible for resource allocation;
2) have been thoroughly tested and shown to work under local conditions;
3) provide an adequate reward to the farmer in order to encourage adoption; and
4) not increase the exposure of the farmer in high-risk situations.

Environmental Factors in Development Planning

In order to ensure that the objectives of an agriculture or rural development project are suited to the local conditions, to identify possible adverse environmental consequences from the proposed

251

development and avoid the occurrence of unforseen problems, adequat studies of the natural resources to be developed followed by proper land suitability evaluation, is essential. Such studies should include, wherever pertinent, climate (particularly rainfall distribution), topography, soils and underlying strata, hydrology (both surface and groundwater), water quality, vegetation, wild lif existing and alternative future farming systems and other land uses infrastructure and the health and social and cultural attributes of the local people. The studies should not only provide an assessmen of the impact of planned development on the environment but also provide for the preservation of irreplaceable genetic resources. Because of the dynamic nature of the environment, the evaluation mu identify potentials for change in conditions both under existing ar possible future systems of land use and the linkages and interactic whereby change in one characteristic may in turn result in changes other related characteristics.

A number of national and international development agencies, including the Bank as well as individuals from developed and developing countries involved in land use planning, have in recent years been concerned over the wide variation in both the methodolo and adequacy of land suitability evaluation as a preliminary to agricultural development. In 1977 an Expert Consultation was held FAO Rome on Land Evaluation Standards for Rainfed Agriculture,(1) and in February 1979 a similar consultation was held on Land Evaluation Criteria for Irrigation. Bank agricultural staff participated actively in both. Last year's consultation endorsed t use of economic principles as a basis for determining the suitabili of lands for irrigation and recommended that FAO prepare a guideli on the principles and procedures involved for the use and guidance developing countries. The methodology will closely follow that developed over the past two decades by the U.S. Bureau of Reclamati though some simplification will be sought to facilitate its adopti by developing countries. This will be a big step forward leading, is hoped, not only to a more uniform approach to land suitability classification but also to a much more complete examination of the factors involved than is undertaken in many countries at the prese time. It will undoubtedly contribute to a better appreciation of t impact of development on the environment and enable the timely identification of possible adverse effects in order that adequate a appropriate safeguards may be incorporated in project designs. Th Bank is enthusiastically supporting

(1) FAO World Resources Reports No. 49.

this development in project planning and is encouraging the introduction of a more broadly-based land classification methodology, even in advance of publication of the FAO guideline, by offering advice to those engaged in project planning and providing reference to useful documentation already available from USBR and elsewhere.

A basic requirement of the recommended methodology, supported by the Bank, is that the evaluation of land as suitable for agricultural development must be on the basis of sustainable production capable of generating an adequate livelihood for the farmer and his family. This requiement for sustainable productivity is wholly consistent with environmental objectives aimed at avoiding environmental degradation though it would not, for example, rule out an extremely long recuperative fallow period between exhaustive cropping periods (shifting cultivation) where such a system is agronomically sound and providing that land availability is adequate to permit the extended fallow necessary to ensure long-term maintenance of fertility.

Environmental Problems Associated with Particular Kinds of Agriculture and Rural Development Projects

This is perhaps a convenient point to look at some typical components of projects located in differing environmental situations and consider the kinds of problems which may be encountered. I will use experiences from particular Bank projects where appropriate as illustrations.

A. Lowland Irrigation Projects

Typically such a project is situated in a rather broad, flat, river valley or a coastal plain. Where topography is relatively flat and soils are moderately fine textured leading to slow infiltration rates, irrigation will probably be by surface basin or furrow application. Irregular topography or coarse-textured soils will necessitate sprinkler application systems, while drip irrigation is limited to certain special crops in situations where water supply is often limiting.

In designing storage reservoirs and distribution systems consideration must be given to their effects on wildlife habitat and on seasonal migratory movements in some countries. It may be necessary to bridge large canals at intervals to avoid obstructing migration routes. Deforestation of catchment areas may result in severe erosion and rapid siltation of the system, and planting of protective forests may be a highly economic proposition in terms of the extended reservoir life. However, over-reforestation of catchments in Britain has seriously depleted inflows to reservoirs in some instances. Manmade lakes with attractively planted protection forests on surrounding slopes have enormous amenity potential if they are not too distant from urban centers and, in evaluating reservoir development, their amenity value should not be overlooked.

253

Farming systems in irrigation projects can cover a wide range but, perhaps, typically involve either rice monocropping or summer rice/winter wheat on heavier textured and rather poorly-drained soils and, when better drainage precludes rice production, a rotation of alternating food crops (wheat) and cash crops (cotton). Few situations support two full crops per year over the entire farm and cropping intensity is more typically about 130% -- say, half the farm in a winter food crop and about 80% planted to cash crops in summer. Fertilizer use in developing countries seldom approaches the levels used in developed countries. Excessive leaching of nutrients into the drainage system leading to excessive plant growth in downstream bodies of water and problems of subsequent oxygen depletion when the growth later dies and begins to decay does not present a problem as a rule.

A more significant problem in developing countries at the present time is the rapidly increasing, often indiscriminate and generally uncontrolled use of pesticides and other agrichemicals. This is particularly the case in irrigation projects where the comparatively high and relatively assured yields make the use of cash inputs, such as pesticides, attractive and where intensive cropping systems and concentration often on a single crop, such as cotton, is conducive to a high incidence of serious pests. Experience over the past decade in the USA and elsewhere has clearly demonstrated that more frequent applications of a wider variety of highly toxic materials merely leads to a more rapid buildup of resistance and a vicious spiral of increasing costs and decreasing effectiveness. This realization has led to the development of an entirely new concept of pest management in which the system of production is modified to keep pest infestations to an acceptable level and permit continued profitable production using prudent minimal insecticide applications, as opposed to the futile efforts to eliminate the pests completely under the earlier system of pest control. The parallel risk of building up resistance to pesticides in the insect vectors of serious human diseases such as malaria through the widespread contamination of the environment with agricultural pesticides is also reduced by modern pest management techniques.

When irrigation water is applied to a crop, a percentage percolates below the rootzone and is lost. In order to ensure sufficient water to meet the needs of the crop over the whole field, some deep percolation losses are bound to occur due to variations in rate of downward water movement from place to place in the field. Though efficiently operated sprinkler systems may use less water than surface application systems, they will still suffer deep percolation losses. The water applied also contains dissolved salts and, as the crop takes up water from the soil, the salts are left behind and accumulate eventually reaching harmful levels which periodically require removal by leaching downwards by a high application of water. Unless drainage of the soil and lower horizons is completely free, these water movements lead to an accumulation of water and salts which, over time, lead to water logging, salinization and other

254

harmful chemical and physical effects. It is essential that, in assessing the suitability of lands for irrigation, a proper diagnosis and prognosis of such effects are undertaken in order that, where necessary, provision for drainage may be made. Where water logging and salinity have already developed, the installation of necessary drainage has to be accompanied by reclamation of the land by leaching out of excess salts. Meanwhile significant reductions in crop yields and possible crop failures may result. The loss is not borne by the designer who failed to install drainage in the first instance but by the unfortunate farmer and his family.

An example of this kind of problem has occurred in Egypt, where the agricultural lands bordering the Nile had traditionally been dependent for crop production on annual inundations by flood waters mainly arising from seasonal rainfall in Ethiopia. These floods spread over the lands adjacent to the river and, as they receded, crops were planted and reached maturity on the residual soil moisture. In order to enable longer season cotton crops to be grown in the Nile Delta, a series of barrages were built, from 1890 onwards, to raise the water level and to provide upstream storage to augment low flows and permit perennial irrigation. Most of Upper Egypt remained under the traditional flood irrigation, however, until work began on the Aswan High Dam, which by reducing peak flows prevented flooding of the basins downstream, necessitating their conversion to perennial irrigation during the 1960s.

With the increasing use of water under the year-round irrigation regime, a rise in the level of groundwater occurred resulting in waterlogging. Furthermore, in the absence of seasonal flooding, which in the past had leached accumulated salts from the root zone, increasing soil salinity became a problem. In order to continue crop production, the provision of drainage is essential in this situation, and it is estimated that some 4.5 million acres, about 2/3 of Egypt's cultivated land, will need to be drained. Since 1970 the Bank has financed four projects to assist in this respect. The projects will together provide essential drainage for some 2.8 million acres of cultivated land and have a major impact in correcting declining production due to waterlogging and salinity. In irrigation projects being prepared for future Bank financing, the Bank stresses the need for a careful examination of the soils drainage characteristics during project preparation and, where a need for drainage is indicated, provision for its installation included in the project.

Health is another important and environmentally-related aspect of irrigation projects. Again, Bank experience in Egypt where the water-associated parasitic disease, Bilharzia (Schistosomiasis) has been a scourge since Pharaonic times is of interest. Under three of the Drainage Projects, the Bank has made provision for assisting in financing equipment and materials for a major program to drastically reduce transmission of the parasite through both treatment of infected people and through the eradication of the water snail alternate host in canals and drains by molluscicide sprays (Annex 2.b). In the First

255

Upper Egypt Drainage Project, the only one in which the Bilharzia component has been operating for a sufficient time to have a significant impact is disease incidence, the number of people infected has been reduced by about 50%.

Unlike the Egypt projects where an existing infestation of Bilharzia is being attacked, the Rahad Irrigation Project in the Sudan is in an area which was previously used only for grazing and limited rainfed cereal production, and no snail-infested bodies of water existed. However, across the Blue Nile the Gezira Project has a Bilharzia infestation, and there is a considerable likelihood of the disease spreading into the Rahad area as it is developed. For this reason, the Bank provided for the project layout to keep settlement villages as far as possible away from canals and drains and to provide uncontaminated water sources for domestic use. By this means, contact with infested water should be kept to a minimum, and this will facilitate control measures when the canals now being built become infested with the snail hosts of the disease.

Another irrigation project of interest is the Seyhan Project in the Adana Plain in Turkey. An IDA credit of US$20 million in 1963 and a further Bank loan and IDA credit of US$12 million each assisted in financing the first two stages of irrigation development comprising irrigation and drainage works serving about 100,000 ha. This land had been a malarious swamp, but the use of DDT for mosquito control during the 1950s eliminated malaria, so opening a potentially, highly fertile area for development. The initial promise has been fulfilled, and cotton production has been extremely successful and profitable, resulting in a most marked change in the economy of the region. However, a resurgence of malaria in the region since 1970 coincident with the expansion of the irrigated area under the project led to criticism that the project was responsible. The Bank has employed an expert to examine the situation. That it is serious there is no doubt. The total number of malaria cases in the region has increased from less than 25 per year from 1961-1969 to 70,000 cases in 1977. What went wrong? In 1964 a WHO report noted an increase in the mosquito vector and warned that this coupled with an annual influx of malaria-infected migrant workers presented a significant risk. This was before any new irrigation development in the area had been completed. Unfortunately, too, the increase in mosquito vectors coincided with cutbacks in mosquito-control efforts as interest declined after a decade free of malaria -- a state of affairs which has come about in many countries at about the same time. Resistance to insecticides in the vector mosquito was another factor -- DDT was replaced in the late 1950s by BHC, then by Dieldrin which, in turn, had to be replaced by Malathion after 1966. It would seem that the rapid build up of resistence to insecticides in the mosquito vector, together with an increasing number of migrant workers from malaria-infected areas, are the main causes of the massive outbreak in Adana. The expansion of irrigation per se is probably not a major cause -- the malaria is more prevalent in poorly-drained urban areas

256

harmful chemical and physical effects. It is essential that, in assessing the suitability of lands for irrigation, a proper diagnosis and prognosis of such effects are undertaken in order that, where necessary, provision for drainage may be made. Where water logging and salinity have already developed, the installation of necessary drainage has to be accompanied by reclamation of the land by leaching out of excess salts. Meanwhile significant reductions in crop yields and possible crop failures may result. The loss is not borne by the designer who failed to install drainage in the first instance but by the unfortunate farmer and his family.

An example of this kind of problem has occurred in Egypt, where the agricultural lands bordering the Nile had traditionally been dependent for crop production on annual inundations by flood waters mainly arising from seasonal rainfall in Ethiopia. These floods spread over the lands adjacent to the river and, as they receded, crops were planted and reached maturity on the residual soil moisture. In order to enable longer season cotton crops to be grown in the Nile Delta, a series of barrages were built, from 1890 onwards, to raise the water level and to provide upstream storage to augment low flows and permit perennial irrigation. Most of Upper Egypt remained under the traditional flood irrigation, however, until work began on the Aswan High Dam, which by reducing peak flows prevented flooding of the basins downstream, necessitating their conversion to perennial irrigation during the 1960s.

With the increasing use of water under the year-round irrigation regime, a rise in the level of groundwater occurred resulting in waterlogging. Furthermore, in the absence of seasonal flooding, which in the past had leached accumulated salts from the root zone, increasing soil salinity became a problem. In order to continue crop production, the provision of drainage is essential in this situation, and it is estimated that some 4.5 million acres, about 2/3 of Egypt's cultivated land, will need to be drained. Since 1970 the Bank has financed four projects to assist in this respect. The projects will together provide essential drainage for some 2.8 million acres of cultivated land and have a major impact in correcting declining production due to waterlogging and salinity. In irrigation projects being prepared for future Bank financing, the Bank stresses the need for a careful examination of the soils drainage characteristics during project preparation and, where a need for drainage is indicated, provision for its installation included in the project.

Health is another important and environmentally-related aspect of irrigation projects. Again, Bank experience in Egypt where the water-associated parasitic disease, Bilharzia (Schistosomiasis) has been a scourge since Pharaonic times is of interest. Under three of the Drainage Projects, the Bank has made provision for assisting in financing equipment and materials for a major program to drastically reduce transmission of the parasite through both treatment of infected people and through the eradication of the water snail alternate host in canals and drains by molluscicide sprays (Annex 2.b). In the First

257

Upper Egypt Drainage Project, the only one in which the Bilharzia component has been operating for a sufficient time to have a significant impact is disease incidence, the number of people infected has been reduced by about 50%.

Unlike the Egypt projects where an existing infestation of Bilharzia is being attacked, the Rahad Irrigation Project in the Sudan is in an area which was previously used only for grazing and limited rainfed cereal production, and no snail-infested bodies of water existed. However, across the Blue Nile the Gezira Project has a Bilharzia infestation, and there is a considerable likelihood of the disease spreading into the Rahad area as it is developed. For this reason, the Bank provided for the project layout to keep settlement villages as far as possible away from canals and drains and to provide uncontaminated water sources for domestic use. By this means, contact with infested water should be kept to a minimum, and this will facilitate control measures when the canals now being built become infested with the snail hosts of the disease.

Another irrigation project of interest is the Seyhan Project in the Adana Plain in Turkey. An IDA credit of US$20 million in 1963 and a further Bank loan and IDA credit of US$12 million each assisted in financing the first two stages of irrigation development comprising irrigation and drainage works serving about 100,000 ha. This land had been a malarious swamp, but the use of DDT for mosquito control during the 1950s eliminated malaria, so opening a potentially, highly fertile area for development. The initial promise has been fulfilled, and cotton production has been extremely successful and profitable, resulting in a most marked change in the economy of the region. However, a resurgence of malaria in the region since 1970 coincident with the expansion of the irrigated area under the project led to criticism that the project was responsible. The Bank has employed an expert to examine the situation. That it is serious there is no doubt. The total number of malaria cases in the region has increased from less than 25 per year from 1961-1969 to 70,000 cases in 1977. What went wrong? In 1964 a WHO report noted an increase in the mosquito vector and warned that this coupled with an annual influx of malaria-infected migrant workers presented a significant risk. This was before any new irrigation development in the area had been completed. Unfortunately, too, the increase in mosquito vectors coincided with cutbacks in mosquito-control efforts as interest declined after a decade free of malaria -- a state of affairs which has come about in many countries at about the same time. Resistance to insecticides in the vector mosquito was another factor -- DDT was replaced in the late 1950s by BHC, then by Dieldrin which, in turn, had to be replaced by Malathion after 1966. It would seem that the rapid build up of resistence to insecticides in the mosquito vector, together with an increasing number of migrant workers from malaria-infected areas, are the main causes of the massive outbreak in Adana. The expansion of irrigation per se is probably not a major cause -- the malaria is more prevalent in poorly-drained urban areas

258

than in the rural villages in the irrigation scheme. There are, of course, other contributing causes -- mosquito breeding in culverts and syphons and undrained borrow areas in the scheme (not by any means unusual inadequacies in such engineering works), an increasingly heavy use of insecticides on the cotton crop to overcome resistance build up in pests, which has contributed to the rapid resistance build-up in the mosquitos, and the declining government control program in the absence of significant malaria cases, are examples. Could and should the problem have been foreseen -- the chances are that in similar situations it most often would not be. It is a good example of the sorts of surprises the environment has in store -- and an example, too, of the willingness of environmentalists to blame the developer when something happens.

B. Upland Area Development Projects

Upland projects are located in much more variable topography. Crop production is usually less intensive because rainfall often limits the farmer to one crop per year. In this respect, such projects present less risk of harm to the environment from such features as the use of agrichemicals. However, many areas selected for such projects have a much more delicately balanced ecology, and so special care is necessary in their design to foresee and avoid possible harmful effects. In particular, cultivation of sloping lands can, without proper safeguards, lead to erosion even in areas of low rainfall; the overgrazing of pasture lands, particularly those adjacent to stock-watering points can lead to serious problems, and the influx of new settler families can raise problems of health and waste disposal as well as a risk of destruction of vegetative cover for domestic fuel, unless provision for this need is made.

The Lilongwe Project in Malawi is well known, and its effects have been extensively studied both from social and environmental aspects. Though the lands are only gently indulating and the soils range from sandy loam to clay, the likelihood of an erosion problem under the planned more-intensive farming system was recognized. The three phases of the project which have been partially financed by IDA credits in 1968, 1971 and 1975, have each included specific provision for erosion control through the construction of drainage channels, contour bunds where necessary and strip-cropping of the sloping lands.

In northeast Brazil, the Alto Turi Settlement Project, financed by the Bank in 1972, was aimed at controlling the massive migration from the drought areas of the northeast and rapid destruction of the forest under a system of slash and burn shifting cultivation. Slow implementation associated with severe cost overruns has unfortunately limited project impact. However, the concept which attempts to regulate settlement and provide settlers with low-cost assistance to develop stable livestock-based production systems as an alternative to

259

shifting cultivation was worth testing on a project scale. The opening-up of somewhat more fertile lands elsewhere in Brazil for settlement has taken some of the pressure off these areas of extremely poor soils, but the problem remains of finding agricultural systems which can sustain production on them as settlement of the Amazon forest lands continues.

The Bank has not subsequently financed any further development projects in the Amazon Region of Brazil, but the possibility that it may do so in the future and its involvement in the massive Transmigration Program in Indonesia has led to considerable discussion within the Bank on the measures needed to ensure that exploitation of these fragile environments is suitably controlled. These areas are characterized by an extremely variable agricultural resource base. Rainfall can range from adequate year-round to a dry season as long as six or seven months, which imposes severe limitations on the kinds of crops which can be grown without irrigation. Most soils are low in fertility, the bulk of the nutrients needed for plant growth being in the forest cover and decomposing litter from which they are recycled in a highly efficient manner by the root systems of the indigenous plant community. Toxic levels of aluminum associated with high levels of soil acidity are common, as are deficiencies of important elements such as phosphorous, magnesium, calcium, zinc and sulphur. While these soils' limitations are in general correctable, to do so requires a high level of land management, and the financial rewards may be negligible. Soil physical characteristics, particularly the tendency to compaction following forest clearing and poor water-holding capacity, which can exacerbate the effects of the dry season, are also important. It is, therefore, essential that development is preceded by careful soil and land suitability characterization so as to ensure, as far as possible, that only those soils which have the potential to support sustained profitable agricultural production are developed.

The selection of appropriate crops and production systems for the development of these difficult environments is also very important. A recent conference on Amazon Agriculture and Land Use Development at the International Center for Research in Tropical Agriculture in Colombia and visits to research centers in the Brazilian Amazon indicated that, while some interesting and promising lines of research are being studied---particularly with regard to tree crops--it would be premature to use them as a basis for large-scale development until they have been more adequately tested. The highly variable conditions also make it impossible to transfer results from one area to another with any degree of reliability, so that local testing of new crops and production techniques is an important preliminary to their commercial introduction.

It would seem expedient to proceed very cautiously with agricultural development in these tropical forest environments in view of the lack of adequately proven technology and the worldwide concern over the cost of destroying the natural forest lands in terms of land degradataion, loss of genetic resources, possible adverse climate

260

changes which may result, and the severe privation and sometimes decimation which has sometimes faced indigenous tribal people as a result of development activities within their traditional lands.

C. Forest Development and Catchment Protection Projects

Lands selected for forestry development are usually those on which the limitations are too severe to permit other forms of profitable agricultural production. In addition, planting of trees and construction of contour bunds, drainage channels and checkdams in gulleys are the most common methods of controlling erosion on steeper slopes, slowing run-off and reducing siltation of streams and reservoirs. The Bank's involvement with forestry projects and project components has developed from the provision of infrastructure -- access roads, sawmills, equipment -- for the exploition of existing forest resources to an approach which emphasizes the need to sustain forest productivity through controlled logging, regeneration and replanting. The destruction of forests, particularly around areas of dense population, to provide building materials and fuel is also a matter of concern, and means of meeting these needs by planting of suitable tree species are being tested and included as project components. Under conditions of low rainfall and low fertility, however, the amount of land necessary under tree plantings to meet a family's minimum needs for fuel can be considerable and, in many places, the pressure on the land to produce food is so great that there is insufficient to grow fuel wood. Furthermore, under fairly adverse conditions the cost of establishing and maintaining a fuel wood plantation can be significant and, even if the local people are able to provide free labour -- in addition to meeting the existing demands for labour, particularly at peak seasons -- and if the benefits are such that they are willing to do so, the other costs may make fuel wood prohibitively expensive for a low-income family unless heavily subsidized.

As an illustration of the kind of project that the Bank is now considering, the Kandi Watershed and Area Development in India is a good example. It is intended as a pilot project for a comprehensive attempt to tackle the problem of reversing the massive ecological degradation in the Himalaya foothills. Besides flood protection works, irrigation development and on-farm works in the agricultural areas below the foothills, the project includes provisions for soil conservation and revegetation in the upper catchment of five typical watersheds. To repair the ravages of erosion will require the building of small stone or gabion checkdam structures, drops and debris basins in gullies, together with reforestation and grass planting in non-gulley areas. Establishment of the newly-planted vegetation will necessitate local livestock being kept from grazing the treated areas for several years, and it will be necessary to compensate landowners for loss of grazing revenues. By choosing suitable fodder grass, timber and fuel wood tree species and locally adapted plants with other economic uses, it should prove possible to greatly increase productivity of the hills in the longer-term, as the

261

vegetative growth increases the water rentention of the soils. At a cost of about $350-$400 equivalent per ha, such a program should prove economically viable on the basis of fairly conservative assumptions of future production.

Another example is the Northern Rural Development Project in Thailand. The project area comprises rolling terrain below 500 m elevation, extensively used for shifting cultivation by ethnic Thais who live in the lowlands, and the more mountainous highlands above 500 m, where only valley-bottom land and foot slopes comprising 20% of the area are suitable for cultivation by the farmers, among whom hill tribes predominate. At the lower elevations, the agricultural development component will include erosion control works -- essentially contour bunds. With improved cultivation, it is anticipated that farmers will be able to move away from shifting agriculture to sustained cropping. As a result, they will no longer be able to obtain timber and fuel from clearing of forest fallow and, under the project, the farmers will be encouraged to plant village wood lots. In the highland area, the cultivators would be assisted in the construction of bench terraces for rainfed annual crops and coffee production to replace the present shifting agriculture. In addition, village wood lots would be planted, and rehabilitation of the forests would be initiated with planting of pine and broadleaf seedlings on land no longer needed for shifting cultivation. The project activities would take place at various sites comprising some 2% of the upland and 3% of the highland area of norther Thailand. Thus, if successful, it could lead to widespread replication of the essentially low-cost technologies.

The Bank's Future Role in Environmental Management

Earlier I spoke of the Bank's concern for environmental aspects of development, and I hope the illustrations I have given have demonstrated how this concern has been increasingly translated into actions to sustain and improve the habitat where development projects are being undertaken. I hope that my illustrations have also demonstrated the Bank's willingness to experiment with new and innovative approaches where these are in the interests of the target groups we are trying to assist, and of our Borrowers.

During 1979, the Executive Directors of the Bank reviewed the environmental policies and practices of the Bank, and gave their strong endorsement to the continuation of the policy that seeks in the Bank's project work, to adapt standards of environmental protection and control to the circumstances of the project and the country, and to incorporate in its projects all appropriate environmental and health measures.

262

In the future, the Bank is determined to make greater efforts to undertake environmental "post-audits" of selected projects to determine the accuracy of ecological predictions, the efficacy of prescribed control measures, and the adequacy of its supervision over the environmental aspects of projects being financed. Such information, it was noted, is important to the improvement of the quality of the Bank's work, as some environmental problems may not appear for years after a project has been in operation.

In addition, the Bank will continue its attempts to persuade other lending institutions especially development finance institutions, many of which currently give less rigourous consideration to the environmental consequences of proposed investments - to harmonize their policies and treatment of environmental issues.

The Bank's efforts to promote national environmental programs and the identification of environmental project will also be expanded, especially in those developing countries whose environmental and renewable resources may have deteriorated to such an extent that remedial action is urgently required.

But attention will also be directed to those countries where the environment has not, as yet, suffered greatly from mismanagement. The growing realization of the part of developing country governments that a relatively small investment in prevention at an early stage is usually far less expensive, as well as more effective, than subsequent remedial actions that are certain to become necessary later on, has gone far in making this aspect of the Bank's work more welcome in recent years. Experience has demonstrated that it is possible to incorporate suitable environmental and health protection measures into development projects, and to do so at a cost between 0% and 3% - that is both small and acceptable to the borrower and developing country governments.

Measures to improve the management of our environment are sometimes expensive in terms of scarce financial and other resources. Unfortunately, economists are still arguing over the appropriate methodology for ranking environmental activities and alternatives in order of priority and cost/benefit. Where benefits cannot be easily valued, it may be difficult to persuade planners to allocate the resources necesary.

On the other hand, where areas of outstanding beauty or unusual interest are being protected and developed, the potential for future income and foreign-exchange generation from tourism may be such that other sources of investment than Bank funds should be easily obtainable and, in such instances, it may be preferable to retain scarce Bank finances for likely less profitable, though still economically viable, investment opportunities. Those who criticize the Bank for being over-conservative might remember that the Bank has to raise its finances on the world's capital markets and to continue

263

to do so effectively has to be seen to be a soundly managed and highly credit-worthy financial institution. Similarly, IDA depends for its resources on contributions from the more affluent member countries, and the wise and efficient use of those resources by management is an important factor in ensuring their continued replenishment.

Compared to industrial production, agriculture is a high-risk business, exposed as it is to all the uncertainties which the environment holds in store. Furthermore, accurate measurements of achievement are notoriously difficult. Our projects now almost always include provision for monitoring of progress and evaluation of results, but to obtain reliable results from sampling of a highly variable population is expensive, and we have to restrain our desires for information to what our Borrowers can afford and consider worth the investment of resources. Successful agricultural development must manage the environment in such as way as to ensure, as far as possible, sustained productivity on which the successful provision of human needs and improvement in rural standards of living of the rural poor of the developing world must depend. The Bank can never hope for 100% success in such an uncertain endeavour. Nevertheless, I suggest that our achievements so far have been impressive and, together with our efforts to introduce innovations on a broad-scale, compare favourably with those of the Bank's critics. With the prospect of a further expansion of agriculture and rural development in the 80s, it is evident that environmental management will be a key feature in the Bank's future strategy which, wisely applied, will benefit not only the direct project participants and the peoples of the countries concerned but the world at large.

264

ANNEX I

THE WORLD BANK: BACKGROUND(1)

Along with the International Monetary Fund (IMF), the International Bank for Reconstruction and Development (IBRD or World Bank) was founded in 1944 at the United Nations Monetary and Financial Conference of 44 governments at Bretton Woods, New Hampshire, USA. These were established as complementary, international finance institutions to meet the needs of international cooperative agreements to deal with monetary and finanacial problems. They are intended to provide the machinery that would enable nations to work together towards world prosperity, thereby aiding political stability and fostering peace among nations.

Although the institutions have the same joint objective, their roles differ. The IMF's main concern is with monetary affairs, and IBRD's with economic development. The main activities of the Fund -- the promotion of international monetary cooperation, the encouragement of expansion and balanced growth in international trade, the promotion of exchange stability, the elimination of exchange restrictions and the correction of balance of payments disequilibria -- complement IBRD's efforts to promote economic growth in member countries through its loans for productive development projects. The two institutions cooperate closely on operational and analytical matters, hold joint annual meetings and are housed in neighboring buildings in Washington, D.C., USA.

Membership in IBRD is open to all members of the IMF and, by December 31, 1979, 134 countries had joined. IBRD is owned and controlled by its member governments. By a formal agreement in accordance with the United Nations (UN) Charter, it is recognized as a special agency of the UN. It began operations in June 1946.

---

(1) Based on World Bank Reports and Publications namely: World Bank/Annual Report 1979; The World Bank, December 1977; The World Bank - Questions and Answers, March 1976; World Bank - International Development Association, April 1978; The International Finance Corporation/Annual Report 1978; and The Paper by Mr. Frederick L. Hotes, World Bank Irrigation Adviser entitled: "World Bank Activities in Financing International Water Resources Efforts" presented at the 1977 Annual Meeting of the University Council on Water Resources, Brookings, South Dakota, USA, July 26, 1977.

265

The Bank is now a group of three institutions: IBRD, IDA (International Development Association) and IFC (International Fina Corporation). A common objective of these institutions is to help raise standards of living in developing countries by channeling financial resources from developed countries to the developing worl

Sources of Funds

IBRD makes or guarantees loans for productive reconstruction a development projects, both from its own capital -- which is provide by its member governments -- and through the mobilization of priva capital. IBRD's share capital is so structured that any risk invo in its operations is shared by all member governments, roughly in proportion to their economic strength. Capital subscription on June 30, 1979, aggregated the equivalent of about current US$37,429 million. Only 10% of the capital has been called and pa in; the remaining 90% is subject to call by IBRD only if and when required to meet the obligations of the Bank created by borrowing guaranteeing loans. Thus investors, i.e. member countries who mig otherwise never become involved in the financing of projects direc are contributing to the economic growth of developing countries.

Lending operations are financed in the world capital markets, including private investors, governments and central banks. Aside from borrowings, paid-in capital subscription, and charges on its loans, IBRD has two other principal sources it can lend. Most important is the flow of repayments on previous loans. In additio it often sells portions of its loans to other investors, chiefly commercial banks. Profit or net earnings are also used to help developing countries by placing these in reserves, which strengthe ability to borrow, and making a reserve available for lending.

To maintain the confidence of both member governments and the international finance community and, thereby, enable a continued source of funds for development, IBRD carefully appraises all aspe of projects submitted to it for financing. Thus, the planning and analyses of projects must be technically and economically sound. also periodically reviews the execution and operation of those projects which it helps finance, and provides advice and assistanc the Borrower in the attainment of project objectives.

IBRD's role as a prudent lender is directed to be in the best interest of all concerned: member governments, lenders to IBRD, a borrowers. The performance of IBRD and its borrowers in the use a repayment of the invested and borrowed capital, so far, continues find general approval of the world financial community, as demonstrated by their continued willingness to provide needed resources to IBRD.

IBRD Loans

IBRD's charter spells out certain basic rules that govern its operations. It must lend only for productive purposes and must stimulate economic growth in the developing countries where it lends. It must pay due regard to the prospects of repayment. Each loan is made to a government or must be guaranteed by the government concerned. The use of loans cannot be restricted to purchases in any particular member country. And IBRD's decision to lend must be based only on economic considerations.

IBRD loans generally have a grace period of 5 years and are repayable over 20 years or less. They are directed towards developing countries at more advanced stages of economic and social growth, which are able to meet established requirements as to credit worthiness. The interest rate that IBRD charges on its loans is calculated in accordance with a formula related to its cost of borrowing.

While IBRD has traditionally financed all kinds of capital infrastructure, such as roads and railways, telecommunications and ports and power facilities, its present development strategy places a greatly increased emphasis on investments that can directly affect the well being of the masses of poor people of developing countries by making them more productive and by integrating them as active partners in the developing process. This strategy is increasingly evident in the agriculture and rural development projects that IBRD and IDA help finance. It is also evident in projects for education and family planning and nutrition, and in the Bank's concern for the urban poor who benefit from projects designed to develop water supply and sewerage facilities, as well as "core" low-cost housing, and to increase the productivity of small industries.

At the same time, lending for traditional projects continues, and is being redirected to be more responsive to the new strategy of deliberately focusing on the poorest segments of society in the developing countries.

IDA

The International Development Association (IDA) was established in 1960 to provide assistance for the same purposes as IBRD, but primarily in the poorer developing countries on terms that would bear less heavily on their balance of payments than IBRD loans. IDA's assistance is, therefore, concentrated on the very poor countries -- mainly those with an annual per capita gross national product of less than US$520 equivalent (in 1975 dollars). More than 50 countries are eligible under this criterion.

267

Membership in IDA is open to all members of IBRD, and 121 of them have joined as of June 30, 1979. The funds used by IDA, called credits to distinguish them from IBRD loans come mostly in the form of subscriptions; general replenishments from its more industrialized and developed members; special contributions by its richer members; and transfers from the net earnings of IBRD. The terms of IDA credits, which are made to governments only, are 10-year grace periods, 50-year maturities, and no interest, but an annual service charge of 0.75% on the disbursed portion of each credit. Although legally and financially distinct from IBRD, IDA is administered by the same staff.

Its standards for reviewing projects are IBRD's standards, and it lends to the same economic sectors for the same purpose as IBRD. Yet the sectoral composition of IBRD loans and IDA credits shows noteworthy differences. These differences result from the varying economic priorities of IBRD borrowers and IDA borrowers.

IFC

The International Finance Corporation (IFC) was established in 1956. Its special purpose is to promote the growth of the private sector and to assist productive private enterprises in its less-developed member countries, where such enterprises can advance economic development. IFC is an affiliate of IBRD and, as such, shares with it common objectives and policies for improving the well-being of the peoples of less-developed member countries.

Membership in IBRD is a prerequisite for membership in IFC, which totals 108 countries as of June 30, 1979. Legally and financially, IFC and IBRD are separate entities; the Corporation has its own operating and legal staff but draws upon IBRD for administration and other services. It has the same President and many of the same Executive Directors.

IFC is not limited as to the form in which it may provide financing, and its terms are flexible. Such financing normally consists of subscriptions to share-capital or long-term loans without guarantee of repayment by governments, or both. It helps mobilize other capital and technical expertise for productive ventures that contribute to economic development and meet sound investment criteria. IFC also has a responsibility to promote such ventures by identifying and bringing together investment opportunities and qualified investors.

268

In addition, IFC seeks to encourage the flow of private capital in the countries it assists. To this end, it supports the establishment or expansion of local capital markets and financial institutions. It also offers technical assistance to member governments in support of their efforts to create an investment climate which will encourage productive and beneficial domestic and foreign investment.

IBRD/IDA/IFC Lending

In FY79 (ending June 30, 1979), IBRD -- together with its affiliates, IDA and IFC -- made lending and investment commitments totaling US$10,435.9 million. One-hundred and forty-two IBRD loans to 44 countries totaling US$6,989.0 million. One hundred and sixteen IDA credits to 43 countries amounted to US$3,021.5 million. IFC made 48 investments amounting to US$425.4 million in 33 countries.

The combined IBRD and IDA lending amounted to US$10,010.5 million and was distributed by sectors, as follows:

Sector	US$ Million	% of Total
Agricultural and Rural Development	2,521.8	25.2
Education	496.0	5.0
Energy	112.4	1.1
Industrial Development and Finance	676.8	6.8
Industry	842.5	8.4
Non-Project	406.5	4.1
Population and Nutrition	114.0	1.1
Power	1,354.9	13.5
Technical Assistance	29.7	0.3
Telecommunications	110.0	1.1
Tourism	113.2	1.1
Transportation	1,904.4	19.0
Urban Development	309.5	3.1
Water Supply and Sewerage	1,018.8	10.2
Total	10,010.5	100.0

The Bank does not fix rigid sectoral priorities; it lends on the basis of the needs of a particular country or a particular region at a particular time. The relatively large amount lent for agriculture reflects the Bank's emphasis in recent years on agriculture development resulting in: (a) a larger proportion of total lending being donated to agriculture; (b) an increased share of agricultural lending going to the poorest countries; (c) a larger number of people benefitting from Bank-supported projects; and (d) projected increases in output by those farmers being assisted.

269

Assistance to small farmers to become more productive accounts for the major share of lending in this sector. The Bank considers the small farmer a critical element as a producer of foodgrains and other food products in many major food-deficit countries. Also, improved economic and social conditions are factors of prime importance in the effort to reduce population growth rates through lower birth rates. Massive rural poverty, sustained and spurred on by an increasing rural population, limited land resources and inadequate supporting systems, is a continuing feature in most of the Bank's member countries. Bank programs aimed at the poverty problem include land and tenancy reform, credit, water supply systems, extension, training and research.

The Bank normally finances from 30-50% of the total project costs. Hence, the loans represent a share of total project costs of more than double the figures shown. Other multilateral and bilateral sources contributed about US$3,250 million to the total project costs, with the remainder being contributed by the borrowing countries. Approximately one-third of the agricultural and rural development lending was for irrigation and drainage projects. The typical Bank-financed irrigation or drainage project can include (in addition to the irrigation supply and distribution system) land preparation, extension and research services, rural water supply, electrification, schools, roads and health facilities, storage and marketing facilities, technical assistance and training. Some of the other agricultural projects, such as agricultural credit, include substantial amounts for irrigation facilities such as tube-wells, minor irrigation systems and improved on-farm irrigation schemes, as well as other infrastructure, purchase of equipment, livestock purchases and production credit.

Operating Methods

Every project -- irrespective of scope and size -- financed by the Bank is considered in the light of a country's total needs, capabilities and policies. Therefore, comprehensive studies are made of the economy of the country requesting assistance. The studies include detailed analyses of individual sectors and relationships between them, which throw light on the relative importance of alternative projects in achieving the country's development goals. Chiefly, on the bases of these studies, and after consultation with the government, a program of Bank operations in the country is drawn up for a five-year period, with an updating annually. This program provides a framework for concrete proposals for action to help the country implement agreed strategy of development. Each individual project is considered within this framework. Equally, project proposals arise out of the joint efforts of government and Bank staff in their search for solutions to common problems. The project is subjected to careful analysis, and a detailed agreement is worked out with the borrower before a loan or credit is approved.

270

Often the Bank will recommend that consultants be hired to prepare detailed plans. Upon completion of the preparatory work, the Bank sends a staff mission to make a thorough appraisal of all aspects of the project. When agreement is reached on the details of a proposed project and on financial requirements, a formal loan or credit agreement is negotiated. If this is satisfactory, the President presents the proposal to the Executive Directors, who represent all member countries, for their approval.

The approval of a loan does not end the Bank's involvement. In most cases, the borrower seeks bids on the basis of international competition for the goods and services required. The Bank releases money only as needed to meet verified expenditures on the project. Goods and services paid for by Bank loans or IDA credits may be obtained from any member country or Switzerland. The Bank pays in whatever currency is required, and the borrower repays in the currency used by the Bank.

Bank involvement continues throughout the life of the project. The borrower provides periodic progress reports, and Bank staff members visit the site from time to time, helping to anticipate and overcome difficulties and ensure that the project's intended benefits to the country are realized. This close supervision is facilitated by the fact that the borrowing country is a part owner of the Bank and shares in the control of its policies and operations. As a cooperative multinational institution, the object of the Bank is to see that each project is carried out at the least possible cost, and that it makes its full contribution to the country's development.

Technical Assistance

The provision of technical assistance, an integral part of the Bank's services to its developing member countries, has been expanding vigorously. Consultations take place between Bank staff and borrowers during project preparation and appraisal, and during country or sector reviews. Aside from this steady flow of technical information, the Bank assists its borrowers with the financing of feasibility studies, engineering, and resource surveys, and in helping build up institutions in such fields as training.

Technical assistance was the exclusive purpose of five credits, for a total of US$29.7 million, during fiscal year 1979. In addition, technical assistance components were included in 176 lending operations for a total of US$329 million. Also, US$12.6 million of financing was provided by the Bank's Project Preparation Facility. The Facility makes temporary advances for studies and other forms of technical support; the borrower repays the advances by refinancing them through a Bank loan or an IDA credit for the project concerned, as soon as it becomes effective. Other forms of assistance are provided on a reimbursable basis, or under equivalent compensatory arrangements, to oil-exporting countries that do not borrow from the Bank.

271

For many years the Bank has served as executing agency for preinvestment and technical assistance projects financed by the United Nations Development Programme (UNDP). A number of UNDP-financed, Bank-executed projects provide economic planning assistance. Typically, they call for small teams of planning advisers, supporting consultant services, and training programs for local counterpart staff. Of great significance to the developing countries if the fact that the Bank-executed, UNDP-financed projects have an operation focus that very often leads to projects suitable for Bank-financing, producing substantial investment follow-up.

The Bank maintains a staff college, the Economic Development Institute (EDI), to train officials of developing countries in the techniques of development. Over 6,000 have attended EDI courses in Washington and overseas.

In addition, the Bank conducts a large, continuing program of research -- both basic and applied -- in virtually every aspect of development with which its members are concerned. At present, this program consists of more than 100 studies. Subjects include economic planning, agriculture and rural development, income distribution, international trade and finance, industry, labor-capital substitution, unemployment, urbanization, regional development, public utilities, transportation, financial institutions, and population and human resources.

International Cooperation

While the Bank is large in relative terms, it is only one of many institutions -- national and international, public and private -- that provide financial and technical assistance to developing countries. In the public sphere alone, a dozen or more international institutions and 25 or 30 national agencies are involved in one way or another. With such a multiplicity of donors, lenders and providers of technical assistance, close cooperation and some degree of coordination are essential. Methods employed by the Bank to achieve this vary widely, depending, among other factors, on the nature and scope of each institution's program.

The largest and oldest of the Cooperative Programs concerning agriculture is that between the Bank and the Food and Agriculture Organization of the United Nations (FAO). During fiscal year 1979, it staffed and carried out 169 missions in 48 countries. Loans for projects prepared by the Program represented about one-third of the year's lending for agriculture. Emphasis was on projects to benefit the rural poor and to promote close involvement of member countries in the formulation of projects.

Type of Missions

There are usually four types of Bank missions involved in generating, financing and implementing agricultural projects. The mission names are derived from the specific functions, i.e. identification, preparation, appraisal and supervision.

272

Identification missions go to the field to make a preliminary determination of the nature and size of potential projects and the establishment of their prima-facie priority. Preparation missions provide advice to governments on project formulation and on the planning and execution of feasibility studies. Occasionally consultants may assist these types of missions. The feasibility study may be performed by the government or by consultants from external government of international agencies or by private consultants.

Appraisal missions evaluate projects on the basis of feasibility or equivalent studies and prepare a report that provides technical, economic and financial justification of the proposed project for review by Bank management and for loan negotiations with the Borrower. The appraisal report also serves as technical background and guide for project implementation. Typical types of consultants or Bank personnel used in project appraisals include: irrigation and drainage engineers, rural infrastructure engineers, agriculturalists, agricultural economists, soil scientists, dam designers, hydrologists, financial analysts, farm mechanization, livestock or agro-industries specialists, and socio-anthropologists.

Supervision missions are sent during project execution, usually twice a year, to review progress in the field. Normally such missions are small and exclusively comprised of Bank staff, but occasionally a need develops for augmenting regular staff or for special expertise to review an unusual field problem. The principal role of the supervision mission is to ascertain that the project is being executed and operated as set forth in the loan documents, but borrowers frequently seek Bank advice during these phases.

The Bank has spent about US$7-8 million annually in recent years to engage the services of the individual consultants that provide special expertise on Bank missions. In some cases, the Bank contracts with a company or an institution for the services of a specific individual expert, if this is the best way to obtain the services of the specialist. The consultants join other mission members to review in the field the project under consideration and, upon return to headquarters, are expected to prepare a complete report for their areas of responsibility which can be incorporated into the mission report.

273

BIOGRAPHICAL SKETCH

Mr. J. C. Collins

Agricultural Advisor, Irrigated Field Crops
Agriculture & Rural Development Department
The World Bank

A British national educated at Reading University in England where he obtained a B.Sc. degree in Horiculture in 1951. After two years of applied research in protected cropping at a Horticultural Research Station, he began his career in tropical agriculture in 1953 going to West Cameroon as a Field Assistant on a group of Banana plantations. In 1955 he joined Bookers Sugar Estates in Guyana where for six years he was engaged in applied research, mainly on sugar cane and advising management of a sugar estate on crop nutrition, pest and disease control and other technical aspects of cane production. In 1961 he returned to Cameroon to manage the research section of the Cameroon Development Corporation undertaking applied research on bananas, oilpalms, rubber, tea and cocoa. In 1963 he joined a British Consulting firm Hunting Technical Services as an Agriculturist and subsequently as a Team Leader for feasibility studies for development, working in Guyana (Canje River Development Study for FAO), Sudan (Rahad/Roseires Irrigation Projects), Indonesia, Somalia (Shebelli Basin Study for FAO), Thailand and Brazil.

In 1972 he joined the World Bank where for four years he was involved in project preparation, appraisal and the supervision in the Middle East and North Africa. Since 1976 he has been responsible for reviewing technical and organizational aspects of agriculture and rural development projects being considered for financing and providing support and advice to agricultural staff directly involved in the preparation, appraisal and supervision of such projects and particularly irrigation projects on a world wide basis.

As an agriculturist, Mr. Collins believes in the importance of the management of the rural environment to achieve sustained profitable production essential to meet the growing needs of the world's population.

274

WATER SUPPLY AND WASTE DISPOSAL

Environmental Considerations

Jozsef B. Buky

Senior Sanitary Engineer
World Bank

June 1980

The opinions expressed in this paper are those of the author and are not necessarily those of the World Bank

International Environmental Management Institute
ENVIRONMENTAL RESEARCH & TECHNOLOGY, INC.
Concord, Massachusetts, USA

275

1 WATER AND THE HUMAN ENVIRONMENT

1.1 Introduction

In recent years, concern for the human environment has been gathering momentum the world over and, particularly, in the United States. Actions range from governmental control to group and individual activities. To the general public, there are two recognizable targets. One is to right the wrongs of the past -- stop continuing pollution and (if possible) rehabilitate -- and, two, prevent activities which would damage some aspect of the environment.

In the field of water supply, during the construction of a facility, the environmental protective measures required are not really different from any other industrial or general development activity -- a large water pipeline should not just be permitted to carve up a beautiful landscape. However, where a water supply service attempts to improve the human environment, we have a difference. We are not necessarily trying to put something right which was badly done in the first place, but we will, more likely, be trying to create something which was not there in the first place. That would be an environment in which even the poorest person can lead a productive, healthy life, being at least relatively free from the debilitating water/waste borne diseases. To create such an environment can be every bit as complex and require just as careful planning and execution as any of the other more visible problems. In providing adequate, convenient and safe water supply, thereby replacing polluted, distant sources, care must be exercised not to create waste disposal problems with equal or greater health hazards than those of the polluted water source.

In order to clearly understand the impact of water supply and waste disposal on the human environment, we must first discuss, briefly, the human health aspects as these are influenced by water supply and waste disposal facilities or the lack of them. Subsequently, the various detailed aspects of water supply and waste disposal are discussed at some length, together with the World Bank's activities in the sector.

1.2 The Basic Needs

The availability of water is a prerequisite for most developments. It is first and foremost a physiological necessity; without one or two liters of water daily, people cannot survive. Water has no substitute. Beyond survival, to attain a reasonable minimum standard of living, people have a "basic need" for 20 to 50 liters daily of safe and convenient water for drinking, food preparation and personal hygiene. Above this basic level, in the range of 50 to 100 liters per person daily depending on climate, culture, etc., water use is important in enabling people to obtain

276

further health benefits through home cleaning, higher standard of hygiene, etc. Above about 100 liters daily, water becomes a convenience, useful for a variety of purposes in the home and garden, including the removal of human waste from dwellings through pipes. 1

Parallel with adequate water supply an equally basic need is the sanitary disposal of human waste, that is, its disposal in such a way as to remove it from human contact. People generally seek to dispose of their extreta as cheaply and easily as possible, and in many rural areas with low population density it is usually possible to do this without large investments in waste disposal facilities. In most urban areas, however, where population is more concentrated, a higher level of service is often required for waste disposal facilities in order to protect not only the individual but community health and prevent environmental degradation.

To meet these needs, there are a wide range of facilities which can be used, from simple latrines to the type of (waterborne) sewerage known in most advanced countries. Naturally, costs also differ widely depending on the methods of transport, treatment and disposal or reuse of human waste which are employed.

The two basic needs of adequate, safe and convenient water supply and a means for sanitary disposal of human waste provide the foundation for a healthy and (therefore) productive life. Without them it is practically impossible to maintain a healthy environment. Nevertheless, the facilities themselves are insufficient to guarantee good health. People must use them properly and this generally requires education in health and hygiene. For example, safe water coming out of taps in a house has some of its value reduced if it is drunk from dirty vessels, if it is not used to wash hands after visits to the toilet, or if people rely for their drinking water on a "preferred" contaminated source because of the "bad" taste of the disinfectant used in the piped water. In more general terms, people also require nutritious food, adequate clothing and shelter, access to primary health care and broader elements of community sanitation such as garbage disposal and clean air if the full benefits of sanitary water and wastes facilities are to be obtained. There are complicated interrelations between these various elements which make it difficult,

---

1 For nondomestic consumers--tourism, industry and services--in both the public and the private sector, water is in most cases a vital input in the production process in the same way as power is an input. Water is, of course, also used for safety purposes, such as firefighting, and is a requirement for the maintenance and beautification of the environment and for municipal cleanliness.

277

if not impossible, to measure the specific benefit or allocate the contribution to health and productivity of any one of them or to assess the extent to which any one element can substitute for another.1.

1.3 Water Supply

In satisfying "basic needs" water is used in essentially two ways: for drinking and cooking on one hand; for personal hygiene on the other. The safety of water, by which we mean the virtual absence of disease-producing organisms and toxic substances, is theoretically more important for the former use than it is for the latter. In practice, however, water may be drunk (or inadvertently ingested) wherever it is available and for whatever purpose it is obtained; thirsty children in particular tend to drink whatever water is convenient. This means that, in general, water must be convenient as well as safe if it is to satisfy basic needs. The substitution of a safe but remote source for one which is easily accessible but hazardous is not sufficient.

In many cases, satisfactory safety standards for water can be met without the use of treatment facilities. This is particularly true in rural areas, where proper location, construction, operation and maintenance of springs and wells has repeatedly been shown to be all that is required to provide convenient supplies of water meeting reasonable safety standard.2 Where springs and wells are unsafe today it is generally because of faulty construction introduced contamination by surface water infiltration, mechanical breakdown of pumps through faulty design, lack of maintenance or vandalism.

A convenient water supply is usually defined as one which enables the user to obtain water without having to spend an inordinate part of the working day either queueing or traveling. In most towns this implies a source within 200 meters of the home (but may have to be much less in denser areas); in villages the distance may be somewhat greater. Where people carry water in containers and live within

---

1 In 1975 the Bank commissioned a background paper on Measurement of the Health Benefits of Investments in Water Supply and convened a panel of experts in medical epidemiology, sanitary engineering and economics to discuss it. The panel concluded that the benefits could not be quantified given the present state of knowledge and data, and that studies to establish a rigorous relationship between water supply and health would be extremely expensive and their conclusions would be of doubtful applications.

2 In general, the sanitary engineer involved in the construction of a water supply project will make a sanitary survey to determine if water safety tests are required, the regularity of such tests and their type.

278

reasonable access of a well or public standpipe, they usually use the 20 to 50 liters per capita per day (lcd) required to meet basic needs.[1] However, when people live far from the source of water, the burden of transport is reflected in their use of water which may, in extreme cases, fall to the three to five lcd necessary for survival; i.e., well below amounts required to satisfy basic needs.

Where water is piped into the house, per capita use is generally at a higher level; for example, with simple indoor plumbing (including a pour-flush toilet), 100 lcd is often regarded as normal per capita consumption. Where indoor plumbing includes a greater number of facilities, including a modern flush toilet, minimum consumption rises to the levels substantially above 100 lcd (from 100 to 400 lcd will be used for toilet flushing alone where modern flush toilets are in use).[2]

1.4 Waste Disposal

Because people use relatively high amounts of water when they have house connections, waste water collection and disposal facilities usually have to be built to prevent environmental pollution and public health hazards. The extra benefits of in-house water supply over those of standpipe supply must therefore be weighed against the extra costs of the disposal of additional wastewater, which include both sullage (kitchen, bath and laundry water) as well as water carrying human waste. Such costs include not only installation but also operation and maintenance since, as with centrally operated water systems, it is crucial that the technical efficiency of the waterborne waste disposal system, including treatment and disposal facilities, be maintained to obtain the health benefits intended. Waste disposal systems can be constructed in many different ways and with widely

---

1 This amount may be lower if, for example, the water pressure in the standpipe or at the well head is low.

2 In most countries, 40 to 45 percent of a household's water consumption is used for flushing the toilet.

279

varying costs. Historically, the stages of development of faci for the disposal of human wastes in the major urban centers of industrialized countries have shown a progression from individu household latrines to household septic tank systems to limited sewer systems to comprehensive sewer systems. 1 2

1.5 System Selection Considerations

What then constitutes a basic minimum of safe and convenie water supply and adequate waste disposal varies in relation to size, income and nature of a community? Large urban areas almo always require systems different from those in small villages b as communities and incomes grow and population becomes more de individual water sources and waste disposal facilities become impractical, while the benefits of a central water supply syste communally organized waste disposal facilities increase. Such benefits include not only direct health benefits to individual households but also a protection of, or contribution to, commu welfare. For example, when all households in the area have sa and sanitary waste disposal methods, the health benefits recei "sanitary" households are not reduced by the actions of their sanitary" neighbors. Also, many of the potential health benef available even to those who, through lack of education or info do not perceive that such benefits exist.

1.6 The Decade Ahead

Having outlined the nature of the problems in creating a satisfactory or even just acceptable human health environment, perhaps useful to put the task ahead into perspective in the t

---

1 Where there are comprehensive systems, the local authorit bans private disposal facilities of any type within their jurisdiction both because of the public health and nuisan problems which such private facilities may cause and beca the concern to maintain the financial viability of the sy

2 The World Bank has just completed a large research effort cost waste disposal--a field which had, until recently, b largely neglected in both developed and developing countr The work aimed at identifying the technologies appropriat providing urban fringe and rural communities with socially environmentally acceptable waste disposal services at a c could afford. The study covered 14 countries at various of development, with different cultural, industrial, and environmental features; it demonstrated quite conclusivel not only are low-cost waste disposal methods functioning successfully in these countries but that the potential fo replication elsewhere is high.

a few numbers. In order to meet the needs of all in water supply and sanitation by 1990 in the developing countries, it is estimated that the following numbers of people (in millions) would have to be provided with these services:

	Water	Sanitation
Urban	640	650
Rural	1,570	1,670
TOTAL	2,210	2,320

The magnitude of this task and the urgent necessity for a concentrated effort to tackle it has been recognized by governments the world over; first at the HABITAT conference in Vancouver in 1976, then at the UN Water Conference in Mar del Plata in 1977, and again at the International Conference in Primary Health Care in Alma-Ata in 1979. The period 1981-1990 has now been declared the "International Water Supply and Sanitation Decade" by the UN General Assembly. All developing countries have been asked to prepare detailed investment plans by 1980 to meet the target of "services to all by 1990."

281

2. THE ISSUES IN WATER SUPPLY AND WASTE DISPOSAL

2.1 General

In addressing the problem of meeting the basic needs of people for water supply and waste disposal, the developing countries today are faced with a number of vexing questions. The issue of water quality standards has already been touched upon. Another issue is the type of water supply system to be installed in any given community: Should house connections be made rather than public standpipes? Who should pay for the house connections? What mix of house connections and standpipes is optimum? Are standpipes socially acceptable? A third issue is how to finance a rapid expansion of service: Does this require new pricing policies? What additional investment funds are needed? A fourth issue relates to waste disposal: Are there acceptable low-cost means of meeting the basic needs for satisfactory waste disposal within the cities and in the fringe areas around them? Can methods be found to upgrade such facilities as the users' demand and ability to pay increases? A fifth issue concerns the types of institutional arrangements to be made: Are present intitutions adequate: Can training programs be developed? How should health and hygiene education be provided? Finally, how are environmental aspects to be evaluated? For example, what is the trade-off between providing water supply house connections, which provide a large quantity of quality water but require expensive wastewater disposal facilities, and standpipe supply of a limited quantity of water which can be contaminated prior to use but does not require the same degree wastewater disposal facilities to protect the environment.

In general, the following points should also be noted: first, projects in the sector have a long lead time, averaging five to eight years from identification of the project to its full implementation; second, sector agencies must develop a systematic framework for the sector, starting from the water sources to be used, through the main transmission networks to the final elements of the distribution networks, with an analysis of the implications for waste disposal at all stages; third, in determining the technologies to be employed in the design of systems, particular attention must be paid to the potential for future upgrading of the systems; and fourth, financial techniques must be found for providing affordable services for all consumers and for generating investment capital and operating funds, given that, in general, consumers should not need to spend more than about five percent of their income on water supply and waste disposal.

2.2 Water Supply Delivery Stystems

From experience gained by the Bank in identifying, appraising and supervising water supply projects, four "realities" have emerged. First, and most obvious, is that whatever the existing system in any community, the development of new source works, together with construction of additional transmission and distribution networks, usually has to occur before new consumers can be provided with service

282

or existing standards of service can be upgraded. There are very few instances where levels of service can be increased, and the quality of service maintained, simply by extending the existing distribution network.

Second, once house connections are available to consumers it would be highly undesirable and indeed politically impossible to "downgrade" their supply to, say, patio connections or standpipes or to reduce water consumption in order to reallocate the "surplus" water (over basic needs) to new standpipe users. Indeed, such a move may be technically impossible where the water supply is associated with sewer connections, since sewers require a certain minimum flow of water to function.

Third, it is usually politically and economically impossible (or self-defeating) to attempt to provide levels and quality of service for the poor which are better than those for the not-so-poor. On the one hand, it is clearly difficult to refuse house connections for water supply to new applicants who can afford to pay the full economic costs of these connections (in practice, such people will usually find a way to obtain an "illegal" connection if a legal one is denied to them). On the other hand, since it is the not-so-poor, partcularly commercial and industrial users but also domestic users with house connections, who will provide the funds with which to operate the system and subsidize service to the poor, they must be provided with the service they want and are willing to pay for.

Fourth, there is usally a shortage of trained and experience manpower in the sector. Even though the design and construction of water supply and waste disposal systems can be carried out by foreign consultants and contractors, the operation, maintenance and management of completed works must be turned over to national staff at an early date to minimize foreign exchange costs, to ensure a community commitment to the system, and to facilitate the training of more national staff.

A major issue in urban water supply projects is the type of delivery system to be installed--i.e., whether it should consist entirely of house connections or of some combination of house and patio connections and standpipes. Most developing countries want the same systems now used in the advanced, industrialized nations, i.e., a centrally controlled and treated source of water, wide-ranging transmission lines, and metered, multiple-tap connections in every house or apartment. It is true that, where people can afford such a system, it can produce large social and economic benefits. It is convenient for the consumer, it reduces the users' costs of storage, there is no need for individual purification and, if it is used universally, it can limit the spread of disease. Meters can be used to levy a range of appropriate tariffs, producing revenues which would create a financially viable public undertaking. Meters will discourage waste, assist investment decisions, and, possibly, help in a general movement to redistribute income. Support of high standard systems also comes from the experience, in both rich and poor

283

countries, of the drawbacks of lower-level systems. Standpipes, for example, are subject to vandalism, and vandalism can bring about wastage; wastage also occurs, of course, when users fail to turn off the taps. Health hazards and nuisances result if adequate drainage is not provided around them. The quantities obtained by each person are limited by the ability to transport and can be contaminated during transport and improper storage. In addition, it is almost impossible to collect revenue from users of standpipes.

The reason that the Bank does not advocate immediate full higher-level delivery systems for all towns and cities in the developing countries is fourfold; first, because many of the potential users are too poor to pay for the full cost of house connections and internal plumbing, [1] second, because the houses are often not suitable for internal plumbing, third, because the community is unable to raise the capital required to construct the facilities, and fourth, because of the costs which the community would have to bear to dispose of the waste water generated by consumers served exclusively through house connections. Consequently, and in spite of their many shortcomings, public standpipes are recommended where water has to be distributed to a large number of people at minimum cost.

For rural communities communal systems with standpipes or properly located and constructed village wells or springs are generally the preferred solution. However, ways must be found to reduce vandalism and waste and to ensure that poor construction and maintenance does not lead to pollution of the water supplied or interruption of service. Where possible, gravity supplies should be used to reduce the need for pumping equipment; where pumps are necessary they should be selected from those which are simple to operate and maintain, and/or local materials. In addition, people must be educated not to contaminate the water at the source and when they carry it from the source or store it at home.

The general planning policies for any water supply and sanitation project should promote a delivery system (i.e., the mix of house connnections, patio connections and standpipes, and sewered and nonsewered sanitation) consistent with the provision of service to all. In some cases this may imply that the government should be

---

1 It should be noted that the costs of standpipes can vary considerably, from a few cents for a cheap tap on an unprotected pipe to hundreds of dollars for a standpipe which is properly secured and consists of a control which limits waste and discourages vandalism. Similarly, house connections can vary in price, depending on the location of the mains, the types of fittings, etc.

prepared to provide funds under the project for making loans to consumers for house connections and/or internal plumbing either through the water supply undertaking or through some other intermediary. In many cases it will mean that institutional and pricing policy changes will be required to achieve sector goals at the least cost.

2.3 Water Quality

It is often urged that the costs of meeting drinking water safety standards, such as those recommended by the WHO, are prohibitive. Nevertheless, Bank experience shows that in many rural areas groundwater, safe for drinking, can be provided without the necessity for treatment. Even for rural communities, having to rely on surface water sources, infiltration systems can frequently be constructed which avoid the need for expensive and complex treatment plants. It is in situations where neither of these low-cost options is available that sedimentation and filtration facilities have to be provided together with some form of disinfection, usually chlorination. In the latter case, it may be possible to serve several villages from the same plant to permit economies of scale and to ensure good operation. In most towns it makes sense to have treatment facilities, because the initial cost of these facilities is generally a very low proportion (often less than five percent) of total system costs. As treatment facilities become more elaborate, however, their operating and maintenance costs can become significant.[1]

A basic policy on water quality could be stated in the following three basic rules:

1) facilities should be capable of supplying safe water at all times and should be designed to take account of the capacity of local personnel to operate them;

2) the safety of water supplied from the new facilities should be equal to, or better than, that provided from the existing sources; and

3) where national water quality standards exist, projects should comply unless facilities or processes are required which are unreasonably costly or the quality of water reflected in the standard is so low as to create serious doubts on the safety of the water.

---

1 It is sometimes argued that teaching people to sterilize or disinfect water could be a low-cost method of providing them with safe water. The educational costs involved have not been calculated; however, the cost of boiling four liters of water each day for every person's drinking needs is about $22 annually, an amount far in excess of what is affordable in most poor countries.

285

2.4 Waste Disposal Systems

The very high costs of providing waterborne sewerage has led to a search for alternative, lower-cost methods of disposing of human waste.[1] Methods exist for the disposal of excreta which can meet every public health test, and which cost one-third to one-tenth as much on a household basis as conventional sewerage. However, because such facilities becomes less suitable as population density increases, it is important to plan facilities in terms of long-term community development, utilizing technologies, to the extent possible, which can be upgraded as the users' requirements and capacity to pay for higher levels of service increase.

It is important to note that a properly located, constructed and maintained latrine will meet all public health requirements for the sanitary disposal of human waste whatever the design, be it a simple vault or borehole, one with a complex water seal, a multiple vault unit or a conventional water flush system.[2] No one design is better than another from the health standpoint; other things being equal, it is a composite of cultural, aesthetic, social and technical factors which lead to selection of one design over another. For example, there are countries in which reuse of human waste on the soil is against local custom, where communal facilities are frowned upon or where, for example, depositon is always into running or stagnant water. In contrast there appear to be no social constraints in any country on waterborne sewerage--possibly because the system (except for depositon facilities) is "unseen." When considering the costs and appropriateness of alternative systems this should be taken into account. As with water supply, it may be necessary to make funds available to finance the connections and in-house plumbing for waste disposal.

2.5 Institution Building, Training and Health Education

Use of different types of technology and service standards for water supply and waste disposal often imply different types of institutional arrangements in the sector. For example, maintenance of a small rural water supply scheme may be best organized through a community-level organization in the villages concerned; waterborne sewerage, however, must usually be organized by a government or

---

1 Summary Report, Appropriate Sanitation Alternatives.

2 There are a number of ways of improving "old" technologies, such as the latrine and the septic tank, which overcome the problems leading to their abandonment in the past.

286

semigovernment institution; simple well protection or cartage of human waste may be carried out by extension agents of the government or by the private sector. The range of organizational structures is wide, but all need trained engineers, maintenance staff, health workers, accountants and administrators. In rural areas it is particularly important that the communities benefiting from the project participate in the decision on the type of supply, methods of construction, operation and maintenance and the system (as the case may be) of tariffs and charges. This is generally achieved through a council or committee of people representing the community.

Much greater emphasis on training as part of project implementation is necessary than has been practiced in the past. The full benefits of investments already made and the continuing realization of such benefits is dependent on systems lasting for their full operational life and functioning 24-hours a day. Many of the benefits are lost at present, and will continue to be lost unless the trained manpower is available to ensure efficient operation and maintenance.

Consumers also need education, and it is clear that this becomes of greater importance the lower are the service standards for water supply and waste disposal. Thus, water supply and waste disposal projects, in particular those designed to benefit urban and rural poor, should incorporate a health hygiene education component.

2.6 Financial and Economic Issues

The most important financial and economic issue is that of the appropriate pricing system for water supply and waste disposal. The actual tariffs and charges set in any given case will depend on the financial goals and requirements of the entity, the social goals of the government, the political viability of tariff changes and the affordability of the tariffs by consumers. Consequently, both the average level of tariffs and their structure will be very much a matter of compromise between these various factors.

Since the health and other benefits of a safe water supply and sanitary waste disposal system are practically impossible to measure, standard cost-benefits approaches cannot normally be used and, as in the case of other sectors such as power and telecommunications, greater emphasis is placed on a pricing policy which relates tariffs to marginal costs. Such a policy provides a means of signaling the justification for an expansion of service as well as establishing a benchmark by which other social or economic objectives may be evaluated.

To overcome the problem that the poor might not be able to afford the service at the managerial cost, tariff structures can be designed which take into account what various groups of consumers can afford while aiming at an overall (weighted) average tariff level which is consistent with marginal cost pricing. Such a structure normally consists of increasing block tariffs with the richest (high) consumers

287

subsidizing the poorest, or, at least, with the tariff for a basic minimum level of consumption for all being subsidized by higher charges for consumption in excess of this minimum amount. The extent of cross-subsidy within the tariff structure will, of course, depend on the amounts demanded by different types of consumers and their ability to pay; if, as is often the case, over 60 percent of domestic consumers account for less than 40 percent of consumption, the other 40 percent of domestic consumers, plus industry and commerce, may not have to be charged much in excess of marginal cost. An important point to remember in this respect is that for efficient pricing and financial viability a service must serve the rich as well as the poor, but the prices charged should subsidize only the poor, not the rich. There are still too many countries in which water charges are so low that they subsidize all consumers. There is no justification for this where fiscal resources are limited and where much of the water produced is consumed by large residential and commercial users.[1]

The potential for introducing a cross-subsidy may depend on the type of "delivery systems." A metered house or patio connection has the greatest potential for obtaining revenue from those who can afford it; it allows many options for charging consumers, ranging from a flat rate to (variable) charges for different quantities consumed. A nonmetered connection tends to be less effective; the revenue collectors must generally rely on a regularly collected fixed charge system, sometimes linked to the size of the property, the size of pipe, the number of fittings, or the estimated number of users but, at best, the charge only approximates to the water actually used. Charges for standpipes are the most difficult to collect; it may be feasible for an attendant to collect payment for volume consumed or for households in the area served to be billed a standard fee. However, in most cases, the standpipe consumers pay no charges at all (even if they are supposed to) and standpipe consumption is hence subsidized by other users, or paid for out of state or local taxes.

It has sometimes been suggested that an increasing block tariff system, particularly one which includes a "life-line" tariff for a basic minimum amount of consumption, also serves income-distribution criteria in an economy. This is true in the limited sense of assuring that the poor have access to service. In most economies, however, the highest proportion of personal income spent on water supply and waste disposal is very small (three to five percent) so that any net transfers to the poor in this sector is of limited overall significance.

---

1 In many countries it is the government users who receive the largest subsidy.

288

Economically efficient pricing in the water and wastes sector can be an important contribution to the overall economic efficiency of the country. However, its contribution can be reduced or even negated if other sectors do not apply the same economic pricing principles. A possible problem is the "technical efficiency" of the sector; if, as is often the case, a large part (20 to 50 percent) of the water produced is not paid for--because of leakages in the supply network, inaccurate meters, deliberate evasion of payment or poor revenue collection procedures--then the subsidization of this amount by those who pay may increase their tariff beyond economically optimal levels.

While there are enough difficulties in developing a suitable tariff structure for urban water supply, the problems are even greater for rural water supply and all types of waste disposal facilities. As a contribution to the recovery of costs of small rural water supply and on-site waste disposal schemes, which generally have a very high labor component, consumers should provide free labor, land, local materials and, possibly, a nominal amount of cash for construction materials. The equivalent value of these contributions in some countries has been as much as 30 percent of system costs but in many cases a lesser contribution (about ten percent) is acceptable, with the balance of funds being provided by the government. In addition, the community should be responsible for operation and maintenance of the system.

For waterborne sewerage, it is usually easiest to put a surcharge on the water tariff to reflect the incremental cost of providing sewerage,[1] even though this will still not justify the type of service selected, nor in many cases, will it give consumers a real opportunity to show willingness to pay. The main justification of this technique of pricing is that it gives the operating entity some control over customers who do not pay their bills. In some countries, particularly in Africa, funds for rural water supply and urban and rural waste disposal come from the general budget of the country. The Bank's work in the sector has shown that in such cases the systems rarely if ever have sufficient funds for proper operation and maintenance or expansion, and hence the health and other benefits they are designed to produce are lost.

---

1 This system can be adopted even where the organization in charge of waste disposal is not the same as the organization in charge of water supply.

289

3. THE WORLD BANK'S ACTIVITIES IN THE WATER SUPPLY AND SANITATION SECTOR

The World Bank started its activities in the sector in 1961 with a loan to Taipei. By the end of fiscal year 1978, over US $2 billion had been lent. In the fiscal year 1979 alone, another US $1 billion had been lent. Because the World Bank usually lends about 40 percent of project values, these amounts represent projects worth about US $7.5 billion.

In the execution of this massive lending program, the World Bank has become thoroughly familiar with the issues discussed in the preceding paragraphs and developed objectives and methods to achieve them. Both are, of course, under continuous review and are modified from time to time to reflect latest experience. In addition, applied research 1 is conducted to find better solutions to water supply and sanitation problems.

3.1 Objectives

The Bank's objectives in lending for water supply are to:

1. assist governments in providing basic infrastructure at least cost;

2. ensure access to public services to all segments of society, particularly lower income groups;

3. build institutions capable of planning and implementing national, regional and local programs;

4. mobilize through adequate pricing policies the funds necessary for physical development and the training of staff; and

5. establish financial viability of implementing agencies so they may cover operation, maintenance and depreciation costs and contribute to future investments.

3.2 Project Analysis

The physical components of projects for which Bank financial assistance is requested are given a thorough technical review 2 to ensure that they represent the least cost method of fulfilling demand. The review covers subjects such as demographic and demand analysis, geology and hydrology. Engineering designs are reviewed for the choice of technology with the view of minimizing capital and

---

1 See 671-46, EWT Index.

2 See "The Project Cycle" for detailed description of World Bank project preparation and approval.

operating costs, and to ensure that the capacities of the components such as source works, treatment and distribution, are appropriately matched. At the time of the review the project's capacity to serve industry, commercial and domestic--including low income--consumers, is established. Often Bank staff assist governments in the early stages of planning and participate in the planning process.

The Bank has no fixed requirements as to the type of organization to which it lends; loans are made to government-owned companies (operating on a national, regional or local scale), municipalities, urban districts and government departments, depending on which organization is considered to be the most efficient for the purpose of the project. As the Bank puts greater emphasis on "new-style" projects designed to reach rural and urban poor, it is likely that existing organizations in developing countries will be asked to onlend to less formal organizations such as village councils, cooperatives, etc. Already, Bank loans are being onlent to committees for small rural projects, and this process should gain momentum in the coming years.

This does not mean that there should be a change in the policy of trying to ensure that Bank borrowers have a reasonable measure of autonomy, that they control costs, and that they be financially viable. The Bank will continue to expect that its borrowers maintain the following characteristics:

1. competent management, with preferably a separation between those responsible for policy and those responsible for management;

2. financial independence, in the sense that the entity is adequately capitalized, empowered to manage its own funds, can make adequate provision for depreciation of assets and occasional adversity or cost overruns, and is able to formulate appropriate investment plans and can fix, alter and collect tariffs;

3. the power to set wages and salaries at competitive levels to attract and retain competent staff, and the authority to engage, dismiss and discipline staff;

4. a separate accounting system, if possible on an accrual basis, capable of making available quickly and reliably the data needed for effective management;

5. the legislative backing to deal with all consumers (including local authorities) who default in payment or violate regulations; and

6. primary responsibility for the procurement of goods and services required.

291

Some of these objectives have proved easier to attain than others. In the rural areas particularly it is usually impossible to achieve them without strong community commitment and participation. Governments are often jealous of their right to set salary scales for everyone in the public sector, and government power of general surveillance often has a tendency to increase rather than decrease, especially when financial difficulties arise or when, for example, tariffs become a pawn of politics. Thus the Bank may have to allow a sufficient time for the objectives listed above to be achieved; in some countries, the move toward full autonomy of the borrower may have to take place over several successive lending operations.

Bank experience suggests that many developing countries do not yet have the capacity to design, prepare and construct an increasing number of water supply and waste disposal projects and then properly manage, operate and maintain them. This is why an increasing number of Bank projects in the sector contain a training component. One example is the loan made in FY77 to the Philippines providing water supplies in provincial cities, which included $200,000 for training local staff in the rural areas to design, build and operate small systems.

The Bank should continue to promote a policy which relates marginal cost to tariffs for all water supply projects while recognizing that there may be theoretical and operational problems in applying the concept in a particular case. One problem is how to deal with the costs of large increases in the source, transmission and distribution capacity of a particular system. No fully satisfactory answer to this has yet been found and so, as a compromise, the operational definition normally comes down to an estimate of incremental operating and investment costs averaged over the project output through time. As a practical matter, it is usually essential to ensure that the entity is financially viable and, to the extent possible, that it is financially independent.

Because of the monopolistic character of most water supply entities, and the fact that their output is normally regarded as a social necessity, it is particularly important to ensure efficient operations and to control costs. The Bank contributes to this objective by reviewing the entity's operations and procedures and recommending (if necessary) that appropriate changes be made either as a precondition of the loan, or, where the required measures are expected to take some time, during the project construction period, or over a longer period which may encompass a series of loans.

Accounting and Budgeting

Where a satisfactory accounting and budgeting system, able to provide sufficient information for financial management, does not exist, the Bank requires that such deficiencies be remedied.

292

Audit

The Bank requires an annual independent audit, and the setting up of satisfactory systems of internal controls where internal financial controls are absent or inadequate.

Management and Staffing

Common problems in all sectors have been the acute shortage of experienced and competent staff, and inadequate training facilities to alleviate this shortage. Thus the Bank has to examine the borrower's level of staffing and training requirements. The problem of overstaffing at lower levels often exists in juxtaposition with the more serious problem of shortages of experienced and competent middle and upper-level staff. Where competent managers cannot readily be found within a country, the Bank is prepared to finance full-time foreign personnel, who, in addition to helping existing managers in day-to-day operations, are also able to train staff in modern management techniques. In some cases, reorgnization is required. For example, scarce skilled manpower may be used to the best advantage when a single unit is given responsibility for planning, construction and operation on a national scale.

Other Factors Affecting Costs

Experience shows that it is also prudent to review other elements affecting capital and operating costs. For example, the Bank generally requires specific satisfactory procurement procedures for items financed from all, including the borrower's own funds. Inventory control may be weak in some instances. Operating and maintenance practices may be poor, partly reflecting the inadequate training of staff. There may be excessive losses of revenue owing to leakage or theft; inadequate billing and collection procedures are a problem with which many enterprises have had to contend.

Loans for water supply are usually made to revenue-earning entities which are financially independent and which are expected to achieve appropriate financial targets and objectives. With few exceptions, these are public sector entities. Many of the entities have a high demand for capital because of the intrinsic capital-intensiveness of their facilities and of the need to catch up with past underinvestment and/or to expand rapidly (doubling or more of capacity every five to ten years) to meet future demand. Given the difficulties faced by many borrowing countries in mobilizing public savings, especially in times of inflation, the absence of or limited access to capital markets, and the competing demands for available resources by other sectors, the Bank requires that the borrower's revenues cover all operating costs and debt service as well as a reasonable part of the investment programs, usually varying between 20 percent and 60 percent. The contribution to investment depends upon the circumstances of each case, including such factors as the stage of development of the beneficiary, the availability and adequacy of external capital sources, the size of the investment program in

293

relation to existing facilities, and the terms of past and p
borrowings. One of the most important factors in judging th
of the financial performance is the rate of return earned on
capital, which serves as a measure of the extent of the cost
from the beneficiaries of the services provided.

Most water utilities face a number of problems in setti
related to the incremental opportunity cost of expanding out
First, since a minimum amount of water is needed to sustain
health irrespective of income levels, high charges for water
unduly burden the lowest income groups, and thus there has b
reluctance to recover all water costs through prices. Secon
supply investments often have to be "lumpy" since it is usua
economic to provide facilities capable of meeting anticipate
in a community for ten years or more; therefore the relation
user charges to incremental costs has, in practice, to be ap
and, where appropriate, averaged over some future period. T
general health benefits to the environment of the project ar
the provision of safe water imply that some form of cross-su
be appropriate.

A usually serious operational problem, mainly related t
water supply sector, is the failure of some borrowers to cor
losses and to collect all the revenue for services rendered.
are three main aspects to this problem: physical losses, in
billings, and poor collections. Many water supply undertaki
obtain payment for as much as half of the water which they p
because of leakages or inability to meter or control consump
such cases the Bank may require special studies to analyze t
problems of metering, theft and leakage prevention, and fol
inclusion or corrective measure in future loans. The Bank a
reviews a borrower's performance on billings and collection
that steps are being taken to bill the consumer properly an
collect the revenue promptly. In most cases such steps mus
before a loan is made or within a reasonable period thereaf

3.3 Criteria of Financial Performance

In preparing a specific lending operation, the Bank an
borrower agree on precise criteria for minimum financial pe
not only for the purpose of achieving the braod objectives
above, but also to assure the continued solvency and financ
viability of the borrower and to assure the implementation
financing plan for the Bank Project. The careful formulati
performance criteria is as much in the interest of the borr
entity as of the government as guarantor, or the Bank as le
Bank recognizes, however, that the application of these cri
have to be reviewed from time to time to ensure their conti
appropriateness when policies evolve and when external even
influence the operations of the borrowing entities.

Among the various tests, usually expressed in the form of covenants agreed to by the borrower, but sometimes agreed informally between the Bank and the borrower in a "plan of action," two tests have developed into standard requirements for practically all loans in these sectors; one aims at maintaining a specific minimum level of earnings throughout the life of the loan (Revenue Covenant), and the other establishes warning signals to prevent the borrower from entering at any given time into commitments which might endanger his solvency, and obliges him to consult with the Bank when these signals are triggered (Debt Limitation Covenant).

3.4 Revenue Covenants

While there are several types of revenue covenants which might be used, historically the Bank has usually employed two types of covenants for water supply and sanitation projects. These are based on:

1. a rate of return on investment (net operating income after taxes as percentage of net fixed assets in operation plus, in some cases, adequate working capital); or

2. a contribution to expansion (internally generated funds after operating expenses and debt service as a percentage of capital expenditures).

The rate of return concept has been by far the most commonly used basis for a revenue covenant. This is because 1) it is a standard measure of financial performace, 2) it reflects generally accepted principles of costing of utility services, 3) it provides an effective means (assuming proper revaluation of assets) of compensating for the effects of inflation, 4) it mirrors concepts of tariff regulation which have been used in many parts of the world, and 5) it is an accurate and objective test. Specific minimum rates of return and of depreciation (preferably straightline) are normally agreed upon. These rates are determined after the Bank has satisfied itself that fixed assets are adequately valued and that suitable arrangements exist for allowing assets to be revalued annually to compensate for inflation and to ensure that net income and depreciation charges are maintained at the appropriate level in constant terms. Indeed, in countries which are experiencing high inflation, the use of a revenue covenant of this type is practical only if periodic revaluation of assets for rate-making purposes is provided for.

In addition to serving as a measure of the adequacy of revenues compared to the cost of capital, the revenue covenant based on the rate of return aims at providing internal cash generation for the specific purposes and requirements of the undertaking. The factors determining the actual level of funds required are analyzed during the Bank's appraisal of the project. They include the existing capitalization of the enterprise, its debt service and any dividend requirements, the incidence of taxation, economic and social considerations such as consumers' ability to pay, the expected growth

295

rate for the services, the prospective investment pattern and the availability of other capital funds. This emphasis on the cash aspects of the rate of return is normally broadly consistent with the parallel objective of having tariffs or fees include an adequate charge for the cost of capital invested in the enterprise; however, in a situation with little, or concessionary, debt or a low rate of expansion of the utility cash requirements, the rate of return might be unacceptably low. Internal cash generation by itself rarely covers all the costs of expansion and is usually supplemented by the infusion of loan or equity capital.

Borrowing countries, reluctant to implement unpopular tariff increases, have often considered a government subsidy as a substitute. The Bank, however normally does not accept this except where the subsidy is given to compensate for losses sustained by the utility in undertaking social programs, e.g., water supply projects designed wholly or in part to meet basic needs of the poor.

The alternative revenue covenant which deals directly with internal cash generation and contribution to expansion (and is sometimes called a cash generation covenant) 1) is more reponsive to changes in the size of the investment program arising from inflation or other reasons, 2) is a direct test of net cash generation, and 3) is easily understood by borrowers and governments particularly in terms of a financing plan for the immediate investment program. However, a cash generation covenant in itself cannot be relied upon as a guide to the adequacy of an entity's earnings for cost recovery purposes. Furthermore, because annual investments are often "lumpy," the cash requirement under this covenant tends to vary greatly from year to year; it is therefore necessary to calculate or estimate sliding averages of investment over periods of several years, and this leads to monitoring difficulties. Even when a cash generation covenant is used, the rate of return implied under the covenant is estimated and borrowers operating under inflationary conditions are asked to revalue their assets regularly; this enables an assessment of real earnings to be made, which in turn helps in determining the appropriate level.

The debt limitation covenant is intended to prevent the borrower from entering into debt obligations which would cause future debt service to become excessive and endanger the borrower's financial viability. Such a covenant places a limit on the amount entities may borrow without Bank agreement and may also prevent an entity from entering into debt obligations having unsuitable terms and conditions. Some examples of such debt are: loans with relatively short maturities compared to the life of the assets financed by such debt, borrowings at very high interest rates, and debts having balloon payments without provisions for accumulating the funds for ultimate repayment.

3.5 Economic Justification

There are three main stages in considering the economic justification of projects in the water supply sector. The first is to make as thorough a study as is feasible of the market demand for the service, reflecting expected economic developments and the effects on demand of alternative pricing policies for the services in question.

The second step is to investigate whether the project is the least costly means of meeting the anticipated level of demand: for example, is the proposed water supply development optimal from the point of view of balance between source development and reduction in system leakage, choice of treatment process, and phasing and sizing of transmission and distribution mains? The determination of the least cost alternative usually involves the comparison of different time streams of capital and operating costs by an appropriate discounting technique. It also usually requires "shadow pricing" of costs where prices of inputs, labor or foreign exchange do not reflect the real economic costs.

The third step is to test whether the project is worth executing, by determining that the benefits of the project to the economy as a whole exceed its economic costs. In practice, this calculation is difficult for two reasons. First, most of the data available for the benefit calculation normally come from the financial accounts of the utility, which do not reflect the full benefits to the economy such as health benefits. The second difficulty arises from the fact that where the project consists of selected parts of an expansion program, it may not be possible to attribute the benefits deriving from these separate parts.

In most cases it will not be possible to quantify the economic benefits by consumers in excess of the amounts they actually pay and therefore the estimation of the social value of the project is precluded. It is normally possible, however, to calculate an incremental financial return, based on revenues from additional sales attributable to the project. When appropriately adjusted for transfer payments, such as taxes and subsidies, and the shadow prices of labor, capital and foreign exchange are taken into account, this usually represents, at least, a minimum estimate of the economic rate of return. If high enough, it suggests that the project is economically justified, even though this will not usually be the determining factor. A low return may simply indicate that tariffs are too low, rather than that the project is not justified.

The World Bank is a non-profit multinational organization. It is directed by representatives of the member countries and has a multinational staff. It seeks to assist its members in their efforts to promote better lives of all people. It recognizes that the provision of potable water in adequate quantity is important for a better life. It assists member countries to provide water by providing financial and technical assistance. In so doing it asks

297

that important social, economic, technical, financial and managerial criteria be met. But it recognizes that these criteria may sometimes be difficult to achieve and is therefore prepared to be flexible in its arrangements with borrowing countries.

The World Bank, of course, is not the only institution providing funds for the construction of water supply and sanitation projects--or their preparation and design. The Annex reproduces a paper giving information on the large number of agencies providing assistance in the sector.

298

Annex

WATER SUPPLY FINANCE, SOURCES, CHANNELS, AND PROCEDU

by

Harold Shipman, Senior Sanitary Engineer
World Bank

August 6, 1976

The opinions expressed in this paper are those of the author and are not necessarily those of the World Bank.

299

WATER SUPPLY FINANCE, SOURCES, CHANNELS, AND PROCEDURES

Water supply officials working in the developing countries frequently are unable to know what sources of funds and technical assistance may be available to them, how they can get information, and what channels may be used. Similarly, they may not know of the range of resources which may be available to them for assistance in the solution of certain problems. In the following paragraphs a partial, but incomplete, presentation of information is given on various aspects of this subject which may help to orient those who desire such information. While an effort has been made to make the information as comprehensive as possible, there will undoubtedly be omissions. The statements on sources, channels, procedures and arrangements have been prepared from the author's personal experiences and understanding and are believed to be accurate. However, in some instances these may be wrong; in others they may have been correct at one time but recent changes may make them no longer valid. The various agencies should therefore be contacted directly by those who need detailed information and wish to request assistance. The views and statements in this paper are those of the author and do not necessarily reflect those of the various agencies mentioned including the World Bank.

Types and Sources of External Assistance for Planning, Project Development, Construction, Operation and Management

The following list shows activities which usually require funds beyond those normally included in the operating budgets of water agencies or which frequently need inputs which would permit more extensive and thorough preparations than possible when only existing staff is employed. Only external sources of assistance are shown; it being assumed that water supply officials will be familiar with local resources.

300

Characteristics of Assistance by Types of Agencies

A. World and Regional Banks - (IBRD, IADB, ASDB, AFDB)

The assistance provided by these Banks is primarily through loans. The regional Banks serve those countries which are within their region and are members. Where these Banks are shown as sources of assistance in Table I, such assistance is normally provided through funds included in project loans and which will have to be repaid with interest over the period of the loan. Some of these Banks have arrangements for making small loans for project development and engineering. In a few situtations, grant funds for project development may be made available but folded into the loan later, if one is made. Loans for water projects by each of the Banks are made following an appraisal which is based on preliminary or final engineering and feasibility status. Organization, management, financial performance, technical approaches and economic aspects are included in the appraisals. A period of three to six months is normally required following appraisal to process the loans. Enquiries on suitability of projects on specific questions concerning criteria and requirement can be addressed directly to the Banks' water supply staff or can be channeled through Ministries of Finance.

Multilateral Agencies of the UN System - UNDP, WHO, UNCRET, UNICEF, ILO, FAO, WMO, IAEA, UNESCO, UNIDO

Specific information on addresses and areas of competence for each of the specialized agencies of the UN system will be available in the office of the UN Resident Representative usually located in the capital city of most countries.

Those agencies which are most active in the fields of public water supply are described in the following paragraphs:

B. UNDP - (United Nations Development Program)

UNDP provides funds to assist countries in the development of high priority projects and to make studies considered as important to the countries' development. Each country is given national allotment of funds for a period of time for planning purposes, referred to as an IPF (Indicative Planning Figure) within which the country can prepare projects. Water project studies have to be assigned a priority sufficiently high to compete with other requests for the scarce funds. The Planning Agency or other designated office of the Government, working with the local representatives of the UN (UN Resident Representative), carries the responsibility for deciding how the UNDP funds will be assigned. Water supply officials can obtain specific information on project possibilities from the local UN office. WHO can help prepare requests to UNDP for project assistance if the Government and the UN Resident Representative give encouragement. UNDP funds are almost always supplemented by contributions of funds, office space, local personnel costs, etc. provided by the host government or its water agency.

TABLE I

Type of Activity	Sources of Assistance
Planning, Programming, Analysis	WHO/IBRD Cooperative Program, Bilateral Agencies
Sector Studies	WHO/IBRD Cooperative Program, Bilateral Agencies
Engineering & Feasibility Studies	UNDP/WHO, IBRD, IADB, AFDB, ASDP, OECD, Bilateral Agencies
Project Financing	IBRD, IADB, ASDB, AFDB, OECD, Bilaterial Agencies, Private
Financing of small equipment items and assistance for rural and fringe areas	UNICEF
Organization & Management Studies	UNDP/WHO, IBRD, IADB, ASDB, AFDB, Bilateral Agencies, Private
Economic & Financial Studies	WHO/IBRD Cooperative Program, IBRD, IADB, ASDB, AFDB, Bilateral Agencies, Private
Manpower Development & Training	WHO, ILO, IBRD, IADB, ASDB, AFDB, OECD, Bilateral Agencies, Private
Special Studies & Testing: water quality, hydraulic, hydrogeologic, soils, chemical, biological, materials, leak detection, metering rates, meteorologic, etc.	UNDP/WHO, IBRD, IADB, ASDB, AFDB, UN, WMO, Bilateral Agencies, Private
Water Resource Studies & Planning	UNDP, UNCRET, WMO, FAO, WHO, IAEA, UNESCO, IBRD, & Regional Banks, Bilateral Agencies

302

WHO/IBRD Cooperative Program

This program is jointly financed by WHO and IBRD and responds to requests from countries desiring assistance in resolving problems associated with water supply. The program to date has concentrated on helping countries to carry out sector studies in the field of water and wastes. These studies analyze the existing situation with respect to number of people currently served, analyze governmental targets or propose targets for consideration, define the principal problems and constraints, and suggest actions which the Government can consider for implementation. The report can serve as a basic document for planning and project development. Follow-up assistance both by WHO country and regional staff, and by staff of the Cooperative Program Unit in Geneva, Switzerland can be arranged. It is possible to request assistance on special problems on which the water agency may wish consultation.

Assistance provided by the Cooperative Program staff is at no expense to the Government except for national staff assigned to work with the Cooperative Program staff; and for local arrangements of transport and office space. Requests for assistance can be directed to the local WHO engineer if one is present; to the WHO regional office serving the country; to the P.I.P. unit of WHO Headquarters in Geneva; or to the World Bank, Washington, D.C.

The Regional Banks take part in, or are consulted on all sector study work carried out by the Cooperative Program in countries which are members of the regional bank concerned.

WHO

WHO has its headquarters in Geneva, Switzerland and has regional offices in Washington, D.C. (Latin America), Copenhagen (Europe), Brazzaville (Africa), Alexandria (Eastern Medditerranean), New Delhi (South Asia) and Manila (Western Pacific). Each of these offices has sanitary engineers whose responsibilities include assistance to the member governments in the field of water supply. In a number of countries, WHO has country engineers working on various aspects of water supply.

WHO normally acts as the executing agency on projects financed by UNDP. It assists countries to develop requests to UNDP for preliminary project financing, and if approved by UNDP, in consultation with Government, employs consultants to carry out the studies. On studies which may result in projects requiring finance, if the country so indicates and if IBRD agrees, the latter Bank may express special interest in the studies and follow them to completion at which time it may consider lending for construction. The Regional Banks may, if they so elect, follow a somewhat similar pattern.

WHO may be approached for assistance on all technical aspects of water supply operation. Assistance requiring the employment and assignment of an engineer or other specialist to the country will

303

require a request from Government to WHO, and the latter will likely have to place the request in its planning budget for consideration along with other requirements. Assuming approval, a period of up to three years may be required before the specialist is available. Short-term assistance can frequently be arranged within fairly short time either out of regional resources or from the Cooperative Program as noted previously.

UNICEF

UNICEF assistance in water supply is usually directed at rural areas or to those fringe areas of urban communities where simple technologies common to rural areas may be employed. Assistance is usually in the form of equipment and supplies which normally have to be imported and which are required for construction and equipping of wells. In some instances limited distribution, piping and storage facilities may be included. Requests for information can be directed to the Ministry of Health; to the local representative of the UN; to local UNICEF staff if present; or to UNICEF Headquarters in New York.

UNCRET (UN Center for Resources, Energy, and Transport - New York)

UNCRET carries out work usually financed by UNDP on broad water resource matters. It has conducted ground water and hydrogeological studies; advised on resource organization and planning, and assisted on matters concerning water law. It currently functions as the Secretariat for the 1977 World Water Conference.

FAO - (Food and Agriculture Organization - Rome, Italy)

FAO is concerned with aspects of water related to agricultural use. Because of the opportunities to assist rural people with water supply as part of water irrigation schemes, and because of the inclusion of rural water in many rural development schemes, FAO is a source of assistance. It works closely with WHO in the consideration of facilities suited to human needs.

WMO - (World Meteorological Organization - Geneva, Switzerland)

WMO provides assistance in the fields of meteorological and hydrological data collection and evaluation.

UNESCO - (Education, Science and Cultural Organization - Paris, France)

UNESCO, in addition to being concerned with general education, works closely with WHO on educational matters concerned with Sanitary Engineers within the framework of university and professional engineering school curricula and development. UNESCO also is involved in water supply through its research and study activities outside the operations side of public water systems.

ILO - (International Labor Organization - Geneva, Switzerland)

ILO is able to assist in the development of training programs for various categories of water works personnel at the sub-professional level.

IAEA - (International Atomic Energy Agency - Vienna, Austria)

IAEA can contribute to studies of surface and ground water where radioactive tracers may prove useful. IAEA would also be a source of assistance in instances where combined nuclear power and desalination plants are being considered.

UNIDO - (United Nations Industrial Development Organization - Geneva, Switzerland)

UNIDO is primarily concerned with industrial water supply, and particularly for industries which may not have access to public supplies.

UNEP - (United Nations Environment Program - Nairobi, Kenya)

UNEP is concerned with those aspects of water supply which concern the environment. Where environmental assessment of the impact of projects may be needed, assistance can be requested.

Bilateral Agencies

Many countries have established agencies through which funds are channeled to assist other countries on a wide range of activities. Over the past 20 years and longer, sums of money and many man years of technical assistance have been provided by these agencies for various activities in the field of water supply. Such assistance has ranged from a few weeks of highly specialized consultations on local technical problems to the financing of all engineering and construction of sizable water systems. Such assistance may take the form of loans or grants. It may be through the supply of one or two experts for a brief period or it may be for consultants who prepare master plans and first step engineering designs. No two agencies will likely be found to have identical requirements nor will the procedure and time required to act on requests be found similar. The place for information on resources available is the local embassies of the various countries. Ministries of State of Finance will likely be the official channel for submission of formal requests. Among the bilaterals which have been active in offering assistance in water supply can be mentioned the following: USAID (USA), SIDA (Swedish), CIDA (Canada), ODM (British), KFW (German), France, Switzerland, Netherlands, Australia and Japan.

Private Sources

Several different kinds of assistance can be noted as available from private sources and each is rather specific to the source. A few of these sources are as follows:

305

Private Banks - A fair number of water supply loans have been made by private banks over the past years. In some cases this has been through direct loans and in others through purchase of national bonds the proceeds of which were used for water supply construction. While not a major source of funding at present, this resource should not be overlooked by those water agencies which are operating on a sound utility basis and where past performance gives assurance that the entity will be able to meet the debt service on loans. Unfortunately, few organizations are currently able to demonstrate this capability to the extent that private banks require.

Suppliers' Credits - A major source of financing for particular items of equipment is Suppliers' Credit. Such credits are usually fairly short-term - 8 to 12 years, and frequently carry high interest charges. The credits cover only the particular contract. Water agencies commonly ask bidders on equipment to submit proposals on financing as well, and at the time of bid evaluation the terms of the credit are compared together with the other evaluations. A number of problems can be encountered in this approach among which is that of the bidder who submits the best price for the best equipment but who is unwilling or unable to arrange the financing.

Private Sources of Technical Assistance

Universities engaged in research, foundations, churches, semi-private technological groups and a number of retired executives' organizations are possible sources of assistance on certain local problems. Assistance from these sources may be at no cost, at cost or something in between. Retired Executives' Organizations in Canada and the U.S.A., for example, are able to provide the services of water supply people with years of experience in nearly every type of activity encountered. Such assistance is provided under an arrangement whereby the individual receives no salary but the country receiving him has to pay the costs of transportation and local living. The local embassies of various countries should have information on addresses and arrangements. If not, they can advise on where to write for such information. Certain foundations and some semi-private agencies such as the International Technology Group in U.K. have contributed varying amounts of assistance in the field of water supply. The Rockefeller Foundation is known to have financed a number of projects having demonstration or stimulation aspects which contributed to countries' approaches to their problems. Those such as the International Technology Group have been concerned with finding technical solutions to problems which avoid undue sophistication but rest above the more primitive methods. These and others exist in various countries and may be known to agencies such as WHO, UNESCO, IBRD, and the commercial attaches of embassies.

Summary

It is apparent that many sources of assistance, technical and financial, are available to developing countries. One common problem in arranging whatever type of assistance as is desired, is the time element. The need for advance planning and scheduling, and the ability to anticipate needs well in advance is the best way to avoid problems of delayed help and of delayed projects. Obviously, the more countries can train their own specialists, and the better the performance of the water supply organizations, the less the reliance that needs to be placed on external assistance. At least for financing, it can be said that the better the organization and its performance, the easier it is to obtain the funds. As time goes on, better organizations can look forward to selling their own bonds to their own nationals. Sound utilities have historically been places for sound investment. Unfortunately, too few such utilities currently exist in the developing countries. The goal is to reach that point as rapidly as possible.

WORLD BANK

ENVIRONMENTAL POLICIES AND PROCEDURES

Hernan Reitze

Office of Environmental Affairs

I. POLICIES

(See World Bank Publication: Environment and Development.)

A. Main Philosophy:

- o Aim at financing environmentally sound and sustainable economic development projects.
- o "In the long run, environmental protection and and economic and social development are not only compatable but interdependent and mutually reinforced."
- o "The bank will not finance any project that seriously compromises health or safety, causes severe or irreversible environmental deterioration, or displaces people without adequate provision for resettlement.

B. Basic Elements:

- o Technical assistance to member countries.
- o Review and evaluation of all investment projects of the World Bank Group.
- o Project components.
- o Environmental projects.

II. PROCEDURES

(See World Bank Publication: "Environmental, Health and Human Ecologic Considerations in Economic Development Projects" ... being updated)

A. Approach:

- o Emphasis is on early and less expensive preventative measures, as opposed to later and more expensive curative measures.
- o Project specific considerations.
- o Sector specific guidelines.

III. INTERNATIONAL ENVIRONMENTAL ACTIVITIES

A. Liaison and coordination with the United Nations Environment Program (UNEP)

B. Activities with other international organizations

"Declaration of Environmental Policies and Procedures Relative to Economic Development" (Adopted by nine major multilateral development assistance institutions.)

C. Liaison with NGO's, PVO's and other organizations working in the field of environment and development.

DECLARATION OF ENVIRONMENTAL POLICIES

AND PROCEDURES RELATING TO

ECONOMIC DEVELOPMENT

WHEREAS, ECONOMIC AND SOCIAL DEVELOPMENT IS ESSENTIAL TO THE ALLEVIATION OF MAJOR ENVIRONMENTAL PROBLEMS BY PROVIDING FOR AN INTEGRAL RELATIONSHIP BETWEEN SOCIETIES AND THEIR ENVIRONMENT, REALIZING ALSO THAT ECONOMIC DEVELOPMENT AND SOCIAL GOALS SHOULD BE PURSUED IN SUCH A MANNER AS TO AVOID OR MINIMIZE ENVIRONMENTAL PROBLEMS PECULIAR TO IT,

RECOGNIZING THAT, THE MAJOR ENVIRONMENTAL PROBLEMS OF THE DEVELOPING COUNTRIES ARE NOT NECESSARILY OF THE SAME NATURE AS THOSE OF DEVELOPED COUNTRIES IN THAT THEY ARE PROBLEMS WHICH OFTEN REFLECT THE IMPACTS OF POVERTY WHICH NOT ONLY AFFECTS THE QUALITY OF LIFE BUT LIFE ITSELF,

CONVINCED, THAT IN THE LONG RUN ENVIRONMENTAL PROTECTION AND ECONOMIC AND SOCIAL DEVELOPMENT ARE NOT ONLY COMPATIBLE BUT INTERDEPENDENT AND MUTUALLY REINFORCING.

ACKNOWLEDGING, THAT THE NEED FOR ENVIRONMENTALLY SENSITIVE AND RESPONSIBLE DEVELOPMENT HAS BECOME MORE IMPORTANT AND URGENT IN LIGHT OF INCREASING POPULATION AND CONCOMITANT PRESSURES ON THE EARTH'S RESOURCES AND LIFE-SUPPORTING ECOLOGICAL SYSTEMS IN SOME AREAS,

ACKNOWLEDGING, THE SOVEREIGN RIGHT OF GOVERNMENTS TO DETERMINE THEIR OWN PRIORITIES AND DEVELOPMENT PATTERNS,

RECALLING, THAT THE STATES WHICH ADOPTED THE DECLARATION OF THE UNITED NATIONS CONFERENCE ON THE HUMAN ENVIRONMENT (STOCKHOLM, 1972) STATED THEIR COMMON CONVICTION (PRINCIPLE 25) THAT THEY WILL ENSURE THAT THE INTERNATIONAL ORGANIZATIONS PLAY A CO-ORDINATED, EFFICIENT AND DYNAMIC ROLE IN THE PROTECTION AND IMPROVEMENT OF THE ENVIRONMENT,

CONSIDERING, FURTHERMORE, THAT INTERNATIONAL DEVELOPMENT ASSISTANT INSTITUTIONS HAVE, ALONG WITH THEIR MEMBER GOVERNMENTS, A RESPONSIBILITY TO ENSURE THE SUSTAINABILITY OF THE ECONOMIC DEVELOPMENT ACTIVITIES FINANCED BY THEM,

THEREFORE, THE UNDERSIGNED DECLARED THAT THEY:

I. REAFFIRM THEIR SUPPORT FOR THE PRINCIPLES AND RECOMMENDATIONS FOR ACTION OF THE UNITED NATIONS CONFERENCE

II. WILL, TO THE BEST OF THEIR ABILITIES, ENDEAVOUR TO:

1. INSTITUTE PROCEDURES FOR SYSTEMATIC EXAMINATION OF ALL DEVELOPMENT ACTIVITIES, INCLUDING POLICIES, PROGRAMMES AND PROJECTS, UNDER CONSIDERATION FOR FINANCING TO ENSURE THAT APPROPRIATE MEASURES ARE PROPOSED FOR COMPLIANCE WITH SECTION I ABOVE;

2. ENTER INTO CO-OPERATIVE NEGOTIATIONS WITH GOVERNMENTS AND RELEVANT INTERNATIONAL ORGANIZATIONS AND AGENCIES, TO ENSURE INTEGRATION OF APPROPRIATE ENVIRONMENTAL MEASURES IN THE DESIGN AND IMPLEMENTATION OF ECONOMIC DEVELOPMENT ACTIVITIES;

3. PROVIDE TECHNICAL ASSISTANCE, INCLUDING TRAINING, ON ENVIRONMENTAL MATTERS TO DEVELOPING COUNTRIES, AT THEIR REQUEST, THUS DEVELOPING THEIR INDIGENEOUS CAPACITY, AND FACILITATING TECHNICAL CO-OPERATION BETWEEN DEVELOPING COUNTRIES.

4. GIVE ACTIVE CONSIDERATION AND, IF APPROPRIATE, SUPPORT PROJECT PROPOSALS THAT ARE SPECIALLY DESIGNED TO PROTECT, REHABILITATE, MANAGE OR OTHERWISE ENHANCE THE HUMAN ENVIRONMENT, THE QUALITY OF LIFE, AND RESOURCES THERETO RELATED;

5. INITIATE AND/OR OTHERWISE CO-OPERATE IN RESEARCH AND STUDIES LEADING TO IMPROVEMENT OF PROJECT APPRAISAL, IMPLEMENTATION AND EVALUATION METHODOLOGIES, INCLUDING COST-BENEFIT ANALYSIS, OF ENVIRONMENTAL PROTECTION MEASURES;

311

6. SUPPORT THE TRAINING AND INFORMING OF OPERATIONAL STAFF IN THE ENVIRONMENTAL DIMENSION OF ECONOMIC DEVELOPMENT;

7. PREPARE, PUBLISH AND DISSEMINATE DOCUMENTATION AND AUDIO-VISUAL MATERIAL PROVIDING GUIDANCE ON THE ENVIRONMENTAL DIMENSION OF ECONOMIC DEVELOPMENT ACTIVITIES.

ADOPTED AT NEW YORK ON 1 FEBRUARY 1980.

THE AFRICAN DEVELOPMENT BANK

Kwame Donkor Fordwor
President

THE ARAB BANK FOR ECONOMIC DEVELOPMENT IN AFRICA

Chadli Ayari
President

THE ASIAN DEVELOPMENT BANK

Taroichi Yoshida
President

THE CARIBBEAN DEVELOPMENT BANK

William Demas
President

THE INTER-AMERICAN DEVELOPMENT BANK

Antonio Ortiz Mena
President

THE WORLD BANK

Robert S. McNamara
President

THE COMMISSION OF THE EUROPEAN COMMUNITIES

Roy Jenkins
President

THE ORGANIZATION OF AMERICAN STATES

Alejandro Orfila
Secretary-General

THE UNITED NATIONS DEVELOPMENT PROGRAMME

Bradford Morse
Administrator

THE UNITED NATIONS ENVIRONMENT PROGRAMME

Mostafa K. Tolba
Executive Director

Statement by Mr. William Clark, Vice President,
External Relations, World Bank

I am pleased on behalf of the World Bank to join with other representatives of organizations active in development assistance in endorsing the "Declaration of Environmental Policies and Procedures Relating to Economic Development."

It is right and proper for all who are committed to the principles stated in this Declaration to renew the pledges made in Stockholm in 1972 at the United Nations Conference on the Human Environment.

Development is an endeavor which will not end with this generation. Our children and their children's children will follow in our footsteps and carry on in support of the same process of world economic development. It is for us to make sure that the conditions in which future generations pursue the fight against poverty and disease are such that progress will indeed be possible and the battle little by little won.

The very first of these conditions is that we leave a world in which the cycle of life is safe and protected. There will be no development for the coming generations if those who are today in charge of economic planning close their eyes to the fundamental importance of protecting those elements which sustain life on this earth.

The World Bank, I am pleased to say, has a record in this respect of which to be proud. Its own policies and procedures match well with those which the Declaration contains. The World Bank has shown that, in practice, it is indeed possible to design and carry out development projects which fully take account of environmental needs and conditions. It is right to say that the Declaration would have little real significance had it not been shown by

Statement by Mr. William Clark, Vice President,
External Relations, World Bank

I am pleased on behalf of the World Bank to join with other representatives of organizations active in development assistance in endorsing the "Declaration of Environmental Policies and Procedures Relating to Economic Development."

It is right and proper for all who are committed to the principles stated in this Declaration to renew the pledges made in Stockholm in 1972 at the United Nations Conference on the Human Environment.

Development is an endeavor which will not end with this generation. Our children and their children's children will follow in our footsteps and carry on in support of the same process of world economic development. It is for us to make sure that the conditions in which future generations pursue the fight against poverty and disease are such that progress will indeed be possible and the battle little by little won.

The very first of these conditions is that we leave a world in which the cycle of life is safe and protected. There will be no development for the coming generations if those who are today in charge of economic planning close their eyes to the fundamental importance of protecting those elements which sustain life on this earth.

The World Bank, I am pleased to say, has a record in this respect of which to be proud. Its own policies and procedures match well with those which the Declaration contains. The World Bank has shown that, in practice, it is indeed possible to design and carry out development projects which fully take account of environmental needs and conditions. It is right to say that the Declaration would have little real significance had it not been shown by

the practitioners of development such as the World Bank that the policies and procedures which it embodies are enforceable and practical and beneficial to those whose economic and social wellbeing is the end object of all efforts.

All this requires the cooperative efforts of the whole international community. It also requires a greater recognition of the reciprocal relationship between the natural environment and all of us as individuals, communities and nations. In the coming decades of danger and of opportunity, the community of nations must follow development policies flexible enough to respond intelligently to the great challenges ahead, above all the challenge of producing a decent life for a global population of 8 billion - double the number today.

The Declaration will help us all in this indispensable global community endeavor. It will make it easier to harmonize development policies and procedures and consequently to improve the efficiency and the pace of development assistance around the world. And the Declaration will make it easier to resist the ever present temptation of quick solutions which overdraw our ecological bank account.

The presence today of representatives of the development community, and particularly of institutions operationally involved in development, is clear testimony to the significance we all attach and will continue to attach to this Declaration.

February 1, 1980

316

A2.8 PROCEDURES USED BY THE WORLD BANK*

A2.8.1 The World Bank

*Based on a preprint written by Dr. J. A. Lee of the World Bank presented in New York, October 14, 1976, at an international briefing sponsored by the Center for International Environmental Information.

The World Bank is a group of three institutions, the International Bank for Reconstruction and Development (IBRD), the International Development Association (IDA), and the International Finance Corporation (IFC). The common objective of these institutions is to help raise standards of living in developing countries by channelling financial resources from developed countries to the developing world.

The Bank has committed itself to helping its 127 member countries with their many intractable development problems, including, among others, questions of income distribution, rural and urban poverty, unemployment, excessive population growth, rapid urbanization and, of late, environmental protection and rehabilitation, and preventive medicine and health care delivery.

A2.8.2 Environmental Considerations in Development Assistance

The environmental problems of the developing countries can be divided into two categories: effects of poverty and effects of economic development.

Under conditions of poverty, the biophysical environment often exhibits the ravages of long years of mismanagement (over-gazing, erosion, denuded forests, surface water pollution, etc.). Not merely the 'quality' of life but life itself is endangered, for it is often very difficult and sometimes impossible for the environment to renew its life-supporting capabilities. Developing countries assign the highest priority to finding solutions to problems of this nature. Here the principal concern is to rehabilitate the environment that has gone through a long period of deterioration.

The other set of problems accompanies the process of development itself. Agricultural growth, for example, calls for construction of irrigation and drainage systems, clearing of forests, use of fertilizers and pesticides – all of which have environmental and health implications. Similarly, the process of industrialization could well result in the release of pollutants and in other environmental problems related to the extraction and processing of raw materials.

In sum, developing countries are now beginning to be concerned with two different types of environmental problems. In the first type, these nations have to alleviate poverty; while in the other, they have to seek ways to prevent the environmental deterioration often associated with development. The first task is considerably more difficult than the second, but the second could also become difficult if the present concern for the environment is not translated into action. The Bank is concerned with both aspects of the problem.

A2.8.3 The World Bank's Approach

Though the World Bank prior to 1971 had concerned itself with the environmental implications of its development activities, no systematic procedure existed to identify and examine those effects. More importantly, methods to prevent or mitigate adverse consequences had not, in many instances, been devised. In late 1970, however, the post of Environmental Adviser was established and given a

strong mandate to review and evaluate every investment project from the standpoint of its potential effects on the environment. That post has now grown into an Office of Environmental and Health Affairs which oversees the Bank's environmental activities, including, especially, ensuring that projects proposed for financing are examined for their ecological, health, and socio-cultural effects and that appropriate measures are taken to prevent or mitigate serious adverse consequences.

Important to this task has been the Bank's handbook *Environmental, Health, and Human Ecological Considerations in Economic Development Projects*. Prepared for use by the Bank's own staff, the handbook has found widespread use throughout the developing world, including government planners, borrowing entities, engineering and construction firms, consultant organizations, universities, etc. As environmental considerations have more and more become a fixed part of Bank operations, these guidelines and criteria now cover many different kinds of project possibilities and settings and are used in the evaluation of environmental impacts of virtually all projects. An example of a set of guidelines (for power plants) is given below in Section A2.8.4 (World Bank, 1974).

Experience in environmental evaluations within the Bank has given rise to a series of operations which are now being followed for each project believed to have significant environmental/health/human ecological impacts.

In brief, these include:

(1) In-house study of the proposed project, utilizing the Bank's technical staff.
(2) On-site 'environmental reconnaissance' to determine likely impact of the project; the problems, if any, likely to result; recommendations for preventing or mitigating such problems; or recommendations for in-depth studies of particular environmental responses.
(3) In-depth studies are the subject of multidisciplinary investigations conducted under terms of reference carefully tailored to the conditions and requirements surrounding the particular project, or component thereof.
(4) Projects of such a nature that their environmental impacts are of unique importance to a regional or global audience, and wherein singularly unique and important environmental values are involved, must, of necessity, be the object of comprehensive and detailed studies to determine how or if the project can proceed.
(5) Projects for which environmental safeguards or controls are to be included are examined during the construction and pre-operation stages to determine their adequacy and sufficiency in light of any changes which may have occurred subsequent to final appraisal.
(6) Projects in operation are examined periodically to determine the continuing adequacy of environmental safeguards and the need, if any, for new or improved controls.
(7) Projects involving 'important ecological systems' are subjected to 'environmental post-audits' at appropriate points in their implementation to determine the accuracy of the pre-project impact assessment and the actual consequences for such systems.

318

In each and every project subjected to one or more of the steps cited above, the environmental safeguards which may be indicated are the object of cost/benefit analysis. Efforts are continuing to develop a more suitable methodology for identifying the diseconomies, social and opportunity costs, and benefits to be anticipated. The difficulties experienced in this regard are many, and are the subject of increased research.

The environmental studies seen as being requisite to financing a project are, in most instances, financed by the borrowing entity, in much the same manner as other aspects of project preparation, such as engineering, geology, marketing, etc. In some cases involving poor countries, the Bank may finance the required studies. Increasingly, the borrowing entity is encouraged to make the necessary studies, while the Bank reserves the right to approve the terms of reference and the qualifications of those employed in their conduct. The Bank does assist, where appropriate, in preparing the terms of reference and in defining the disciplines to be used in the studies. In some instances, the Bank will conduct the required studies being financed by the borrower. In any event, findings of environmental studies are shared jointly with the borrower, member country government, and the Bank.

Thus, while no formal 'impact statement' on the environmental consequences of a development project is strictly required, the Bank does require that major adverse effects be avoided or mitigated and, as indicated, has established systematic procedures for accomplishing this. To date, all projects requiring safeguard measures have been successfully negotiated with the borrower and member country.

Industrial projects are of especial concern to the Bank – in FY 1976 the Bank and IFC loaned over $800 million in that sector. Like projects in the other sectors, industrial projects are examined for their environmental, occupational health, and worker safety aspects.

In addition to the extensive guidelines provided in the Bank's handbook, more specific and detailed effluent and emission guidelines have been prepared for the many types of industries financed by the Bank (World Bank, 1977). There are close working relationships with the WHO, UNIDO, ILO, ECE, and others active in the industrial field.

A2.8.4 An Example of a Set of Environmental Guidelines (World Bank, 1974, pp. 38–40)

POWER PLANTS (FOSSIL-FUELED, NUCLEAR-FUELED AND HYDROELECTRIC)

A. Environmental/Resource Linkages

- ☐ What site selection criteria will be used?
- ☐ Will they include environmental considerations, such as effects on air and water quality, and the resulting impact on residents of the area, fish, wildlife, and vegetation?
- ☐ Will alternative sites and alternative orientation of the plant be considered in order to minimize adverse environmental impacts?

- ☐ Does the site correspond to other local or regional development and land-use plans?
- ☐ Have the environmental consequences of power transmission and fuel storage been considered in site selection?

B. Project Design and Construction

- ☐ Will the power-plant construction activities be carried out in a manner that will minimize damage to the natural environment?
- ☐ Is there a consolidated construction plan that takes into account spatial planning and ecological factors?
- ☐ Are road patterns, land excavations, fill sites, and refuse disposal activities consistent with good environmental protection practices?
- ☐ Will land in construction areas be restored by filling, grading and reseeding to prevent erosion?
- ☐ Will air pollution be a problem and, if so, how will it be controlled?
- ☐ How vulnerable is the power plant to surface subsidence, earthquakes, tornadoes, and other catastrophes?
- ☐ What is the extent and impact of the environmental degradation which could be expected in the event of such catastrophes?
- ☐ What steps are planned to avoid soil erosion and the silting of streams, as transmission facilities and access roads are constructed?

C. Operations

- ☐ What disposition will be made of solid and liquid residues (e.g., ashes, nuclear wastes)?
- ☐ How will fuel be stored?
- ☐ Are low-sulphur fuels available for fossil plants?
- ☐ Have alternative fuel schedules been developed?
- ☐ Does the disposal or storage method include adequate cassetting or neutralization to minimize the danger of soil or water pollution?
- ☐ What steps are planned to contain and reclaim ash dumps to avoid pollution of surface and groundwater by acid-laden runoff?
- ☐ If waste disposal into water bodies is planned, what will be the effects on aquatic life?
- ☐ To what degree will tidal action and currents dilute plant effluents?
- ☐ What provision will be made for controlling the release of radioactive waste material into water bodies?
- ☐ If additional units are constructed, what will the total load of radioactive waste materials be?
- ☐ Is the makeup of the plant's gaseous emissions known in terms of chemistry and volume?
- ☐ What downwind environmental effects can be anticipated with respect to humans, crops, forests, and wildlife?
- ☐ How can such effects be minimized?

- ☐ Will emission control equipment be installed? If so, is the level of control adequate?
- ☐ What impact will thermal effluents have on the receiving waters?
- ☐ What temperature increase can be anticipated, and how will this affect indigenous biota?
- ☐ Is there sufficient water motion in the receiving bodies to dissipate heat effectively?
- ☐ Has the use of cooling towers or ponds been sufficiently explored?
- ☐ What is the probability of producing undesirable fog conditions through the dissipation of waste heat?
- ☐ What impact will the impoundment for a hydroelectric plant have in terms of the destruction of agricultural and forest lands, and habitats for fish and wildlife?
- ☐ What measures are planned to mitigate the loss of natural habitats for fish and wildlife?
- ☐ To what degree will archaeological and scenic values be affected?
- ☐ How will the reservoir and downstream flow affect water quality parameters, such as temperature, dissolved oxygen, nutrients, nitrogen concentration, hydrogen sulfide, and color?

D. Sociocultural Factors

- ☐ Will construction or operation of the plant adversely affect agricultural, economic or commercial practices in the area, such as farming or access ways in a reservoir impoundment area?
- ☐ Will plant construction cause displacement of peoples because of flooding, required rights-of-way or because of new opportunities?
- ☐ Will plant effluent adversely affect agriculture, aquaculture or related practices?

E. Health Impacts

- ☐ What new public health problems may arise from the project?
- ☐ Will changes in water velocities, temperatures and depth result in a more favorable environment for disease-bearing organisms?
- ☐ Will the changes in water patterns introduce disease-bearing organisms into previously unaffected areas?
- ☐ Will long-term exposure to gaseous emissions prove a significant health problem?
- ☐ Are contingency resources available to deal with unexpected problems of health maintenance or disease control? In the case of nuclear power plants, is there a contingency plan for dealing with emergency health problems and accidents in the event of an emergency?

F. Long-Term Considerations

- ☐ What provision has been made for industrial development associated with the power plant?
- ☐ What impact due to increased immigration will that activity have on the environment?

321

References

World Bank (1974) *Environmental, Health and Human Ecological Considerations in Economic Development Projects*. The World Bank: Washington, D.C., U.S.A. 142 pp.

World Bank (1975) *Environment and Development*. The World Bank: Washington, D.C., U.S.A. 33 pp.

World Bank (1977) *Manual on General Environmental Protection for the Industrial Sector*. The World Bank: Washington, D.C., U.S.A.

322

WORLD POPULATION GROWTH

By Cynthia P. Green
Deputy Director, Education and
Public Policy

Population Crisis Committee
Washington, D.C.

Paper presented at the "Seminar on Principles of Environmental Management in Developing Countries," sponsored by the International Environmental Management Institute, Concord, Massachusetts, June 13, 1980

323

Never before in the Earth's history have so many people inhabited the planet, nor have our numbers grown so rapidly in any other century. We are presently engaged in an unprecedented global experiment to see if the human species can humanely limit its numbers without massive starvation, violent social upheavals, or nuclear holocaust. No one knows precisely how many people the globe can support, but it seems obvious that a large proportion of the world's 4.4 billion people is living on a slender thread. Accommodating the additional 2 billion people expected by the year 2000 will require superhuman efforts, massive infusions of capital and technology, and unwavering political commitment on the part of both developed and developing countries alike.

I. Population Trends

The human species has existed on Earth for only about 2 million years and has grown very slowly until the past two centuries. In the year 1 A.D., there were about 250 million people on Earth, less than the Soviet Union's population today. The world reached its first billion around 1800. The second billion took about 130 years to 1930; the third billion was reached in 1960 after only 30 years, and the fourth in 1975, after 15 years. The fifth billion is expected to take just 12 years.

The rapid growth in the world's population is primarily the result of a dramatic reduction in deaths due to improved public health measures and food production techniques. Since 1940, the world's death rate has been cut in half while the birth rate has remained essentially the same, declining slightly in the past few years. Worldwide, the average person born in the late 1940's could expect to live to the age of 40; today's life expectancy at birth is 61.

Nearly 90 percent of the world's population growth is taking place in the developing nations, with India and the People's Republic of China accounting for one-third of the world's annual growth. At present growth rates, Africa's population would

324

double in just 24 years, Latin America's in 26 years, and that of the Middle East in 25 years. Mexico now adds more people to its population annually than the United States, and Brazil adds more than the Soviet Union. On the whole, the Asian population is growing more slowly, at about 1.8 percent annually. However, several countries, including Afghanistan, Bangladesh, Iran and Pakistan are growing at 2.6 percent or more each year.

In contrast, the industrialized countries are growing at less than 1 percent annually. Six European countries have reached zero population growth, and many other countries have reached replacement-level fertility (the number of children needed to replace the two parents, calculated to be 2.1 children in countries with low mortality rates). Between now and the year 2000, the number of people in developed countries is expected to grow only slightly, from 1.1 billion to 1.3 billion, an increase of 12 percent. The developing countries, on the other hand, are projected to grow from 3.3 billion people to 4.9 billion, an increase of 49 percent.

Because of declining birth rates over the past decade, world population growth has slowed somewhat, dropping from a peak of 1.9 percent in 1970 to 1.7 percent in 1980. Nevertheless, at this growth rate world population would double in just 41 years. Even though a 1.7 percent growth rate sounds like a low level, when it is multiplied by billions of people and compounded year after year, it adds up to large increases. For example, in 1960, about 60 million people were added to the world's population. This year some 75 million people will be added, and by the year 2000 this annual increase will be 97-100 million, assuming the annual growth rate drops to 1.6 percent.

The most recent United Nations projections estimate that world population will be 6.2 billion in the year 2000, 9.0 billion in 2025, and 11.1 billion in 2050. Some experts believe that world population could level off at about 11 billion, while others question whether the Earth's biosphere, already under heavy environmental strains,

325

can support even 6 or 8 billion. Even with miraculous technological advances that would provide unlimited supplies of food and energy, most experts acknowledge that supporting larger numbers of people over the long-term will probably require a minimal standard of living for most of the world's people. Scientists calculate that the world could support only 700 million people (16 percent of its present population) at the American standard of living and about 2 billion people at the European standard.

If the entire world achieved replacement-level fertility by the year 2000, world population would stop growing at around 8 billion. For every decade after the year 2000 that replacement-level fertility is delayed, world population would be 10 to 15 percent higher. Worldwide, average fertility is about 3.8 children per woman. To achieve replacement-level fertility by the year 2000 would require a 44 percent reduction in fertility in just 20 years.

The reason that population growth continues for 50-70 years after replacement-level fertility is reached is that a large proportion of the world's population consists of young people who have not yet reached their childbearing years. Today, 35 percent of the world's population is under the age of 15. Some 45 million young women enter the reproductive age group each year while only about 23 million women leave it. The decisions that today's young people make regarding family size and child spacing will have major ramifications for world population size in the next few decades.

II. Consequences of Population Growth

Population growth has far-reaching and significant consequences for both industrialized and developing countries alike. Growing numbers of people hinder government efforts to alleviate poverty and to provide basic public services such as schools, utilities, waste disposal, housing, and police and fire protection. In developing countries, population growth especially affects the poor majority by increasing competition for limited food supplies, jobs and land. Most of the industrialized countries, including Europe, Japan and the United States, already have a large population in relation to their available land and natural resources.

32 16

Planners need to take today's demographic realities into account when devising development and social service programs. For example, the primary-school attenders six years from now are already born, as are the job-seekers 15 to 20 years from now. In establishing programs and priorities for the future, planners must take into account the large numbers of young people who will soon be needing schools, jobs, housing, health care and other services. In addition, planners need to examine the relative demand for services resulting from alternative population projections. In Jordan, for example, food requirements will more than double by the year 2000 and will triple by 2010 if the present fertility of 6.5 children per woman continues. If a three-child average were attained by the year 2000, the demand for food would be 25 percent less, and if a two-child average were attained by the turn of the century, food import requirements would be half of what they are today.

Following are some specific problems associated with population growth around the world:

Economic Development

From 1960 to 1976, overall economic growth in low-income developing countries nearly matched that of the industrialized countries, and economic growth in middle-income developing countries was even greater. Nevertheless, because of rapid population growth, the developing world's per capita income remained considerably lower than that of the developed countries. Rapid population growth often cancels out development efforts by constantly adding to the numbers of needy people living a subsistence-level existence. For example, in Mexico a new classroom is built every 50 minutes but in the same short time 240 children are born. At current rates of population growth, most developing countries will have to double their economic output in the next 25 years just to stay even with population growth. Any improvements in living conditions would require even greater economic expansion.

327

Employment

Between now and the year 2000, 780 million new workers will be added to the 283 million people currently unemployed or underemployed in the non-Communist developing world, according to estimates by the International Labor Organization. Thus, over a billion jobs will need to be created in the next two decades; this is more than the total labor force of the industrialized countries. Job creation is extremely costly, as the Egyptian government learned when it calculated that the average cost to create just one new job is about $10,000 (U.S.). Unemployment is particularly high among urban youth aged 15 to 24, politically and socially the most volatile of all age groups.

Urbanization

When there is not enough work in rural areas to support their burgeoning population, large numbers of people move to already overcrowded cities looking for jobs, often in vain. While the populations of developing countries are doubling every 25-30 years, their large cities are doubling in size every 10-15 years and their urban slums or shantytowns every 5-7 years. By the year 2000, 40 cities in the developing world will have more than 5 million people, and the developed world will have 12 such cities, according to World Bank estimates. The concentration of poor people into urban agglomerations without a livelihood and without basic amenities such as adequate water, sanitation, health care facilities, and durable housing is likely to contribute to alienation and frustration on a massive scale.

Food

About 500 million people in the world are severely malnourished, and about half of the world's population has an inadequate diet, according to the U.N. Food and Agriculture Organization. Furthermore, this situation is likely to worsen, since the demand for food is expected to double by the year 2000 because of population growth and rising affluence.

328

Although world food production has increased by record levels since 1950, it has not kept pace with population growth in the developing countries. Per capita food production worldwide has dropped since 1973. Many developing countries have become net food importers and are using scarce foreign capital to buy basic foodstuffs. For example, Egypt is presently spending $1.7 billion (U.S.) annually to subsidize imports of food and other basic commodities.

Some experts are skeptical that food production can continue to increase at the rapid rates of the past, since millions of acres of fertile farmland are being lost each year due to the growth of cities, erosion, desertification, salinization, deforestation, overgrazing, and dam construction. Most of the well-watered, arable land in the world is already under production, and the potentially tillable land left requires special care of tropical soils or supplementary water supplies.

Housing

In both urban and rural areas, housing is a critical problem. In Asia, the backlog of needed housing units in urban areas increased from 22 million dwellings in 1960 to 72 million in 1975. In Asia's rural areas, the need for housing units went from 125 million dwellings to 219 million in the same 15-year period. An increasingly large proportion of the world's population is living in cardboard shacks in urban shantytowns or in other substandard housing.

Health Care

Health facilities are finding it increasingly difficult to keep up with population growth. Part of the explanation of the recent slowdown in mortality declines in developing countries is that health services have failed to keep up with the demand. The World Health Organization estimates that 80 to 90 percent of rural populations in developing countries have no access to health care. The urban poor are scarcely better off. In Sao Paulo, for example, infant mortality has risen recently, and malaria and bubonic plague have reappeared.

School Enrollment

Between 1960 and 1974, the number of children in school in the non-Communist developing world nearly doubled, from 117 million to 231 million. However, because of rapid population growth, the number of children not in school increased by 29 percent, from 210 million to 270 million during the same period.

Energy and Mineral Resources

Rich and poor countries alike face the prospect of increasingly more expensive, scarcer supplies of energy and non-renewable mineral resources. The world's finite fossil-fuel mineral reserves are being rapidly depleted as a result of population growth coupled with increased consumption due to greater affluence and wasteful energy usage. No one knows how long these supplies can last, but they are certain to become more costly and therefore beyond the reach of the poor majority of the world's people. At present consumption levels, known reserves of minerals essential to modern manufacturing processes will be used up within the next few decades. Each additional person added to the total number of consumers, particularly in the industrialized countries, hastens the depletion of resources and shortens the amount of time available to develop alternative substitutes or technologies.

Environmental Degradation

In recent decades, the Earth's land, water, vegetation and atmosphere have undergone a sharply increased rate of pollution and depletion. Air pollution is a problem in every major city in the world, and the continued emission of toxic substances into the air may cause irreversible changes in the Earth's atmosphere and climate. Water pollution and shortages are common throughout the world. Only one-fifth of the world's population has access to processed drinking water. By the year 2000, worldwide water consumption is expected to be five times greater than today's level due to population growth, increased agricultural production and industrialization.

In creating greater demands for living space, farmland and lumber, rapid population growth also affects the destruction of grasslands and tropical rain forests.

Half of the world's forests have disappeared since 1950, and at current consumption levels forests in the developing countries are expected to be completely destroyed within 40 years. The world's forests are being used up faster than they can be replenished, with serious environmental consequences such as soil erosion, desertification, and possible global climate changes.

Environmental degradation also results from the desperate efforts of impoverished people to survive. Vast areas of Africa, South and Southeast Asia, the Middle East and Latin America have been devastated by slash-and-burn agriculture, overcropping and overgrazing with consequent soil erosion and depletion.

III. Population Policies and Programs

Over the past 10-15 years, awareness of the need to curb population growth has grown, and many governments have adopted comprehensive national population policies. In 1960, only two countries--India and Pakistan--supported organized family planning programs for the avowed purpose of reducing birthrates. By 1978, 35 developing countries representing 77 percent of the population in the Third World had official policies to reduce population growth. Another 30 countries, with 15 percent of the Third World population, supported family planning programs for social and health reasons. Only 7 percent of the people in the Third World live in the 66 nations that have no family planning activities.

Two major international conferences have underscored the importance of national population policies and programs. At the 1974 U.N. World Population Conference held in Bucharest, 136 governments adopted a World Population Plan of Action which recommends the formulation of national population policies "consistent with basic human rights and national goals and values." The Plan of Action also calls upon governments to "Respect and ensure, regardless of their over-all demographic goals, the right of persons to determine, in a free and informed manner, the number and spacing of their children." In 1979, parliamentarians from 58 countries met in Colombo and

adopted the Colombo Declaration on Population and Development which reaffirmed the 1974 Plan of Action and urged governments to "formulate appropriate population policies," integrate population programs in all development activities, and ensure the basic right of couples and individuals to decide on the number and spacing of their children.

The major policy options for governments seeking to reduce population growth include the provision of family planning programs and improvements in selected socio-economic factors associated with fertility declines. While the issue of family planning "versus" development has been hotly debated in recent years, most experts agree that this is a false dichotomy, since the countries with the greatest fertility declines are generally those with both strong national family planning programs and favorable social settings. Broad economic and social development is needed to create the motivation for smaller families and to reduce the dependence of parents on their children as laborers and as support for them in their old age. At the same time, family planning programs are needed to enable couples to implement their desires regarding family size and child spacing.

Family Planning Programs

A large proportion of the births in the world today are unwanted--as many as one in four in developing countries and one in 10 in the United States. Based on World Fertility Survey studies in 15 countries, about half of the married women of reproductive age in developing countries want no more children; yet only about half of these women are using effective methods of family planning. The high incidence of abortion throughout the world indicates that millions of women do not have access to effective contraceptive methods. Worldwide, about one in four pregnancies is terminated by abortion. Half of these abortions occur illegally and now represent a leading cause of death among women of childbearing age. In Latin America, the Middle East and other areas where family planning services are scarce, the medical complications of illegal abortions are reaching epidemic dimensions.

332

An estimated 671 million women worldwide are in need of family planning services. Only about 35 percent of these women--mainly those residing in the industrialized countries--now have reasonable access to family planning information and services. For governments wishing to reduce fertility, the provision of safe, effective and convenient family planning methods should be a priority, since there are already many highly motivated couples wishing to limit their families. Family planning also provides important health benefits for mothers and children and can be justified solely on these grounds alone.

Those family planning programs which have been found to be effective in reducing fertility generally include the following elements: 1) Strong commitment from national, regional and local leaders; 2) Close involvement of community residents in program planning and implementation; 3) The availability of a wide array of contraceptive methods through various channels, including clinics, village depots and commercial outlets; and 4) Greater involvement of women and paramedics in programs.

In many countries, family planning programs began with a small privately-run clinic operated in the capital city. Eventually a network of clinics and contraceptive distribution centers were established, and activities were expanded to include public education, training of medical staff and fieldworkers, and community outreach. At this stage, many governments began to provide family planning services through their own health facilities, and the private sector played a complementary role by testing new aproaches, supplementing the government's activities and expanding programs to rural areas. To provide family planning services to all those in need of them usually requires both a comprehensive national program run, or at least sanctioned, by the government as well as energetic private efforts to ensure continued expansion and improvement of the program.

One of the most successful national family planning programs is in Indonesia where the government has introduced an extensive community participation program

333

in rural areas. About 25,000 villages in Java and Bali have set up contraceptive distribution centers using local volunteers to distribute contraceptive pills and condoms. The centers are supplemented by a network of family planning clinics and fieldworkers who refer patients to the clinics for IUD insertions and voluntary sterilization operations. It is estimated that 27 percent of the eligible couples nationwide were using contraceptives in 1977.

In Colombia, the private family planning association, Profamilia, provides about half the family planning services in the country through an extensive network of clinics and 3,000 distribution posts. Contraceptives are made available in isolated mountain coffee-growing communities as well as in urban slums in all the major cities, in conjunction with community groups. The Ministry of Health also provides family planning services through its health care facilities. About 46 percent of the eligible couples were using contraceptives in 1978, and average family size has dropped from 6 children per woman in 1964 to 3.9 today.

In Egypt, an experimental household distribution program in one rural province convinced skeptical government officials that there was a large demand for family planning services in the rural areas. The program has since been extended to other areas and will ultimately reach one-third of Egypt's 7 million rural people. In the test area, contraceptive usage among married women increased from 18 to 31 percent within one year. The project has been the catalyst for other programs to meet village needs, including improved health services, literacy clases for women, and up-graded day-care facilities.

In recent years, there is mounting evidence that family planning programs can achieve substantial decreases in fertility, even in countries which have not had considerable socio-economic development. Programs in many diverse areas of the world have demonstrated that there is a strong demand for family planning and that poor, illiterate women want and are able to use contraceptives.

334

Improved Social and Economic Conditions

While meeting the demand for family planning services, governments can also promote conditions leading to sustained low fertility by emphasizing those programs associated with smaller families. In most countries, an improvement in the general wellbeing of the average citizen has accompanied declining fertility rates. Factors associated with smaller families include: more equitable income distribution, stable employment, adequate nutrition, access to health services, and educational attainment. Even where average family income has increased only slightly, couples who experience some improvements in the quality of their lives have opted for smaller families. In general, couples who have a day-to-day, subsistence-level standard of living have difficulty planning their families; the very concept of planning for the future is unfamiliar to them.

Economic growth alleviates poverty, therefore contributing to fertility declines, only if the masses of the people participate in that growth through increased employment, incomes, and consumption of goods and services. Typically, in developing countries the upper 20 percent of the population receive about 55 percent of the national income, while the lowest 20 percent receive about 5 percent. Some 40 percent of the population is entirely outside the development process. Increasing the productivity and income of the rural and urban poor will ultimately lead to lower fertility rates as a result of improved health, education and living standards.

Increased Education

Expansion of basic education, especially for girls, has been associated with fertility declines in a number of countries. For both men and women in traditional environments, schooling broadens the students' view of the opportunities and potentialities of life, encourages independent thinking, and reduces their suspicion of social change, including family planning. Girls who attend school tend to marry later and to have increased prospects for finding employment outside the home. Studies in

335

Latin America reveal that women who have completed primary school average about two fewer children than those who have not.

Improved Status of Women

Most observers agree that programs to enhance the social, economic and poliical status of women could contribute more than any other measure to reduced fertility. In many cultures, women are valued solely as mothers and are denied access to education and employment opportunities that would provide alternative roles for them. Women play an important but little-recognized role in childrearing, farming, marketing and housework and need to be valued for the highly productive work that they perform both inside and outside the home. Governments can play a crucial role in expanding opportunities for women by including them in development programs, providing them with credit and technical assistance, and encouraging them to occupy leadership positions.

Later Marriages

Women who marry later tend to have smaller families and to be better prepared for their role as parents. Between 35 and 40 percent of the birthrate decline in developing countries from 1965 to 1975 has been attributed to the rising age of marriage, especially of women. Later marriage enables women to take advantage of educational and employment opportunities and may increase a couple's ability to accumulate savings and to improve their socioeconomic status. In Sri Lanka, where women have the lowest fertility of any country in South Asia--an average of 3.4 children per women--the average age at marriage is 28 for men and 24 for women.

Governments which have instituted strong family planning programs coupled with effective socio-economic development programs have observed measurable declines in fertility over the past 5-10 years. It takes time to build successful programs because of the need to develop extensive infrastructures and facilities. to

336

reach down into communities, and to change traditional attitudes regarding family size. Also, in many countries, the data to document program accomplishments are difficult to obtain and often lag two or three years behind the actual program results.

Policies and programs implemented to reduce fertility require the long-term, unwavering commitment of national and local leaders. The problem of excess fertility is likely to be felt in much of the Third World for several decades to come. Postponing action only makes the problem worse and even more unmanageable. At the same time, policymakers and program administrators should not expect miraculous changes overnight. Family size norms have developed over centuries of tradition and cannot be greatly altered in the absence of other social and cultural changes. Dramatic declines in mortality have altered the traditional balance between births and deaths, and it is proving much more difficult to influence fertility than it was to introduce the changes that led to sharp decreases in mortality.

One of the fundamental challenges our generation faces is whether we will responsibly and humanely limit our numbers in accordance with the carrying capacity of our ecosystem or whether we will continue to despoil our environment, possibly triggering irreversible changes that will spell the end of all mankind. The decisions we make today and the actions we take will determine whether future generations are condemned to a life of deprivation and misery or whether the basic needs of the world's poor are met.

337

ENVIRONMENTAL HEALTH

Radiation Protection

Dade Moeller

Professor and Chairman
Department of Environmental Health Sciences
School of Public Health
Harvard University

June 1980

International Environmental Management Institute
ENVIRONMENTAL RESEARCH & TECHNOLOGY, INC.
Concord, Massachusetts, USA

338

EXECUTIVE SUMMARY

The control of an environmental contaminant, such as radiation exposure, requires an understanding of:

a) the major sources affecting the population
b) the avenues or pathways through which these sources reach people
c) the effects they have on health, and
d) techniques available for their evaluation and control.

This review of radiation exposure shows that, in spite of the many contributions by man, natural background radiation remains the greatest contributor of dose to the general public. Among the man-made sources, the one that contributes the greatest exposure to the public is the use of x-rays in medicine and dentistry. Other man-made sources include nuclear reactor operations, ranging from the mining of the fuel to the disposition of radioactive wastes; radiation machines and radioactive materials used in industry and medicine; low-level fallout from atmospheric detonations of nuclear weapons; and a host of consumer products ranging from airport x-ray inspection systems to clocks and watches with luminous dials.

In terms of its potential impact on health, radiation can have both somatic and genetic effects. Examples of somatic effects are certain blood abnormalities, metabolic diseases, and certain congenital-physical abnormalities. Examples of somatic effects are leukemia and other forms of cancer. To evaluate the potential health effects on man from external sources, direct reading instruments are available to assess the dose or potential the source has for imparting energy to tissue. Units traditionally used for expressing such doses are the roentgen (for assessing the ionization of x- or gamma rays in air), the rad (for assessing the energy impacted to matter as a result of being exposed to radiation), and the rem (for assessing the potential biological effects of a given absorbed dose). Newer units proposed by the International Commission on Radiological Protection include the Gray (equal to 100 rad) and the Sievert (equal to 100 rem). Since all such units are large in terms of normal doses to the public, smaller units such as the millirem (one thousandth of a rem) and the millisievert (100 millirem) have been developed. For the assessment of exposures arising through the inhalation or ingestion of radioactive materials into the body, environmental surveys can be conducted to estimate the intake of airborne radioactive materials through the atmospheric pathway and the intake of food and waterborne radioactive materials through the terrestrial, aquatic, and marine pathways. Finally, assessments of the actual concentrations of radioactive materials in the human body can be made through analyses of body excreta and through whole body counting.

The control of occupational doses in the applications of external radiation sources generally involves utilization of a combination of time, distance and shielding. The limitation of doses to patients from medical x-rays is primarily dependent upon the application of controls to the x-ray machines, themselves. Such controls include collimation (to restrict the size of the beam) and filtration (to

339

remove the softer x-rays from the beam). The control of exposures from the inhalation and ingestion of radioactive materials generally is dependent upon confining the materials to minimize their releases to the environment. In all radiation control, the goal should be to maintain doses as low as reasonably achievable. To achieve this goal, the use of optimization techniques is mandatory. Also needed, but not yet completely developed, is a methodology for setting priorities for dose reduction to assure that those funds directed to the control of radiation sources are spent effectively.

340

PRINCIPLES OF RADIATION PROTECTION

I. Introduction

The purpose of this outline is to provide information on the sources of radiation exposure, its effects on people, and methods for its control. Emphasis is placed on those sources of primary importance in the less developed countries. Because the author is most familiar with conditions in the United States, most examples are taken from activities within that country. It is hoped that the principles outlined, however, will be of assistance in assessing the magnitude of this occupational and environmental problem in other countries, and in developing effective procedures for its control.

II. Sources of Radiation Exposure

The human race has always been exposed to ionizing radiation of cosmic origin and from natural sources in the environment and within the body. Detailed information on background radiation is important because man has reached his present state of development in its presence and it thus represents an amount which he can apparently withstand successfully.

On the average, the population of the world receives about 78 millirems per year of dose equivalent from natural background radiation.(1) Of this total, about 17 millirems per year are attributable to radioactive materials deposited within the body, about 28 millirems per year arise through cosmic radiation, and about 32 millirems per year come from terrestrial sources. As may be noted from the accompanying graph (Figure 1), there is a wide range in specific dose rates received by people living in different geographical areas of the U.S. A similar range in population doses from natural background would probably apply in most countries of the world. Such differences are the result of variations in the intensity of cosmic radiation with altitude and latitude, and differences in the amounts of natural radioactive material present in the soil in different areas. For example, cosmic radiation increases by a factor of 3 in going from sea level to an altitude of 3,000 meters and by 10% to 20% in moving from 0° to 50° geomagnetic latitude. Within the United States, terrestrial dose rates are generally at a minimum along the Atlantic Coastal Plain and at a maximum in the Colorado Plateau area (Figure 2). In some parts of the world (such as the Kerala regions of India and the States of Rio de Janeiro and Espirito of Brazil), much higher levels prevail. Because of the radiation from thorium-bearing monazite sands, the external environmental absorbed dose in these areas can range up to 10 to 30 times the world average.

Today, background radiation is only one of many sources to which the world's population is exposed. Radiation-generating machines and radioactive materials, which are present in many phases of the environment, constitute the principal man-made sources.

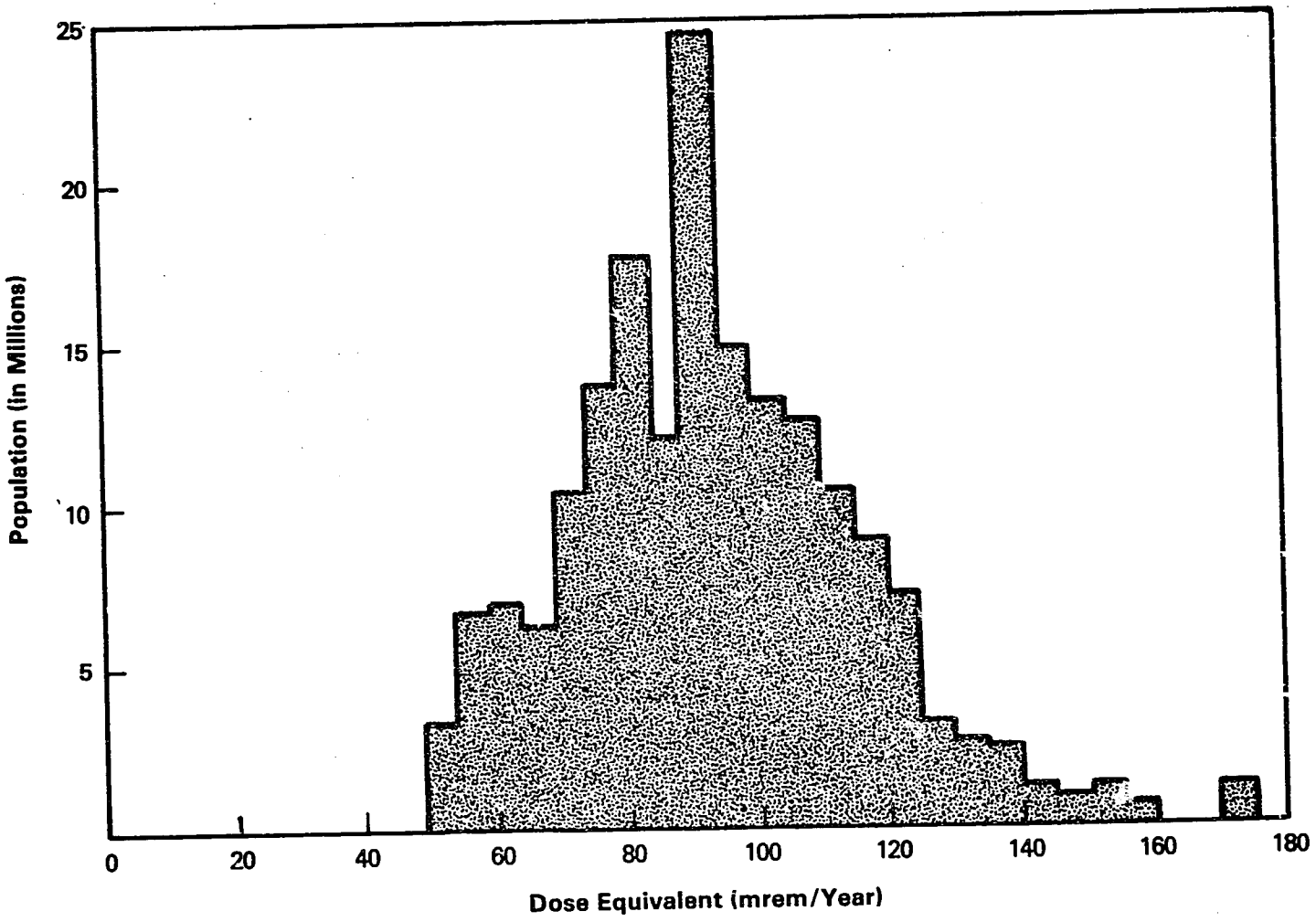


Figure 1 U.S. Population Distribution vs. Dose from Natural Background Radiation

342

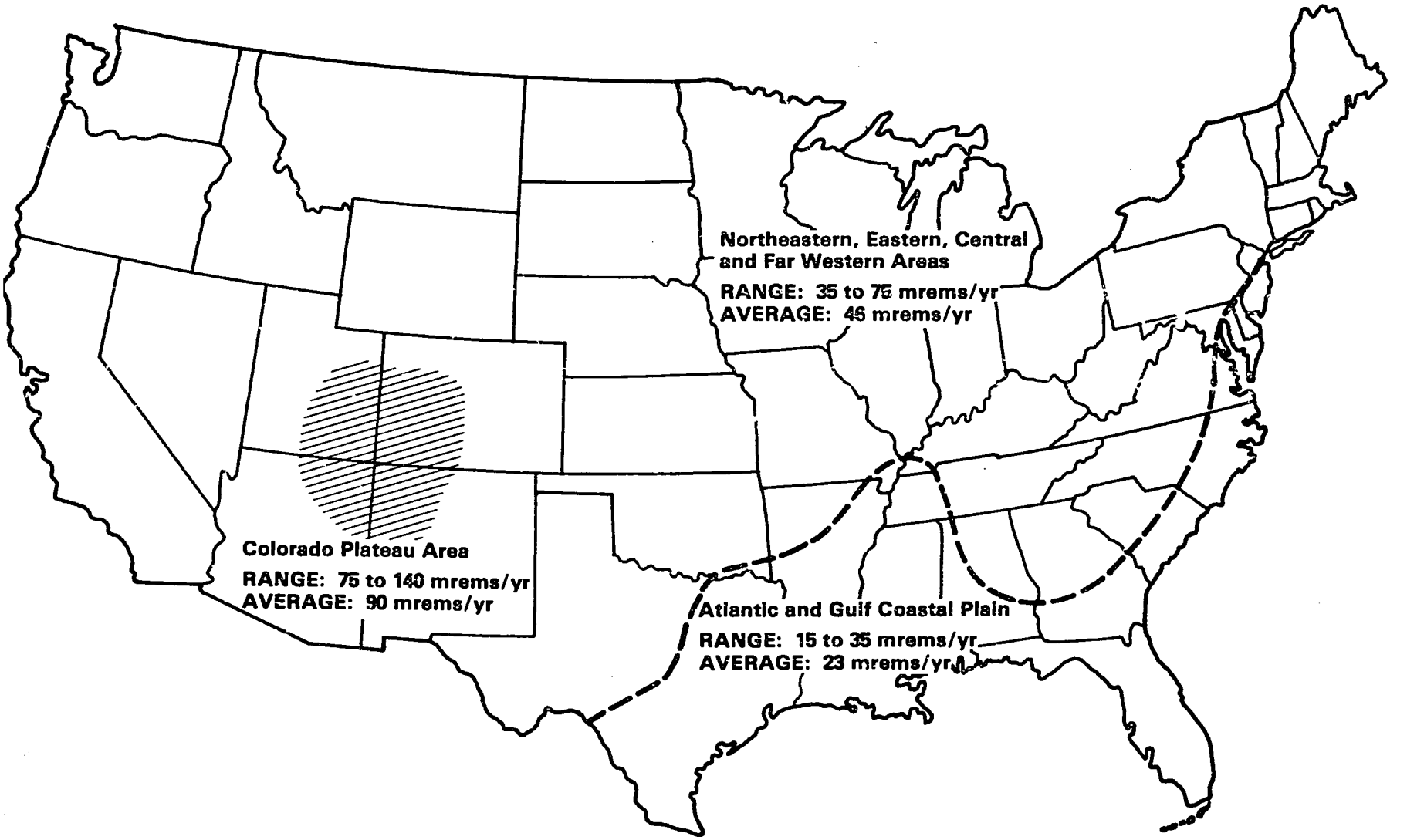


Figure 2 Terrestrial Dose Rates in the U.S.

343

A. X-Radiation

X-ray machines have found widespread use in industry, medicine, commerce, and research. All such applications are potential sources of exposure.

1. Medical and Dental Use

The use of x-ray machines in medicine and dentistry represents the greatest source of man-made radiation exposure to the population in essentially every country of the world.(1) This being the case, it is important that exposures from this source be carefully assessed.(2) In the U.S., for example, surveys show that there are over 300,000 x-ray units being used for diagnosis and therapy. About 170,000 of these units are being used by dentists and about 130,000 are being used by physicians, chiropractors, veterinarians, etc. Surveys show that 39.0% of the medical units are located in hospitals; 29.9% in medical doctors' offices (including osteopaths'); 9.0% in chiropractors' offices; 7.0% in veterinarians' offices; 7.4% in clinics; 4.0% in podiatrists' offices; and 3.5% in other facilities (such as for education and research). Over 250 units are still being used in mobile x-ray survey vans.

It has been estimated that 800,000 to 1,000,000 medical-technical personnel are occupationally exposed in the operation of these machines. In addition, a considerable portion of the general population is exposed in the course of diagnostic and therapeutic procedures. On the average, about 65% of the people in the United States are exposed to x-rays for medical or dental purposes each year. In 1970, the number of people so exposed was 129 million with the following distribution:

75 million for radiographic procedures
59 million for dental diagnosis
9 million for fluoroscopy
400 thousand for x-ray therapy

As would be expected, the extent of the use of x-ray machines in medicine and dentistry varies widely from country to country. Summarized in the table below are data on the number of x-ray machines in several countries of the world as well as estimates of the number of films taken annual per thousand members of the population.

MEDICAL X-RAY USAGE

Country	Number of Machines per 10,000 people	Number of Films per 10,000 people per year
Kenya	< 1	< 100
Sweden	∿ 1	∿10,000
United States	∿10	∿30,000

Estimates of the genetically significant dose (GSD) to the U.S. population resulting from radiographic examinations in 1970 were

344

20 millirads (millirems); this compares to an estimate of 17 millirads (millirems) in 1964, and represents a dose equal to approximately one-fourth of that resulting from natural background. The GSD is an index of the presumed genetic impact of radiation exposure on the population; doses to specific body organs, such as the chest, which are subjected to the direct x-ray beam during routine x-ray diagnostic procedures, would, of course, be higher. For example, the estimated per capita mean bone marrow dose to U.S. adults from diagnostic radiology procedures in 1970 was 103 millirads (millrems), compared to 83 millirads (millirems) in 1964. Estimates are that medical radiographic procedures contributed approximately 77% of the dose, while fluoroscopic and dental examinations contributed about 20% and 3%, respectively.

2. Industrial Uses

Industrial x-ray devices include primarily (a) radiographic and fluoroscopic units used for the determination of defects in castings, fabricated structures and welds, and (b) fluoroscopic units used for the detection of foreign material in items such as food products. At present, there are about 8,000 industrial radiographic installations in use in the United States with about 30,000 to 40,000 people being occupationally exposed in their operation. Such applications are common throughout the world.

3. Commercial Use

Historically, one of the largest commercial uses of x-ray machines has been in shoe-fitting. In 1950, there were almost 10,000 such units in operation in the United States. Because health authorities considered such exposures unnecessary, the application of x-ray fluoroscopes in shoefitting has been banned or severely restricted in most all states. The number remaining in operation today is small.

Another commercial application of x-ray machines which has been increasing rapidly in recent years is in the inspection of passengers' luggage at airports. This practice, which was initiated in response to concern over aircraft hijacking and bombing threats, resulted in the purchase and installation of 279 x-ray fluoroscopic scanning systems at about 40 U.S. airports by 1974 and today the total number of such systems in use is probably over 600. Although the traveler often walks alongside the cabinet-type x-ray equipment as his or her baggage is being examined, personnel exposures are low (in the microrem range or less) because of the advanced design of these systems.

4. Research Use

High voltage x-ray machines and particle accelerators are familiar features of research laboratories in universities and similar institutions throughout the world. In 1941, there were only 16 cyclotron laboratories in the United States. Today, over 1,100 cyclotrons, synchrotrons, van de Graaff generators and betatrons are in

345

operation within this country. Other x-ray equipment used in research includes diffraction units (about 10,000 in use in the United States) and electron microscopes (3,000 in use). Studies show that a significant number of radiation injuries have resulted from accidents involving diffraction equipment.

An emerging source of man-made machine produced radiation is the neutron generator. In 1966, about 150 of these were in use in the U.S. with about 50 additional units being sold annually. Also to be considered are cathode-ray tubes, high voltage vacuum switch and cold cathode gas discharge tubes, all of which can be significant sources of x-ray exposure if voltages are high and protection is inadequate.

5. Recreational Use

Other potential sources of x-ray exposure are projection television tubes and home-style color television sets. In 1967, a major U.S. manufacturer announced it would repair 90,000 defective color TV sets which it had sold and which were giving off a weak, although abnormal, amount of x-radiation. In 1975, color television sets from two other manufacturers were found capable of emitting radiation in excess of the 0.5 milliroentgen per hour maximum permissible limit. This incident involved over 300,000 sets, 240,000 of which had already been sold to consumers. Although the hazards to the viewers were minimal, these incidents illustrate the fact that radiation exposure can arise through a variety of sources and that constant attention must be given to the problem.

B. Radionuclides

1. Naturally Occurring

The naturally occurring radionuclide most widely used in medicine and industry is radium-226. The latest reported data indicate that there are a total of 3,579 facilities in the U.S. currently using radium or its daughter product, radon. These include 1,281 industrial operations and 1,806 medical institutions (which use a total of about 1,000 curies). In medical applications, it is important to note that many individuals besides the patient are potentially exposed to radiation. These include other patients, nurses, technicians, radiologists, and physicians.

The history of the application of radium and its daughter products is replete with instances of injury and death. This is particularly true in the radium dial painting industry. Radium also continues to be a problem today in its applications for medical purposes. Of 24 hospitals that used radium and were surveyed in the U.S. in 1966, eight were found to have one or more leading sources. In only five of the hospitals did the staffs routinely perform leak tests of sealed radium sources.

The Bureau of Radiological Health of the U.S. Department of Health and Human Services has summarized data resulting from an analysis of 396 radium incident reports in the U.S. Most of the incidents involved the loss of sealed radium sources from medical facilities, primarily during irradiation of the patient or during

removal of the radium from the patient. Complete recovery was effected in 64% of all losses and thefts, partial recovery in 5% and no recovery in 31%. Fifty-four percent of the recoveries of radium lost from medical facilities occurred in trash systems. In general, these recoveries were made in municipal dumps or sanitary landfills. That this problem is continuing is confirmed by the fact that there were 32 reported incidents involving radium or radon in the U.S. during fiscal year 1974. In fiscal year 1975, the number of such incidents had increased to 51.

In industry, one of the principal applications of radium is for radiography. Estimates are that 50 to 100 grams (curies) are currently being used for this purpose in the U.S. Another important industrial application is in luminous compounds. Several hundred curies were used for this purpose during World War II and about 2,000 people were employed in this work in the U.S.

Static eliminators employing polonium or radium are widely used in industry. Typical of industries where they may be found are the textile and paper trades, printing, photographic processing, and telephone and telegraph companies. Static eliminators are also used with analytical balances and microtomes.

2. Artificially Produced

As of December 13, 1977, the U.S. Nuclear Regulatory Commission (NRC) and state governments had issued over 20,200 licenses to some 13,000 organizations or individuals authorizing various applications of radioactive materials. The Nuclear Regulatory Commission has responsibility for enforcing its regulations for less than half (8,766) of these licenses, including those which involve the greatest potential hazards. State governments have responsibility under agreements with NRC for enforcing regulations for the remaining 11,473 licenses. Approximately one-third of NRC's licenses relate to the use of radioactive materials in the field of medicine.

It is anticipated that the approximately 10,000 physicians licensed by the U.S. Nuclear Regulatory Commission apply radionuclides in the diagnosis or treatment of 10 to 12 million patients each year. Such applications are currently increasing at a rate of 15% to 20% a year. Similar increases are occurring in countries throughout the world. Exposures can take place during the preparation, handling, application and transportation of the associated radionuclides.[3] Other exposures can occur through the release of these materials to the environment. Studies show, for example, that over 50% of the medical users in the U.S. dispose of their wastes through direct discharge to the sewer. Lastly, there is the exposure to the patient, as well as to members of his or her family, particularly where people are treated on an out-patient basis. Studies in the U.S. have shown that other members of a family can be readily contaminated by a patient who has been given radioactive materials for medical therapy and then permitted to return home.

Since inception of the commercial distribution of radionuclides in the U.S. in 1946, the program has grown to a point where over 5 million curies are shipped annually to medical users and almost 10 million curies are shipped annually to industrial users. During

347

1975, the total number of radionuclide shipments in the U.S. was almost 2.5 million; projections are that this will increase to about 5.5 million by 1985.

C. Nuclear Reactor Operations

As of June 30, 1978, a total of over 220 nuclear power plants were in operation in the world; 70 of these were in operation in the U.S. Worldwide (exclusive of the U.S.), an additional 155 reactors were under construction and 45 more were on order. By the year 2000, projections are that there may be as many as 1,000 nuclear power plants in operation worldwide. Added to these are many nuclear power units being operated by the military services. The U.S., for example, has over 100 nuclear powered submarines in operation.

During 1976, 9.4% of the electricity generated in the U.S. was provided by nuclear power plants. In Belgium, nuclear power contributed 21%; for Sweden and Switzerland, the nuclear contribution was 18%; for the United Kingdom, it was 13%; for Spain, 10.6%; and for the U.S.S.R., 3%. Projections are that by the year 2000, the nuclear power contribution to electric generating capacity will be 90% in France, 67.5% in Spain, 60% in Pakistan, 54% in Denmark, 50% in Iran, 43% in the Arab Republic, 40% in Finland, Portugal and the U.S., and 20% in the U.S.S.R.

Sources of radiation exposures associated with nuclear reactor operations include the reactor itself, its ventilating and cooling wastes, procedures associated with the removal and processing of its "spent" fuel, and procedures associated with the mining, milling, and fabrication of new fuels. Several thousand workers are engaged in uranium mining and milling in the region of the Colorado Plateau. Extensive uranium mining operations are also conducted in Australia, Canada, Niger, South Africa, and the U.S.S.R. Experience has shown that many of the miners have been exposed to excessive amounts of radon gas and its daughter products and this has led to a significant increase in the incidence of lung cancer in these workers. Until a few years ago, the release of radium bearing liquid and gaseous wastes from uranium mills also resulted in low-level exposures (through ingestion and inhalation) to large segments of the downwind and downstream population. At the present time, there are 20 uranium mills in operation in the United States; there are 21 additional mills which were formerly in operation that have subsequently been shut down. Twenty-one fuel fabrication plants are also currently in operation.

It is important to note that each uranium mill results in the generation of millions of tons of tailings waste which contains long-lived naturally occurring radionuclides and toxic chemicals. Each mill tailings area, in effect, constitutes a low-level radioactive waste disposal site which, because of the long-lived nature of the radionuclides present, must be confined essentially forever. Escaping radon and radioactive particulates present a potential health risk both during operation and after the mill has been shut down. There are currently 100 million tons of tailings at the 20 active uranium mills in the U.S. By the year 2000, it is projected that there will be nearly a billion tons of tailings on hand that will have to be managed.

348

Other sources of radioactive wastes from the nuclear industry include the discharge of low-level fission product wastes to the atmosphere and aquatic environment from "spent" fuel chemical processing plants. Millions of gallons of high-level liquid wastes resulting from chemical processing operations during and following World War II (when the major effort was the production of plutonium for weapons) are now being stored in the U.S. and await development of satisfactory methods for their final "disposal." For example, about 60 million gallons of such material are being held in underground tanks at Richland, Washington. Although an active program is underway to separate out the longer lived materials from these wastes and to convert the remaining liquid into a "salt cake," leaks have developed in a number of the tanks still containing wastes in liquid form and sizable quantities of radioactive material have gained access to the nearby environment. Improvements in processing techniques subsequent to the war time era have resulted in a large reduction in the volumes of high-level wastes now being generated and further advances and improvements will undoubtedly be forthcoming in the years ahead. As a result, the quantities of liquid wastes produced through the commercial application of nuclear reactors for the generation of electricity should be far reduced from those which have resulted from chemical processing operations in the past.

D. Weapons Testing

1. Fission Devices

The nature of the radioactive materials yielded in the testing of fission type nuclear weapons is very similar to that resulting from the chemical processing of reactor fuels. Fortunately, because of the moratorium on atmospheric tests, there has in recent years been a substantial reduction in the quantities of such materials released to the environment. Except for the occasional venting of gaseous radioactive materials from underground tests and limited testing by nations non-signatory to the test ban treaty, the quantities of radioactive materials released to the atmosphere today from weapons tests are very limited.

However, because of the reservoir of radioactive material in the upper atmosphere from past weapons stests and the limited releases cited above, small quantitites of radioactive material will continue to be deposited on the earth for some time to come. These materials and wastes gaining access to the environment from nuclear reactor operations enter the food chain and represent a small-scale source of exposure to large segments of the world's population. The current annual whole body dose equivalent to the U.S. population from this source is about 5 millirem.

2. Fusion Devices

Also worthy of comment is the application of the fusion principle in the detonation of the hydrogen bomb and its possible future use as a source of power for generating electricity or as an explosive in major earth moving projects.

Although this source of energy (as compared to present day nuclear reactors) would result in the production of a considerably smaller quantity of fission products, it will not be without its associated radioactive material. Two of the products resulting from the atmospheric detonation of a fusion weapon are carbon-14 and hydrogen-3 (tritium). There are about 20 times as many units of activity of these two radionuclides released in the detonation of a pure hydrogen bomb as there are of strontium-90, cesium-137 and carbon-14 in the detonation of a fission-type device of the same explosive power. Thus, both fission and fusion weapons result in the release of large quantities of radioactive material.

III. Effects of Radiation on Man

All radiation, whether from radioactive materials or from radiation-producing machines, can produce changes in the human body either by direct or indirect action.(1) With direct interactions the radiation collides with atoms of important molecules within the cells, ionizing or exciting these molecules and thus disrupting cellular function. Indirectly, cells may be damaged by toxic agents (such as free radicals and hydrogen peroxide) which are formed as a result of the ionization of water molecules in the cells. Both direct and indirect effects of radiation may interfere with normal life processes.

A. External Exposure

The resulting injury from external radiation exposure depends on the (a) total dose, (b) dose rate, and (c) percent and region of the body exposed. In general, the harm increases with increasing dose and dose rate and the greater the percentage of the body receiving the dose, the greater the resulting injury.

The basic unit of radiation exposure is the roentgen (symbol, R) named in honor of Wilhelm Roentgen, the discoverer of x-rays. The roentgen is a measure of the ability of x- or gamma rays to bring about ionization in air, and, strictly speaking, is applicable only to these forms of radiation. One roentgen represents the absorption of about 86 ergs of energy per gram of air. This corresponds to the production of about 2 billion ion pairs per cubic centimeter. Although this represents a large number, it is only a small fraction (about 1 in every 10 billion) of the total atoms present within this volume.

Because the biological effects of ionization vary according to the types of radiation that cause it (and the manner in which the energy is deposited), additional units have been developed for expressing radiation dose. One of these is the rad which is the unit of absorbed dose and is equivalent to the absorption of 100 ergs/gram of matter; another is the rem which is the unit of dose equivalent and in numerically equal to the product of the absorbed dose (in rads), the quality factor, Q, and the product of all other modifying factors, N. The quality factor, Q, is intended to allow for the effect of microscopic differences in the distribution of the absorbed energy. The modifying factor, N, is available to take into account

350

differences, for example, in the absorbed dose rate, in the dose fractionation, and in the manner (uniform or non-uniform) in which a radionuclide is deposited within a given body tissue. Although the values of Q and N are important for many types of exposure, they are essentially unity for external sources of x- and gamma radiation. As a result, for these types of radiation, an exposure of 1 roentgen is essentially equal to an absorbed dose of 1 rad which is essentially equal to a dose equivalent of 1 rem.

In a recent publication,[4] the International Commission on Radiological Protection has recommended usage of new terms for expressing radiation dose. Fortunately, these are directly related to the rem and rad, the specific relationships being as follows.

The unit of dose equivalent is the sievert, where:

1 sievert = 1 Sv = 100 rem.
Following this pattern:
1 rem = 0.01 Sv = 10 millisievert = 10 mSv.

Similarly, the unit of absorbed dose is the gray, where:
1 gray = 1 Gy = 100 rad.

B. Internal Exposure

Internal exposure results from the presence of radioactive materials within the body. The potential harm from such exposure depends on the types and quantities of radioactive material consumed. In general, alpha emitters constitute a greater hazard than beta or gamma, and the greater the quantity of a given material, the greater the hazard.

Maximum permissible body burdens for a large number of radionuclides and annual limits for intake in air and water for occupation exposures have been recommended by the International Commission on Radiological Protection[5]. Assessment of the hazard in a given circumstance can be made by comparing the known amounts or concentrations to these published values. Where the source of contamination is the air or water, standard techniques for sampling with subsequent analysis by gamma spectrometry or radiochemistry may be used to measure the specific radionuclide concentrations present. Gamma emitting radionuclides already present in the body can be evaluated by whole body counting (gamma spectrometry). Estimates of beta emitting radionuclides in the body can be made through analysis of body excreta (urine or feces), samples of hair or extracted teeth, or through analysis of tissue samples from accident victims.

C. Classification of Exposures

On the basis of total dose and dose rate, radiation exposures can be classified as acute or chronic. Acute exposures are large doses, usually to the total body administered within a short period of time. Chronic exposures (the type most generally encountered in environmental health) consist of repeated low doses, to all or only a portion of the body, administered over a long period of time.

351

The effects of chronic exposure may be classified as genetic (those which directly affect the germ cells), or somatic (those which affect cells other than the germ cells). Examples of genetic effects are certain blood abnormalities, certain metabolic diseases, and certain congenital-physical abnormalities. Examples of somatic effects are leukemias and other cancers. The effects of radiation exposures may also be classified as stochastic or non-stochastic. Stochastic effects are those for which the probability of harm is a function of dose; examples are chomosomal aberrations, mutations in spermatagonia, ovarian tumors, and cancer production. Non-stochastic effects are those in which the severity is a function of dose; examples are the production of cataracts, erythema of the skin, and acute death.(4)

D. Philosophy of Exposure Control

As a basic approach for control, it is generally assumed that radiation damage has no threshold--that is, regardless of how small the dose may be, there is some deleterious effect. As a result, each application of radiation must be evaluated in terms of the benefits to be accrued versus the risks being taken. Such an evaluation is difficult and, as would be expected, it often leads to controversy in the justification for the construction or application of a given radiation source, particularly those which potentially could have a major negative impact on the surrounding environment.

IV. Control Procedures

With increasing knowledge and experience in radiological health, appropriate measures for minimizing radiation exposures have been developed.

A. X-ray Control

Control procedures for protecting the operator of medical, dental, and industrial x-ray machines consist of limiting the time of exposure, maintaining an adequate distance between the x-ray beam and the operator, and the use of adequate shielding. Generally a combination of these three safety measures can be applied to restrict the dose to acceptable levels.

In protecting the patient, two important factors are limitation of the size of the beam through proper coning or collimation, and filtration of the beam to remove soft x-rays which would otherwise be absorbed by the body.(2) Experience has shown that the use of proper filtration can result in a 2- to 5-fold reduction in the dose to the reproductive organs of the patient; through proper coning, the genetic dose can be reduced by a factor of 200 to 500.

B. Radioactive Materials

Control of radioactive materials may involve containment and isolation, dilution and dispersion, or a combination of the two. For low-volume high-level wastes, containment is the method of choice;

358

dilution and dispersion is generally feasible only for large volume low-level wastes. Intermediate level wastes are often handled by a combination of the two approaches, that is, their radioactive material content is concentrated and confined with the decontaminated residual being released to the environment. Because of the chemical nature of certain radionuclides, however, this combined approach is sometimes difficult to apply. Notable examples are hydrogen-3 (tritium) and krypton-85, two of the contaminants produced in nuclear reactor operations.

Assessment of exposures from radioactive materials released through the operation of nuclear power reactors and chemical fuel processing plants generally necessitates a program of on-site monitoring and off-site surveillance.(6) Although it is not anticipated that the less developed countries will have a large number of power reactors or facilities for the chemical processing of fuels, it is important that environmental health officials in these countries have knowledge of radiation surveillance techniques for the evaluation of environmental radiation levels. Data show, for example, that environmental releases of certain radionuclides from a major medical center can easily be comparable or in excess of those from a nuclear power plant. Although routine environmental surveillance around medical centers is not generally recommended, periodic checks would certainly appear to be justified.

Guides for monitoring environmental radionuclide releases both under routine and emergency conditions have been published by the International Atomic Energy Agency(7). Similar recommendations have been published by the World Health Organization and the International Commission on Radiological Protection. Although existing ICRP recommendations permit individuals within the general public to receive radiation exposures at a level of 10% of those permitted under occupational conditions, it is important to note that such individuals are assumed to be present within the so-called "critical population group." Average environmental levels will hopefully be kept far below concentrations that would result in members of the public receiving doses as high as 10% of those permitted under occupational conditions. In fact, the ICRP suggests that the average dose equivalent rate to the general population should not exceed 50 mrem/y (0.5 mSv/y).(4)

V. Commentary

Essentially every country in the world uses x-ray equipment in medicine and dentistry. Applications of radionuclides in medical diagnosis and therapy, in industrial applications, and in medical, agricultural, biological and industrial research, are becoming commonplace. The same is true of the use of natural and man-made radionuclides in a variety of consumer products, such as luminous dial watches, aircraft instruments, static eliminators, smoke detectors, glass and ceramics, and false teeth. Similarly, a wide variety of commercial and industrial equipment can be sources of radiation exposure. These sources include television receivers, airport x-ray inspection systems, electron microscopes, cathode gas discharge tubes, and spark gap irradiators. Most countries also continue to receive

low level fission product fallout into the environment as a result of prior atmospheric weapons tests and all receive exposure from natural background sources, both as they exist in nature and as they have been modified (technically enhanced) by man.

Because of the multitude of radiation sources that exist, it is important to assure that those funds that are available for the control of the resulting exposures are effectively applied. For this reason, it is essential that detailed data be developed on the various sources of exposure that are present within each country and on the relative contribution of each such source to the population dose. If this information is supplemented with data on the technical and economical feasibility of controlling each source, then an effective control program can be implemented. Unfortunately, practical procedures for setting priorities for dose reduction have yet to be developed. Hopefully, such guidance will soon be forthcoming and will be made available for application on a local basis.

354

REFERENCES

1. "Sources and Effects of Ionizing Radiation," United Nations Scientific Committee on the Effects of Atomic Radiation, 1977 Report to the General Assembly, United Nations, New York (1977).

2. "Protection of the Patient in X-ray Diagnosis," International Commission on Radiological Protection, Report Prepared by a Task Group of Committee 3. ICRP Publication 16, Permagon Press, Oxford (1970).

3. "The Handling, Storage, Use and Disposal of Unsealed Radionuclides in Hospitals and Medical Research Establishments," International Commission on Radiological Protection, Publication 25, Annals of the ICRP, Vol. 1, No. 2 (1977).

4. "Recommendations of the International Commission on Radiological Protection (Adopted January 17, 1977)," ICRP Publication 26, Pergamon Press, Oxford, Annals of the ICRP, Vol. 1, No. 3 (1977).

5. "Limits for Intakes of Radionuclides by Workers," International Commission on Radiological Protection, Publication 30, Annals of the ICRP, Vol. 2, No. 3/4 (1979).

6. "Radionuclide Release into the Environment: Assessment of Doses to Man," International Commission on Radiological Protection, Publication 29, Annals of the ICRP, Vol. 2, No. 2 (1979).

7. "Monitoring of Airborne and Liquid Radioactive Releases from Nuclear Facilities to the Environment," Safety Series No. 46, International Atomic Energy Agency, Vienna, Austria (1978).

355

DADE WILLIAM MOELLER

Dade Moeller is Professor of Engineering in Environmental Health, and Chairman of the Department of Environmental Health Sciences, School of Public Health, Harvard University. Professor Moeller also is Associate Director of The Kresge Center for Environmental Health of the Harvard School of Public Health.

Prior to his present position, Professor Moeller served for 18 years as a member of the Commissioned Corps of the U.S. Public Health Service. Within the Health Service, his principal experience was related to health problems associated with nuclear power reactor cooling water systems, the management of radioactive wastes, and environmental radiation surveillance. His duty assignments included the Oak Ridge, Tennessee and Los Alamos, New Mexico installations of the U.S. Atomic Energy Commission and the headquarters office of the Radiological Health Program of the Public Health Service in Washington, DC.

Assignments at Harvard University have included research on natural background radiation, nuclear air cleaning systems, and planning for nuclear emergencies. Primary teaching responsibilities have been related to radiation protection and general environmental health.

In 1978, the National Academy of Engineering elected Professor Moeller to membership in the Academy. Such election is the highest professional distinction that can be conferred on an engineer and honors those who have made important contributions to engineering theory and practice or who have demonstrated unusual accomplishments in the pioneering of new and developing fields of technology. The citation was for "Leadership in education and research and services to governmental agencies in the control of radiation in the environment."

Professor Moeller received a Bachelor of Science degree in Civil Engineering and a Master of Science degreee in Sanitary Engineering from Georgia Institute of Technology, and a Doctor of Philosophy in Nuclear Engineering from North Carolina State University.

ENVIRONMENTAL HEALTH CASE STUDY

Environmental Consequences of Electrical Power Generation by Hydro-Electric, Nuclear, and Fossil Fuels

Dade W. Moeller, Ph.D.

Professor and Chairman
Department of Environmental Health Sciences
School of Public Health
Harvard University

June 1980

International Environmental Management Institute
ENVIRONMENTAL RESEARCH & TECHNOLOGY, INC.
Concord, Massachusetts, USA

357

Environmental Consequences of Electrical Power Generation by Hydro-Electric, Nuclear, and Fossil Fuels

by

Dade W. Moeller, Ph.D.
School of Public Health
Harvard University

I. Introduction

Today there is considerable discussion of environmental pollution, and a major portion of the commentary has been with respect to the generation of electricity in electric power stations. This is due to the fact that where coal and oil are used, the smoke from the tall stacks accompanying such plants is clearly visible and easily subject to public comment. In addition, the major alternative to coal and oil is nuclear power and this, in itself, is a subject that raises the emotions of the population and therefore provokes extensive discussion. Presented in this paper is a discussion of the various methods of generating electricity with particular emphasis on their relative environmental impact. This discussion is intended to serve as a Case Study for purposes of this Seminar.

Figure 1 shows trends in the population of the United States and also the trends in our associated use of electricity over the past twenty years with projections to the year 2000. As you will note, the use of electricity is growing much more rapidly than the population. Whereas in past years the population was increasing at an annual rate of 2%, the use of electricity in this country was increasing at a rate of 5% to 6% per year. Similar relationships exist in many other countries. Although in recent years the rates of growth for both of these items in the U.S. have decreased, the rate of increase in the use of electricity is still substantially above that for the population. As a result, the amount of electricity being used has been doubling every 10 years for the past three or four decades. At the present time, 98% of the work done in the U.S. is performed using inanimate energy, only 2% being done by horse power or man power. The United States currently consumes 34% of the world's energy, and, of that amount, 25% is in the form of electricity.

II. Electric Power Production

Today there are three basic ways of producing electricity in the United States. The first is the use of hydro-electric power, next is power generation through the combustion of fossil fuels and last is the production of electricity through the fission of nuclear fuels. In the paragraphs that follow, each of these processes is discussed in terms of its associated environmental risks and benefits.

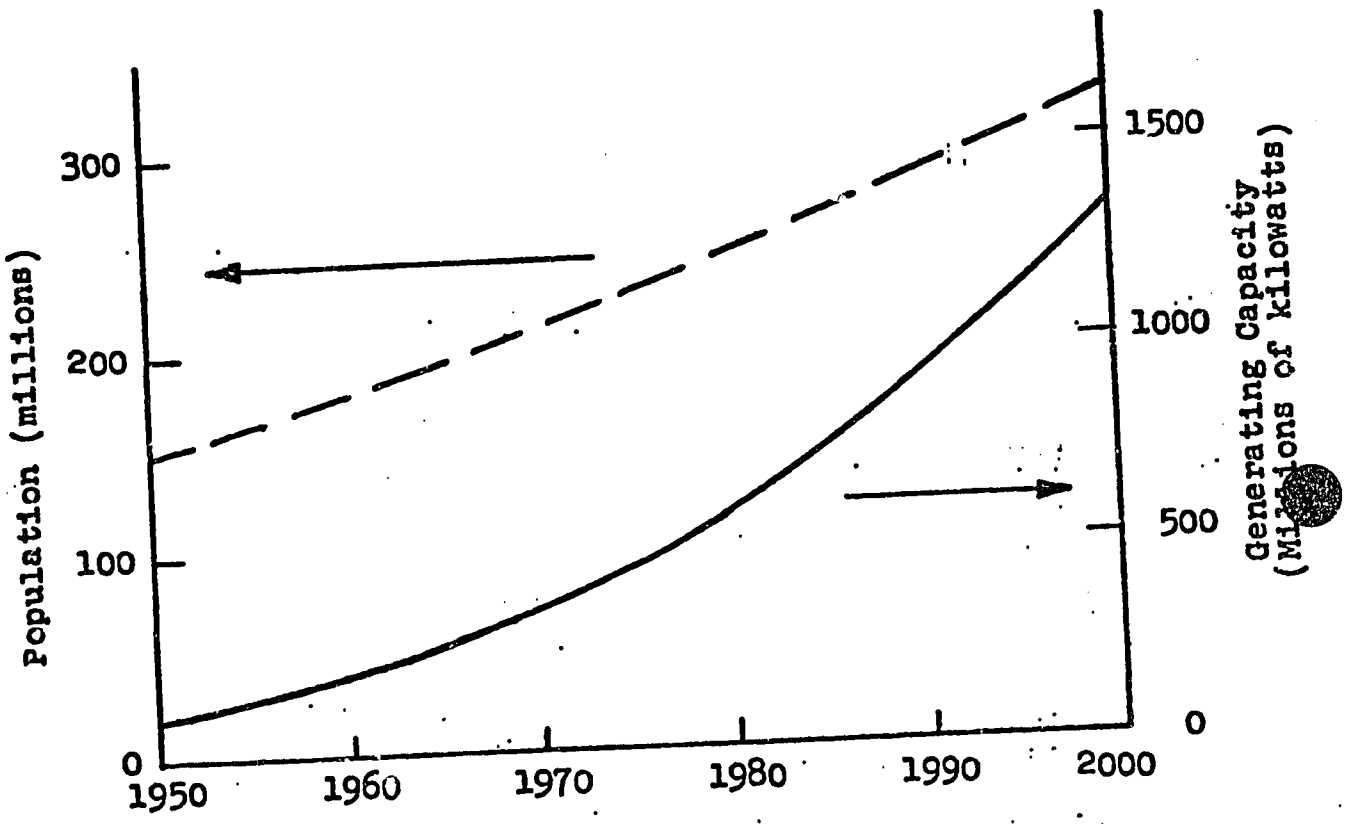


Figure 1. INCREASE IN THE U.S. POPULATION AND USE OF ELECTRICITY

A. Hydro-electric Power

Everyone is familiar with hydro-electric power. In this process, use is made of the potential energy of water in an elevated lake, which is being held behind a dam. Advantage is taken of the potential energy in the water to turn turbines and to generate electricity. Many people consider this to be a very simple process without any large detrimental effects on the environment. But even the construction of a dam to harness water power for producing electricity has both its benefits and its risks. There is no method for producing electricity today which does not have its associated environmental impact. One of the best modern examples of the problems which can accompany the development and use of hydro-electric power was the construction of the Aswan High Dam on the Nile River in Egypt. The concept here was simply to dam up the River and then to use the water to produce electric power and to irrigate the nearby desert, thereby producing vast amounts of new farmland. But what happened as a result of constructing and placing this system into operation?

First of all, when the river originally flowed in its natural state, it carried to the Mediterranean Sea each year a tremendous quantity of silt and organic matter. This material was dumped into the Sea at the mouth of the River. Prior to the construction of the dam, fishermen used to catch vast quantities of fish near the mouth of the River. The quantity caught in 1965, for example, was 18,000 tons. By 1968, after construction of the dam had been completed and there was no longer as much food material being discharged into the Mediterranean Sea, the quantity of fish caught had been reduced to only 500 tons and 4500 people (fishermen) had been put out of work.

Secondly, the River in its normal state annually flooded the plains along its banks. The deposition of silt and organic matter (estimated to be about 50 million tons per year) in these areas made them excellent farmlands. After installation of the dam, the River no longer flooded the plains, there was no longer any deposition of silt and organic matter, and the usefulness of the plains as good farming areas declined. In fact, the loss of farmland through the loss of the use of the plains was equivalent to that gained through the use of the irrigation system that was set up to use the water in the lake behind the dam for producing additional farmland in the area. So the expected increase in farmland through construction of the dam has never been attained.

A third impact of the construction of this installation was that the water-table under the land around the lake formed by the dam was raised. This water, unfortunately, dissolved salts within the ground and brought them up into the top-soil, thereby contaminating it and making it less usable for the growing of crops. As a result, the land around the lake is not as good for farming as had originally been hoped.

Lastly, because of the flooding of the area by the lake cre-

Lastly, because of the flooding of the area by the lake created by the dam, there were 50,000 to 100,000 people displaced. These people then had to be relocated and new homes had to be found for them to live in. As can be seen, hydro-electric power can indeed have a significant impact upon the environment.

B. Nuclear Fossil Fuels

Now let us consider some of the environmental implications of electric power generation using nuclear or fossil fuels. The basic principles of this process are shown in Figure 2. In this type of system, the fuel is used to produce heat. Whether it is nuclear fuel or fossil fuel, it is used to produce heat which converts water to steam. The steam in turn is sent to a turbine, which is coupled to a generator for producing electricity. Cooling water, usually from a nearby river, is used to condense the steam leaving the discharge side of the turbine, and the hot water is then returned to the heat source for reheating. Condensation of the steam leaving the turbine is necessary to produce a vacuum at that point in the system, so that the incoming steam will have the necessary pressure to turn the turbines. Nonetheless, it should be recognized that in such a process, twice as much energy--that is twice as much heat--is discharged to the environment with the cooling water as is converted into electricity. This is the reason that power plants of this type are increasingly being challenged as sources of so-called thermal pollution. Such plants are also sources of releases of contamination to the atmoshpere in the form of various gases and particulates, and they also release certain smaller quantities of pollutants in the form of liquid wastes. These will be discussed later in the paper.

In terms of nuclear power plants, there are two basic types in use in the United States today. These are the so-called Pressurized Water Reactor or the PWR, and the so-called Boiling Water Reactor or the BWR. Because they differ in terms of their environmental releases, distinguishing characteristics of these two types of plants will be discussed at this time. The Boiling Water Reactor operates essentially as outlined by the schematic diagram in Figure 2. The Pressurized Water Reactor, however, is different in that it has a primary system in which the water heated by the reactor is kept under pressure so that it does not change into steam. Through means of an intermediate heat exchanger (Figure 3), this water, in turn, converts water in a secondary system into steam which goes on to turn the turbine. As a result, any leakage of water or gases around the turbine in a BWR--a Boiling Water Reactor--will be radioactive water or gases which have been in direct contact with the nuclear fuel in the system. Consequently, such leakage will carry with it radioactive material into the environment. In the case of the Pressurized Water Reactor, such leakage would be water from the secondary system--water that has not been in contact with the nuclear fuel and therefore should

261

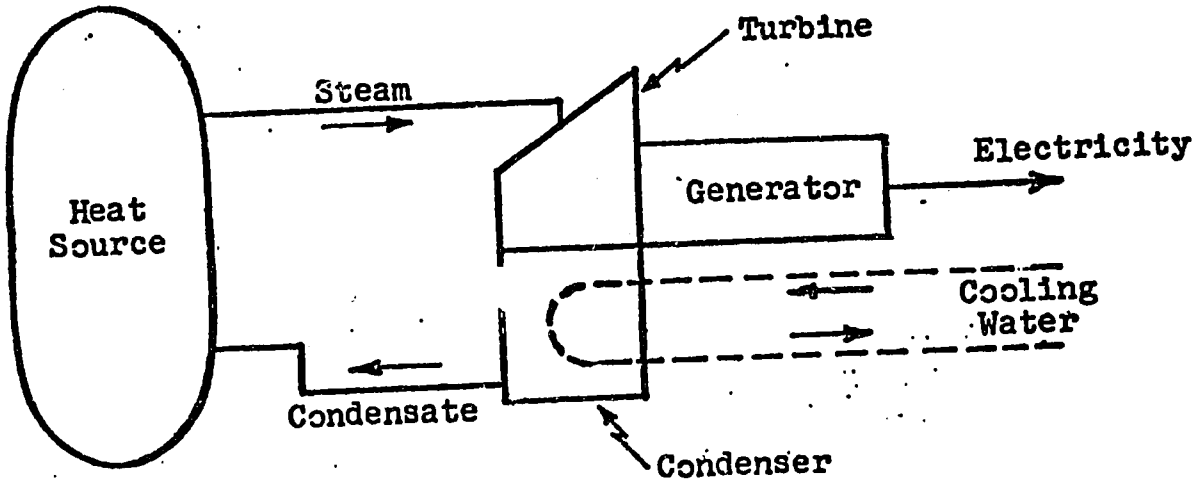


Figure 2. SCHEMATIC DIAGRAM OF ELECTRIC POWER PLANT.

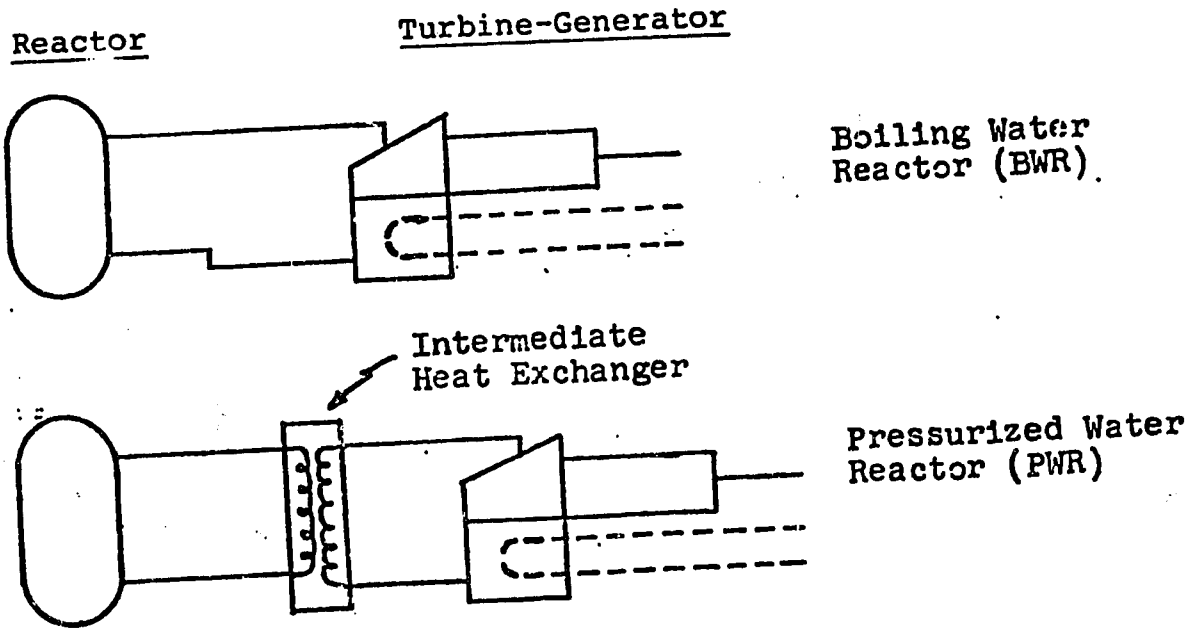


Figure 3. SCHEMATIC DIAGRAMS OF BOILING WATER AND PRESSURIZED WATER REACTORS.

362

theoretically not be radioactive. In actual practice, however, often-times there is leakage of water from the primary system into the secondary system in PWRs due to leaks that develop in the heat exchangers (steam generators). For this reason, and because extensive noble gas delay systems have been installed on Boiling Water Reactors, there is generally a somewhat greater release of airborne radioactive materials from a PWR than from a BWR. This matter will be discussed in more detail later in this paper. This discussion will include the presentation of quantitative data through which airborne releases from these two types of nuclear power plants can be compared.

III. Assessing the Environmental Impact

In assessing the environmental impact of electric power generation, consideration must be given to all the steps required in the total operation. Some concept of this is shown in Table I. The analytical approach used will be similar to that employed in the assessment of the impact of hydro-electric power.

Table I

STEPS IN THE GENERATION OF ELECTRICITY THAT CAN HAVE ENVIRONMENTAL IMPACTS

1. Fuel Acquisition
2. Fuel Transportation
3. Power Plant Wastes
4. Processing and Disposal of Spent Fuel
5. Power Transmission

A. Acquisition of Fuel

The first step in the operation of a typical electric power station is the acquisition of the fuel. What impact has this had on the status of the environment or on the health of the population? Let us begin with the case of coal. With the acquisition of coal, there is first the consideration of the mining process. If the coal is acquired through the process of strip mining or surface mining, and the land is not restored to its original state after the mining process has been completed, then extensive defacing of the environment results. With underground mines, there are frequent problems of what is called "acid mine drainage." Various acids drain out of the mine over a period of time after the mine is first opened. This results in the release of liquid wastes to the environment and to nearby streams. Also to be considered are the occupational health problems associated with the people who work in the mines. For example, data show that about 100,000 men have been killed in mine accidents in the U.S. to date. This is

362

equal to approximately 3 human deaths for each day underground mines have been in use. It is estimated that an additional 100,000 miners are affected with black lung disease, so-called "coal miners pneumoconiosis," which leads in its later stages to emphysema. Relating these figures to the generation of electricity, it can be shown that the mining of coal for one 1,000 MWe power station results in one case of black lung disease per year. It is further estimated that the death rate from respiratory illnesses among coal miners is five times greater than that for other types of workers.

In similar fashion, let us look at the situation with respect to the acquisition of uranium as a nuclear fuel. In the western portion of the United States there are some 6,000 people who are currently working, or who formerly worked, in uranium mines. It is estimated that 15% to 20% of these men will die from lung cancer--that is, about 1,000 of them will die from lung cancer--within the next 10 to 20 years. As in the case with underground coal mining, such activities have had a tremendous impact upon the public and the public's health.

What about the acquisition of oil? There are problems even with the drilling for oil on land. However, the greatest attention in recent years has been directed to the environmental impact of the drilling for oil in off-shore situations. Notable examples were the Santa Barbara and Gulf of Mexico oil spills of recent years. Leaks from off-shore drilling operations can cause considerable contamination of the marine environment and its associated animal life. Additional pollution, particularly the release of airborne wastes, results from the operation of oil refineries.

B. Fuel Transportation

The next step in the process of the operation of a fossil or nuclear fueled plant is the transportation of the fuel to the plant. In general, the quantities involved are tremendous. For purposes of analysis, let us consider a 1,000 megawatt electric generating station. This is typical of the major size plants being built today. To fuel one of these plants, assuming it uses coal, requires over 2 million tons each year. If it uses oil, the requirement is over one-half billion gallons per year. If the fuel for the plant is natural gas, the consumption is almost 7 billion cubic feet per year. If, on the other hand, the plant is powered by nuclear fuels, only one ton of pure fuel is required each year. Of course, one must recognize that the nuclear fuel would contain certain additional amounts of ores that could not be fissioned and therefore could not be used. So the true quantity of fuel required in a nuclear plant might realistically approach something like 30 to 50 tons per year. But, in any event, it is considerably less than that required for any of the fossil fueled plants.

Let us now consider the coal fired plant and examine in more detail the problems of transporting fuel to it. As previously stated, such a plant would annually require over 2 million tons of coal. On a daily basis, this amounts to about 8,000 tons, which is equivalent to a hundred or more fully loaded railroad cars. It is estimated that the transportation of this amount of coal to a 1,000 MWe power plant results, on the average, in one fatality every two years due to accidents at railroad crossings. It is for these reasons that the concept of the "mine mouth power plant" is being developed today. Following this approach, the electric power plant is constructed near the mouth of the mine and then the principle of "shipping the power, not the coal," is followed. There are certain problems even with this approach, but it does look attractive in many ways and is being implemented in the western areas of the United States.

Now let us briefly examine the problems in the transportation of oil. As all of you know, there are problems of accidents with oil tankers and there have been many incidents in recent years in which large quantities of oil have leaked from such vessels. This was highlighted by the wreck of the Torrey Canyon in 1967, which resulted in the leakage of approximately 30 million gallons of oil into the English Channel and onto nearby beaches, the grounding and subsequent breakup of the Argo Merchant off Cape Cod, Massachusetts, in December, 1976, and other similar accidents in more recent years. This latter accident resulted in the leakage of over 7 million gallons of oil into the Atlantic Ocean. Studies by researchers of the characteristics of typical tanker accidents have shown that most occur within 10 miles of shore, that they usually affect a recreational area, and that the median amount of oil spilled is over 25,000 barrels. This is equivalent to over one million gallons of oil per accident. Data show that the costs of cleanup total about $75 per gallon of oil released.

Similar problems exist in the ocean shipment of natural gas. For example, a modern tanker transports about 125,000 cubic meters of natural gas in liquefied form at a temperature of -160°C. When the tanker reaches its destination, the liquefied gas is allowed to warm and re-gasify as it is transferred to storage tanks for later distribution to consumers. In the course of re-gassifying, the volume of the gas increases by a factor of over 600. A very significant danger is that an accident might occur as a tanker is unloading its cargo in port and result in the release of some 80 million cubic meters of natural gas (in expanded cloud form) as a blanket over a city. If the cloud were later ignited, such an event could lead to widespread death and destruction.

365

C. Power Plant Wastes

The next step in the evaluation of the environmental impact of electric power generation is the consideration of wastes from the power plant, itself. In a fossil fueled plant, there will be releases of oxides of sulfur, oxides of nitrogen, carbon dioxide, carbon monoxide and particulates. Such a plant will also discharge some radioactive material (of natural origin from within the fuel). A nuclear powered plant will not release oxides of sulfur, oxides of nitrogen, carbon dioxide or carbon monoxide. However, there will be releases of radioactive gases and liquids. All such releases will be discussed in greater detail later in this paper.

D. Processing and Disposal of Spent Fuels

Next, let us consider the ashes which result from the combustion of fuel in a particular plant. In the case of a nuclear plant, such ashes are referred to as "spent fuel." With a gas fired plant, there is no problem of ashes because gas burns cleanly and results in no ash. For an oil fired plant, there is also little problem in terms of ashes. For a coal fired plant, it is a completely different situation. As was mentioned previously, a 1,000 megawatt plant requires a fuel input of over one hundred railroad cars of coal each day. Since 12% to 18% of the coal ends up as ash, this same plant would require from 10 to 20 railroad cars for the daily removal of its ashes.

In the case of a nuclear plant, the removal of the "ashes" or spent fuel represents a serious problem but fortunately the quantities are small. Also, as these plants are currently operated, the used fuel is only removed on an annual or biennial basis.

E. Power Transmission

After the electricity is generated, the next step is to distribute it to the consumer. Estimates are that about 10% to 12% of the total electricity generated is lost during transmission. As a result, there has been much discussion in recent years about developing new more efficient transmission systems, a prominent one being new super cold cables installed underground. The power losses in such a system would be less than those currently experienced in the high tension overhead power lines. In addition, an underground system would avoid much of the environmental degradation caused by overhead lines. Many people object to the swathes cut through forests and towns in order to install overhead power lines. Examined closely, one would find that the degradation caused by such lines is quite extensive. For example, there are today over 300,000 miles of overhead electric transmission lines in the United States and they consume about 4 million acres of land in terms of right of way. In New England alone, there are 80,000 acres devoted to such

power lines. It is estimated that for the United States, as a whole, 100,000 additional miles of overhead power lines will have to be constructed during the next decade. Although there is hope that underground cables will see increasing use, a key factor is economics. Overhead lines cost on the order of 1 million dollars per mile to construct; estimates are that underground systems will cost as much as 10 to 20 million dollars per mile. For this reason, it will probably be some time before there is a major change in the current approach.

IV. Comparison of Pollution from Different Type Plants

A. Fossil Fueled Power Plants

As the next step in our evaluation, let us consider the relative amounts of pollution from each of the different types of fossil fueled power plants. Data on this subject are summarized in Table II which lists the quantities of the major pollutants from a coal, an oil, and a gas fired plant. In each case, the assumption is made that the plant has an electric generating capacity of one thousand megawatts, and that it is a modern facility equipped with up-to-date airborne effluent control systems.

As may be noted, a typical release rate for oxides of sulfur from a coal fired plant of this size is about 10 to 15 tons per day. For an oil fired plant, the discharge of this contaminant is about 30 to 35 tons per day. For a gas fired plant, the production of oxides of sulfur is essentially zero. On this basis, it can be concluded that in terms of SO_2, an oil fired plant places two to three times the stress on the environment as does a coal fired plant. Both the coal and oil fired plants are far more polluting in this respect than a gas fired plant.

Using this same approach, similar evaluations can be made in terms of the oxides of nitrogen. Checking the data in Table II, one finds that a coal fired plant releases over twice the amount of this contaminant as does an oil fired plant of similar capacity, and that an oil fired plant is perhaps one and a half times as polluting as a plant fueled by natural gas. In terms of carbon monoxide, the coal fired plant places two to three times the stress on the environment as does a plant fueled by oil or natural gas. From the standpoint of particulates, the coal and oil fired plants are about equal in terms of their releases of this contaminate and both are four to five times worse than a plant fueled with natural gas.

In terms of each of the specific contaminants listed in Table II, the plant fueled by natural gas is far superior. For this reason, one might logically ask the question: Why do not the

367

Table II

AIRBORNE EMISSIONS FROM MODERN WELL-EQUIPPED FOSSIL FUELED ELECTRIC POWER PLANTS

Pollutant	Tons Per Day from a 1000 MWe Plant[1]		
	Coal	Oil	Natural Gas
Oxides of Sulfur	12	32	0.06
Oxides of Nitrogen	86	36	23
Carbon Monoxide	6	2.5	1.8
Particulates	3.6	4.6	1

public utilities completely convert to natural gas as a source of fuel for the generation of electricity? The answer is simple. The quantities that would be required are not available. Although special facilities are being designed today to convert coal into gas, the practicality of such conversion is not complete or economical enough for application on a routine large scale commercial basis.

B. Nuclear Power Plants

Next, let us consider in similar detail the production of various airborne waste materials from a nuclear plant. Data on this subject are summarized in Table III.[2][3] For purposes of comparison, data are given for model installations of both the Pressurized Water Reactor (PWR) and the Boiling Water Reactor (BWR). In terms of gaseous pollutants, such as krypton-85, xenon-133, and hydrogen-3 (tritium), the Table shows that the quantities released from the PWR are greater than those from the BWR. For ^{14}C, the releases from these two types of plants are about equal; for ^{131}I, the releases from the BWR are greater than those from the PWR.

V. Comparison of Fossil and Nuclear Plants

These, in essence, are the wastes released from the several types of basic power plants. Now, let us consider the question that is foremost in our minds. That is: how do nuclear plants compare to fossil fueled plants in terms of the relative stress they place upon the environment?

A. Comparison Based on Atmospheric Dilution Requirements

To make such a comparison is difficult. Data resulting from one approach are shown in Table IV. Here, the method used was simply to compare the volumes of air required to dilute the critical airborne effluents from each type of plant to acceptable levels for breathing by the general population.(4)(5) Again, to make the data comparable, the assumption was made that each plant had an electrical generating capacity of 1,000 megawatts. Applying this approach to a coal fired plant, one finds that the critical contaminant discharged from such a facility is NO_2 and that the volume of of air required to dilute this release to an acceptable concentration for breathing would be 3×10^{14} cubic meters. This is equal to 300 trillion cubic meters or approximately 80,000 cubic miles. Obviously, this is a tremendous volume of air.

For the case of an oil fired plant, one finds that the quantity of diluting air required for its critical pollutants (which, in this case, is SO_2) would be about 1.3×10^{14} cubic meters per year. Again, for purposes of better visualization, this would be equivalent to a volume of about 30,000 cubic miles of air. This, too, is a very sizable volume. For a gas fired plant, the critical pollutant is nitrogen dioxide and the quantity of air required in this case would be about 8×10^{13} cubic meters per year. This is approximately one fourth that required for the coal fired plant and is equivalent to about 20,000 cubic miles. Although this is still a large volume, once again it is significantly less than that required for a coal fired plant of comparable size.

Lastly, let us look at a nuclear plant. In this case, the most critical airborne pollutants are the noble gases and iodine-131. As may be noted from Table IV, the quantity of air required for diluting these specific releases from a PWR would be about 5×10^9 cubic meters per year. This is less than one thousandth of the volume of diluting air required in the case of a coal, oil or natural gas fueled facility. In fact, volume-wise, it amounts to only about ten cubic miles per year for a one thousand megawatt nuclear generating station. For a BWR, the volume of diluting air would be even less.

B. Potential Errors in this Approach

On the basis of these data, one might quickly conclude that a nuclear plant is far superior to any of the other types. It is important to note, however, that in the last case the calculations are for the nuclear plant alone. They do not include the associated dilution requirements for the airborne wastes that would

Table III

AIRBORNE EMISSIONS FROM MODEL NUCLEAR FUELED PLANTS

Pollutant	Curies/Yr from a 1000 MWe Plant[2][3] Pressurized Water Reactor	Boiling Water Reactor
^{85}Kr	470	290
^{133}Xe	12,000	3,200
^{14}C	40	40
^{131}I	0.025	0.3
^{3}H	1,100	43

Table IV

ANNUAL DILUTION REQUIREMENTS

(1,000 MWe Power Plant)

Type Plant	Critical Pollutant	Required Dilution* Cubic Meters	Cubic Miles
Coal	NO_2	3×10^{14}	80,000
Oil	SO_2	1.3×10^{14}	30,000
Natural Gas	NO_2	8×10^{13}	20,000
Nuclear (PWR)	Noble Gases $+^{131}I$	5×10^{9}	10

*Note: Values are approximate only

result from the operation of the chemical processing plant which would be necessary to reclaim the "spent fuel." As a result, the data in Table IV are in a sense biased to show nuclear plants in a more favorable light than they truly should be shown.

It is also important to recognize that when the effluents from various types of plants are compared, there are many factors which can influence the final numerical results. For example, the results depend upon the standards applied. When calculating the volume of air required to dilute a given contaminant to an acceptable level, the assumption is made that there is a single universally accepted concentration to which a population group can be exposed. If a higher acceptable concentration is chosen, the calculated quantities of diluting air will be reduced. The calculations also depend on whether it is correct to evaluate various pollutants individually. For example, in a coal fired plant, both particulates and gases are released simultaneously. There are serious questions whether such pollutants can accurately be evaluated one at a time. If the combination of pollutants has the potential of producing synergistic effects, then they should be evaluated as a totality. Also tending to make the coal and oil fired plants appear less favorable is the fact that there are natural processes which remove pollutants such as SO_2, NO_2, and particulates from the air. Had these been taken into consideration, the quantities of diluting air required for the coal, oil, and gas fired plants would have been reduced.

In addition to these considerations, there are other related factors that many people would want to have taken into consideration in an overall evaluation of the environmental and public health impact of electric power plants. In the case of fossil fueled facilities, these considerations include the production of "acid rain" by the release of sulfur compounds into the atmosphere, and the impact of the "Greenhouse effect" that results from the release of CO_2. In the case of nuclear powered plants, such considerations include the long term disposal of the associated high level radioactive wastes, and the evaluation of the potential of a serious accident that might result in the release of large quantities of radionuclides into the environment. All of these events could have far reaching and long range effects of large magnitude. However, it is beyond the scope of this review to attempt to evaluate each of them quantitatively at this time.

Considering all such factors (including the atmospheric pollution problems associated with the processing of spent fuel from a nuclear plant), one would find that a nuclear powered plant would be equal or superior to an electric power station fueled by oil or natural gas. All three types of facilities would appear to be superior to a plant fueled with coal. If improved types of adsorption systems were employed to delay the noble gases from the nuclear plant as well as its associated fuel reprocessing facility, then the nuclear plant would clearly be superior from the standpoint of airborne releases under normal operation.

371

VI. Future Trends in Electric Power Generation

Projections of the relative contribution of each of the major methods of generating electricity in the United States during the next 25 years are summarized in Table V. These data show that the use of nuclear power is expected to increase steadily during this time. In fact, by 1980, data showed that about 13% of the electric generating capacity in the U.S. was nuclear in origin. Even greater uses of nuclear power are projected for other countries. For example, data show that, for 1976, 21% of the electricity generated in Belgium was by nuclear power; for Sweden and Switzerland the nuclear contribution was 18%; for the United Kingdom the contribution from nuclear energy was 13%; for Spain, 10.6%; and for the U.S.S.R., 3%. Projections are that by the year 2000, the nuclear power contribution to electric generating capacity will be 90% in France, 67.5% in Spain, 60% in Pakistan, 54% in Denmark, 50% in Iran, 43% in the Arab Republic, 40% in Finland and Portugal, and 20% in the U.S.S.R.

By the year 2010, it is expected that nuclear reactors will be providing 25% to 30% of the electricity in the U.S. Subsequent expansion both here and abroad will depend on the development and use of liquid metal cooled fast breeder reactors. Such units, which are undergoing rapid development in countries such as France, Great Britain, Japan, the Federal Republic of Germany, and the U.S.S.R., operate at essentially atmospheric pressure and use liquid sodium as a coolant. Operation at reduced pressure will make these plants (at least from this particular aspect) potentially safer than the PWR or BWR. Fast breeder reactors will also have improved efficiencies over conventional plants, thus reducing the amount of heat rejected into the environment. In addition, experience has shown that occupational exposures associated with the operation of this type of reactor have been substantially less than those for light water reactors. Lastly, fast breeder reactors will represent essentially an unlimited energy supply because they will produce more fuel than they consume (hence the origin of the name,"breeder"). With improved waste effluent clean-up systems, particularly for the gaseous emissions, fast breeder reactors have the potentiality of representing a source of reduced stress on the environment.

Even with nuclear power and increased dependence on clean sources such as solar power, however, it will not be possible to solve all of our environmental pollution problems. This is well demonstrated by Figure 4 which shows projections for long range releases of sulfur dioxide into the atmosphere in the United States. The uppermost curve shows the projected quantities of SO_2 in terms of millions of tons discharged per year if all of our future electrical needs are met by fossil fueled plants and there is no improvement in current removal techniques. If it is

372

Table V

RELATIVE CONTRIBUTIONS OF DIFFERENT FUEL SOURCES TO THE GENERATION OF ELECTRICITY IN THE UNITED STATES

Fuel Source	Percent of Total 1968	1977	2010*
Coal	51.9	27.1	31.9
Oil	7.0	32.4	10.3
Natural Gas	23.0	32.0	17.2
Nuclear	0.8	4.5	26.9
Hydropower	17.3	4.0	3.2
Other (Solar)	0	0	10.5

*Projected

373

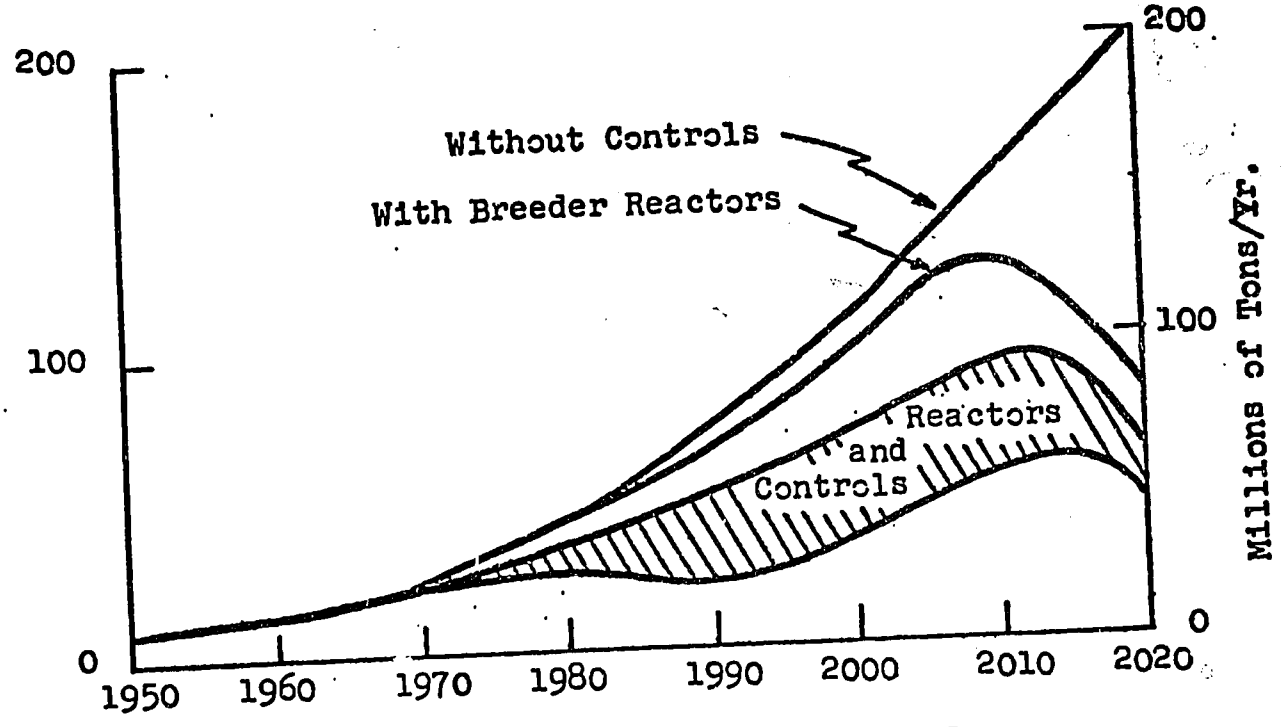


Figure 4. PROJECTED EMISSIONS OF SULFUR DIOXIDE.

374

possible to apply fast breeder reactors on a large scale commercial basis, the projections of SO_2 releases will be as shown by the second curve. In this case, SO_2 production will reach a maximum about the year 2010 and then decline thereafter as fossil fueled plants are phased out.

With widespread application of fast breeder reactors coupled with increased control of SO_2 released from fossil fueled plants, projections will be within the range denoted by the cross-hatched section between the two lower curves. But the fact to note in the Figure is that, even with our best efforts (denoted by the curve at the bottom of the cross-hatched section), experts predict that by the year 2015, SO_2 releases in the United States will be two to three times what they are today. Obviously, much work remains to be done.

VI. Commentary

In the final analysis, the basic question is how much power (and particularly, how much electricity) can safely be used on earth. One way to reduce the amount of inanimate energy being consumed would be to return to the horse and buggy era. If, however, all of our electric motors and modern machines were replaced by horses, there would really be an environmental waste problem! So before taking steps to return to the horse and buggy era, consideration should be given to the many problems which would be associated with such a change.

If one examines the situation closely, he or she would find that electricity is essential to the management of many of our current environmentally and socially related problems. Better lighting has been shown to reduce accidents on the highways and crime. Electricity is necessary to clean our air and to operate water purification facilities and sewage treatment plants. Electricity is also required for the disposal of old automobiles and for recycling other types of solid waste. It is the source of energy which powers many of the conveniences in modern homes and brings us entertainment in the form of radio and television. Electricity is essential to the quality of modern life. Although conservation can assist in reducing our demands for energy, overall electricity needs are almost certain to increase in the future and more power plants are going to be needed. The basic challenge is to educate the people to use energy supplies more efficiently and to encourage the commercial sector to design, construct and operate electric generating stations that function at maximum efficiency with minimal pollution impact.

375

Specific References

1. Nero, A.J., Jr., "Health and Safety Impacts of Nuclear, Geothermal, and Fossil-Fuel Electric Generation in California: Overview Report," Report Number LBL-5924, Lawrence Berkley Laboratory, University of California, Berkeley, California (January, 1977).

2. "Radiological Impact Caused by Emissions of Radionuclides into Air in the United States - Preliminary Report," U.S. Environmental Protection Agency, Report EPA 520/7-79-006, Washington, D.C. (August, 1979).

3. McBride, J.P., Moore, R.E., Witherspoon, J.P., and Blanco, R.E., "Radiological Impact of Airborne Effluents from Coal and Nuclear Plants," Science, Vol. 202, No. 4372, pages 1045-1050 (December 8, 1978).

4. Ferris, Benjamin G., Jr., "Health Effects of Exposure to Low Levels of Regulated Air Pollutants--A Critical Review," Journal of Air Pollution Control Association, Vol., No. 5, pages 482-497 (May, 1978).

5. "Standards for Protection Against Radiation," Code of Federal Regulations, Title 10, Part 20, Appendix B, Table II, Washington, D.C. (1980).

376

General References

1. Keeny, Spurgeon, M., Jr., Chairman, The Nuclear Energy Policy Study Group, "Nuclear Power Issues and Choices," Report sponsored by the Ford Foundation; published by the Ballinger Publishing Company, Cambridge, MA (1977).

   See, in particular:

   Chapter 5: "Health Effects", (Nuclear Power and Coal-Fueled Power Generation), pages 159-196;

   Chapter 6, "Environmental Effects," pages 197-211.

2. Lewis, Harold W., "The Safety of Fission Reactors," Scientific American, Vol 242, No. 3, pages 53-65 (March, 1980).

3. Bethe, H.A., "The Necessity of Fission Power," Scientific American, Vol. 234, No. 1, pages 21-31 (January, 1976).

4. Abrahamson, Dean E. "Environmental Cost of Electric Power," a Workbook issued by the Scientists' Institute for Public Information, 30 East 68th St. New York, NY 10021 (1970).

5. Rose, David J., Walsh, Patrick W. and Leskovjan, "Nuclear Power--Compared to What?" American Scientist, Vol. 64, No. 3, pages 291-299 (May-June, 1976).

6. Eicholz, Geoffrey G., "Environmental Aspects of Nuclear Power," Ann Arbor Science Publishers, Inc., Ann Arbor, Michigan (1976).

7. Comar, C.L. and Sagan, L.A., "Health Effects of Energy Production and Conversion," in Annual Review of Energy, Vol. 1, Annual Reviews, Inc., Palo Alto, CA, pages 581-600 (1976).

8. Axtmann, Robert C., "Environmental Impact of a Geothermal Power Plant," Science, Vol. 187, No. 4179, pages 795-803 (7 March 1975).

9. Robertson, D.E., Crecelius, E.A., Fruchter, J.S., and Ludwick, J.D., "Mercury Emissions from Geothermal Power Plants," Science, Vol 196, No. 4294, pages 1094-1087 (3 June 1977).

10. Neyman, Jerzy, "Public Health Hazards from Electricity-Producing Plants," Science, Vol. 195, No. 4280, pages 754-758 (25 Feb. 1977).

11. Asbury, Joseph, G. and Mueller, Ronald O., "Solar Energy and Electric Utilities: Should They be Interfaced?" Science, Vol. 195, No. 4277, pages 445-450 (4 Feb. 1977).

377

12. Council Report, "Health Evaluation of Energy-Generating Sources," AMA Council on Scientific Affairs, JAMA, Vol. 240, No. 20 (Nov. 10, 1978).

13. McBride, J.P., Moore, R.E., Witherspoon, J.P., Blanco, R.E., "Radiological Impact of Airborne Effluents of Coal and Nuclear Plants," Science, Vol. 202, No. 4372, pages 1045-1050 (Dec. 8, 1978).

14. Schikarski, W., Jansen, P. and Jordan, S., "An Approach to Comparing Air Pollution from Fossil-Fuel and Nuclear Power Plants," Papaer IAEA-SM-146/57, pages 977-899, in Proceedings of a Symposium on the "Environmental Aspects of Nuclear Power Stations," New York, NY, August 10-14, 1970. Published by the International Atomic Energy Agency, Vienna, Austria, Report STI/PUB/261 (1971).

15. Zaleski, C.P., "Breeder Reactors in France," Science, Vol. 208, No. 4440, pages 137-144 (11 April 1980).

16. Hamilton, L.D., and Manne, A.S., "Health and Economic Costs of Alternative Energy Sources," Paper IAEA-CN-36/448, International Conference on Nuclear Power and Its Fuel Cycle, Salzburg, Austria (May 2-13, 1977).

17. Budnitz, R.J., Hamilton, L.D., Holdren, J.P., and Morgan, J.D., "U.S. Electricity through the Year 2000: Coal or Nuclear?," CRC Forum on Energy, CRC Press, Inc., Cleveland, OH (1977).

18. "The Direct Use of Coal, Prospects and Problems of Production and Combustion," Office of Technology Assessment, Congress of the United States, Washington, D.C. (April, 1979).

19. Gotchy, R.L., "Health Effects Attributable to Coal and Nuclear Fuel Cycle Alternatives," Report NUREG-0332 (Draft), U.S. Nuclear Regulatory Commission, Washington, D.C. (September, 1977).

20. "Energy in Transition, 1985-2010," Report of the Committee on Nuclear and Alternative Energy Systems, National Academy of Sciences, Washington, DC (1980).

5/80

UOC-2

PN-AAP-436/62
ISN-33716

PREFACE

This workbook, in two volumes, presents the papers of the second International Seminar on Principles of Environmental Management in Developing Countries, held from 9 to 20 June 1980. The seminar was conducted by the International Environmental Management Institute of Environmental Research & Technology, Inc.

The purpose of the seminar is to strengthen the environmental management, planning, and analytical skills of top-level policy makers and administrators concerned with environmental protection during economic development in developing countries. The seminar presents general principles of environmental management through papers and discussions that reflect years of experience by practicing experts assisting governmental and industrial clients in developing workable solutions to environmental problems.

The papers do not necessarily include all the considerations presented during the seminar. Because of its purpose and design, the workbook should be used as a reference guide rather than a textbook.

The seminar is offered by Environmental Research & Technology, Inc. as a private initiative undertaken without contract or grant support.

Please address your comments or inquiries to the author or to:

John Whitman
International Environmental Management Institute
Environmental Research & Technology, Inc.
696 Virginia Road
Concord, Massachusetts 01742 U.S.A.

Telephone: (617) 369-8910
Telex: 923 335 ENVIRORES CNCD

Copyright © 1980 by International Environmental Management Institute

379

TABLE OF CONTENTS

Volume 1

PREFACE

ACKNOWLEDGMENTS

SECTION	TAB
Introduction	1
Opening Addresses:	
• Environment, Development and Human Health	2
• Conservation: A Management Challenge of the Eighties	3
Definition of Environmental Issues	4
Benefit/Cost Analysis of Environmental Programs	5
The Role of Environmental Standards and Regulations in the Management of Industrial Development	6
Environmental Monitoring:	
• Principles of Environmental Monitoring	7
• Remote Sensing	8
• Air Monitoring	9
• Water Monitoring	10
• Case Study: Industrial Zone Water Monitoring System in Kuwait	
Environmental Impact Assessment Methodology	11
The World Bank and the Environment:	
• Agriculture	12
• Water Supply and Waste Disposal	13
• Environmental Policies and Procedures	14
World Population Growth	15
Environmental Health: Radiation Protection	16
• Case Study: Environmental Consequences of Electrical Power Generation by Hydro-electric, Nuclear, and Fossil Fuels	

380

Volume 2

SECTION	TAB
Sector Considerations:	
• Transportation: Issues Related to Control of Automotive Air Pollution	17
• Petroleum	18
• Extraction	19
Solid Waste Management in Developing Countries	20
Environmental Modeling:	
• Air Modeling	21
• Water Modeling	22
Advanced Environmental Information Systems:	23
• Case Study: Hydrologic Information Service	
Environmental Education and Training	24
ADMINISTRATIVE CASE STUDIES:	
• William D. Ruckelshaus and the Environmental Protection Agency	25
• Develotech Siting Commission (A)	26
• Develotech Siting Commission (B)	27
LIST OF PARTICIPANTS	28
SEMINAR SCHEDULE	29

ACKNOWLEDGMENTS

The International Seminar on Principles of Environmental Management in Developing Countries is a program independently offered by Environmental Research & Technology, Inc. (ERT), a subsidiary of COMSAT (Communications Satellite Corporation).

We would like to acknowledge and thank the following organizations for their contributions to this effort to strengthen environmental management in the developing world, either by sponsoring the attendance of scholarship participants or by providing speakers to take part in the 1979 or 1980 sessions.

- Canadian International Development Agency
- Economic Commission for Latin America
- Food and Agriculture Organization of the United Nations
- German Marshall Fund of the United States
- United Nations Environment Program
- United States Agency for International Development
- United States International Communication Agency
- The World Bank
- World Health Organization

We also wish to thank the members of our International Advisory Board for their voluntary assistance in guiding the development of the seminar:

N. Brown
Jamaica

N. Castaneda
Mexico

C.A. Cochrane
United Kingdom

C. Jeanneret
Canada

M. Kassas
Egypt

F. Lopez de Alba
Mexico

B. Lundholm
Sweden

We would also like to pay particular thanks to Dianne Belanger and Mary Gallagher for their immense contribution in handling the varying needs of over fifty participants from more than 20 countries and international organizations on a daily basis for two weeks with the greatest professional ability, effectiveness, and good humor. All the participants join us in saluting Dianne and Mary.

Finally, we thank the many hundreds of other ERT employees for their cooperation and contribution during the seminar; indeed, the participants were impressed by such a large group of enthusiastic and first-rate professionals working on issues of environmental management.

Norman E. Gaut, President
Environmental Research & Technology, Inc.

James R. Mahoney, Senior Vice President
Environmental Research & Technology, Inc.

John R. Whitman, Director
International Environmental Management Institute

June 1980

ISSUES RELATED TO CONTROL OF AUTOMOTIVE AIR POLLUTION

Eric O. Stork

Visiting Professor
Technology and Public Policy

Automotive Transportation Center
Institute for Interdisciplinary Engineering Studies
Purdue University
West Lafayette, Indiana 47907
U.S.A.

For Presentation At

Seminar on Principles of
Environmental Management
In Developing Countries

Environmental Research & Technology
Concord, Massachusetts
June 16, 1980

384

I. Overview

- Automotive air pollution is a specialized sub-set of the total problem of air pollution
- Caused when many cars operate in a small area
- Potentially affects every city as its auto population grows
- Does not occur suddenly, and cannot be solved quickly once it has manifested itself
- Much easier to prevent than to cure
- Correcting the problem -- once it has occurred -- is not easy. Solution requires changes of socio/political nature, in addition to use of modern technology
- May or may not be the most important next thing on which to spend available resources -- need for control of automobile air pollution should be evaluated in context of other social problems

II. Health Effects of Automotive Pollutants

A Adverse effects of human exposure to automotive pollutants.

1 HC -- in most cases no direct health effect (but there is concern about benzene, PNA, aldehydes)

2 CO -- reduces ability of blood to carry oxygen, increases reaction time, exacerbates angina

3 NOx -- pulmonary problems

4 Ox -- pulmonary problems, eye irritation

5 Particulates -- pulmonary problems, potential carcinogens

6 Lead -- increases blood level of lead, may contribute to mental retardation

B Concern over health effects of automotive pollutants depends on levels of concentration in ambient air

1 There are differences in views in different countries about the levels of concentration at which there is a concern about health effects. Reasons: limited data, value judgments implicit in air quality goals

2 Examples of Ambient Air Quality Goals

Pollutants (in mg/m^3)

	CO	time	NO_2	time	Ox	time
WHO	40 10	1 hr 8 hr	.19-.32	1 hr	.12 .06	1 hr 8 hr
Japan	23 11.5	8 hr 24 hr	.08-.12	24 hr	.16	1 hr
U.S.A.	40 10	1 hr 8 hr	.1	1 yr	.24	1 hr
W.Germany	30 10	1 hr 24 hr	.3	0.5 hr		

III. Determining the Need for Control of Automotive Air Pollution

A Monitoring of Air Quality in Urban Areas -- first must determine the existing levels of air pollution

B Emission Inventory

- It is necessary to know the sources that contribute to air pollution in a jurisdiction
- An inventory should include non-mobile sources of the relevant pollutants

C Projection of Future Air Quality -- need to project future levels of concentration of pollutants

D The technology of monitoring air quality, making emission inventories, and modeling future air quality involve specialized science that requires competent execution if results are to be useful

IV. Technological Issues.

A The principal automotive pollutants are

1 HC -- unburned fuel

2 CO -- partially burned fuel

3 NOx -- O + N combined by heat

4 Ox -- Photochemical Oxidant, formed from HC and NOx in the presence of sunlight

5 Particulates -- carbon particles, mainly from diesels

6 Lead -- a particulate from leaded gasoline, gives rise to special health concern

B Sources of automobile emissions

1 Crank-case vapors -- easily and cheaply controlled, helps a lot

2 Evaporation from gas tank and carburetor -- can be controlled with seals and traps

3 Exhaust emissions -- the most difficult technical problem

C Basic engine exhaust emission-control

1 Spark retard helps lower HC & NOx

2 Enleanment of air/fuel (A/F) mixture helps lower HC & CO

3 Heated intake air helps lower HC & CO

4 Injecting air into exhaust helps oxidize HC & CO

5 Exhaust Gas Recirculation (EGR) reduces NOx

6 Engine modification plus EGR, AIR, PCV, and EVAP is the basic system used in the U.S. up through 1974, and is used today in Europe and Australia. (Spark retard tends to increase fuel consumption, as does simple EGR)

D Alternative Reciprocating Engines

1 Diesel engines have inherently low HC & CO, but are hard to control for NOx. Also have high levels of particulate emissions, some of which may be carcinogenic. Visible diesel smoke is unecessary, and from a technological standpoint can easily be cleaned up

2 Stratified Charge Engines have significant potential for low emissions, but not so low as to meet the most stringent standards without catalysts.

D Catalytic Emission Control

1 Oxidation Catalysts can greatly lower HC & CO levels after the exhaust has left the engine itself. Avoids need to use spark retard (which increase fuel consumption)

2 Dual Catalyst Systems can -- in addition to controlling HC & CO -- also lower the levels of NOx. But have not been used on production vehicles because of higher cost and need for poor fuel-economy engine calibrations

3 Three-Way Catalyst Systems make it possible to control HC, CO, & NOx simultaneously, with good fuel-economy. Require sophisticated control of air-fuel mixtures and spark timing. Most cars in the U.S. will soon be equipped with 3-way catatlyst systems

4 Lead-free gasoline is currently needed for all catalytic emission control systems because lead poisons (and thus inactivates) the catalysts. Lead-tolerant catalysts are being explored and developed, but their effectiveness and durability is yet to be proven

E Alternative Fuels

1 LPG, CNG, LNG are difficult to use and require specialized engine adaptations. They have no special advantage over catalytic control of gasoline engines

2 Electric Vehicles are a long time off because of inadequate battery technology. Even with better batteries, will always have limited range because of time-consuming refueling

3 Alcohol can be used as a fuel, either by itself or mixed with gasoline. But it is not without problems

- gashol (mixture of alcohol & gasoline) tends to increase the octane (anti-knock) rating of fuel
- for engines calibrated rich, gasohol tends to reduce exhaust emissions of HC & CO, and increase NOx
- for engines calibrated lean, gasohol may induce lean-misfire and increase exhaust HC
- alcohol substantially increases exhaust emissions of aldehydes, which are a suspected carcinogen (but catalytic emission control is effective for aldehydes)
- gasohol has higher vapor pressure than gasoline, substantially increases evaporative emissions of HC
- alcohols may adversely affect elastomers in fuel system if car was not designed for alcohol fuel
- alcohol has less heat value than gasoline, hence range is reduced for equivalent volume of fuel

V. Establishing Programs to Control Automotive Emissions.

A The first step is to define automotive emissions. To do that one must have an emission test procedure (TP)

1 TP consists of

- instruments that measure chemicals
- driving cycle

2 Three major test procedures are used in the world

- USA
- Europe
- Japan
- There are also some obsolete test procedures that are still used in some smaller markets for cars

3 Because of major differences, these test procedures produce results that cannot be easily or precisely compared

4 How would a country go about establishing a TP?

- developing TP from scratch is a large task
- it is better to adopt an established TP

5 There are significant implications in adopting one of the several existing TP's

- how well does the TP account for the relevant emissions?
- selection of a TP creates ties to a country (or group of countries) for getting technical help in conduct of the control program
- selection of a TP tends to create ties to a market for cars

B Getting the auto industry to build clean new cars

1 Establishing emission standards

a for which pollutants?

b how stringent?

2 Defining <u>compliance</u> with emission standards

a The goal of the control program is achieved by compliance of the mean vehicle

b Each-car compliance is nevertheless advocated by some authorities

- Each-car compliance requirement greatly increases the effective stringency of the emission standard
- Each-car compliance with standards greatly increases the cost of compliance, thus the cost and complexity of cars

c Defining compliance in terms of mean emissions from a sub-set of the manufacturer's production is the better approach

3 Assuring that new cars are designed and built to meet the emission standards

a Current practice is to require manufacturers to demonstrate prior to being allowed to sell cars that their vehicles are designed to meet standards for their useful lives

- But there are major technical problems that suggest that such an approach has limited validity, and that it provides a poor basis for predicting how well cars will do in actual use
- Also, such systems are costly to administer, both for governments and industry

b Some countries also require testing of individual cars on the assembly-line, and others have considered requiring dealers to test cars before delivering them to customers

- but emission tests of new (not yet broken-in) cars have questionable significance
- new-car testing tells nothing about durability of the control system

c An alternative approach would evaluate compliance in terms of results of in-use vehicle testing

- tests would be made of cars in-use, after some period of use
- for classes of cars that fail to meet standards, manufacturer would have to pay fees or fines
- advantage is that real objective -- i.e., clean cars in-use -- becomes manufacturers' goal, instead of the manufacturers focussing on how to beat the pre-production testing requirement
- a problem might be in whether government has political willingness to impose fees or fines when classes of cars are found to fail to meet standards

C What can (or needs to be) done to help assure that cars stay clean while in use?

1 It is important to conduct surveillance testing over the life of the cars, so as to have data on how the program is working and where it needs to be improved

- Such programs have consistently shown that the main reason for cars-in-use having excessive emissions is that they are not adjusted to their manufacturers specifications

2 Periodic Inspection/Maintenance programs are often suggested as a way of controlling in-use vehicle emissions

a in I/M programs, every car is required to be inspected once or twice a year by a short emission test. Cars that fail are required to be repaired

b but there are many technical obstacles to carrying out effective I/M programs

- The main obstacle is that there are no good short tests that can correlate with a full emission test
- I/M is costly, not only in money but also in public inconvenience
- the prospects for I/M being cost-effective are not good

3 Limited adjustability of emission-sensitive parameters (e.g., idle mixture, choke setting) can be required on new cars to reduce the problem of maladjustment in the field.

4 Mechanic Training is important. Mechanics tend to adjust cars for optimum performance, which may not be the same as minimum emissions

5 Retrofit of In-Use Cars is technically feasible, but is probably not logistically or economically feasible

6 Warranty of emission control systems has been required in the U.S., but is difficult to enforce because owners have little interest in emission performance of their cars

7 Recall of defective cars has been carried out extensively in the U.S. It is a costly sanction against manufacturers, and may not be cost effective in terms of money spent for pollution abated. A system of fees or fines (instead of government-mandated recalls) may be more efficient

D There are also non-technological approaches to reducing auto air pollution

1 Reductions in VMT, parking restrictions, street and highway planning

2 These are difficult to administer and interfere with vehicle use, thus may be very unpopular

VI. Costs of Automotive Emission Control

A Emission control adds some costs to new vehicles, but very significant levels of control can be achieved with a new-car cost increase of 5% or less.

B Conducting control programs costs money, requires highly-skilled talent, and takes a long time to become effective

- Measuring Emissions from Automobiles requires well-equipped laboratory facilities and trained technicians
- There is no quick, cheap, or easy way of getting valid emission test results

C Most significant is the issue of emission controls' impact on fuel economy

- By using unleaded gasoline and catalytic emission controls, a great deal of control can be achieved without loss in fuel economy
- The simpler, non-catalytic approaches tend to increase fuel consumption

VII. Summing Up

- First, collect and analyze data to see if you have, or are likely to have a problem. Don't decide without knowing where you are and where you are likely to be in the future
- Control of auto pollution is not cheap; don't invest in it unless there is a current or prospective demonstrated need for control. Don't just do it because others are doing it
- If you decide you need to control motor vehicle emissions, get help from people who have experience. Avoid their mistakes. Adapt their successes to your needs.
- Oxidation-catalyst emission control is highly effective and does not reduce fuel economy, but currently requires exclusive use of unleaded gasoline in catalyst-equipped cars

######

Bibliography

Automotive Air Pollution and Noise: Implications for Public Policy. Organization for Economic Cooperation and Development, Paris, October 1972.

Automotive Emission Control - The Development Status, Trends, and Outlook. U.S. Environmental Protection Agency, Washington D.C., April 1977.

Air Quality Criteria Documents (on Carbon Monoxide, Oxides of Nitrogen, Oxidants, Lead), U.S. Environmental Protection Agency, Washington D.C., various publication dates.

The Report by The Federal Task Force on Motor Vehicle Goals Beyond 1980, (published only in draft), U.S. Department of Transportation, September 1976.

An Analysis of Alternative Motor Vehicle Emission Standards, U.S. Department of Transportation, U.S. Environmental Protection Agency, Federal Energy Administration, Washington D.C., May 1977.

E.O. Stork, Issues Related to Control of Air Pollution from Automobiles, Report to Department of Transport, Commonwealth of Australia, Purdue ...University, February 1979.

E.O.Stork, Control of Exhaust Emissions from Automobiles in Sweden, Report to National Swedish Environmental Protection Board, Purdue University, December 1979.

ERIC O. STORK

Visiting Professor
Institute for Interdisciplinary
Engineering Studies
Purdue University
West Lafayette, Indiana 47907

BA, Political Science, Reed College, 1950
MS, Public Administration, Syracuse University, 1951
Public Affairs Fellow, Stanford University, 1968-69

Professional Background:

1978-present: Purdue University, lecturer on regulatory policy. Lecturer on auto emission control for World Bank. Advisor to foreign governments on automobile emission control programs (Mexico, Australia, Sweden, Brazil, United Nations).

1970-1978: Deputy Assistant Administrator for Mobile Source Air Pollution Control, U.S. Environmental Protection Agency, Washington D.C.

1966-1970: Deputy Director, Bureau of Regulatory Compliance, U.S. Food and Drug Administration, Washington D.C.

1962-1966: Executive Officer, Airports Service, U.S. Federal Aviation Agency, Washington D.C.

International Experience:

Principal U.S. Delegate to OECD meetings on motor vehicle emission control, 1971-72

Head of U.S. delegation to UN Environment Program Conferences on automobiles, 1976 and 1978

Participant for U.S. in meeting of WP-29 (European auto standard setting group), 1978

Head, U.S. Side, joint project on motor vehicle emission control with USSR, 1973-78

Head, U.S. Side, joint project on motor vehicle emission control with Japan, 1973-78

Advisor to Mexico, Australia, Sweden, Brazil, United Nations on automobile emission control matters, 1978-80

Recent Publications:

Control of Air Pollution from Automobiles, Report to Department of Transport, Commonwealth of Australia, 1979

Control of Exhaust Emissions from Automobiles in Sweden, report to Swedish National Environmental Protection Board, 1979

The Regulatory Budget as a Management Tool for Regulatory Reform, report to Joint Economic Committee, U.S. Congress, (project organizer & co-author) 1979

Planning for Motor Vehicle Emission Control, Industry and Environment Quarterly (published by United Nations Environment Program), 1979

##########

ENVIRONMENTAL ISSUES
in
THE PETROLEUM REFINING INDUSTRY

Leigh Short

Director
Environmental Engineering Group
Environmental Research & Technology, Inc.

June 1980

International Environmental Management Institute
ENVIRONMENTAL RESEARCH & TECHNOLOGY, INC.
Concord, Massachusetts, USA

400

Environmental Issues in The Petroleum Refining Industry

The petroleum industry may be broadly classified into five areas:

- Exploration and drilling (onshore and offshore)
- Production
- Transportation and supply
- Refining
- Marketing and distribution

This paper will emphasize the environmental issues in the petroleum refining industry, together with some discussion of risk assessment. The methodology of this latter area is useful within many branches of the petroleum industry.

Petroleum refineries, are exceedingly complex sequences of various processes. The equipment necessary to process crude oil into the necessary finished products depends upon:

- Types and quantities of crude oil available - sweet (low sulfur) or sour (high sulfur); high API gravity (produce a relatively large volume of gasoline) or low API gravity (produce a relatively large volume of heavy products which must be upgraded into more desirable lighter products).
- Type and specification of products to be produced.
- The cost of energy - some processes are much more energy intensive than others that may make the same products.

It is probably correct that there is no such thing as a typical refinery - they are all individually tailored to the available crude oils and the needed refined products. However, the process sequence shown in Figure 1 is representative of that contained in many refineries, both in the United States and abroad. Given the complexity of this block flow diagram, one can understand that describing the pollution emissions from a refinery would not be a simple task. This is true not only because of the complex processing sequences, but also because the emissions (particularly air) are dependent to considerable degree on the type of crude oil processed.

A. Refinery Processes

The major process units in a refinery and their function are described below (not all are shown in the block flow diagram).

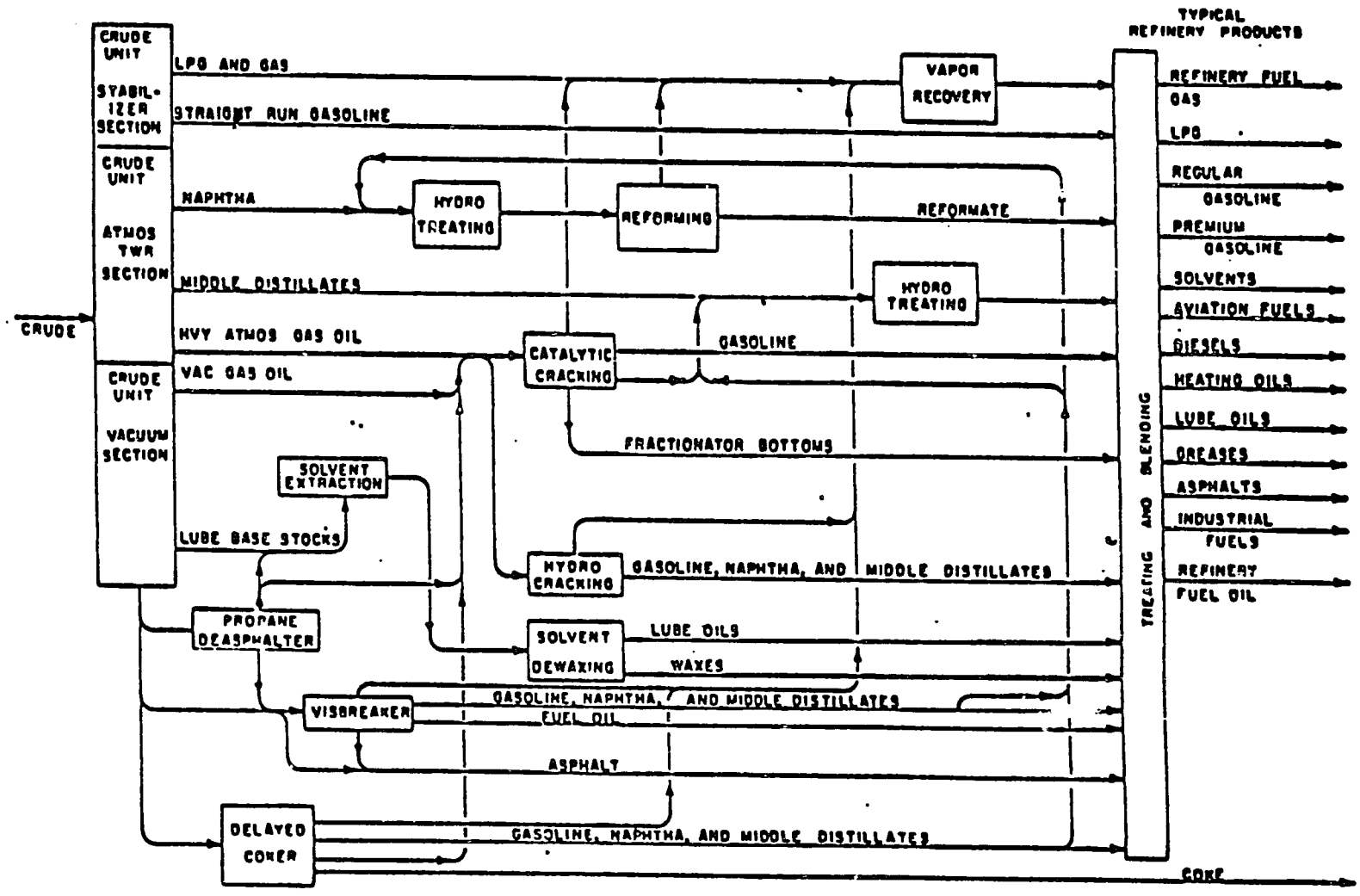


FIG. 1 Refinery Flow Diagram

204

1.0 Separation Processes

1.1 Desalting

Crude oil is normally contaminated by water, salt and sand, much, but not all, of which will settle out during storage. The portion which does not settle out is removed by electrical desalting, or less commonly by chemical desalting.

1.2 Crude Distillation

This is the first operation in refining crude oil (after desalting). In this process the crude oil is separated into various fractions by distillation (both atmospheric and vacuum).

1.3 Deasphalting

This process separates vacuum tower bottoms (the heaviest product from crude distillation) into resins and more viscous materials by liquid extraction (usually with propane).

2.0 Decomposition Processes

2.1 Catalytic Cracking

This is a technique for breaking down heavier distillation fractions (gas oils) into gasoline using a catalyst, usually in a process unit called a fluid catalytic cracker (FCC).

2.2 Hydrocracking

These units perform both cracking and hydrogenation. The products, primarily saturated hydrocarbons, and are used for blending in the production of gasoline, jet fuel, heating oil and diesel fuels.

2.3 Coking

Coking is essentially a severe form of thermal (non-catalytic) cracking. The products are primarily coke and gasoline.

2.4 Visobreaking

This is a milder form of thermal cracking than coking.

3.0 Formation Processes

3.1 Catalytic Reforming

Saturated straight chain paraffins (e.g., normal octane) have very low octane numbers. In catalytic reforming these low octane materials are upgraded to high octane ring or branch materials such as benzene, toluene. (This process is also called platforming, ultraforming and rheniforming).

403

TABLE I

Summary of Major Sources of Air Emissions
Within a Refinery

Process Units	Emission Type
Crude Unit Including Desalter	None.
Vacuum Unit	Non-condensable vapors from steam barometric condenser hot wells. If surface condensers are used this source will be essentially eliminated.
Catalytic Cracking	SO_2, NO_x, particulates, carbon monoxide, hydrocarbons, aldehydes, ammonia. These emissions are released from the regenerator and not the reactor.
Catalytic Reforming	Generally none, althouth some hydrocarbons may release during regeneration. If regeneration is continuous, minor amounts of CO may be released. The quantities of NH_3 and/or H_2S which may be formed are typically recovered in the sour water or a refinery fuel gas stream.
Catalytic Hydrocracking	Emissions from catalyst regenerations which may release significant quantities of CO over relatively short time frames. As in the case of catalytic reformers, any NH_3/H_2S formed is captured either in the refinery fuel gas system or the sour water system.
Alkylation	None.
Light Ends Recovery	Essentially none.
Catalytic Hydrotreating	Similar to catalytic hydrocracking.
Hydrogen Manufacture	None.
Solvent Deasphalting	None.
Residual Oil Hydrodesulfurizing	None, other than catalyst regeneration.
Asphalt Blowing	None, assuming the vent gases, which are highly odorous, are unvented before release.
Coking	Wind blown coke dust and emissions from the storage containers for the water used in cutting the coke.

404

TABLE 1 (continued)

Other Refinery Units	Emission Type
Storage and Blending	All storage tanks containing light hydrocarbons, including crude have the potential to emit hydrocarbons to the atmosphere. Breathing losses can result from weathering or during emptying and filling. Also the seals of the floating roof tanks will leak to a certain extent.
Process Heaters	Particulates, SO_x, CO, hydrocarbons, aldehydes, NO_x. The quantities will of course depend upon the source of fuel - gas, oil, residual oil etc., the physical properties of each, and the burner design (for NO_x emissions, particularly).
Wastewater Treatment	API Separator (hydrocarbons).
Pressure Relief and Flare Systems	Hydrocarbons.

Water Emissions Within a Refinery

Source	Pollutant Type
Desalter	Salt water, oils, phenols, sulfides.
Crude Distillation	Stripping steam condensate containing sulfides, phenols, ammonia etc.
Vacuum Distillation	Same as crude distillation except vacuum jet water may also be present.
Light Ends Recovery and Distillation	Liquid streams associated with caustic and water scrubbing.
H_2S Removal	Spent amine solutions.
Catalytic Desulfurization	Sour water from regeneration and perhaps from separator injection.
Catalytic Reforming	Similar to desulfurization.
Alkylation	Water from caustic scrubbing.
Chemical Sweetening	Water washing after scrubbing or treating.
Catalytic Cracking	Water from catalyst stripping section, sour water containing NH_3, H_2S, CN^-, etc.
Hydrocracking	Sour water containing NH_3 and H_2S.
Lube Oils	Solvent containing waters.
Lube Hydrotreating	Sour water.
Deasphalting	Waste water sources are minimal other than condensate from steam in solvent/asphalt stripping towers, which will contain oils.
Coking	Water used for cutting coke - contains oils, sulfur compounds, etc. Also water is often drawn from the overhead accumulator and resulting from steaming from the coke drum.
Cooling Towers	Blowdown water which contains heavy metals, notably chromium.

Source	Pollutant Type
Miscellaneous	Quench waters - water resulting from steaming during startups, cleaning of vessels, etc.; storm-water - even if segregated since it will contain oils picked up from spills, etc., in the process units.

406

3.2 Alkylation

This is another gasoline producing process in which olefins (propene, butene) react with isobutane in the presence of a catalyst - sulfuric acid.

4.0 Treating Processes

4.1 Catalytic Treating (Hydrotreating)

This process, with the appropriate catalyst, is used to remove sulfur, nitrogen, decolorize and stabilize products and correct odor problems.

5.0 Recovery Operations

These processes consist of sulfur recovery and fuel gas recovery.

B. Sources of Emissions from a Refinery

A modern, integrated refinery will emit considerable quantities of air, water and solid waste emissions.

1.0 Air Emissions

The primary air pollutants emitted by refineries subject to regulatory control within the United States are SO_x, CO, hydrocarbons (non-methane), particulates, NO_x, sulfur compounds (H_2S) and benzene. Table 1 summarizes the major sources of air pollutants by process source (i.e., from the various types of process units described above). In addition to these sources, tanks, loading docks, truck loading racks, etc. will also be potential sources of air pollution. One other major source is fugitive emissions - leaks from valves, flanges, pumps, compressors, etc..

2.0 Water Emissions

Table 2 summarizes the major sources of water emissions from a refinery. Although the volume of process water discharged from a refinery treating system is not large, relative to many other types of industries, the quantity and types of pollutants which must be removed is significant.

3.0 Solid Waste Emissions

The sources of solid waste emissions from a "typical refinery" are shown in Table 3. Some of these may be classified as hazardous - i.e., requiring special handling and disposal practices but many are not. The US EPA has defined the following as hazardous:

- Leaded tank bottoms
- API separator sludge
- Cooling tower blowdown sludge
- Sludge from heat exchanger cleaning
- DAF float

The above wastes are defined to be hazardous because of the presence of toxic metals - lead, chromium, etc..

TRACE CONCENTRATION UNITS

UNIT	10^{-6} 1 ppm	10^{-9} 1 ppb	10^{-12} 1 ppt
LENGTH	1 inch/16 miles	1 inch/16,000 miles	1 inch/16,000,000 miles (A six inch leap on a journey to the sun)
TIME	1 minute/2 years	1 second/32 years	1 second/320 centuries
MONEY	1¢/$10,000	1¢/$10,000,000	1¢/$10,000,000,000
WEIGHT	1 ounce/31 tons potato chips	1 pinch salt/10 tons potato chips	1 pinch salt/10,000 tons potato chips
VOLUME	1 drop vermouth/ 80 "fifths" gin	1 drop vermouth/ 500 barrels gin	1 drop vermouth/ 250,000 hogsheads gin or 1 drop vermouth in a pool of gin covering the area of a football field-43' deep or 1 drop vermouth in 520 30,000 gal tank cars of gin
AREA	1 sq. ft/23 acres	1 sq. ft/36 sq. miles	1 sq. in/250 sq miles
ACTION	1 bogey/3,500 golf tournaments	1 bogey/3,500,000 golf tournaments	1 bogey/3,500,000,000 golf tournaments
	1 lob/1,200 tennis matches	1 lob/1,200,000 tennis matches	1 lob/1,200,000,000 tennis matches
QUALITY	1 bad apple/2,000 barrels	1 bad apple/2,000,000 barrels	1 bad apple/2,000,000,000 barrels
RATE	1 dented fender/10 car lifetimes	1 dented fender/10,000 car lifetimes	1 dented fender/10,000,000 car lifetimes

NOV 13 1979
ERT
GRO

408

4.0 Control Technologies

The type of control technology selected depends in large part upon the degree of control required (removal efficiency). This in turn depends upon the regulatory philosophy in any particular region, and in some cases on specific sites. Often in the specification of removal efficiencies, processes are required to meet effluent concentrations of parts per million or even in some cases, parts per billion. It is difficult to visualize how small these numbers really are. The information shown in Table 4 helps to relate these very low concentrations to things with which most people are familiar - albiet in some rather strange units such as lobs/tennis match.

4.1 Air Pollution Controls

Within the United States a source is defined as major, and therefore requiring air pollution controls if the emission rates exceed a "de minimus" value. These deminimus rates are shown in Table 5. Very few refineries of any size or complementary fail to exceed these rates and hence require controls.

Again, within the United States, one of two types of control is required - best available control technology (BACT) and lowest achievable emission rate (LAER) technology. The essential distinctions between the two are:

- BACT is applicable when the region is attainment - i.e., ambient values of the pollutant do not exceed some specified value. In specifying BACT one most considers the economic costs of the various competing technologies.
- LAER is applicable when a region is non-attainment - i.e., ambient values of the pollutant exceed some specified value. In the specification of LAER technology economics are not considered.

The level of control (removal efficiency) is typically specified via a new source performance standard (NSPS). These standards do not specify technology but rather the degree of control required. A refiner is free to select whatever technology is appropriate provided it meets BACT or, if necessary, LAER guidelines. Examples of the types of regulations which may be imposed are:

- The allowable NO_x emissions from process heaters is 0.2 lb/million BTU fired.
- The allowable sulfur content of refinery fuel gas is 10 grains per 1000 cubic feet.
- The minimum recovery of sulfur in a Claus plant is 99%.

As an example of the differences between BACT and LAER technology, consider the different methods of NO_x control technology. The allowable NO_x emissions referred to above (0.2 lb/million BTU) is higher than that allowed in some regions of the United States (especially California) where values of 0.1 lb/million BTU or less are proposed.

Pollutant	Emission Rate
Carbon Monoxide	100 tons per year
Nitrogen Dioxide	10 tons per year
Total Suspended Particulates	10 tons per year
Sulfur Dioxide	10 tons per year
Ozone	10 tons per year of volatile organic compounds
Lead	1 ton per year
Mercury	.2 tons per year
Beryllium	0.004 ton per year
Asbestos	1 ton per year
Fluorides	0.02 ton per year
Sulfuric Acid Mist	1 ton per year
Vinyl chloride	1 ton per year
Total Reduced Sulfur:	
Hydrogen sulfide	1 ton per year
Methyl mercaptan	1 ton per year
Dimethyl sulfide	1 ton per year
Dimethyl disulfide	1 ton per year
Reduced Sulfur Compounds:	
Hydrogen sulfide	(see above)
Carbon disulfide	10 tons per year
Carbonyl sulfide	10 tons per year

410

TABLE 7

EXAMPLE EFFECT OF TANK/SEAL TYPE AND WIND SPEED

Tank/Seal Type	Hydrocarbon Emissions (lbs/yr) Long Beach, CA.	Galveston, TX.
Welded Tanks		
Mechanical Shoe Seal		
Primary	13,842	31,939
Shoe-Mounted Secondary	5,311	10,371
Rim-Mounted Secondary	919	1,605
Liquid-Mounted Resilient Flu Filled Seal		
Primary Only	5,056	8,828
Weather Seal	3,058	5,048
Rim-Mounted Secondary	1,067	1,332
Vapor-Mounted Resilient Filled Seal		
Primary Only	60,358	217,504
Weather Seal	37,658	128,346
Rim-Mounted Secondary	17,401	74,117
Riveted Tanks		
Mechanical Shoe Primary Only	14,995	34,599
Shoe-Mounted Secondary	9,295	18,151
Rim-Mounted Secondary	2,772	6,765

Calculated Using API 2517, (February 1980)

TABLE 8

SUMMARY STATISTICS AND ESTIMATED VAPOR EMISSION FACTORS FOR NONMETHANE HYDROCARBONS

Source Type	Number Screened	Number Leaking	Percent Leaking	Emission Factor Estimate (lb/hr/source)
Valves				
Gas Vapor Streams	563	154	27.4	0.059
Light Liquid/Two-Phase	913	330	36.1	0.024
Heavy Liquid	485	32	6.6	0.0005
Hydrogen	135	59	43.7	0.018
Open-Ended Valves	129	30	23.3	0.005
Pumps				
Light Liquid Streams	470	296	63.0	0.25
Heavy Liquid Streams	292	66	22.6	0.046
Drains	257	49	19.1	0.070
Flanges	2094	62	3.0	0.00056
Relief Valves	148	58	39.2	0.19
Compressors				
Hydrocarbons Service	142	102	71.8	1.4
Hydrogen Service	83	69	83.1	0.11

TABLE 6

AIR POLLUTION CONTROL TECHNOLOGIES
PETROLEUM REFINERIES

Pollutant	Source	Control Techniques
SO_2	FCC Unit	None required at present but some companies use caustic scrubbing. Also flue gas desulfurization processes developed for the utility industry are being evaluated for their applicability.
	Claus Plant Tail Gas	SCOT process, Wellman Loid Process
	Boiler	Flue gas desulfurization or low sulfur fuel.
H_2S	Hydrocracking, Hydrotreating, etc.	Amine Scrubbers and the recovered H_2S is sent to the Claus Plant for conversion to sulfur.
CO	FCC Unit	High temperature regeneration or CO boiler to recover the waste heat.
Particulates	FCC Unit Delayed Coker	Cyclones or electrostatic precipitators. Keeping particulates as well as feasible.
NO_x	Process Furnaces	Low NO_x burners, flue gas recirculation.

NO_x is formed by two basic routes: fixation of the nitrogen in the air, and oxidation of fuel bound nitrogen. The precise mechanisms by which the NO_x is formed are different in each case, as are the relative conversions per unit of nitrogen present in each source.

The control technologies currently available are:

- Off stoichiometric combustion
- Flue gas recirculation
- Oxygen control
- Low NO_x burners
- Thermal deNO_x with ammonia injection
- Selective catalytic reduction with ammonia injection

BACT technology is typically low NO_x burners, which are capable of reducing NO_x emissions to 0.13 lb/million BTU's for the least cost of the available methods. However, if one must reach an emission level below 0.13 - i.e. LAER, selective catalytic reduction with ammonia injection is used. The cost of this latter technology is several times higher (per unit NOx removed) than is the use of low NO_x burners.

The commonly used technologies employed within a refinery for air pollution control are summarized in Table 6.

There are three primary sources of hydrocarbon emissions within a refinery: the API separator, tanks and fugitive sources (valves, etc). If hydrocarbons from the API separator must be controlled the only feasible method is to cover the separator and vent the hydrocarbons to a flare. This technique will recover about 95% of the hydrocarbons.

Control of emissions from tanks depends upon the particular type of tank and the material stored in it. Normally floating roof tanks are used whenever the vapor pressure of the stored material exceeds 1.5 psia. The hydrocarbon emissions are also very dependent upon the area in which they are located. This is illustrated by the calculated emissions for various tank types in two locations Long Beach California and Galveston, Texas (much windier), shown in Table 7. The same material is stored in the tank in each case.

Fugitive emissions are controllable only through inspection and maintenance programs. If one is implemented, it is probably only cost effective for valves, pumps and compressors, since the large bulk of fugitive emissions comes from these sources. This is shown by the data presented in Table 8.

4.2 Water Pollution Control

The number of disposal techniques used to treat refinery wastewaters is quite large. The specific unit processes selected depend upon the waste characteristics, which in turn depend upon the crude oils processed and the actual processing sequence.

414

Generally a refinery wastewater system consists of:

- A drainage collection system.
- Gravity type oil water separators to remove oil and sediment.
- Treatment units or disposal facilities to handle segregated chemical solutions and other process wastes and to remove toxics.
- Some form of secondary treatment (e.g., activated sludge) following the gravity treatment.
- If needed some form of polishing such as activated carbon (this may also be added to the activated sludge process).

An example of a plan for the collection and treatment of refinery liquid wastes is shown in Figure 2.

4.3 Solid Wastes

One of the most important aspects of solid waste management is prudent segregation practices. For example, the wastes may be segregated as follows:

- Oily process sludges - e.g. API sludge
- Non-oily wastes - e.g., storm sewer cleanings
- Biological sludges
- Sanitary wastes
- All others

A major management tool is source reduction. Examples of commonly used techniques are:

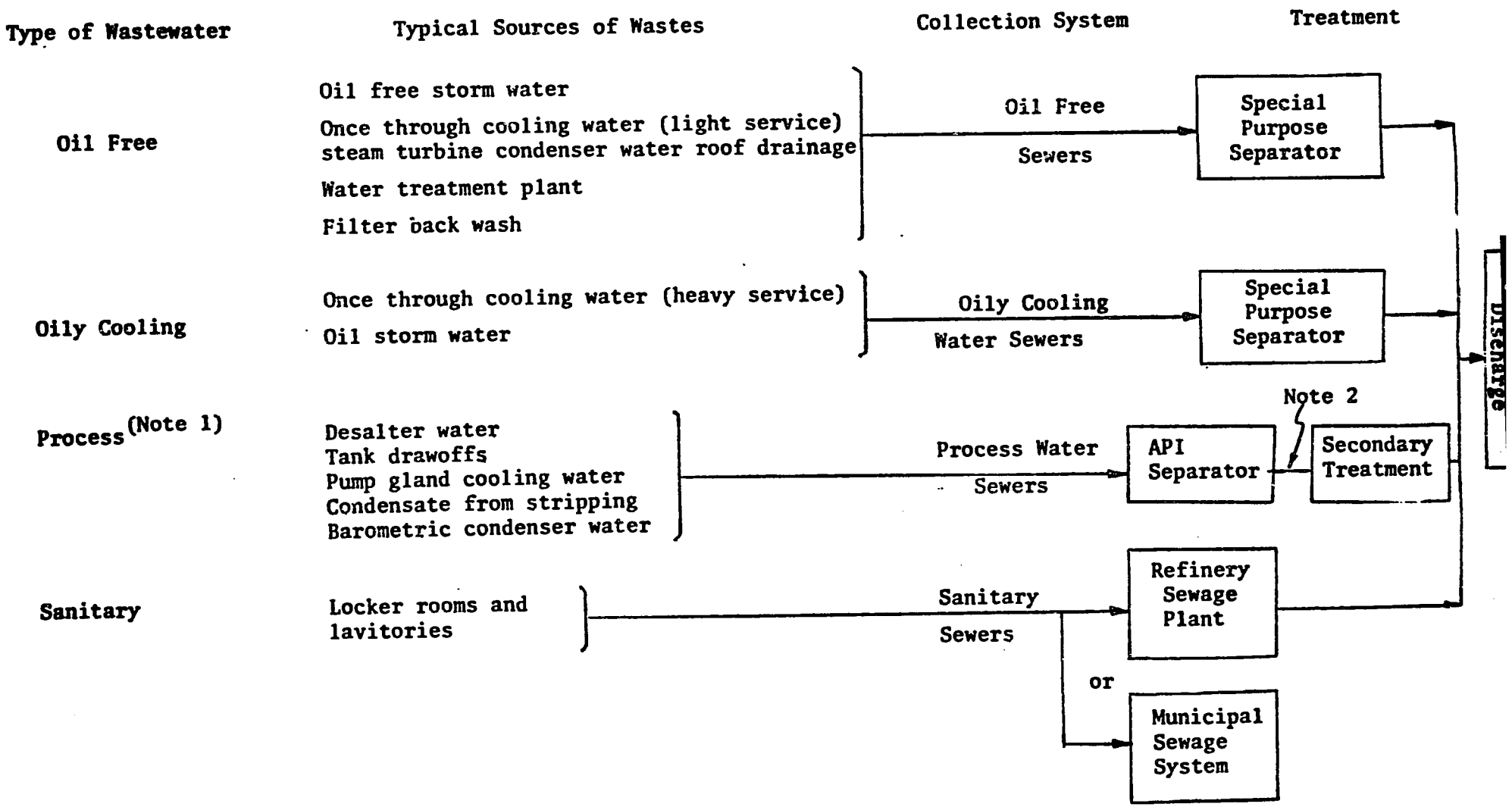
- Tank cleaning - variable angle mixers in storage tanks used in conjunction with selected solvents.
- Biosludge from water treatment
  - Increase the sludge age via use of a well operated air flotation or sand filter system before the bio-unit.
  - Ensure aerobic sludge digestion.
  - Chemical treatment (acid) to enhance organics oxidation and sludge dewatering.
  - Addition of polyelectrolytes to the air flotation unit.

It is also extremely important to minimize the amount of sludge to be disposed of (in addition to those methods suggested above) by various sludge concentration techniques. These methods are:

Gravity - gravity thickening, dissolved air flotation, chemical flocculation.

FIGURE 2

EXAMPLE OF REFINERY WASTEWATER TREATMENT SYSTEM



Notes:

(10 Effluents from treatment units such as sulfide oxidizers, over water strippers may discharge to either secondary treatment or to receiving water.

(2) Discharge from the API separator can go to a municipal (public) treatment works.

Mechanical Dewatering - centrifugation, hydrocyclone, disc centrifuge, scroll centrifuge comperforate basket centrifuge, pressure filtration, vacuum filtration, and gravity belt filtration.

Incineration - burner type, fluidized bed multiple hearth, monohearth incinerators, grate incinerators and rotary kilns

Pyrolysis

Finally, we must select an "ultimate" disposal method. The commonly used methods are:

- Land fill
- Sand lime stabilization
- Chemical fiation
- Landfarming (both oily and biological sludges)

The appropriate method to select is very site specific and waste specific. No matter what method is employed, one must ensure that the hazardous (toxic) materials do not migrate in any manner from the site.

5.0 Risk Assessment of Tanker Spills

A large amount of crude oil is transported into a refinery via tanker. Similarly many products are also removed by tanker. There is always the possibility of environmental damage by oil spill-from any variety of type of accident.

Fairly elaborate methods have been developed to predict the frequency and quantity of oil spills from tanker accidents. This methodology is described in the attached paper by Brian Murphy (of ERT) and co-authors.

The methodology described has been used to study the potential for oil spills at the terminus of the Northern Tier Pipeline and for an on shore crude oil storage area associated with the offshore oil fields in the Gulf of Mexico.

Another method of assessing the risk of environmental hazard is fault tree synthesis. This technique is current less well developed than that described above. A paper describing this approach is also attached.

a Ramirez

COMPUTER-AIDED FAULT TREE SYNTHESIS FOR ENVIRONMENTAL RISK ASSESSMENT

by

Gary J. Powers
Steven A. Lapp

Department of Chemical Engineering
Carnegie-Mellon University
Pittsburgh, Pennsylvania 15213

Presented at the September 1975 AIChE Meeting in Boston, Massachusetts

418

Abstract

Fault tree analysis is one means for systematically identifying cause-and-effect chains of events which could lead to environmental hazards. Once a fault tree has been constructed it is possible to compute the time dependent probability of occurrence of the hazard given the probability of occurrence of causing events. The two major problems with this approach are in 1) generating the tree and 2) gathering the appropriate probability data. We have developed a computer program which aids in the generation of fault trees for chemical processes. It uses signed digraph models for equipment. The fault tree is deduced directly from this simple model of the system. Extensions to other environmental risk situations will be discussed. An example is presented for the analysis of environmental risks due to the operation of a gas scrubber.

Environmental risk assessment is becoming a more important aspect of the design of chemical processing plants. Environmental impact statements, potential fines, and lawsuits make the potential environmental risks an important business issue. In the assessment of risks it is necessary to determine 1) the consequences of each potential risk, 2) the probability of occurrence of each event, 3) the chains of events which could cause the risk and 4) the costs of potential changes to the process and its operation which might reduce the probability or consequences of the event.

A number of techniques have been advocated for determining the consequences of risks. They are commonly based on simulations of the transport and interaction of released chemicals with people and the environment. The results of the simulation are estimates of the potential damages which might be caused by releases of various size and type. The adequacy of these estimates is often dependent on the state of knowledge of the reactivity of the chemicals. At low concentration levels of exposure the prediction of consequences is very uncertain. In the following discussion only high concentration exposures, which usually occur over short time periods, are considered.

The prediction of the probabilities of exposure is a more difficult issue. Intuitive techniques are less suited for the prediction of probabilities than they are for consequence estimation. The following sections describe a technique which we have developed for using computers to aid in the generation of fault trees. The programs place the generation of fault trees on a basis from which risk studies can be made very routinely, quickly, and accurately.

In this paper we outline a method for identifying chemical process hazards and estimating their costs and probabilities. The basis of the approach is the fault tree method of safety analysis. Following identification of hazards a safety simulation of the process is performed. A symbolic model of the process is prepared in the form of a digraph. The digraph's nodes are events within the process. The digraph edges indicate how events may propagate within the system. The steady state gain and dynamics of each propagation are considered in the construction of the digraph. The fault tree for the hazard may be deduced directly from the digraph for the process. From the fault tree and probability data on failures and disturbances within the system, the probability of the system hazard may be computed. A computer program (Fault Tree Synthesis - FTS) which aids the safety analyst will be described.

Introduction

'Safety First' is a motto used by many chemical companies. It illustrates the importance industry places on preventing personal, equipment, and business interruption hazards. The employee safety records of the major chemical companies have been good. The probability of being injured in a chemical processing plant is less than in many other industries and much less than staying at home. However, the process loss situation has not been as encouraging. A number of major losses have occurred due to fires, explosions, and releases of chemicals in chemical plants. In addition, more stringent laws are being promulgated to ensure worker safety and to prevent releases of toxic or otherwise hazardous materials into the environment. How can the chemical industry improve the safety and reliability of their processes? How can they counteract well-meaning but sometimes misdirected governmental agencies? The key lies in careful attention to the design and operation of each part of the chemical processes.

Designers must be able to analyze processes to foresee potential failures. Operators of processes, as well as the automatic control systems, must be trained to respond rapidly to process failures. In dealing with governmental agencies process designers must show that "all reasonable precautions have been taken to reduce the probability of events to acceptable levels". This last sentence contains the key features of the safety problem. The law is written so that the industry is responsible for 1) identifying the potential events, 2) deciding on reasonable precautions, and 3) reducing the probability of these events to acceptable levels. These three areas are where meaningful contributions to the safety analysis of chemical processes can be made. One needs to 1) identify events, 2) decide how to prevent these events from occurring, and 3) compute and determine what constitutes acceptable probabilities.

The following sections describe one approach to this analysis problem. The fundamental concepts for this approach have been described in previous papers (Powers and Tompkins (1974), Fussell, Powers, Bennetts, (1974)). In this paper we will briefly describe the FTS (Fault Tree Synthesis) program and illustrate by a simple example how it might be used. The major points to be covered are 1) hazard identification, 2) hazard consequence estimation, 3) digraph models of individual equipment and complete chemical processes, 4) fault tree synthesis, 5) fault tree evaluation (probability calculations) and 6) use of the program for new designs and for the review of existing processes.

Computer-Aided Safety Analysis

Figure 1 illustrates the major steps required to carry out the quantitative safety analysis of a chemical process. Initially the process flow diagram must be identified. Second, the hazardous events which might occur within or around the process must be discovered. Data are required on the physical and chemical properties of the species in the process and the mechanical and electrical properties of the process equipment. Each potential hazardous event may then be evaluated to determine its possible costs (loss of life, loss of equipment and material, loss of business, and damage of the environment). With the information derived from these steps a ranked list of potential hazards may be constructed. What is required is the probability of occurrence of each hazard.

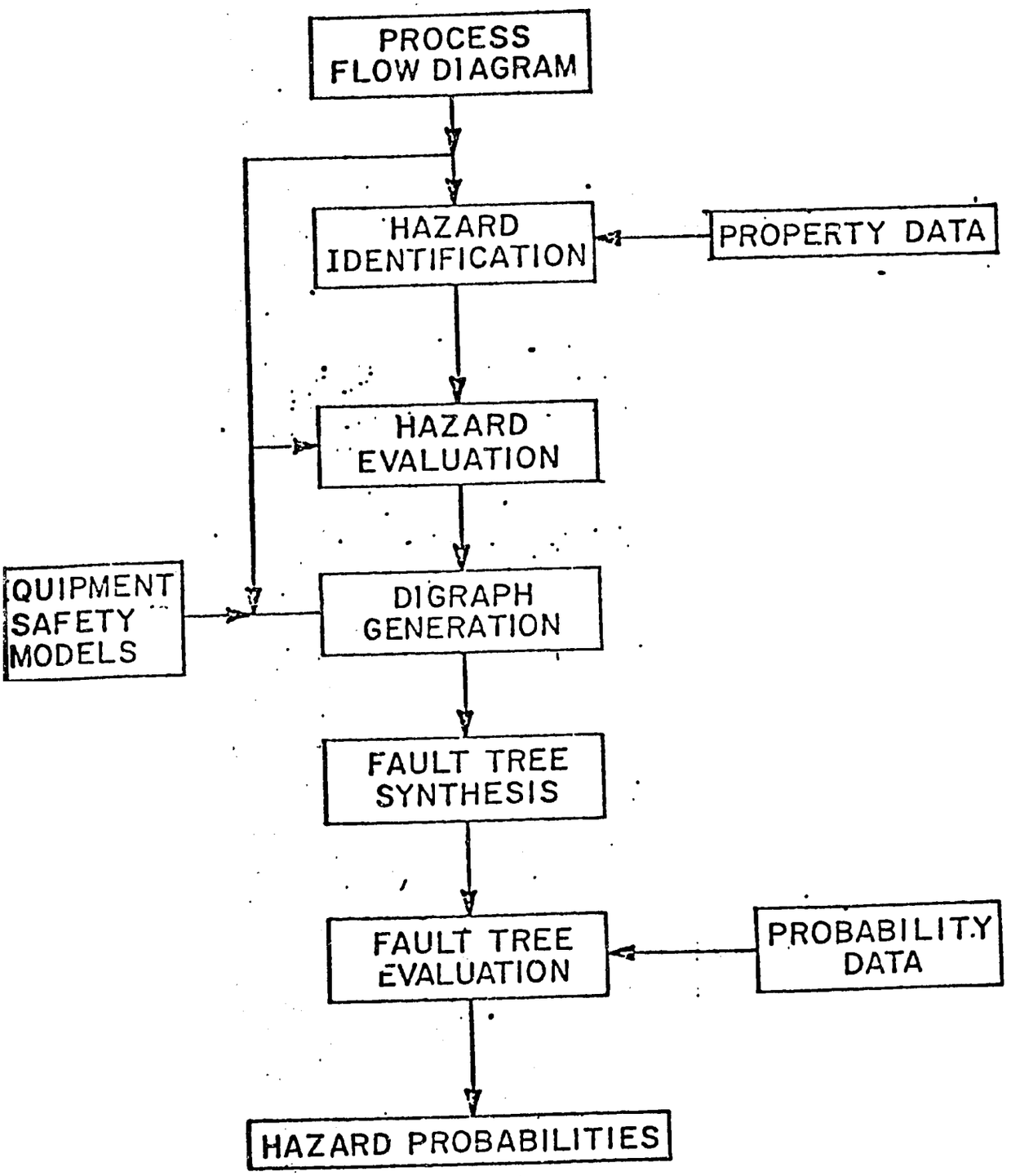


Fig. 1. Steps in Hazard Assessment

Since most of these events will occur very infrequently, it is not possible to take a direct statistical approach to the estimation of their rate of occurrence. What is needed is a means for estimating the probability of hazardous events from the probabilities of more common (and hence more accurately determined) events. Fault tree analysis (FTA) is one means for carrying out this estimation. FTA is based on the assumption that the hazard is a logical consequence of other events. That is, if we knew the probability of occurrence of the set of events which contains the necessary precursors to a fire we could estimate the probability of the fire. In this manner, the causative events are reduced to smaller and smaller sets of events until a level is reached at which sufficient probability data are available.

One major problem in this approach is the generation of the sets of precursor events. These sets must contain 'all' the important events in the proper logical relationships. The generation of fault trees can be a very time consuming and error-prone procedure. For example, in an average chemical process there will commonly be over 50 hazardous events. This large number of events is because a single generic hazard, such as release of toxic material, could occur at a number of different locations within the process. Each fault tree will often require two to three man-days to carry out the generation, documentation, and computation of probabilities of failure. Hence, several man-years of effort are commonly required to carry out a fault tree analysis. A recent study by the U.S. Atomic Energy Commission (WASH-1400) required over twenty-five man-years to generate the fault trees for one boiling water reactor and one pressurized water reactor. In addition, high quality people are required to carry out the analysis. The magnitude of the time required for analysis has retarded the growth of the fault tree method in the chemical process industry. We are currently developing procedures and computer programs (FTS) which we hope will greatly reduce the time required for quantitative safety analysis.

423

FTS-Fault Tree Synthesis Program

The FTS program is essentially a symbolic process simulation. Following identification and evaluation of process hazards a symbolic model of the complete process is assembled from models of individual pieces of equipment within the process. The models have been developed by experts and hopefully represent the latest thinking on the normal and failed behavior of processing equipment. The models are signed digraphs. We have developed an algorithm which deduces the fault tree directly from the properties of the digraph. Once the fault tree has been generated, it is placed in minimal cut-set form and the probability of the top event is computed.

Flowdiagram Input

The flowdiagram is entered in a manner similar to other flowdiagram simulators. The equipment and streams are numbered and the topology of the process network defined. The characteristics of each piece of equipment and each stream are entered as well. The program constructs a multilinked data structure which contains the information on the process.

Hazard Identification

Potential hazards are identified by considering the physical and chemical properties of the species within the process and the strength of the equipment. The species hazards are determined from 1) single species property data such as detonation tendencies, toxicity, flammability, explosiveness, etc. and 2) binary species data. The binary data are required to determine whether species within the process react with each other and if so under what conditions. A binary species reaction matrix is constructed from data in the program's library and from the program user. Equipment related hazards are identified by considering the pressure, temperature, and corrosion ratings of the equipment. The result of hazard identification is a list of hazards and the conditions required for their occurrence. Figure 2 gives the hazard "equation" for explosion.

424

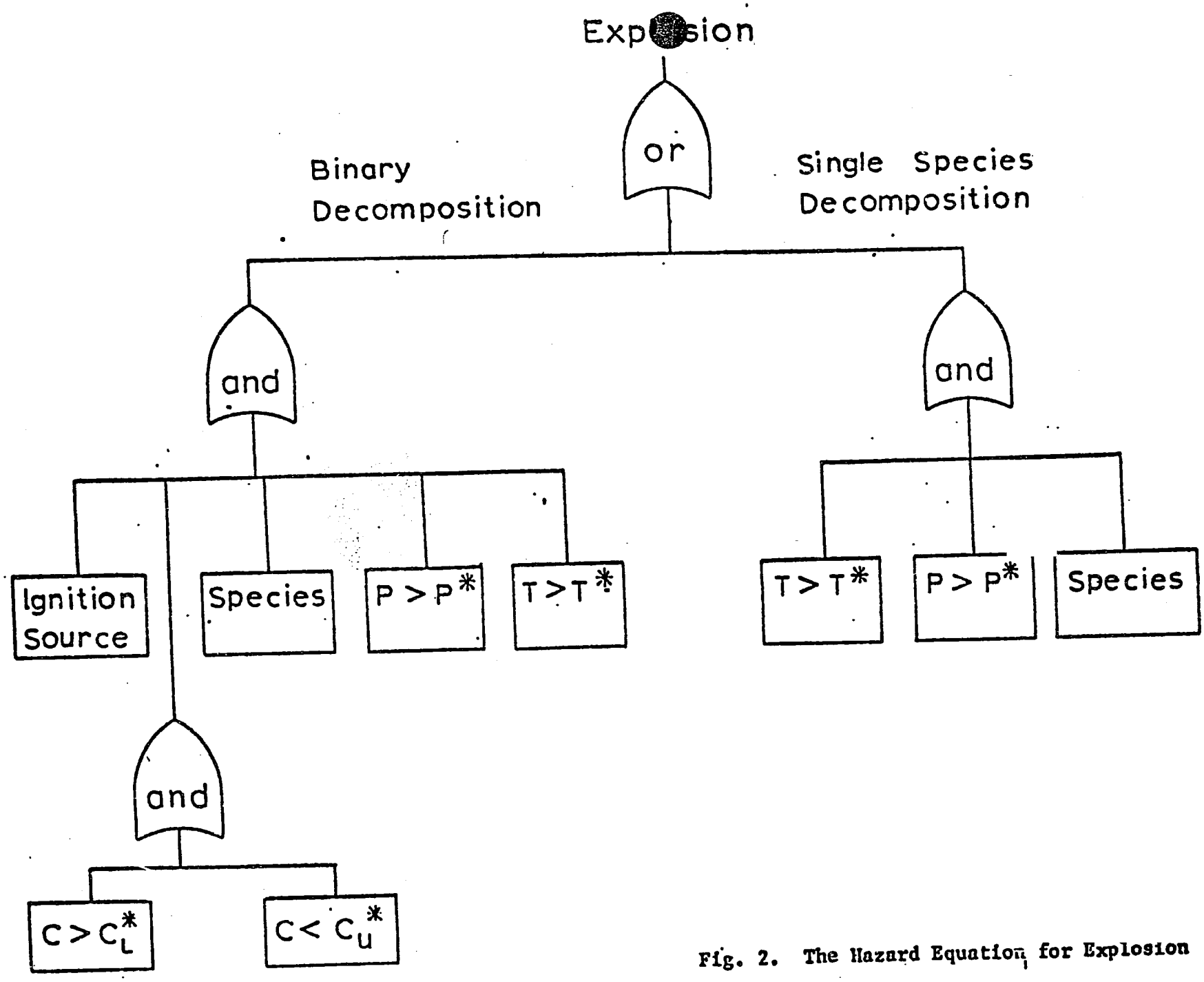


Fig. 2. The Hazard Equation for Explosion

Hazard Evaluation

The total cost of each potential hazard is determined in several ways. First, a detailed calculation of the blast wave radius and high radiation fire radius are computed. Equipment, people, and raw materials within these radii are used in the cost evaluation. Business interruption expenses are computed from product rates and values, and the current delivery times for major pieces of process equipment. The impact of the release of toxic material is based upon the magnitude of the release, plume spread calculations, and toxic nature of the chemical species. These features of the cost of a hazard are then combined to measure the total potential cost for each hazard. These estimates are used as a first approximation of the cost of a hazard. More detailed estimates of each hazard will commonly follow the generation of the fault trees.

The program also contains several rating schemes used by major insurance and chemical companies in the United States. These schemes use a relative rating scale for species, equipment, etc. The ratings are based on past loss data and intuition. These methods give a very rapid means for screening potential total process hazards. They are usually not discriminating enough to use on specific equipment faults within a process.

Following the evaluation of hazards within the process a ranked list of hazards is constructed. What remains is to determine the probability of each hazard.

Digraph Generation

Signed digraphs are used as models for faults in the FTS program. Models have been prepared for pieces of equipment normally found in chemical processes (reactors, pumps, pipes, mixers, tees, valves, sensors, controllers, etc.). Each module is an input/output matrix for the piece of equipment. The inputs are variables whose information could flow into the equipment. In addition to the normal inputs all known failure modes are considered as inputs. That is, if a failure occurs, how does it change an output variable? Finally, any changes in relationships between input and output variables due to failure modes are indicated. For example, plugging of a pipe changes the input/output relation for pressure in that pipe.

426

Given a particular hazard equation and process flowdiagram, the FTS program assembles a digraph for the complete process. The assembly of the process digraph requires consideration of the gains and time constants for each input/output relationship and for loops within the digraph. The digraph is analyzed to determine the dominant loops with respect to gains and dynamics. This reduced digraph is converted to a signed digraph where the gains are +1,0,-1, +10, and -10. The gains of ±10 indicate large changes which exceed the capacity of corrective actions such as occur with negative feedback loops. Modules also have been developed for the human operator's actions in the sensing of variables, computation of control action, and taking control action. External failure models which predict the propagation of failures outside of the process pipes are also being developed.

Fault Tree Synthesis

Lapp has developed an algorithm which deduces the correct system fault tree from a signed digraph for the process. The algorithm is based on a general classification of cut-sets in signed digraphs. The key features of the algorithm are: 1) The topology of the digraph is extremely important. Negative feedback and feedforward loops are detected and their cut sets determined. Cases of nested loops are also considered. 2) Conditional expansion of events is performed. That is, certain events may preclude others from occurring. The test for these conditions is performed at each expansion of an event. 3) The changes in relationships between variables due to failures are included. 4) Common cause failures are detected directly from the digraph. 5) Human operator actions are included. 6) Large deviations from normal conditions which alter relationships between variables are considered. 7) Events which have been previously developed are detected and copied. This results in a large computation time savings.

Fault tree synthesis by this algorithm is rapid. Trees containing 100 gates are generated in 10 cpu seconds on an IBM-360-67 computer. Following generation, the trees are "drawn" on a line printer.

Fault Tree Evaluation

The fault tree is passed to a subroutine which first places the tree in its minimal cut set form. An algorithm similar to that used by Fussell and Vesely (1972) has been developed for this task. Once in cut set form probability calculations are performed. At present, simple deterministic probability values are used. We are extending the algorithm to handle time dependent failure rates with repair.

Consider the flowdiagram given in Figure 3. Ammonia and hydrogen sulfide are being steam stripped from a refinery stream. The bottoms from the column go to a biological waste treatment facility. The "bugs" used in this facility are very sensitive to the concentration of ammonia in the waste. Several 'kills' of the bugs have occurred due to misoperation or failures of the stripper system. These losses of the waste disposal unit have caused fairly large releases of organics to the river into which the unit discharges.

The stripper system contains several control loops for maintaining the constant operation of the unit. A reduced digraph for the concentration of ammonia in the bottoms is given in Figure 4. This digraph was constructed from unit models for the valves, sensors, controllers, stripper column, pressure relief valve, etc., which make up the stripper system. The fault tree for this digraph is given in Figure 5.

From the fault tree and probability data on the causing events it is possible to determine the important sets of events which might lead to high ammonia concentrations. Corrective designs could then be considered if the probability of occurrence proved to be too high.

428

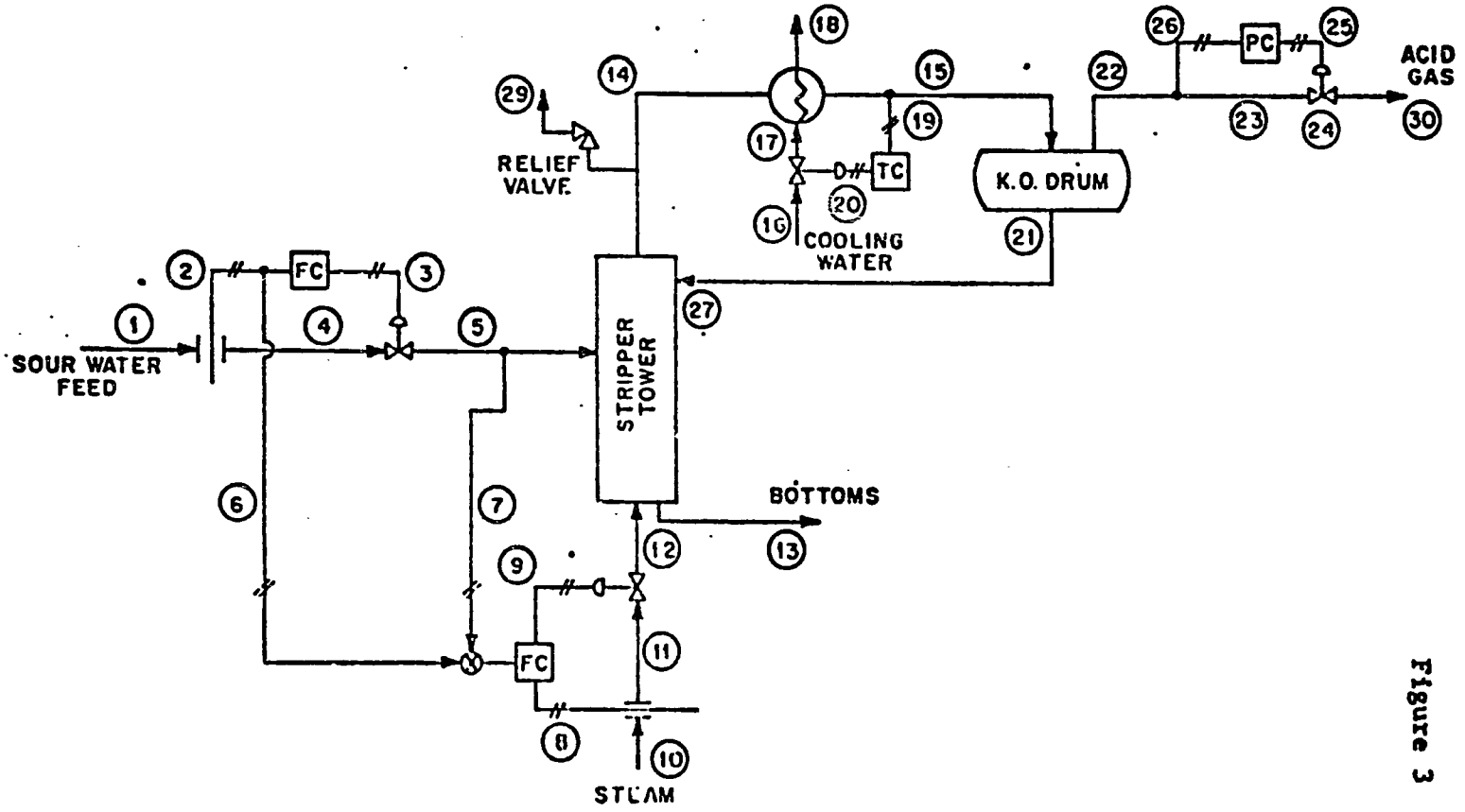

SOUR WATER FEED
FC
STRIPPER TOWER
RELIEF VALVE
TC
COOLING WATER
K.O. DRUM
PC
ACID GAS
BOTTOMS
FC
STEAM

Figure 3

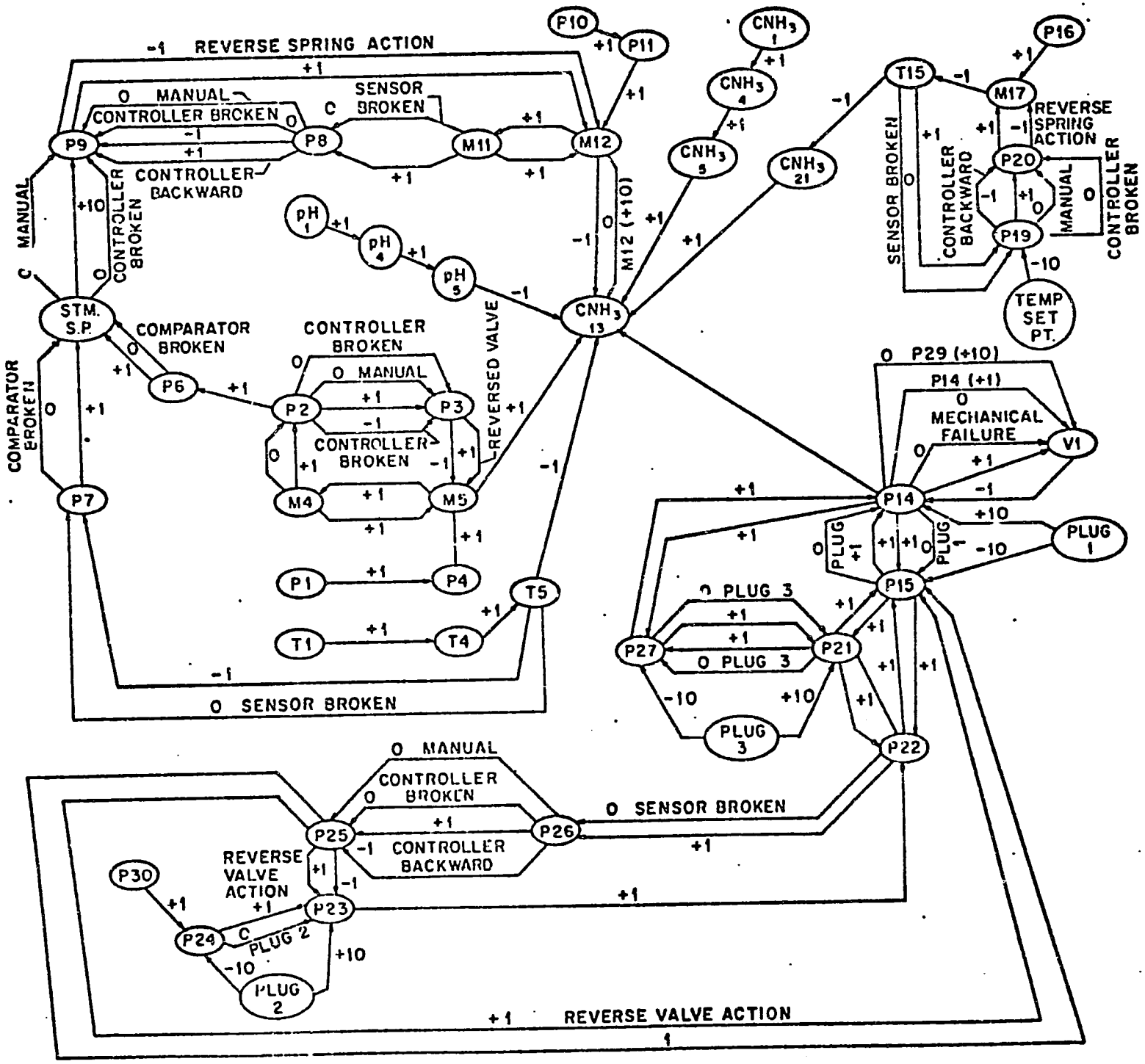

-1 REVERSE SPRING ACTION
+1
0 MANUAL
CONTROLLER BROKEN
C SENSOR BROKEN
CONTROLLER BACKWARD
P9
P8
M11
M12
P10
P11
CNH3 1
CNH3 4
CNH3 5
CNH3 21
CNH3 13
T15
M17
P16
REVERSE SPRING ACTION
P20
P19
SENSOR BROKEN
CONTROLLER BACKWARD
MANUAL
CONTROLLER BROKEN
TEMP SET PT.
M12 (+10)
pH 1
pH 4
pH 5
REVERSED VALVE
MANUAL
CONTROLLER BROKEN
STM. S.P.
COMPARATOR BROKEN
P6
P7
CONTROLLER BROKEN
P2
P3
M4
M5
P1
P4
T1
T4
T5
SENSOR BROKEN
P29 (+10)
P14 (+1)
MECHANICAL FAILURE
V1
P14
PLUG 1
P15
PLUG 3
P27
P21
P22
MANUAL
CONTROLLER BROKEN
SENSOR BROKEN
P25
P26
CONTROLLER BACKWARD
REVERSE VALVE ACTION
P30
P23
P24
PLUG 2
REVERSE VALVE ACTION

Figure 4

430

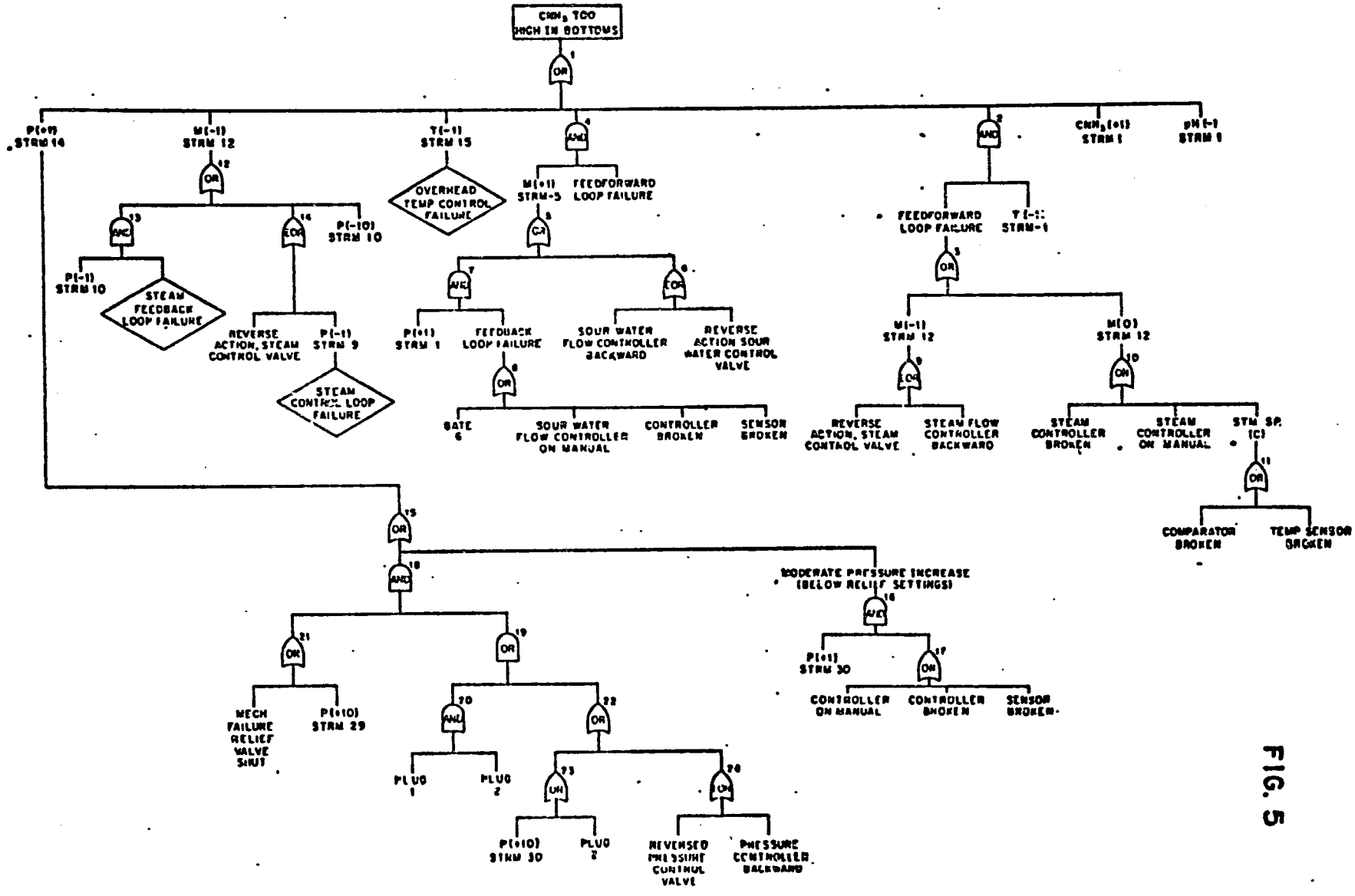


FIG. 5

Best Available Document

References

1. Fussell, J.B. and W.E. Vesely, "A New Methodology for Obtaining Cut Sets for Fault Trees," Trans. Am. Nuclear. Soc., 15 (1), 1972.

2. Fussell, J.B., "Synthetic Tree Model-A Formal Methodology for Fault Tree Construction," Aerojet Nuclear Report ANCR 01098, 1973.

3. Powers, G.J., and F.C. Tompkins, Jr., "Fault Tree Synthesis for Chemical Processes," AIChE Journal, Vol. 20, No. 2, p. 376, March, 1974.

4. Fussell, J.B., G.J. Powers, and R.G. Bennetts, "Fault Trees - A State of the Art Discussion," IEEE Trans. on Reliability, Vol. R-23, No. 1, April, 1974.

5. Powers, G.J., and F.C. Tompkins, Jr., "A Synthesis Strategy for Fault Trees in Chemical Processing Systems," Loss Prevention - Vol. 8 - Chem. Engr. Progress Technical Manual, AIChE, New York, 1974.

432

A COMPARATIVE RISK ASSESSMENT TECHNIQUE FOR TANKER OIL SPILLS

Halûk Özkaynak and Brian L. Murphy
Environmental Research & Technology, Inc.
3 Militia Drive, Lexington, Massachusetts 02173

Joel J. Watson
Acurex
3203 Woman's Club Drive
Raleigh, North Carolina 27612

ABSTRACT: *The tanker oil spill risk assessment model (TRAM) allows a user to investigate the way in which oil spill probabilities, and amounts spilled, vary with such factors as fleet composition, navigational aids, or particular properties of the route. Such a comparison of alternatives is generally required for an environmental impact statement.*

TRAM operates through multiplication of a series of matrices: P, Q, R, and S. The rows and columns of all matrices are parameterized by accident type (such as collision or grounding) and location (such as at a pier, or in a harbor). The probability of an accident (P) and of a spill following an accident (Q) are based on world tanker fleet data. The matrix S expresses the conditional probability that if there is a spill, the vessel will be a total loss. This enables catastrophic spills in which spill size can be related to vessel size to be distinguished from minor spills in which vessel size is generally not a factor.

The matrix R contains most of the unique features of the model. It accounts for vessel and route-specific features that reasonably may be expected to alter the world tanker fleet data. Examples are given from the literature for the elements of R corresponding to: fleet composition (domestic/foreign carrier); navigation aids such as vessel traffic system; vessel age, and construction (double hull, inerting system, segregated ballast, etc.); and various features of the tanker route, such as channel width and traffic density, based on Macduff's causation probability formalism. The practical usage of the model is demonstrated by applying it to a hypothetical project involving tanker oil transportation. The extension of this analysis technique to other forms of risk analysis studies (including operations other than oil transport) is also discussed.

Varying oil spill risks are associated with most oil transport by tankers. The magnitude and severity of the incremental risks that can be assigned to a proposed project involving tanker oil transport, however, are related to the environmental and geographical characterization of the area as well as to the baseline description of oil spill risks associated with the current operations. A comprehensive study of oil spill probabilities and the expected amounts of oil spilled is, therefore, based on such factors as fleet composition, navigational aids, and particular properties of the route. Such a site-specific study and comparison of available alternatives is generally required for an environmental impact statement (EIS) of a proposed project. Study of the available alternatives to assess various oil spill risks and thus determine the most desirable alternative solution for project operations forms the basis of such comparisons. (The most desirable solutions may minimize the extent of potential environmental damages or may be associated with other project cost-benefit objectives.)

Tanker oil spills are caused by either routine tanker operations or accidental tanker casualties. Operational spills occur more frequently than casualty-related spills. However, casualty-related spill sizes can be quite large, making them of considerable environmental importance. In this paper, we have attempted to quantify the risks of casualty-related oil spills to investigate the ways and means in which oil spill probabilities and the amounts spilled vary. The formalism to be introduced is oriented toward comparing and assessing oil spill risks caused by alternative tanker oil transportation examples. For this purpose, we present a tanker oil spill risk assessment model (TRAM) and demonstrate its uses.

Formalism and model description

In the discussion of casualty-related oil spills, we consider the following accident and spill probabilities:

- the probability P per trip of a tanker accident
- the probability Q of a spill once an accident has occurred
- the probability S that the vessel is a total loss, given that an accidental spill occurs
- the matrix R, accounting for vessel-specific and route-specific features used to alter P, Q, and S

The conditional probabilities P, Q, and S are based on worldwide tanker casualty and spill statistics data presented by Keith and Porricelli,[7] J. J. Henry Company,[8] SES,[9] OIW,[9] and the U.S. Senate Report.[10]

TRAM operates through multiplication of the series of matrices P, Q, R, and S. The rows and columns of all matrices are parameterized by accident type (index i, shown in Table 1), accident location (index j, shown in Table 2), and vessel type (index n). The probability S is introduced so that catastrophic losses (when the volume of oil released depends on the volume of oil carried by the vessel) could be distinguished from smaller (and more frequent) accidental spills that may be characterized by an average volume of oil released independent of vessel size. For N^n number of tankers of vessel type-size (n), each making T^n annual trips, the spill probabilities can be formulated as being proportional to number of port calls (T^nN^n) for the given vessel type and size category, denoted by index (n).

TRAM computes the following spill probabilities and expected (annual average) spill volumes for each location of interest:

1. P_{tj} — the probability per year of an accidental spill in location (j) (that is, pier, harbor, entrance, coast, or sea) where the loaded vessel is a total loss, and P_t ($= \Sigma P_{tj}$) — the total loss probability along the entire route

433

Table 1. Accident types

Parameter (i =)	Casualty	Description
1	Collisions	Two vessels strike (ship to ship casualty)
2	Rammings	A moving vessel strikes a fixed object, such as a pier or an offshore drilling platform (ship to object casualty)
3	Groundings	A moving vessel strikes the ocean bottom, where the water is not deep enough for the ship to continue moving
4	Breakdowns	Some mechanical failure aboard ship leads to an accident
5	Fires and explosions	A fire or explosion aboard ship causes an accident
6	Structural failures	A ship's structure fails and an accident results
7	Capsizing	A tanker sinks at the pier because of a faulty valve, and possibly other types of accidents in addition to capsizing occur

2. V_{t_j} — the expected annual spill size at location (j) caused by total vessel losses, and V_t ($= \Sigma V_{t_j}$) — the expected annual spill size along the entire route from total vessel losses
3. [illegible] — the probability per year that an accidental spill not involving a total vessel loss will occur at location j, and P_{lt} ($= \Sigma P_{lt_j}$) — the less-than-total-loss accidental spill probability per year along the entire tanker route
4. V_{lt_j} — the expected annual spill size at location (j) caused by accidental spills not involving total vessel losses, and V_{lt} ($= \Sigma V_{lt_j}$) — the expected annual spill size along the entire tanker route from accidental spills not involving total vessel losses

These eight probabilities or expectation values can now be formulated for T^nN^n, P^n, Q^n, R^n, S^n, V^n, and V_i^n, where V^n is the average cargo capacity in terms of barrels of oil for tanker class (n) and V_i^n is the (historical) average spill size for a given type of casualty (i) for all tanker classes, n (see Table 3). Note that the data set defining V_i^n is assumed to be an average to which both loaded and ballasted conditions contribute and, therefore, no distinction is made between inbound and outbound transits of a tanker port call.

Table 2. Accident locations

Parameter (j =)	Location	Description
1	Pier	Vessels in contact with a wharf, pier, dock, quay, and so forth
2	Harbor	Vessels within the confines of a harbor, bay, river, and so forth
3	Entrance	Vessels at the entrance to a harbor, bay, river or a strait
[illegible]	Coast	Vessels within 50 nautical miles of shore
	Sea	Vessels outside the 50-nautical-mile limit

Table 3. Base tanker fleet composition used in the oil spill risk assessment of alternatives,

Parameter (n)	Size class (thousands of dwt)	Average loaded oil volume in barrels (V^n)
Predominantly domestic carriers		
1	190	1.32×10^6
2	165	1.16×10^6
3	120	0.84×10^6
4	80	0.53×10^6
5	50	0.36×10^6
Predominantly foreign carriers		
6	>300	2.35×10^6
7	250	1.73×10^6
8	225	1.59×10^6
9	175-200	1.40×10^6
10	150-175	1.12×10^6
11	100-125	0.82×10^6

1. All alternatives will be chosen to comply with the project capacity of 500,000 bpd.

The spill frequency and size estimates computed by TRAM are defined by:

$$P_{t_j} = \tfrac{1}{2} \sum_n T^n N^n P_{t_j}^n \quad (1)$$

$$V_{t_j} = \tfrac{1}{2} \sum_n V^n T^n N^n P_{t_j}^n \quad (2)$$

$$P_{lt_j} = \sum_n T^n N^n P_{lt_j}^n \quad (3)$$

$$V_{lt_j} = \sum_n T^n N^n V_{lt_j}^n \quad (4)$$

where $P_{t_j}^n$, $P_{lt_j}^n$, and $V_{lt_j}^n$ are defined as:

$$P_{t_j}^n = \sum_i R_{ij}^n S_i P_{ij}^n Q_{ij}^n \quad (5)$$

$$P_{lt_j}^n = \sum_i R_{ij}^n (1 - S_i) P_{ij}^n Q_{ij}^n \quad (6)$$

$$V_{lt_j}^n = \sum_i R_{ij}^n V_i (1 - S_i) P_{ij}^n Q_{ij}^n \quad (7)$$

Note that various indices have been suppressed in writing these equations. The combination of superscripts and subscripts occurring in the equations reflects the degree to which the data have been aggregated due to sparseness.

Note that after summation by casualty types (over index i), each equation represents the value of the quantity under consideration for any given location (index j). For example, when j = 3,

$$P_{t_3} = \sum_n T^n N^n P_{t_3}^n$$

gives the probability of a total loss inside the entrance. Summation over the j indices gives the aggregate probability of a total loss over all the locations along the tanker traffic route.

The route-specific and vessel-specific factors used in R^n to modify the P^n and Q^n matrices, however, are either based on specific vessel characteristics (such as fleet composition, vessel age, and construction) or on other project specific features. Fleet composition determines the casualty-exposure factor, and its specific choice (or its modification via R^n) is perhaps the single most important factor that influences the outcome of any type of oil spill risk analysis.

A number of choices for this factor, some even differing by orders of magnitude from each other (see, for example, Doolittle[1]), have been used. The reason for these wide variations depends on the meth-

Best Available Document

434

ods used in estimating the site-specific casualty/exposure factors. The 4.37×10^{-3} value (used in the application below) has been estimated by the Oceanographic Institute of Washington.[8] This risk exposure factor also can be obtained from the data presented in the U.S. Senate Report[11] on the analysis of oil tanker casualties from the 1969-to-1974 data base. The number of incidents divided by the total number of round trips during this six-year period yields a value of 3.95×10^{-3} casualties per round trip.

Different size tankers (different n) are also shown to have varying relative risks in terms of nondimensional analysis that is used to compare relative casualty to the whole sample population (worldwide fleet) they are selected from. We define fleet-composition-dependent modifications of relative risks or casualty/exposure factors by f_{ij}^{n}. The influence of navigational aids such as vessel traffic systems (VTS) generally reduces the casualty risks by modifying the P, probabilities. For brevity, we call those reduction factors that are defined in R and that are used to alter the elements of the P matrix, P_{ij}.

There may be a number of these considerations. For example, structural failures can be correlated with vessel age for a given size class; or fire and explosions at sea could be reduced by vessels equipped with inerting systems; or route-specific features such as channel width, traffic density, and so forth, can influence the grounding, ramming, and collision probabilities inside channels or harbors.

There may be, say, k different categories based on such considerations that can be used for P_{ij} (we denote these by P_{ij}^{kn} since each reduction factor is used separately in a multiplicative fashion). Similarly, there may be l different categories that can be considered in reducing spill risks by changing the structure of the Q matrix. These we define by factors denoted by q_{ij}^{ln}. Choices for q_{ij}^{ln} can include: reduction in oil spill probabilities from safer vessel construction (double hull, inerting systems, defensive segregated ballast, and so forth), or from differences in vessel age and casualty relationships (such as structural failures, fires, and explostions).

The R^n matrix is then defined as:

$$R_{ij}^{n} = \prod_{k} \prod_{l} f_{ij}^{n} p_{ij}^{kn} q_{ij}^{ln} \tag{8}$$

Estimation of relative accident probabilities using site-specific features. In the discussion presented so far, the risk analysis has been based on estimates derived from world tanker fleet experience. The questions arise whether site-specific features can alter risks systematically. The objective is, therefore, to investigate whether significant variations from the initial data base can occur as a result of alternative site-specific analysis.

Examples of attempts to relate accident probabilities to site- and vessel-specific characteristics, such as density of ship traffic or other obstacles, channel width, vessel size, turning radius, and stopping distance, can be found in the literature.[6,10,11,12]

As discussed in these references, the accident probability over a voyage of length S can be written as

$$P_A = P_B P_c S \tag{9}$$

where P_B is the probability per unit distance that a blind, randomly-navigated vessel would suffer an accident from a specific cause such as collision or grounding; P_c, Macduff's[6] "causation probability", represents the effect of ordinary care and competency on the part of the master/pilot and crew in reducing the accident risk. It should be noted that P_A is the probability of an accident that may or may not involve an oil spill.

The advantage of Equation 9 is that all site-specific features such as channel width, density of vessels, or other objects enter explicitly in the calculation of P_B. For example, for a vessel of (straight line) stopping distance T in a channel of uniform width C, the probability of grounding per unit distance along the channel for a blind pilot when $T \leq C$, is:

$$P_B = \frac{2T}{\pi C} \tag{10}$$

The probability P_c must be obtained from accident data, as provided for example by Macduff[6] and by Tetra Tech.[10]

The estimated values for collisions involving two ships can be based on the analysis of Macduff and data by Tetra Tech. In this case, P_B is calculated from the formula:

$$P_B = \eta_0 \sigma_c \frac{Y}{S} \tag{11}$$

where η_0 is the density of ships for which a collision would be of the type of interest (crossing, parallel, or anti-parallel traffic) and σ_c is the collision cross section based on ship dimensions. The value σ_c is calculated in a frame of reference in which the "target" vessels are stationary; this introduces the factor Y/S, where Y is the distance traveled in this frame of reference. The details of this ship collision model were set out by the U.S. Bureau of Land Management.[13] In the following application, Equations 10 and 11, and Macduff's collision model will be used to investigate the possibility of large deviations from the mean probabilities due to route-specific features.

In the discussion of geometrical probabilities of vessel collisions and grounding probabilities, we have delineated the key factors that influence the outcome of casualties as being tanker traffic densities, channel width, and stopping distances. Through these parameters, the elements of R_{ij}^{n} reflecting the particular properties of the route can be estimated. Again, only significant variations from the worldwide fleet estimates are to be considered in further augmenting R_{ij}^{n} through route-specific modifications to Equation 8. In fact, it can be shown that historical worldwide casualty and spill data do represent quite adequately the casualty and oil spill risks of most world entrances and harbors.[13]

Model application

To demonstrate the use of the comparative tanker oil spill risk assessment model (TRAM), we have chosen a hypothetical project, involving 500,000 barrels per day (bpd) of crude oil transportation. We have assumed that tanker fleet composition and certain aspects of the proposed tanker route can be subject to some alterations. (In reality, however, not all proposed projects involving tanker oil transportation plans will have as many available alternatives as will be considered below.) The alternative examples are chosen so that the estimated influences of fleet composition and other site or route-specific features of the project on oil spill risks can be compared.

The proposed project requires an EIS evaluating the oil spill risks associated with the transport of 500,000 bpd of crude oil. The oil spill risks associated with the project alternatives are from oil transport in coastal waters, through an entrance to a harbor, and finally to a fixed berth facility at a pier. To select the most environmentally desirable and economically viable alternative by using TRAM, the following choices are compared:

1. Choice of fleet composition — composition of domestic versus foreign tankers; distribution of tanker size classes; and oil spill risks associated with specific tanker size (in deadweight tons, dwt) classes
2. Choice of data base for estimating relative oil spill risks (or casualty/exposure) factors — uniform casualty/exposure with each size class; relative oil spill risks for each size class derived from 1969-1972 worldwide tanker fleet data; and relative oil spill risks associated with each size class based on the data in the U.S. Senate Report[11]
3. Choice of alternative route-specific examples — no additional route-specific features (that is, assume 1969-1972 worldwide tanker fleet casualty data base can generate correctly the oil spill risk estimates for the proposed project); the effect of (level 3) VTS on oil spill risk probabilities; and the influence of such factors as channel width, traffic density, and tanker stopping distance

To determine the influence of tanker fleet composition on oil spill risk estimates, a base tanker fleet composition is assumed (Table 3). Five size classes for domestic carriers and six for foreign carriers have been adopted. For the analysis of fleet-specific project alternatives, three distinct tanker fleet compositions (I, II, III) have specifically been selected from the base tanker fleet composition (Table 4). Com-

435

Table 4. Description of tanker fleet composition alternatives

Annual Port Calls, (T^nN^n) Based on Fleet Composition	Alternative Fleet Compositions, IA,	IB,	IIA	IIB	IIIA	IIIB
T^1N^1	5	4	12	9	0	0
T^2N^2	15	11	24	18	0	0
T^3N^3	40	30	60	46	36	27
T^4N^4	90	68	53	40	130	99
T^5N^5	43	33	0	0	60	46
T^6N^6	5	7	0	0	10	14
T^7N^7	5	7	0	0	10	15
T^8N^8	5	8	0	0	13	20
T^9N^9	5	8	0	0	0	0
$T^{10}N^{10}$	20	30	40	61	0	0
$T^{11}N^{11}$	5	8	19	28	0	0

1. Total crude oil supply for each alternative is 500,000 bpd.
2. Alternatives denoted with letter A represent two-thirds of crude oil delivery by domestic carriers and one-third by foreign tankers.
3. Alternatives denoted with letter B represent 250,000 bpd delivery by domestic carriers and 250,000 bpd by foreign tankers.

position alternative I is considered to be a more typical tanker fleet mix. Compositions II and III are introduced to investigate the effects of deviations from the more typical tanker size distribution, I. Alternatives denoted by A represent two-thirds of crude oil delivery by domestic carriers and one-third by foreign vessels. On the other hand, alternatives denoted by B represent delivery of half of the capacity by domestic carriers and the other half by the foreign carriers.

We note here again that the terminology "foreign carriers" is *only* used to denote an average sample of tankers chosen from a worldwide collection of tankers. Since the special characteristics of these vessels cannot be determined in advance, only carriers with known construction characteristics (that is, domestic vessels) are subjected to additional considerations, leading to possible reductions in their associated casualty or oil spill probabilities.

The conditional probability of oil spills, P^n_{ij} per voyage, and probability of an oil spill after an accident, Q^n_{ij}, representing worldwide tanker fleet data (1969-1972), are shown in Tables 5 and 6, respectively. For domestic carriers of certain size classes (due to their age or construction), the probabilities presented in Tables 5 and 6 can be modified appropriately. Foreign carriers, however, would be treated without scaling these matrices. Table 7 displays the probability of total vessel loss S_i and the average spill volume V^n_i for all losses excluding total losses. Other fleet-specific parameters that are used in the construction of the R^n_{ij} probability matrix are shown in Table 8.

Table 5. Probability of accidents per voyage based on 1969-1972 world tanker fleet data, (P^n_{ij})

Parameter (i=)	Casualty	Accident Location (j=) j=1 Pier	2 Harbor	3 Entrance	4 Coast	5 At Sea
1	Collisions	0.030	0.550	0.210	0.280	0.040
2	Rammings	0.300	0.250	0.050	0.030	0.020
3	Groundings	0.010	0.370	0.380	0.270	0.005
4	Breakdowns	0.010	0.050	0.020	0.140	0.270
5	Fires and Explosions	0.170	0.050	0.010	0.060	0.130
6	Structural Failures	0.030	0.030	0.010	0.030	0.520
7	Capsizing	0.004	0.003	0.001	0.010	0.010

1. All values are to be scaled by the factor 10^{-3}.

Table 6. Probability of an oil spill after a tanker accident based on 1969-1972 world tanker fleet data (Q^n_{ij})

Parameter (i=)	Casualty	Accident Location (j=) j=1 Pier	2 Harbor	3 Entrance	4 Coast	5 At Sea
1	Collisions	0.210	0.150	0.290	0.340	0.320
2	Rammings	0.100	0.310	0.130	0.0	0.200
3	Groundings	0.0	0.190	0.200	0.400	0.0
4	Breakdowns	0.140	0.070	0.060	0.040	0.040
5	Fires and Explosions	0.430	0.310	0.190	0.430	0.220
6	Structural Failures	0.740	0.350	0.540	0.330	0.230
7	Capsizing	1.000	1.000	1.000	0.830	1.000

The various fleet-specific parameters that are used (that is, q^n_{ij}, p^n_{ij} and f^n_{ij}, as shown in Table 8) are primarily based on: J. J. Henry Co.,[1] Keith and Porricelli,[3] and U.S. Senate Report.[11] The choice of different f^n_{ij} values representing the relative oil spill risks of each tanker size class is introduced to compare model estimates based on different relative risk criteria. The primary alternatives 1, 2, and 3 assume equal relative oil spill risks for each tanker size class (percent of pollution-causing incidents to percent of tanker in each size class). Alternatives 6, 7, and 8 (Table 8) assume relative risks that are computed from the 1969-1972 data base. Alternative 9, however, assumes the relative risk values computed from the U.S. Senate Report[11] findings, based on 1969-1974 worldwide tanker fleet casualty and oil spill records.

Table 7. Probability of a total vessel loss (S_i) and average spill volumes (V^n_i) for all losses (excluding total losses) based on 1969-1972 world tanker fleet data

Casualty	Total loss probability (S_i)	Average volume (excluding total losses) V^n_i (barrels)
Collisions	0.08	1,955
Rammings	0.0	1,453
Groundings	0.08	3,569
Breakdowns	0.06	4
Fires and explosions	0.18	1,001
Structural failures	0.15	1,127
Capsizing	0.60	71

The P and Q data provided above are altered by the (hypothetical) specific composition of the projected domestic tanker fleet supplying crude oil as follows:

Of the 34 fire and explosion incidents noted in Keith and Porricelli,[3] 9 explosions occurred with the tanker in ballast. Of these 9 incidents, 5 occurred during tank cleaning, and 7 (or possibly 8) occurred at sea. Since there are no known cargo tank explosions for tankers with inerting systems, the at-sea fire and explosion probability is decreased by a multiplicative factor of 0.85 (total, less tank cleaning/total = 29/34 = 0.85), for those tankers with such a system (tankers denoted with n = 1,2). This is a very conservative reduction, since a number of additional fire and explosion incidents for which there is insufficient information might also have been prevented by an inerting system.

Tanker size classes n = 1,2,3 have defensive ballast around approximately 70 percent of the ship perimeter; therefore, the possibility that a collision or ramming would result in a spill is reduced by a multiplicative factor of 0.7. Tankers of 120,000 dwt (n = 3) have both defensive ballast and a double hull. The double hull, which has a separation distance of 3 meters, is assumed to reduce the probability of a spill resulting from grounding by a multiplicative factor of 0.06. This factor is based on the data for groundings,[3] where 2 out of 33 incidents shown involved a depth of penetration in excess of 3 meters.

436

Table 8. Description of alternatives used in TRAM comparative risk assessment application

Alternative	Description	Fleet-Specific Parameters	Route-Specific Parameters
1A	Corresponds to tanker fleet composition I^A_n, with no route-specific modifications in R^n	$f^n_{ij} = 1$ n=1-11 $p_{55} = 0.85$ $q^n_{1j} = q^n_{2j} = 0.7$ for n=1,2,3 $q_{3j} = 0.06$ for n=3 $q_{6j} = 0.73$ for n=1,2,3,4,5,6	None
1B	Corresponds to tanker fleet composition I^B_n, with no route-specific modifications in R^n	Same as for alternative 1A	None
2A	Corresponds to tanker fleet composition II^A_n, with no route-specific modifications in R^n	Same as for alternative 1A	None
2B	Corresponds to tanker fleet composition II^B_n, with no route-specific modifications in R^n	Same as for alternative 1A	None
3A	Corresponds to tanker fleet composition III^A_n, with no route-specific modifications in R^n	Same as for alternative 1A	None
3B	Corresponds to tanker fleet composition III^B_n, with no route-specific modifications in R^n	Same as for alternative 1A	None
4A	Corresponds to tanker fleet composition 1A, with VTS (Level 3) modifications in R^n	Same as for alternative 1A	$p^n_{13} = 0.4$ $p^n_{23} = 0.7$ $p^n_{33} = 0.5$ for n=1-11
5A	Corresponds to tanker fleet composition 1A, with channel and tanker traffic specific modification in R^n	Same as for alternative 1A	$p^n_{13} = 2$ $p^n_{33} = 2$ for n=1-11
6A	Same as for alternative 1A	Same as for alternative 1A except f^n_{ij} are now: $f^n_{ij} = 0.85$ for n=1,2,9,10 $f^3_{ij} = 1.09$; $f^4_{ij} = 1.39$ $f^5_{ij} = 1.23$; $f^n_{ij} = 2.14$ for n=6,7,8 $f^{11}_{ij} = 1.09$	None
7A	Same as for alternative 4A	Same as for alternative 6A	Same as for alternative 4A
8A	Same as for alternative 5A	Same as for alternative 6A	Same as for alternative 5A
9A	Same as for alternative 1A	Same as for alternative 1A except f^n_{ij} are now: $f^n_{ij} = 1.0$ for n=1,2,6,7,8,9,10 $f^n_{ij} = 0.95$ for n=3,11 $f^n_{ij} = 0.82$ for n = 4,5	None

Based on the distribution of the 64 polluting structural failures and their outflows as a function of tanker age during the 1971-1972 period, the Q^n_{6j} probabilities of an oil spill after an accident are reduced by a multiplicative factor of 0.73.

The choice of route-specific features or alternatives (as represented by alternatives 4A, 5A, 7A, and 8A shown in Table 8) is made so that route-specific influences on oil spill estimates can be compared. The influence of Level 3 VTS is determined based on the estimates of OIW.[8] The effect of (Level 3) VTS in entrance collision, grounding, and ramming probabilities has been found to be substantial. As a result, the P^n_{i3} values for collisions (i = 1), rammings (i = 2), and groundings (i = 3) at the entrance were estimated to be reduced by multiplicative factors of 0.4, 0.7, and 0.5, respectively.

The effects of channel width, tanker stopping distance, tanker density, and so forth can be estimated using the results of geometrical probability formulations, presented in Equations 10 and 11. Since these formulations are by no means definitive, they are used here for purposes of relative comparisons. We have assumed a relatively "unsafe route" in alternatives 5A and 8A by selecting $P^n_{13} = P^n_{33} = 2$ for all n. In reality, these larger risks may result from the use of narrower channels (T/C ~ 1 in Equation 10) and/or from the use of densely populated channels or harbors (that is, large σ_c or η values in Equation 11.

The summary of all project alternatives is presented in Table 8. Results of TRAM simulations runs for these project alternatives are displayed in Tables 9 and 10.

Best Available Document

437

Table 9. Results of TRAM simulation runs for alternative 1A

Estimated Spill Probability and Size		Location of Spill: Pier (j=1)	Harbor (j=2)	Entrance (j=3)	Coast (j=4)	Sea (j=5)
Total Loss Spill Probability (per year)	(P_{t_j})	0.0023 (1 in 431 yrs)	0.0020 (1 in 498 yrs)	0.0013 (1 in 746 yrs)	0.0030 (1 in 330 yrs)	0.0031 (1 in 323 yrs)
Total Loss Spill Size (barrels per year)	(V_{t_j})	1,789	1,527	1,015	2,303	2,437
Spill Probability Excluding Total Losses (per year)	(P_{1t_j})	0.0285 (1 in 35 yrs)	0.0415 (1 in 24 yrs)	0.0294 (1 in 34 yrs)	0.0478 (1 in 21 yrs)	0.0305 (1 in 33 yrs)
Spill Size for Less than Total Losses (barrels per year)	(V_{1t_j})	35	93	78	116	32
Total Spill Probability (per year)	($P_t + P_{1t}$)	0.0308 (1 in 32 yrs)	0.0435 (1 in 23 yrs)	0.0307 (1 in 33 yrs)	0.0509 (1 in 20 yrs)	0.0336 (1 in 30 yrs)
Total Spill Size (barrels)	($V_t + V_{1t}$)	1,824	1,619	1,093	2,419	2,469

Table 10. Results of TRAM simulation runs for alternatives

Tanker Fleet Alternative	Estimated Probability: Total Loss Spill Probability P_t (per year)	Total Loss Spill Size V_t (barrels)	Less Than Total Loss Spill Probability P_{1t} (per year)	Less Than Total Losses Spill Size V_{1t} (barrels)	Total Spill Probability $P_t + P_{1t}$ (per year)	Total Spill Size $V_t + V_{1t}$ (barrels)
1A	0.0087 (1 in 115 yrs)	6,634	0.1471 (1 in 7 yrs)	320	0.1558 (1 in 6 yrs)	6,954
1B	0.0079 (1 in 127 yrs)	6,834	0.1347 (1 in 7 yrs)	295	0.1426 (1 in 7 yrs)	7,129
2A	0.0072 (1 in 139 yrs)	6,357	0.1194 (1 in 8 yrs)	253	0.1266 (1 in 8 yrs)	6,610
2B	0.0072 (1 in 139 yrs)	6,621	0.1210 (1 in 8 yrs)	259	0.1282 (1 in 8 yrs)	6,877
3A	0.0096 (1 in 104 yrs)	6,734	0.1642 (1 in 6 yrs)	359	0.1738 (1 in 6 yrs)	7,093
3B	0.0083 (1 in 120 yrs)	6,863	0.1415 (1 in 7 yrs)	310	0.1498 (1 in 7 yrs)	7,173
4A	0.0081 (1 in 123 yrs)	6,163	0.1323 (1 in 8 yrs)	280	0.1404 (1 in 7 yrs)	6,443
5A	0.0098 (1 in 102 yrs)	7,496	0.1734 (1 in 6 yrs)	394	0.1832 (1 in 5 yrs)	7,890
6A	0.0110 (1 in 91 yrs)	8,566	0.1865 (1 in 5 yrs)	408	0.1975 (1 in 5 yrs)	8,974
7A	0.0102 (1 in 98 yrs)	7,950	0.1676 (1 in 6 yrs)	356	0.1778 (1 in 6 yrs)	8,306
	0.0124 (1 in 81 yrs)	9,693	0.2201 (1 in 5 yrs)	502	0.2325 (1 in 4.3 yrs)	10,195
8A	0.0081 (1 in 123 yrs)	6,280	0.1367 (1 in 7 yrs)	297	0.1448 (1 in 7 yrs)	6,577

. Spill frequency and spill size values are the sums of pier, harbor, entrance, and coastal spill probability and size estimates (that is, ... l-sea probability in the totals presented).

Best Available Document

438

Discussion of results

Various spill probabilities and the location of spills, which are computed using Equations 1 to 7, are detailed in Table 9, based on TRAM output. At-sea spill probabilities are only presented for purposes of comparison and completeness. Subsequent results presented in Table 10 exclude all at-sea oil spill frequency and spill volume estimates.

Results of the tanker risk analysis model indicate that for the alternative 1A (corresponding to fleet mix 1A), the highest total loss spill frequency and spill volumes are predicted to occur at coastal areas or at sea. One spill in 330 years is expected to take place in coastal areas, with an annual average spill size of 2,303 barrels. On the other hand, at the entrance portion of the tanker route, total loss spill probabilities are expected to be the lowest (one spill in 498 years, with an annual average spill size of 1,527 barrels). Harbor and coastal areas are predicted to have more frequent but smaller size spills (spill probability excluding total losses is one in 24 years at the harbor area, with an estimated annual average spill size of 93 barrels). Overall, total loss spill probabilities (excluding at-sea estimates) are predicted to be one in 115 years (see also Table 10), with an annual average spill volume of 6,634 barrels. Spills excluding total losses are predicted to occur once in 7 years, with an annual total spill size of 320 barrels.

Results of TRAM simulations runs for the first six alternatives 1A, 1B, 2A, 3A, 3B representing the impact of different tanker fleet mixes, or oil spill risks, do not display significant variations in terms of the projected oil spill probabilities. Total spill probabilities at most vary by 25 percent and the total annual average spill sizes by 8 percent. Alternative II is suggested as the choice leading to the smallest of all oil spill probabilities. On the other hand, alternative III suggests the highest oil spill risks. These predictions, however, are expected since alternative II is composed mostly of tankers constructed with double hulls, inerting systems, and so forth, whereas in alternative III the weighting is given to tankers without such safety features. Again, in this case, all estimates are very similar, and alternative I seems to be the representative average.

The influence of route-specific features on estimated oil spill risks is also demonstrated in Table 10. For alternative 1A, the influence of VTS in the entrance results in smaller spill frequency and spill size estimates. (The difference between alternatives 4A and 1A is about 500 barrels per year less oil spilled and a change from one total loss in 123 years to one total loss in 115 years). Doubling the collision and grounding probabilities in the entrance, however, results in more significant changes. Differences between alternatives 5A and 4A suggest that route alternative 5A will lead to an expected 1,000 barrels more of average oil spilled per year than the alternative 4A. Total loss spill probabilities also change from one in 123 years to one in 102 years.

Finally, the selection and the use of different relative risk values for tanker size classes is also performed by TRAM. Differences between the use of size-class dependent relative risks influence the results of the model application the most.

Based on the results presented above, TRAM provides a relatively simple and useful means of exploring various project alternatives. The utility of incorporating a large number of project-specific variables as well as being able to alter the data base is perhaps the most attractive feature desired from any risk assessment method. The ultimate choice of fleet composition or other route-dependent factors now can be partially based on the results of multiple-simulation tests, similar to the ones shown in Table 10. Obviously, for any project there are always certain deterministically unquantifiable oil spill risks (such as environmental risks due to storms and fogs); however, performing a comparative risk assessment analysis prior to the final selection of the project alternatives should be most useful and desirable in many ways.

Extensions of TRAM applications

We would like to discuss briefly here the possible extensions of the analysis technique introduced above to other forms of risk analysis studies (not all of them including oil transport operations).

Some of the areas of risk analysis or related reliability problems are: pipeline oil spill risk estimates; oil spill risks at single point mooring (SPM) facilities; other casualty-related studies, such as fire and explosion; meteorology or process-dependent reliability or risk estimates; semi-empirical modeling of physical processes to determine various model component relationships; and other types of reliability or risk analysis studies.

The most natural extension of the analysis presented in this paper has been to the first four topics mentioned above. Pipeline oil spill risks (based on separation of catastrophic or large spills from the smaller leaks) have been performed in NTPC.[7] Operational oil spill risks at SPM facilities have been subject to a number of different treatments.[7,8] Based on the limited number of oil spill records at SPM facilities, it has been possible to replace at-pier oil spill risks in TRAM by suitable numbers categorizing various spill sizes as small, moderate, and large.[7]

Similarly, various operational fire and explosion hazards have been treated in BLM[11] and NTPC.[7] More subtle extension of the analysis to study the relationship of meteorological conditions to grain elevator fires and explosions has been treated in ERT.[2] The extended analysis proposed in ERT[2] has also included a number of spectral analysis techniques to determine the elements of probability matrices similar in character to the ones used in TRAM. In many similar ways, therefore, other types of reliability or risk analysis studies as well as semi-empirical modeling efforts may benefit from the analysis technique presented in this paper.

References

1. Doolittle, J. C., 1975. Shell Oil Company Highlights of Testimony of December 5, 1975 to Washington House Transportation and Utilities Subcommittee. State of Washington, Olympia, Washington
2. Environmental Research and Technology, Inc., 1978. The Relationship of Meteorological Conditions to Grain Elevator Fires or Explosions. Internal Technical Paper. Concord, Massachusetts
3. Federal Power Commission, 1976. Alaska Natural Gas Transportation System, Final Environmental Impact Statement. Vol. II, Appendix D
4. Henry, J. J., Company, Inc., 1973. An Analysis of Oil Outflows to Tanker Accidents. AD-780 315. National Technical Information Service, Springfield, Virginia
5. Keith, V. F. and J. D. Porricelli, 1973. An Analysis of Oil Outflows Due to Tanker Accidents. *Proceedings of the 1973 Oil Spill Conference.* American Petroleum Institute, Washington, D.C. pp3-14
6. Macduff, T., 1974. The probability of vessel collisions. *Ocean Industry.* September 1974, pp144-148
7. Northern Tier Pipeline Company, 1978. Application for Site Certification. submitted to State of Washington Energy Facilities Siting Council, State of Washington, Olympia, Washington
8. Oceanographic Institute of Washington, 1974. Offshore Petroleum Transfer System for Washington. Seattle, Washington
9. Socio-Economic Systems, 1976. Tanker traffic study—Valdez to Long Beach. for Port of Long Beach, Long Beach, California
10. Tetra Tech, 1976. Environmental Assessment Report, Crude Oil Transportation Systems: Valdez, Alaska, to Long Beach, California, Appendix B: Oil Spill Analysis Prepared for U.S. Army Corps of Engineers. Tetra-Tech, Pasadena, California
11. U.S. Army Corps of Engineers, 1974. Waterborne Commerce Statistics.
12. U.S. Bureau of Land Management, 1977. Final Environmental Impact Statement—Crude Oil Transportation System: Valdez, Alaska to Midland, Texas. Department of Interior, Washington, D.C.
13. U.S. Senate, 1978. An Analysis of Oil Tanker Casualties 1969-1974. Committee on Commerce, Science, and Transportation, U.S. Government Printing Office, Washington, D.C.

Best Available Document

439

NATIONAL PETROLEUM REFINERS ASSOCIATION

SUITE 1000
1899 L STREET, N W
WASHINGTON, D C 20036

AM-80-55

DETERMINING THE ENVIRONMENTAL CHARACTERISTICS OF REFINERY SOLID WASTE

by

Alan Gradet, Environmental Engineer
W. Leigh Short, Manager, Houston Engineering Office
Environmental Research & Technology, Inc.
Houston, Texas

Presented at the

1980 NPRA ANNUAL MEETING

March 23-25, 1980
New Orleans, Louisiana

440

DETERMINING THE ENVIRONMENTAL CHARACTERISTICS OF REFINERY SOLID WASTES

INTRODUCTION

1. Rationale and Purpose

This paper describes a systematic approach to determining the environmental characteristics of refinery solid wastes. The need for such an approach to solid waste data collection evolves directly from statutory and regulatory requirements that will demand clear and accurate information on the composition of individual waste streams. An ultimate goal is sufficient data and documentation for standardized data collection and reporting procedures and, of course, a better understanding of refinery waste composition and characteristics.

The need for systematic environmental data on solid wastes can be specifically defined in terms of regulatory considerations, technical considerations and economic considerations. The primary regulatory consideration, pursuant to the pending RCRA regulations, is the classification of a given waste stream as hazardous or non-hazardous. It is well known, based on proposed regulations, that the Environmental Protection Agency intends to designate several refinery waste streams as hazardous (e.g., API sludge, DAF sludge, HF alkylation sludge). Although specific procedures for non-inclusion are unknown, it can be assumed that a non-inclusion decision will require accurate environmental data.

Another consideration is collecting accurate data for evaluating alternative technologies for solid and hazardous waste management. The number and type of technologies available is such that economic evaluations may not be sufficient for preliminary decision-making. Sound environmental data in combination with engineering cost data will allow proper evaluation of all alternatives.

A final consideration involves the cost of environmental analyses. The costs for laboratory analyses of conventional environmental parameters, such as trace metals, are relatively low considering the established state-of-art; however, analyses for trace organics which will be of concern with many refinery wastes are relatively expensive. Because of the larger number of pollutants and more expensive analyses, a better understanding of refinery waste composition can provide a screening mechanism for future analyses.

2. Definitions

Before describing environmental analyses and their application it is appropriate to establish definitions for some of the terms that will be periodically used. These definitions are summarized in Table 1.

The definition of "solid waste" is based on that provided by RCRA (PL94 580, Section 1004 (27)) although the term "**solid**" is somewhat arbitrary as the following examples will show:

- API separator sludges — rarely greater than 4% solids.
- Aerobic digester sludges — rarely greater than 3% solids.

The term "**waste**" is also somewhat arbitrary. Some materials may be considered wastes only because of their disposition and the current economics of re-use or recycle. That is, certain wastes may contain valuable resources or products.

The term "**waste matrix**" is used to designate an entire waste stream including its transport medium. The most obvious example does not directly apply to the refinery industry but does provide the best perspective. Coal ash from power generation can be handled in either dry or wet systems. In dry handling, the ash itself is the entire waste matrix; however, in wet systems the ash and its sluicing water represents the entire waste matrix. This viewpoint becomes critical when defining proper analytical procedures and management technologies.

The terms "**solids and liquid fraction**" as commonly applied to all solid wastes actually implies three fractions within a given waste matrix as shown in Table 1. The term solid fraction refers to particulate solids, only, although specific analytical procedures yield quantification of total solids. The term liquid fraction refers to solids dissolved within the liquid portion of the waste matrix. The oil fraction is neither solid nor liquid but a third general fraction of the total waste matrix.

The term "**composition**" refers to the chemical make-up of the waste matrix. This includes major chemical parameters such as calcium and aluminum in ash and minor parameters (in terms of quantity) such as trace metals and synthetic organics. A portion of this paper is concerned with determining the composition of waste streams.

The term "**Environmental Characteristics**" refers to the relationship between a given waste matrix and its ultimate resting place in the environment. Environmental characteristics include composition and are usually determined by laboratory tests which are actually simulations of the interaction between a waste matrix and the environment. The majority of these tests are not engineering tests in that the resulting information is not directly applicable to the design of a specific solid waste management technology. Another portion of this paper deals directly with determining environmental characteristics and the proper application of

44

the resulting data.

3. Format

The remainder of this paper concerns: (1) compositional analyses of refinery solid wastes; (2) environmental characteristics of solid wastes; and (3) how the resulting data is applied to a given set of situations and problems. The latter subject is actually iterative; that is, the definition of a given problem will define what analyses should be performed. Therefore, the discussions of environmental analysis indicate a somewhat more comprehensive data collection procedure than will probably be required for any given situation. This issue is discussed in detail in the last section of this paper.

COMPOSITIONAL ANALYSES

1. First Level Compositional Breakdown

Most refinery solid wastes are composed of three fractions: solids, liquid and oil. The objective of the first level of compositional analysis is to separate the waste into these fractions. As will be shown later, these data have little importance with regard to direct regulatory activities, but have great importance in defining proper handling, disposal and management of solid wastes. It should also be noted that, in some cases, the oil and dissolved solids fractions of a given waste matrix can be considered insignificant; however, it is suggested that this fact be documented by the proper analytical procedures.

The analyses commonly used to separate the three waste fractions are shown in Table 2. These specific laboratory procedures actually apply only to a waste which is filterable such as biological treatment sludge and aerobic digester sludge. For wastes which are not filterable, it is suggested that the liquid portion of the waste be separated by decanting or centrifuging and analyses for total solids and volatile solids be performed on the separate fractions.

A standard oil and grease analysis, as suggested in Table 2, is adequate for the purposes of this level of determinations; however, its limitations and application should be understood. First, the procedure does result in the loss of certain volatile oil components. Second, it should be understood that the analysis of volatile solids in both particulate and dissolved fractions will include most oils. Thus, there is considerable overlap between the various analyses suggested. As will be shown in a later discussion, the value of these data is not minimized as long as their limitations are understood.

The cost of each of the analyses suggested for first level determinations is shown in Table 2. It is apparent that these costs are not insignificant when considering a large number of samples; however, when compared to the total cost of a solid waste management program including design and construction of proper management facilities, the cost of first level compositional determinations is not a major expenditure.

2. Second Level Compositional Breakdown

Contained within the three waste fractions defined by the first level of compositional determinations are particular compounds and chemicals which are of primary environmental importance. The objective of the second level of compositional determinations is to quantify these specific compounds in terms of their relative concentration. A complete assay of each waste material is neither suggested nor required. The actual selection of specific parameters must be based on the objectives of the particular environmental program. The issue of parameter selection is discussed in a later portion of this paper.

General parameter categories that are applicable to most refinery wastes and are of obvious importance environmentally are listed in Table 3. As mentioned previously, for some waste streams, the definition of oil fractions is inappropriate.

The inorganic parameters listed in Table 3 can apply to either particulate or dissolved solids fractions. Recent studies by the American Petroleum Institute (API, 1976) have indicated that, at least for trace metals, dissolved fractions appear to be insignificant. It is suggested, however, that trace metal analyses be conducted on the entire waste matrix unless the liquid and solid fractions are to be handled separately. In cases where dissolved metals are expected to be of importance, separate analyses of dissolved and particulate trace metals are suggested. The separation of dissolved versus liquid fractions is more important with regard to other inorganic components such as sulfides, ammonia and fluoride.

The three oil fractions suggested for second level determinations relate to the possible interactions between oil hydrocarbons and the environment. The asphaltic fraction includes those oil hydrocarbons which are degraded very slowly by natural biological mechanisms. The aromatic fraction includes compounds which are volatile to varying degrees under ambient environmental conditions. Finally, saturate fractions include the non-aromatic hydrocarbons which have been shown to be readily degradable by natural biological mechanisms. Data regarding these three fractions is clearly important with regards to land-based disposal.

Trace organic parameters are perhaps the most difficult to select because only indirect or limited information is currently available. Using a regulatory perspective, the EPA priority pollutant list is an available starting point; however, the cost for quantitative analysis of every solid waste sample for 116 organic priority

442

pollutants is unacceptable. Two options for second level determinations are suggested. The first option is to screen samples on a site and waste specific basis using a semi-quantitative analytical technique. Full quantitative analyses can then be conducted on those compounds or classes of compounds identified in the sample. A second option is to analyze each waste for parameters which are believed to be present. The list included in Table 3 are parameters which have been identified in either refinery solid wastes or wastewaters.

The costs for second level analytical determinations, shown in Table 4, are dominated by organic analyses when specific compounds are not identified. However, costs can be controlled by careful parameter selection and screening of both inorganic and organic components.

ENVIRONMENTAL ANALYSES

1. Introduction

Environmental analyses are standard laboratory procedures which evaluate how a waste material will biologically, chemically, and physically respond in the ambient environment. It is critical to note that these are not engineering tests; that is, environmental analyses will not define the rate at which a given physical, chemical or biological reaction will occur but simply the possibility of the response simulated by the test. The purpose of this section is to discuss the most important solid waste environmental test in view of their obvious limitations.

2. Hazardous Waste Tests

The tests recommended by EPA in December of 1978 for classifying solid wastes as hazardous or non-hazardous (for unlisted wastes only) are already the most often used procedures for solid waste evaluations. Of the four tests proposed (toxicity, ignitability, corrosivity and reactivity), the toxicity test is the most often applied and, perhaps, the least understood. The stated purpose of the toxicity test, known commonly as the extraction procedure, is:

> ". . . to measure the tendency of the constituents of a waste to migrate out and become available to contaminate the environment under poor management conditions." (43FR58952)

The EPA extraction test is not intended to simulate a land disposal condition or to indicate the quantity of pollutants which will leach. The test is designed as a mechanism for relative screening of all solid wastes.

Given these somewhat severe limitations for applications other than regulatory responses, is there a use for the extraction procedure that will provide valuable technical information? The procedure recommended by EPA indicates that the solid waste extract on which chemical analyses (i.e., second level determinations) are performed is actually a combination of the waste matrix's liquid phases before and after extraction. In some cases, it can be assumed that a waste may be classified as hazardous because of constituents dissolved in the original liquid phase, not constituents that "migrate out" of the solid phase. In order to monitor this possibility, the procedure shown in Table 5 is suggested. In this way, if a waste extract is found to exceed the concentration limits established by EPA, it can be determined if the "hazardous" portion of the waste is the original solid fraction or original liquid fraction. This may not directly affect regulatory activity but may indicate the proper handling, and disposal techniques to employ.

The remaining three hazardous waste tests are even more limited in terms of their applicability in other than regulatory responses. Few refinery wastes are truly ignitable or reactive, as these tests are designed for special categories of waste. Corrosivity criteria include both a test limit (.25 inches per year of steel) and a pH limit. Except for highly acid or caustic wastes, it is also doubtful that refinery wastes would be classified as corrosive.

APPLICATION OF DATA

1. Regulatory Responses

The most immediate need for refinery solid waste data is responding to the pending hazardous waste regulations, specifically section 3001 which defines classification criteria for hazardous wastes. Although these regulations are expected to change somewhat over the next several months, we can use the original proposed regulations (43FR58954) as a guide for determining the proper response.

In the proposed regulations EPA listed eight specific wastes associated with petroleum refineries as designated hazardous wastes. These are shown in Table 6 along with the EPA criteria for listing these wastes. Any refinery generating these wastes has two options for response. The first is to accept the hazardous waste designation and subsequently handle the wastes in accordance with the required standards for hazardous waste management. A second response is to determine if a particular refinery's waste meets the criteria or basis assumed by EPA. The actual non-inclusion procedure is very unclear in the proposed regulations; however, regardless of the final form of the regulations, some refinery wastes will be designated as hazardous. Non-inclusion will require the submittal of specific data relating to the composition and environmental characteristics of the wastes. It can be anticipated that the required composition data will include trace metals and trace organics and required environ-

443

mental characteristics will include similar components of the wastes leaching extract.

Refineries generate several other waste streams in addition to those listed in Table 6. These unlisted wastes include cooling tower sludges, waste catalysts, tank bottoms (other than loaded), storm water silts and biosludges. In these cases, it is strongly suggested that hazardous waste tests be performed in order to document a non-hazardous classification. This is actually a requirement since the burden-of-proof for unlisted waste classification is on the generator. According to the proposed regulations, the required tests would be toxicity, ignitability, corrosivity and reactivity.

2. Technology Assessments

The most important long-term use of environmental and compositional data is the assessment of alternative solid waste management technologies. The data described previously can be used directly for evaluating the relative advantages, conceptual designs and the required environmental management of different technologies.

First level compositional data (solid, liquid, oil fractions) provides important screening information regarding a broad range of possible technologies. For example, consider a case where a refinery generates a waste of unknown composition and requires information concerning the optimal management strategy for that material. A first level compositional analysis can provide all the information shown in Table 7.

With regard to land based disposal technologies, three specific types of information can be gained from separating a waste matrix into its solid, liquid and oil fractions. The simplest is a determination of whether a landfill or impoundment will be necessary based on the relative percentages of solids and liquids. Specifically with regard to impoundments, determination of suspended solids can indicate long-term volumetric requirements. Also, the advantages gained by dewatering prior to disposal can be determined from first level composition data.

First level composition data can also provide substantial information regarding landfarming. Volatile solids and total oil data can be used to estimate organic and oil loading rates when combined with literature based degradation rates. These estimates, in turn, can be used to calculate land requirements. Finally, total solids data can be used to calculate solids and hydraulic loading rates. The obvious advantage of first level compositional data is that preliminary costs for landfarming can be based on simple analytical procedures.

First level data provides some information regarding combustion alternatives, specifically with regard to the results of incinerating a given waste. When combined with standard engineering tests, such as ultimate analyses and heat (BTU) value, these data can also be used to develop preliminary costs.

Second level composition data can be used to refine preliminary technology evaluations or as specific indicators of potential environmental effects. Oil fractionation data is most applicable to landfarming as an indicator of the relative composition of volatile fractions which may be potential air contaminants and heavy oils which will degrade more slowly than other fractions. Trace metal and inorganic parameter data are applicable to all technologies. For landfarms, these data indicate possible soil accumulation problems. With regard to landfills or impoundments, inorganic data, especially if separated into particulate and dissolved portions, indicates potential leachate and runoff problems. Finally, for incineration, trace metal data in combination with first level composition data can be used to calculate metal concentrations in combustion ash. Trace organic data is also applicable to a combustion option. In this case, the relative advantage of incineration is, in part, dependent on its potential efficiency in the destruction of priority trace organics.

All second level data are generally predictive of potential environmental problems. Specific target pollutants identified in waste analysis can become part of the monitoring plan for a management or disposal facility. Second level composition data can limit a monitoring program and control management costs.

One application of the results of environmental analyses, specifically the proposed extraction/toxicity test, has already been discussed. As previously described, the maximum use of the proposed analytical procedure can indicate possible handling and treatment alternatives (such as dewatering). The data can also be used for a better definition of ground water monitoring target pollutants.

SUMMARY

In the near future, most refineries will be faced with economically important decisions regarding the management of as many as ten different solid waste streams. Primarily, these decisions will include the proper response to environmental regulations and the selection of the optimum technology for managing a particular waste. Considering the number of different waste streams and the number of available technical options, these decisions will be difficult.

This paper has shown that solid waste data collected using current analytical techniques can be used to greatly simplify the decision-making process. Data on the composition and characteristics of refinery solid wastes can be used directly to:

(1) document a position with regard to a regulatory classification of solid wastes;

(2) screen technology options with regard to advan-

444

tages, disadvantages and preliminary costs; and

(3) define site and waste specific environmental monitoring.

The cost for collecting solid waste data and applying the information to specific needs is certainly greater than previously experienced for such programs. It is suggested that the current perspective on solid waste management costs will change due obviously to regulatory activity. As solid waste management costs increase, the relative cost of collecting solid waste data will seem less severe and the relative advantages will increase.

TABLE 1
DEFINITIONS

- Solid waste — any solid, semi-solid or liquid emission except:
  - (1) Products or usable intermediates and by-products
  - (2) Water and wastewater discharges carrying an NPDES permit
  - (3) Materials subject to the Atomic Energy Act of 1954
  - (4) Permitted air emissions
- Waste matrix — the entire waste stream including transport medium
- Waste fractions — three definable fractions in refinery wastes
  - (1) Particulate Solids (Solid)
  - (2) Dissolved Solids (liquid)
  - (3) Total oil
- Composition — the chemical components of the entire waste matrix
- Environmental characteristics — the relationship between a waste's composition and the environment

TABLE 2
ANALYSES AND COSTS — FIRST LEVEL COMPOSITIONAL ANALYSIS

Analysis	Estimated Cost/Sample $
Total solids	5-10
Total suspended solids	5-10
Total dissolved solids	5-10
Total volatile solids	5-10
Volatile suspended solids	5-10
Total oil and grease	15-30

TABLE 3
ANALYSES — SECOND LEVEL COMPOSITIONAL DETERMINATIONS

Inorganics	Oil	Organics
Trace metals	Saturates	Option 1
Sulfides	Aromatics	Priority Pollutants (screening)
Ammonia	Asphaltics	
		Option 2
		Phenol
		PAH
		Benzene
		Phthalates

TABLE 4
COST — SECOND LEVEL COMPOSITIONAL DETERMINATIONS

Parameter Category	Estimated Cost/Sample $
Trace metals	200-300
Sulfide/ammonia/fluoride	30-50
Oil fractions	100-200
Priority organics	1000-1500

445

TABLE 5
ADDITIONAL ANALYTICAL PROCEDURES FOR EPA EXTRACTION TEST

- Measure total solids in waste matrix
- Measure total solids in original liquid fraction
- Measure pH in total waste matrix, original liquid fraction and combined liquid fraction
- Analyze both original liquid fraction and combined liquid fraction for regulated constituents

TABLE 7
TECHNOLOGY ASSESSMENT APPLICATIONS FIRST LEVEL COMPOSITIONAL DATA

- Disposal technologies
  - (1) Landfill versus impoundment
  - (2) Impoundment volume requirements
  - (3) Advantages of dewatering
- Landfarming
  - (1) Estimated organic loading rates
  - (2) Estimated oil loading rates
  - (3) Hydraulic loading rates
  - (4) Solids loading rates
  - (5) Land requirements
- Combustion
  - (1) Estimated ash content
  - (2) Estimated combustible materials
  - (3) Estimated heat loss due to water

TABLE 6
LISTED HAZARDOUS WASTE

	EPA Basis			
Waste	Toxic Waste	Ignitable Waste	Contains Toxic Organics	Contains Mutagenic Substances
• HF alkylation sludge	X		X	X
• DAF sludge	X	X	X	
• Kerosene filter clays	X		X	X
• Lube oil filtration clays	X		X	X
• Slop oil emulsion solids	X	X	X	
• Exchange bundle cleaning solvents	X		X	
• API sludge	X		X	
• Leaded tank bottoms	X			

446

EXTRACTION

Russell Moore

Program Manager
Environmental Research & Technology, Inc.

June 1980

International Environmental Management Institute
ENVIRONMENTAL RESEARCH & TECHNOLOGY, INC.
Concord, Massachusetts, USA

447

EXECUTIVE SUMMARY

As a world industry, mining is second only to agriculture in age and importance. Throughout history the localized occurrence of minerals, as opposed to their widespread demand, has contributed heavily to international commerce. The ready availability of mineral resources has encouraged the development of mineral-dependent societies in most developed countries. This heavy dependence has led to increasing global exploration and mining activity. Along with the increased demands for mineral resources have come increased social interest in the side effects of mining and processing activities, especially air and water pollution effects.

The nature and severity of environmental problems are closely related to the type of mineral resource being removed and the type of extraction methods involved. For convenience of discussion, minerals and extraction methods are grouped here into broad categories producing similar environmental effects. These categories are the following:

1) Solid fossil fuels (coal, oil shale, lignite, etc.)
   A. Surface mining
   B. Underground mining

2) Hard rock minerals (copper, iron, phosphate, uranium, etc.)
   A. Open pit
   B. Underground
   C. Placer (primarily dredging)
   D. In situ leaching

3) Liquid and gaseous minerals (oil and natural gas)

4) Construction minerals (sand, gravel, limestone, granite, etc.)
   A. Rock quarrying
   B. Sand and gravel dredging
   C. Sand and gravel open pit

(This discussion excludes off-shore drilling and undersea mining because of the vastly different environmental effects involved.)

The environmental aspects of the fourth category are shared almost universally since such low-valued construction materials are ubiquitous and seldom transported beyond short distances. Minerals in the other three categories are typically localized enough to warrant international commerce. Hence, specific environmental effects may be concentrated in those areas where extraction of an individual mineral occurs. Because of the localized occurrence (or development) of most minerals, it is common for most of the world's supply of a given mineral to be produced by only a few countries. Primary examples include: gold and diamonds - South Africa; molybdenum - Canada and United States; tin - Malaysia and Bolivia; and chrome ore - U.S.S.R. and South Africa.

448

The significance of environmental impacts associated with mining relates to local land uses, population densities, and the environmental awareness of the local society. To date the principal countries which have instituted regulatory controls on the environmental impacts of mining are those with relatively high per capita incomes. As developing nations become more affluent, it is to be expected that more emphasis will be placed on control and mitigation of mining impacts.

As consumption levels of mineral ores have increased in recent decades, it has become necessary, in many cases, to utilize lower grades of ore, resulting in far greater volumes of ore being processed and higher potentials for environmental degradation. As it becomes economical to process lower grade ores, the total quantity of recoverable mineral and the number of locations where it may be obtained increase dramatically. At the extreme of this progression are sand and gravel building materials which are abundant in most regions, command low values, and are typically extracted in relatively small operations.

For more developing nations, the environmental concerns related to mineral extraction will focus on:

- prevention of direct safety hazards;
- preservation of water quality for local domestic and agricultural uses;
- prevention of air quality in heavily populated areas; and
- maximum practical reclamation of mined areas to other beneficial uses.

In order to achieve these objectives, environmental control or mitigation measures may be implemented at each or any of the sequential stages in the development and life of a mining operation. Depending on the specific operational process and the emphasis to be placed on local environmental concerns, such measures may be either preventative or remedial in nature.

4149

INTRODUCTION

Since humans first began to use stone tools there has been a steady demand for an increasingly diverse array of mineral resources suitable for specific purposes. The first uses of mineral resoures were based on gross physical characteristics of the ore, e.g. suitability for chipping into a crude blade or axe. Over the centuries, man has learned to extract desired minerals from the host rock and to process and combine these minerals into even more useful products. This evolution of the mining industry has been based on two underlying factors: development of applications to utilize an ever increasing diversity of minerals; and continual development of more sophisticated methods for locating, extracting, and processing these minerals.

Availability of mineral resources has been closely tied to development of major civilizations throughout history. The widespread demand for mineral resources and their localized occurrence contributed strongly to early trade between neighboring peoples and today constitutes a major factor in international commerce. This demand for mineral resources, closely related to population levels and standard of living, has provided the impetus for continuous mineral exploration and the development of lower quality deposits.

Along with the acceleration in mineral extraction has come an increasing concern for environmental effects of mining activities. The significance of environmental impacts associated with mining relates to local land uses, population densities, and the environmental awareness of the local society. To date the principal countries which have instituted regulatory controls on the environmental impacts of mining are those with relatively high per capita incomes. As developing nations become more affluent, it is to be expected that more emphasis will be placed on control and mitigation of mining impacts.

As consumption levels of mineral ores have increased in recent decades, it has become necessary, in many cases, to utilize lower grades of ore, resulting in far greater volumes of ore being processed and higher potentials for environmental degradation. For example, around 1800 the world's largest copper mine in North Wales produced copper ore containing about 6% copper. Today, much of the copper ore contains less than 0.5% copper. Likewise, the United States iron industry in the Great Lakes region which was built on high grade ores has largely shifted to the more abundant, but lower grade, taconite ores. As it becomes economical to process lower grade ores, the total quantity of recoverable mineral and the number of locations where it may be obtained increase dramatically. At the extreme of this progression are sand and gravel building materials which are abundant in most regions, command low values, and are typically extracted in relatively small operations.

TYPES OF MINING OPERATIONS

The nature and severity of environmental problems are closely related to the type of mineral resource being removed and the type of extraction methods involved. The basic mineral categories and most common mining methods for each are discussed below.

Solid Fossil Fuels

This category includes anthracite and bituminous coal, lignite, oil shale, and tar sands. Excavation of these materials may be conducted by either surface or underground methods. The type of method used at a particular site depends on the thickness, dip, and accessibility of the deposit as well as on various economic and engineering factors. Contour surface mining with equipment ranging from bulldozers to large shovels is common in mountainous terrain where mining occurs as a narrow strip along the mineral outcrop line. In flatter terrain where coal seams lie roughly parallel to the ground surface and are overlain by relatively soft strata, large draglines or bucket wheel excavators may be utilized in area surface mining. Extremely thick coal seams, thick steeply dipping coal seams, and oil shale are commonly excavated in open pit fashion. Coal or oil shale deposits of suitable quality which lie more than 100 to 200 m below the ground surface are typically recovered by underground mining methods, normally room-and-pillar. In areas of suitable geologic characteristics, longwall underground mining is advantageous since it allows a higher level of mineral recovery.

Current research with oil shale indicates that in situ retorting may be practical; similar procedures may also be used in some areas for direct conversion of coal to gaseous or liquid fuels.

Hard Rock or Metalliferous Minerals (plus some nonmetals)

The minerals in this category commonly occur as (1) veins of rich minerals within the surrounding host rock, (2) mineralized zones or pockets within the surrounding rock, or (3) stream-laid deposits of the heavier minerals in gravels and sands of ancient stream beds and lake bottoms. The first type of deposit is commonly excavated by simple shafts following the mineral veins. Larger mineralized zones, often of low grade ore, are typically excavated by open pit surface mining or, if considered more practical because of the surrounding geology, by underground methods, such as room-and-pillar or stoping (caving). Under certain geologic and hyrologic conditions, uranium and a few other minerals may be extracted by solution mining in which a leaching solution is pumped into and recovered from the mineral deposit. The stream-laid deposits mentioned above are commonly excavated by dredging.

451

Liquid and Gaseous Minerals

Petroleum and natural gas constitute the major minerals in this category. In almost all cases these materials are extracted from free flowing or pumped wells.

Industrial Materials (most nonmetals)

Included in this category are the common building and industrial materials such as sand and gravel, limestone, granite, sandstone, bentonite and pumice. Most operations excavating these materials are relatively small and mining is primarily by surface techniques determined largely by the size of operation and type of materials. These materials are most frequently excavated in small, open pit fashion, but other methods, including dredging of sand and gravel, may be used in particular situations.

TYPES OF ACTIVITIES INVOLVED IN A MINING OPERATION

It is possible to further dissect all of the categories above with respect to a set of sequential activities which are common to almost all mining operations. These basic activities are identified below.

Exploration

While seldom considered by non-mining personnel as a major component of the mineral extraction process, exploration activities may take several years on a given site and can contribute significantly to environmental impacts. Exploratory drilling and the associated access road development can be quite extensive for major mineral deposits.

Facilities Development

With the exception of small scale operations, most mineral extraction operations require on site office buildings, equipment maintenance shops, storage buildings, and parking lots.

Excavation for Mineral Access

This activity may range from drilling of wells (petroleum, natural gas, solution mining) to major excavations for large open pit operations. In the case of most excavations, substantial quantities of waste rock must be disposed of in the mine vicinity.

Mineral Extraction

Although this is the key element of the operation, it is commonly a minor element from the standpoint of environmental concerns. This activity along with some of the following activities typically continues throughout the life of the mining operation.

Mineral Transport

From the ore body, the mineral resource is typically transported to some on site or nearby preliminary processing facility. This facility may involve crushing, washing, sorting, or complete refining. Transport of solid ores to this point is usually by truck, conveyor, or rail. Transport beyond this point is often by a different type of carrier and is not considered in this discussion as part of the mineral extraction process.

Mineral Processing

The extent of mineral processing occurring on site normally depends on the size of mining operation, the weight ratio of mineral to ore, the cost of transport to external processing plants, and the cost of development for on site processing. Some types of processing such as uranium milling, coal crushing, copper smelting, and phosphate beneficiation are typically conducted at or near major mine ites. Other types of ore such as bauxite, iron ore, chromite, and ores of rare earth elements commonly enter international trade before they are processed. In fact, may nations heavily involved in steel and aluminum refining have no domestic ore supplies.

Reclamation

The extent of economically feasible reclamation differs considerably between different types of mining operations. Within the United States and several European countries the reclamation of coal mined lands has become an accepted part of each operation. On the other hand, few people would seriously suggest that the market cost of copper, iron, and similar minerals be increased to cover the substantial costs of backfilling and fully reclaiming major open pit mines. In most countries where environmental concerns are a major factor in mine design and development, the type and extent of reclamation is a key environmental issue.

NATURE OF ENVIRONMENTAL PROBLEMS

In their book "Environmental Impact of Mining", Down and Stocks (1977) categorize environmental problems according to the effect of the problem upon man. Their categories will be used for this discussion.

Direct Hazards to Human Safety and Health

Such hazards may exist with respect to either the mine employees or the general population. In almost all countries, strict laws and regulations exist to protect employees from most major safety and health hazards. Obviously, some of the less industrialized nations are still evolving legislation in this area, particularly with respect to the less conspicuous chronic health hazards.

In general, regulations protecting mine workers aid in protecting the local populace as well. Various types of hazards, however, may be generated by mining operations which do threaten public safety. Such hazards include the following as well as other problems:

- Failure of tailings dikes, reservoirs, and waste dumps,
- Major subsidence of underground mined areas,
- Abandoned shafts and water filled pits,
- Abandoned explosives,
- Flying rock and debris from blasting,
- Traffic accidents, and
- Toxic effluents into the atmosphere or local water supplies

Indirect Hazards to Human Safety and Health

Although most legislative attention has been focused on the direct and obvious hazards, several nations have, during the past decade or two, developed regulations concerning those activities which may affect public health and safety over a long period of exposure. Primary examples of such possible hazards include:

- Air pollution and dust,
- Water pollution below toxic levels, and
- Noise.

Damage to Property, Crops, and Livestock

Several of the same problems that pose hazards to human health and safety will commonly result in economic losses of buildings, animals, and crops. Various effluents may also be toxic to plants or animals without creating direct hazards to humans. Subsidence and ground vibrations from blasting can frequently cause structural damage to local buildings. Thus, mining aspects commonly leading to damage in this category include:

- Air pollution from mining activities and on-site or nearby mineral processing plants,
- Water pollution,
- Subsidence, and
- Vibration and shock from blasting.

454

Loss of Quality of Life and Aesthetic Values

During the past decade increasing emphasis has been directed in several nations to the loss or impairment of intangible values such as solitude and scenic beauty. At severe levels of impact, most individuals agree that damage has occurred. More commonly, however, intermediate impact levels lead to subjective questions of whether the nuisance aspect is acceptable or unacceptable. Obviously, these subjective questions are strongly affected by other considerations such as governmental goals, economics and alternative employment. Thus, practices which may result in an unacceptable nuisance in one situation may not only be tolerated, but welcomed wholeheartedly in other situations.

The principle factors contributing to loss of quality of life and aesthetic values include:

- Noise,
- Visual instrusion,
- Non-hazardous air pollution, and
- Changes in land use patterns.

Resource Depletion or Irreversible Commitment

The rapid (and accelerating) rate of mineral consumption during recent decades has lead to a growing concern for future supplies of these materials, or for the other resources such as land, water, wildlife habitat, and labor which may be committed over a long term while mineral development occurs. While depletion of easily accessible, high grade ores has obviously occurred during past centuries, present reserves of most minerals continue to grow with increased exploration and improved recovery and processing technology. Additionally, as a given mineral becomes less available and more expensive, there are tendencies toward (1) greater recycling of that mineral, (2) greater substitution with more abundant materials, and (3) increased exploration and processing research to utilize lower grade ores.

FACTORS AFFECTING ENVIRONMENTAL IMPACTS

The severity of impacts associated with a particular mining development will be determined in large part by the type of mining operation (type of mineral and method of extraction), the size of operation, and the location or the sensitivity of adjacent land uses.

455

Type of Mining Operation

The aforementioned types of minerals each possess tendencies for relatively consistent environmental problems. Thus, an open-pit copper mine in the southwestern United States will likely generate similar environmental problems to an open-pit copper mine in Australia. Obviously, some differences in problems will occur when the natural environment is drastically different between two sites.

Solid Fossil Fuels

Coal represents by far the major mineral of current interest in the solid fossil fuels group. On a world-wide basis, both underground and surface extraction methods are common. Since most coal seams are but a few meters thick, a given operation typically extends over large areas. Thus, with underground mining, subsidence may become an extensive problem; with surface mining, large areas are left to be reclaimed. Underground mines may also be accompanied by disposal of substantial quantities of carbonaceous earth and other waste materials.

Since coal seams in some regions are associated with concentrations of pyrite, the weathering of waste materials and exposed surfaces frequently results in acid formation which must be controlled or treated to prevent serious water pollution problems.

Surface mining operations, particularly at the scale conducted in the United States and West Germany, often involve major commitment of local non-mineral resources and long-term changes in land uses.

The use of long wall underground mining in those areas of suitable geology not only allows a higher recovery of the coal resource than by conventional underground methods, but also helps minimize the impacts of subsidence. Within the realm of surface mining, the use of bucket wheel excavators or trucks and scrapers for removing the overburden are noteworthy. These methods permit selective replacement of overburden strata, thus allowing deep burial of potentially toxic or otherwise undesirable materials.

Hard Rock Minerals

In most cases these minerals occur as low grade ores which are refined at nearby processing plants. Recovery of such minerals typically results in production of large volumes of waste rock prior to processing and rejection of 90% or more of the ore material as waste tailing. Tailings materials are normally ground and pulverized during processing and commonly contaminated with strong acidic or alkaline chemicals. Thus, waste tailings are typically piped as a slurry to nearby impoundments or abandoned mine pits. Dewatering of most tailings is hampered or prevented by the fine texture of solids.

456

Recovery of metalliferous minerals usually involves sophisticated processing to handle the low grade ores. Such processing is frequently accompanied by air pollution (in the form of dust and smelter fumes) and water pollution (resulting from accidental spillage of chemicals, uncontrolled waste discharge, and seepage from tailings impoundments). The severity of such effluents depends on the specific minerals and processes involved. Various minerals in this category, as well as many of the processing reagents, are toxic to humans, animals, and vegetation. Thus, environmental impacts of the processing activities may range from negligible to severe depending on the process technology and degree of environmental control.

Mining of hard rock minerals may involve either surface or underground operations. With underground mining, the primary environmental impacts include contamination of nearby streams, subsidence, and problems associated with disposal of waste rock and tailings. Surface mining for these minerals may involve extensive dredging, thus severely impacting local streams and associated water uses, or development of sizable open pits which will likely never be reclaimed. These surface methods also involve the extraction of substantial quantities of waste rock in order to reach the ore. In dredging operations, such waste materials are commonly replaced in previously dredged areas. Waste materials produced by open-pit operations are typically disposed of in nearby valleys.

Solution mining, normally for uranium, avoids the drastic surface disturbance of open-pit operations and the problem of tailings and waste rock disposal. The only significant environmental impacts from solution operations involve potential contamination of local groundwater supplies with the alkaline or acidic leaching solutions. Such contamination can largely be avoided if recovery wells are properly spaced and if the recovery area is properly flushed following solution mining. Within the United States, such operations must carefully monitor the water in local aquifers to prevent possible contamination.

Liquid and Gaseous Minerals

The primary environmental impacts associated with petroleum and natural gas development include spillage and leakage at the well site, similar spillage in transport, and air and water pollution at the refinery location. Since petroleum refineries are seldom located at the point of extraction, they are not considered further in this discussion. On site spillage is most common along with discharge of drilling muds and other waste materials during installation of the well. Steps may easily be taken to impound and remove such wastes before they contaminate local water supplies.

457

Industrial Minerals

While these minerals seldom command a high value, their widespread occurrence and consumption render this a major category of mining activity. Most extraction operations for these minerals are small in comparison to other types of mining and neither the products nor processes involve toxic materials. Thus, the most common environmental problems associated with mining of industrial minerals include noise, dust, stream sediments, aesthetic impacts, and reclamation difficulties. These problems are commonly aggrevated by the proximity of such operations to major population centers where the products are consumed.

Size of Operation

In almost all cases the severity of environmental impacts is directly related to the size of the mining operation involved. The relationship may or may not be linear since an increase in operational size may necessitate a disproportionate increase in excavating or processing facilities. Small mining operations for metalliferous minerals seldom involve on site processing facilities. Thus, upon reaching a given threshold at which it becomes economically desirable to install a processing facility, the environmental aspects change dramatically.

Location and Sensitivity of Adjacent Land Uses

Aside from the environmental impacts involving direct hazards to human health and safety, most environmental impacts become more severe as they are perceived by increasing numbers of the local population. Thus, mining methods which are environmentally acceptable in a remote location may become unacceptable as a population center develops around the mine. Likewise, water or air pollution levels may not create problems in the absence of sensitive receptors. Public and governmental attitudes also affect the determination of what is environmentally acceptable. Economically depressed countries or regions are commonly willing to accept greater environmental impacts in order to stimulate the desired economic growth. Public attitude is also affected by the history of mining in the vicinity. Thus, some communities are conditioned to mining operations and the environmental problems involved. On the other hand, a history of local mining with extremely severe environmental problems may result in negative attitudes toward additional mine development.

SOURCES OF POLLUTION DURING MINERAL EXTRACTION

As indicated in a previous section, all mining operations can be viewed as comprising a limited number of similar activities. The sequential activity stages mentioned previously may be further subdivided into basic operational activities which are similar from

458

mine to mine regardless of whether a given mining operation includes a few or all of them. For example, construction of stream crossings at different mines causes relatively similar environmental problems regardless of the type of mining involved.

In an analysis of mining impacts prepared under contract to the U.S. Fish and Wildlife Service, ERT and Hittman Associates, Incorporated (Moore and Mills 1977) developed a list of basic operational activities and their potential for generating specific types of environmental impacts. A modification of this list is shown in Table 1 (Streeter et al. 1979).* Obviously, this analysis is highly generalized and oriented toward environmental resource concerns present in the Western United States, but the same approach may be used for analyzing the potential effects of any given mining operation.

As shown in this analysis, primary sources for dust and other air pollutants include areas of initial surface disturbance, overburden removal and disposal operations, smelting or processing plant operations, and tailings disposal sites. Major sources of water pollution and sediments include areas of surface disturbance, overburden or waste rock disposal areas, smelters or other processing plants, and tailings disposal areas. Other potential environmental impacts may accompany changes in available water supplies, soils, vegetation and crops, topographic characteristics, and land use; or result from solid waste disposal, fires, direct livestock and wildlife mortality, and human disturbance and noise in the area. This table focuses on impacts of mining on environmental resources exclusive of hazards to human safety. A similar analysis could be performed with respect to human hazards.

In general, it can be shown that the majority of significant environmental impacts result from a small number of mining activities. Among these activities are the initial disturbance of land surfaces, dumping and storage of rock and earthern materials, excavation of earthern materials, earthmoving operations, distrubances of local stream channels, traffic to and from the site, disposal of tailings and wastes, and operation of on-site processing facilities. Efforts to control or mitigate environmental problems should be oriented toward those particular processes. As an example, in areas where severe water pollution occurs as a result of acid mine drainage from surface coal mines, the mines may be made environmentally acceptable if the acidic potential of the soil materal is neutralized, or if the material is selectively replaced to minimize or prevent weathering of the pyritic minerals. Often the substitution of one methodology for another may be used to overcome environmental problems. For example, the West German coal field of North-Rhine Westphalia could be mined by other, perhaps cheaper techniques, but the bucket wheel excavator and conveyor systems in use are conducive to the desired types of reclamation.

---

*Tables appear at the end of the paper.

459

TABLE 1

INTENSITY OF IMPACTS TO LOCAL BIOTA FROM VARIOUS MINING ACTIVITIES, SUMMARIZED BY MINE TYPE

Mining activity	Coal area surface	Coal underground	Coal contour surface	Uranium solution	Uranium small surface	Uranium large surface	Oil shale surface
Exploration	2[a]	2	3	2	2	2	2
Surface clearing	1	3	2	3	[illegible]	1	1
Construction of facilities	2	2	3	3	3	2	2
Excavation	1	3	2	–	3	1	1
Mineral removal	3	–	2	2	3	2	2
Mineral storage	2	2	3	3	3	2	2
Mineral transport	1	2	3	3	3	3	2
Operation of support facilities	2	2	2	2	3	1	1
Waste materials containment & disposal (including sediment)	2	2	2	3	3	1	1
Personnel transport	2	2	2	3	3	1	1
Employment	1	1	2	3	3	1	1
Reclamation	1	3	2	3	3	2	1

[a]1 = Major, 2 = Moderate, 3 = Slight, – = Unanticipated or insignificant.

(Source: Streeter et al. 197[illegible]).

460

INTERNATIONAL OVERVIEW OF MINERAL AND ENVIRONMENTAL PROBLEMS

As mentioned earlier, many industrialized nations process minerals for which they have no domestic ores. The highly important role of developing nations in world production of metals is shown in Table 2.

Table 3 presents a summary of the principle mineral commodities produced by individual nations and Table 4 identifies for individual minerals, the countries possessing known reserves, the major types of mining used, and the major environmental concerns associated with development of that mineral.

These summaries indicate that a large number of countries share, at least to some degree, environmental problems from both surface and underground mining of a wide variety of mineral products. Thus, it appears possible to learn from the experience of other mineral producing nations which possess similar developments.

It is also apparent from this view that the primary environmental problems associated with mineral extraction on a world-wide basis constitute a relatively short list, including:

- Excavation and extraction activities
  - Dust
  - Water pollution
    - sediments
    - leached chemicals from wastes and minerals
  - Visual intrusion
  - Land use conflicts
  - Reclamation difficulties (especially for open pit or dredge operations)
  - Noise
- Mineral processing activities
  - Dust
  - Fumes
    - SO_2 or acidic mist
    - trace elements
    - toxic mineral compounds
    - odor
  - Water pollution
    - accidental discharges and spillage
    - low level effluents
    - seepage from tailings impoundments
    - dumping of waste materials
  - Visual impacts

461

TABLE 2

DISTRIBUTION OF WORLD METAL PRODUCTION 1978.[1]
(Percent)

Countries	Alumina	Aluminum	Copper (smelted)	Copper (refined)	Lead	Nickel	Tin	Zinc
	Metal							
United States	20.5	31.4	16.8	19.1	17.9	6.3	2.0	7.5
Other developed countries	45.5	42.7	29.1	33.9	36.1	50.6[2]	14.0	52.8
Developing countries	17.0	7.0	32.0	20.7	15.3	15.2	62.0	9.2
Centrally planned economies	17.0	18.9	22.1	26.3	30.7	27.9	22.0	30.5
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

[1]Preliminary data.

[2]Includes New Caledonia, a French territory.

(Sources: U.S. Secretary of Interior 1979).

462

TABLE 3

SUMMARY OF INTERNATIONAL MINERAL PRODUCTION BY COUNTRY
(SOURCE: U. S. BUREAU OF MINES 1973).

Country	Metals[1]	Nonmetals[2]	Mineral Fuels
Algeria	Antimony Copper Iron Lead Mercury Silver	Barite Cement Bentonite Diatomite Phosphate Gypsum Lime Pyrite Salt Sulfur	Coal Natural gas Petroleum
Angola	Iron Manganese	Cement Diamonds Gypsum Kaolin Salt	Natural gas Petroleum
Argentina	Beryllium Columbian-tantalum Copper Iron Lead Manganese Silver Tin Tungsten Uranium Zinc	Asbestos Barite Bentonite Boron Cement Chalk Diatomite Feldspar Fluorspar Graphite Gypsum Kaolin Lithium Mica Pumice Salt Sulfur Sulfates Talc Vermiculite	Coal Natural gas Petroleum

[1]Various of the minerals shown, especially for the industrialized European nations, result from processing of imported ores rather than from ores produced locally. To the extent practical, mineral production from imported ores has been deleted from this summary.

[2]Not including common varieties of sand, gravel, and stone; nor full listing of clays and fertilizer materials.

463

TABLE 3 (Continued)

Country	Metals[1]	Nonmetals[2]	Mineral Fuels
Australia	Antimony Bauxite Bismuth Cadmium Cobalt Columbian-tantalum Copper Gold Iron Lead Manganese Monazite Nickel Platinum Selenium Silver Tin Titanium Tungsten Uranium Zinc Zirconium	Asbestos Barite Bentonite Cement Diatomite Feldspar Gem Stone Gympsum Kaolin Lime Lithium Magnesite Phosphate Pyrites Salt Talc	Coal Natural gas (limited) Petroleum (limited)
Austria	Antimony Bauxite Copper Germanium Iron Lead Manganese Silver Zinc	Barite Cement Diatomite Feldspar Graphite Gypsum Kaolin Lime Magnesite Pumice Salt Sulfur Talc	Lignite Natural gas Petroleum (limited)
Belgium and Luxembourg		Cement Gypsum Lime	Coal
Bolvia	Antimony Bauxite Copper Gold Iron Lead Silver Tin Tungsten Zinc	Gypsum Sulfur	Natural gas Petroleum

TABLE 3 (Continued)

Country	Metals[1]	Nonmetals[2]	Mineral Fuels
Brazil	Arsenic Bauxite Berylium Chromite Columbium-tantalum Copper Gold Iron Lead Manganese Monazite Nickel Silver Tin Titanium Tungsten Zinc Zirconium	Asbestos Barite Cement Diamond Fluorspar Gem Stone Graphite Gypsum Lime Lithium Magnesite Mica Phosphate Quartz Salt Talc Vermiculate	Coal Natural gas Petroleum
Bulgaria	Cadmium Copper Iron Lead Manganese Zinc	Asbestos Cement Gypsum Kaolin Lime Pyrite Salt	Lignite Natural gas (limited) Petroleum (limited)
Burma	Antimony Copper Iron (limited production) Lead Silver Tin Tungsten Zinc	Barite Gypsum Gem Stones	Coal Natural gas (limited) Petroleum (limited)
Canada	Bismuth Cadmium Calcium Cobalt Columbium Copper Gold Iron Lead	Asbestos Barite Cement Diatomite Feldspar Fluorspar Gypsum Lime Magnesite Potash	Coal Natural gas Petroleum Tar sand

465

TABLE 3 (Continued)

Country	Metals[1]	Nonmetals[2]	Mineral Fuels
Canada (Con't)	Magnesium Mercury Molybdemum Nickel Platinum & Related Metals Selenium Silver Tellurium Titanium Tungsten Uranium Yttrium Zinc	Pyrite Salt Strontium Sulfur Talc	
Chile	Copper Gold Iron Manganese Mercury Molybdenum Silver Zinc	Barite Cement Feldspar Gem Stones Gypsum Iodine Kaolin Nitrates Phosphate Quartz Salt Sulfate Sulfur Talc	Coal Natural gas Petroleum
China	Antimony Bauxite Bismuth Copper Gold Iron Lead Magnesium Manganese Mercury Molybdenum Silver Tin Tungsten Zinc	Asbestos Barite Cement Fluorspar Graphite Gypsum Magnesite Phosphate Pyrite Salt Sulfur Talc	Coal Natural gas Petroleum Shale Oil
Columbia	Gold Iron	Asbestos Barite	Coal Natural gas

466

TABLE 3 (Continued)

Country	Metals[1]	Nonmetals[2]	Mineral Fuels
Columbia (Con't)	Mercury Nickel Platinum Silver	Cement Diatomite Feldspar Gem Stones Gypsum Kaolin Lime Salt Talc	Petroleum
Cyprus	Chromite Copper	Asbestos Bentonite Cement Gypsum Lime Pyrites Salt	
Czechoslovakia	Antimony Copper Iron Lead Manganese Mercury Nickel Silver Uranium Zinc	Barite Cement Fluorspar Gypsum Kaolin Lime Magnesite Perlite Phosphate Pyrite Salt	Coal Lignite Natural gas Petroleum
Egypt	Iron Manganese Titanium	Cement Diatomite Feldspar Kaolin Phosphate Salt Talc	Natural gas Petroleum
Finland	Chromite Cobalt Copper Gold Iron Lead Mercury Nickel Platinum Selenium Silver	Asbestos Cement Feldspar Lime Pyrite Talc	

467

TABLE 3 (Continued)

Country	Metals[1]	Nonmetals[2]	Mineral Fuels
Finland (cont'd)	Titanium Vanadium Zinc		
France	Arsenic Bauxite Bismuth Cadmium Cobalt Gold Iron Lead Magnesium Silver Tin Uranium Vanadium Zinc	Asbestos Barite Bentonite Bromine Cement Diatomite Feldspar Fluorspar Gypsum Kaolin Lime Mica Phosphatic chalk Potash Pumice Quartz Salt Sulfur Talc	Lignite Natural gas Petroleum
Gabon	Gold Iron Manganese Uranium		Natural gas Petroleum
East Germany	Copper Iron Lead Silver Tin Zinc	Barite Boron Cement Fluorspar Gypsum Lime Potash Pyrite Salt Sulfur	Coal Lignite Natural gas Petroleum (limited)
West Germany	Bauxite Bismuth Cadmium Cobalt Copper Gold Iron	Barite Bromine, fluorine, iodine Cement Diatomite Feldspar Fluorspar	Coal Lignite Natural gas Petroleum

468

TABLE 3 (Continued)

Country	Metals[1]	Nonmetals[2]	Mineral Fuels
West Germany (Cont'd)	Lead Nickel Platinum Silver Zinc	Graphite Gypsum Kaolin Lime Potash Pumice Pyrite Quartz Salt Sulfur	
Ghana	Bauxite Beryllium Gold Manganese	Cement Diamond Salt	Petroleum
Greece	Bauxite Chromium Iron Lead Manganese Nickel Zinc	Barite Bentonite Cement Gypsum Magnesite Kaolin Pumice Salt Talc	Lignite
Hungary	Bauxite Gold Iron Lead Manganese Silver Zinc	Cement Bentonite Kaolin Lime Pyrite Talc	Coal Lignite Natural gas Petroleum
India	Bauxite Beryllium Chromite Copper Gold Iron Lead Manganese Monazite Silver Titanium	Asbestos Barite Cement Chalk Diamond Feldspar Fluorspar Gem Stones Gypsum Kaolin Lime	Coal Lignite Natural gas Petroleum

469

TABLE 3 (Continued)

Country	Metals[1]	Nonmetals[2]	Mineral Fuels
India (Cont'd)	Uranium Zinc	Magnesite Mica Phosphate Quartz Salt Talc Vermiculite	
Indonesia	Bauxite Copper Gold Iron Manganese Mercury Nickel Silver Tin	Barite Cement Diamond Kaolin Salt Sulfur	Coal Natural gas Petroleum
Iran	Bauxite Chromite Copper Iron Lead Manganese Zinc	Barite Bentonite Cement Gem Stones Gypsum Kaolin Lime Magnesite Salt Sulfates Sulfur	Natural gas Petroleum
Iraq	Iron	Cement Sulfur	Natural gas Petroleum
Ireland	Copper Lead Mercury Silver Zinc	Barite Cement Gypsum Lime	Coal Petroleum
Israel	Copper Iron	Cement Lime Phosphate	Natural gas (limited) Petroleum (limited)
Italy	Antimony Bauxite Cadmium Copper Iron Lead	Asbestos Barite Bentonite Cement Diatomite Feldspar	Coal (limited) Lignite Natural gas Petroleum

470

TABLE 3 (Continued)

Country	Metals[1]	Nonmetals[2]	Mineral Fuels
Italy (Cont'd)	Magnesium Manganese Mercury Mercury Silver Zinc	Fluorspar Graphite Gypsum Lime Perlite Potash Pumice Pyrite Salt Sulfur Talc	
Japan	Arsenic Bismuth Cadmium Chromite Columbium-tantalum Copper Germanium Gold Iron Lead Manganese Mercury Silver Tin Tungsten Uranium Zinc	Asbestos Barite Cement Feldspar Graphite Gypsum Koalin Lime Pyrite Sulfur Talc	Coal Petroleum (limited)
Kenya	Copper Gold Lead Silver	Barite Cement Diatomite Feldspar Gem Stones Gypsum Kaolin Lime Magnesite Salt Soda ash	
North Korea	Cadmium Copper Gold	Barite Cement Fluorspar	Coal

471

TABLE 3 (Continued)

Country	Metals[1]	Nonmetals	Mineral Fuels
North Korea (Con't)		Iron Magnesite Phosphorus Pyrite Salt Talc	Graphite
South Korea	Antimony Bismuth Copper Gold Iron Lead Manganese Molybdenum Silver Tungsten Zinc	Asbestos Cement Diatomite Feldspar Graphite Kaolin Salt Talc	Coal
Kuwait		Lime Salt Sulfur	Natural gas Petroleum Petroleum
Liberia	Gold Iron	Cement Diamond Kyanite	
Libya	Iron	Cement Gypsum Salt	Natural gas Petroleum
Malaysia	Antimony Bauxite Columbium-tantalum Copper Iron Manganese Monazite Tin Titanium Tungsten Zirconium	Cement Koalin	Petroleum
Mexico	Antimony Arsenic Bismuth	Barite Bentonite Cement	Coal Natural gas Petroleum

472

TABLE 3 (Continued)

Country	Metals[1]	Nonmetals[2]	Mineral Fuels
Mexico (Con't)	Cadmium Copper Gold Iron Lead Manganese Mercury Molybdenum Nickel Selenium Silver Tin Tungsten Zinc	Diatomite Feldspar Fluorspar Graphite Gypsum Kaolin Magnesite Mica Perlite Phosphate Salt Strontium Sulfur Sulfates Talc	
Morocco	Antimony Cobolt Copper Iron Lead Manganese Nickel Silver Tin Zinc	Barite Bentonite Cement Fluorspar Phosphate Pyrrhotite Salt	Coal (limited) Natural gas (limited) Petroleum (limited)
Mozambique	Bauxite Beryllium Cesium Columbium-tantalum Copper Iron Nickel Uranium	Asbestos Bentonite Cement Fluorspar Gem Stones Kaolin Lime Quarz	
Netherlands		Cement	Natural gas (off-shore) Petroleum (off-shore)
New Zealand	Bauxite Cadmium Copper Gold Iron Lead Silver Tunsten Zinc	Cement Bentonite Diatomite Kaolin Limestone Magnesite Perlite Pumice Salt Sulfur	Coal Natural gas Petroleum (limited)

473

TABLE 3 (Continued)

Country	Metals[1]	Nonmetals[2]	Mineral Fuels
Nigeria	Columbium Gold Iron Monazite Tin	Cement Kaolin Limestone	Coal Natural gas Petroleum
Norway	Copper Iron Lead Molybdenum Nickel Titanium Vanadium Zinc	Cement Feldspar Graphite Lime Mica Olivine Pyrite Sulfur Talc	Coal (limited) Natural gas Petroleum (off-shore)
Pakistan (Including Bangladesh)	Antimony Arsenic Bauxite Chromite Iron Platinum Uranium	Barite Cement Gem Stones Gypsum Salt	Coal (limited) Petroleum (limited)
Peru	Antimony Arsenic Bismuth Cadmium Copper Gold Indium Iron Lead Manganese Mercury Silver Tellurium Tin Tungsten Zinc	Barite Bentonite Cement Diatomite Feldspar Gypsum Kaolin Lime Phosphate (guano) Salt Talc	Coal Natural gas
Phillipines	Bauxite Cadmium Chromite Copper Gold Iron	Asbestos Bentonite Cement Diatomite Feldspar Gypsum	Coal

474

TABLE 3 (Continued)

Country	Metals[1]	Nonmetals[2]	Mineral Fuels
Phillipines (Con't)	Lead Manganese Mercury Molybdenum Nickel Platinum Silver Zinc	Lime Perlite Phosphate Pyrite Sulfur Talc	
Poland	Copper Iron Lead Nickel Silver Zinc	Barite Bentonite Cement Feldspar Gypsum Magnesite Phosphates Pyrite Salt Sulfur	Coal Natural gas Petroleum (limited)
Portugal	Arsenic Beryllium Columbium-tantalium Copper Gold Iron Lead Manganese Molybdenum Silver Tin Titanium Tungsten Uranium Zinc	Asbestos Barite Cement Diatomite Feldspar Gypsum Kaolin Lime Lithium Mica Pyrite Salt Sulfur Talc	Coal (limited)
Romania	Bauxite Bismuth Cadmium Copper Gold Iron Lead Manganese Silver Zinc	Barite Bentonite Cement Fluorspar Graphite Kaolin Lime Pyrite Salt Talc	Coal Lignite Natural gas Petroleum

475

TABLE 3 (Continued)

Country	Metals[1]	Nonmetals[2]	Mineral Fuels
Saudi Arabia	Copper Lead Silver Zinc	Cement Gypsum Lime Sulfur	Natural gas Petroleum
Sierra Leone	Bauxite Iron Titanium	Cement Diamond	
Republic of South Africa	Antimony Beryllium Bismuth Chromite Columbium-tantalum Copper Gold Iron Manganese Nickel Platinum Silver Tin Titanium Tungsten Uranium Vanadium Zinc Zirconium	Asbestos Barite Bentonite Cement Corundum Diamond Diatomite Feldspar Fluorspar Gem Stones Graphite Gypsum Kaolin Lime Lithium Magnesite Mica Phosphate Pyrite Quartz Salt Talc Vermiculite	Coal
South-West Africa	Arsenic Bismuth Cadmium Cesium Columbium-tantalum Copper Gold Iron Lead Manganese Molybdenum Silver Tin Tungsten Vanadium Zinc	Diamond Fluorspar Graphite Lime Lithium Mica Gem Stones Salt	

476

TABLE 3 (Continued)

Country	Metals[1]	Nonmetals[2]	Mineral Fuels
Spain	Bauxite Antimony Arsenic Bismuth Cadmium Copper Iron Lead Manganese Mercury Silver Tin Titanium Tungsten Uranium Zinc	Barite Bentonite Cement Chalk Diatomite Feldspar Fluorspar Gypsum Kaolin Lime Mangesite Pumice Phosphate Potash Pyrite Salt Strontium Sulfur Sulfates Talc	Coal Lignite Petroleum
Sweden	Arsenic Bismuth Copper Gold Iron Lead Manganese Selenium Silicon Silver Uranium Zinc	Cement Chalk Diatomite Feldspar Kaolin Limestone Pyrite Talc	Coal (limited) Oil Shale (limited)
Tanzania	Gold Silver Tin Tungsten	Cement Diamond Gem Stones Gypsum Kaolin Lime Magnesite Mica Salt Vermiculite	Coal

477

TABLE 3 (Continued)

Country	Metals[1]	Nonmetals[2]	Mineral Fuels
Taiwan	Copper Gold Silver	Asbestos Cement Limestone Pyrite Sulfur Talc	Coal Natural gas Petroleum (limited)
Thailand	Antimony Chromite Columbium - tantalum Iron Lead Manganese Monazite Tin Tungsten Zinc Zirconium	Barite Cement Fluorspar Gypsum Kaolin Talc	Lignite Petroleum (limited)
Tunisia	Iron Lead Mercury Silver Zinc	Barite Cement Fluorspar Gypsum Lime Phosphate	Natural gas Petroleum
Turkey	Antimony Bauxite Chromite Copper Iron Lead Manganese Mercury Zinc	Asbestos Barite Boron Cement Emery Fluorspar Gypsum Magnesite Phosphate Pyrite Salt Sulfur	Coal Lignite Petroleum
Uganda	Beryllium Bismuth Columbium - tantalum Copper Gold Iron Tin Tungsten	Cement Lime Phosphate	

478

TABLE 3 (Continued)

Country	Metals[1]	Nonmetals[2]	Mineral Fuels
U.S.S.R.	Antimony Arsenic Bauxite Beryllium Bismuth Cadmium Chromite Cobalt Copper Gold Iron Lead Magnesium Manganese Mercury Molybdenum Nickel Platinum Silver Tin Titanium Tungsten Vanadium Zinc	Asbestos Barite Boron Cement Corundum Diamond Diatomite Feldspar Fluorspar Graphite Gypsum Kaolin Lime Magnesite Mica Phosphate Potash Pyrite Salt Sulfur Talc	Coal Lignite Natural gas Oil Shale Petroleum
United Kingdom	Cadmium Copper Iron Lead Magnesium Nickel Tin Tungsten Zinc	Barite Cement Chalk Diatomite Feldspar Fluorspar Gypsum Kaolin Salt Strontium Talc	Coal Natural gas (off-shore) Petroleum (off-shore)
Venezuela	Gold Iron	Cement Diamond Gypsum Limestone Phosphate Salt	Coal Natural gas Petroleum

479

TABLE 3 (Continued)

Country	Metals[1]	Nonmetals[2]	Mineral Fuels
Yugoslavia	Bauxite Antimony Bismuth Cadmium Chromite Copper Gold Iron Lead Manganese Mercury Selenium Silver Zinc	Asbestos Barite Cement Feldspar Gypsum Lime Magnesite Mica Phosphate Pyrite Salt	Coal Lignite Natural gas
Zaire	Beryllium Cadmium Cobalt Columbium - tantalum Copper Germanium Gold Manganese Monazite Silver Tin Tungsten Zinc	Cement Diamond	Coal Petroleum (limited)
Zambia	Calmium Cobalt Copper Gold Manganese Selenium Silver Zinc	Amethyst Cement Gypsum Lime Talc	Coal (limited)
Other Central American Countries			
British Hondoros		Limestone	
Costa Rica	Gold	Cement Diatomite Limestone	

480

TABLE 3 (Continued)

Country	Metals[1]	Nonmetals[2]	Mineral Fuels
Other Central American Countries (Cont'd)			
El Salvador	Gold Silver	Cement Gypsum Limestone Salt	
Guatamala	Antimony Iron Lead Zinc	Cement Feldspar Gypsum Limestone Quartz	
Honduras	Antimony Cadmium Gold Lead Silver Zinc	Cement Gypsum Salt	
Nicaragua	Copper Gold Silver Zinc	Cement Gypsum Salt	
Panama	Iron	Cement Limestone Salt	
Other South American Countries			
Ecuador	Cadmium Copper Gold Silver Zinc	Cement Kaolin Sulfur	Natural gas Petroleum
French Guiana	Gold	Clays	
Guyana	Bauxite Gold	Diamond	
Paraguay		Cement Gypsum Kaolin Lime Talc	

481

TABLE 3 (Continued)

Country	Metals[1]	Nonmetals[2]	Mineral Fuels
Surinam	Bauxite Gold	Clays	
Uruguay	Iron	Cement Clays Feldspar Gem Stones Sulfur Talc	
Other European Countries			
Albania	Chromite Copper Iron	Cement	Lignite Petroleum
Denmark (Including Greenland)	Iron Lead Zinc	Cement Diatomite Lime Salt	Lignite Petroleum
Iceland		Cement Diatomite Pumice	
Switzerland		Cement Gypsum Lime Salt	
Other African Countries			
Botswana	Copper Manganese Nickel	Diamond Gem Stones Talc	
Burundi	Bastnaesite Columbium-tantalum Gold Tin Tungsten	Lime	
Cameroon	Gold Tin	Cement	
Central African Republic		Diamond	
Chad		Sodium carbonate	

482

TABLE 3 (Continued)

Country	Metals[1]	Nonmetals[2]	Mineral Fuels
Congo (Brazzaville)	Copper Gold Lead Tin Zinc	Potash	Natural gac Petroleum
Ethiopia	Gold Platinum	Cement Feldspar Gypsum Kaolin Limestone Pumice Salt	
Guinea	Bauxite Gold	Diamond	
Ivory Coast	Columbium-tantalum Manganese	Cement Diamond	
Lesotho		Diamond	
Malagasy Republic	Bastnaesite Beryllium Chromite Gold Monazite Zirconium	Cement Corundum Feldspar Garnet Gem Stones Graphite Mica Quartz Salt	
Malawi		Cement Corundum Kyanite Limestone Salt	
Mali	Gold	Salt	
Mauritania	Copper Iron Monazite	Salt	
Mauritius		Salt	

483

TABLE 3 (Continued)

Country	Metals[1]	Nonmetals[2]	Mineral Fuels
Other African Countries (Con't)			
Niger	Gold Tin Tungsten Uranium	Cement Gypsum Salt Limestone	
Rhodesia	Beryllium Chromite Columbium-tantalum Copper Gold Iron Nickel	Asbestos Cement Fluorspar Graphite Limestone Lithium Magnesite Mica Pyrite	Coal
Rwanda	Veryllium Columbium-tantalum Tin Tungsten		
Sengal		Cement Clay Phosphate Salt	
Somali		Salt	
Sudan	Chromite Iron Manganese	Cement Gypsum Magnesite Mica Salt	
Swaziland	Iron Tin	Asbestos Barite Kaolin Talc	Coal
Togo		Cement Clay Phosphate	

484

TABLE 3 (Continued)

Country	Metals[1]	Nonmetals[2]	Mineral Fuels
Other Near East Countries			
Bahrain			Natural gas Patroleum
Jordan		Cement Gypsum Limestone Phosphate Salt	
Lebanon		Cement Gypsum Lime Salt	
Oman			Natural gas Petroleum
People's Democratic Republic of Yemen			
Qatar		Cement	Natural gas Petroleum
Syrian Arab Republic		Cement Gypsum Salt	Petroleum
United Arab Emirates			
Abu Dhabi			Natural gas Petroleum
Dubai			Natural gas Petroleum
Yemen		Salt	
Other Far Eastern and South Asian Countries			
Afghanistan		Cement Gem Stones Salt	Coal Natural gas
Brunei			Natural gas Petroleum

485

TABLE 3 (Continued)

Country	Metals[1]	Nonmetals[2]	Mineral Fuels
Other Far Eastern and South Asian Countries (Con't)			
Sri Lanka	Monazite Titanium Zirconium	Cement Feldspar Gem Stones Graphite Kaolin Limestone Mica Salt	
Hong Kong		Cement Feldspar Graphite Kaolin Quartz	
Khmer Republic	Gold	Cement Gem Stones Phosphate Salt	
Laos	Tin	Salt	
Mongolia		Cement Fluorspar Gypsum Lime Salt	Coal Petroleum
Singapore		Cement	
North Vietnam		Cement Phosphate Salt	Coal
South Vietnam		Cement Kaolin Limestone Salt	

486

TABLE 4

SUMMARY OF MAJOR MINERAL RESOURCES, THEIR INTERNATIONAL DISTRIBUTION, MOST COMMON EXTRACTION METHODS, AND PRINCIPAL ENVIRONMENTAL CONCERNS (SOURCE: BUREAU OF MINES 1970)

Minerals	Distribution of Known Major Deposits[1]		Primary Extraction Methods[2]	Principal Environmental Concerns
Energy Minerals				
Coal and Lignite	United States U.S.S.R. China Belgium France West Germany	North Vietnam North Korea South Korea United Kingdom Rep. S. Africa Netherlands	R&PUG CSM ASM	• subsidence • acid water drainage • solid waste disposal • surface reclamation
Natural Gas	United States U.S.S.R. Algeria Iran Netherlands	Saudi Arabia Canada Kuwait United Kingdom	Wells	• usually minor
Petroleum	Saudi Arabia Kuwait U.S.S.R. United States Libya Iraq	Abu Dhabi Venezuela China Indonesia Canada Algeria	Wells	• water pollution (brine discharge) • air pollution related to consumption • spills in transport
Oil Shale and Tar Sands	United States Brazil Canada China Rep. S. Africa	Uruguay Paraguay Australia Spain France	R&PUG OPSM ISR	• solid waste disposal • water pollution • water consumption for • air pollution • surface reclamation
Uranium	United States Canada Rep. S. Africa U.S.S.R. France Spain Australia Sweden	Argentina Portugal Zaire Nigeria Morocco India Japan	OPSM R&PUG SUG LWUG SOI	• tailings disposal • water pollution from processing • radiation during all stages from mining to disposal of spent fuel • reclamation of mine and tailings

487

TABLE 4 (Continued)

Minerals	Distribution of Known Major Deposits[1]		Primary Extraction Methods[2]	Principal Environmental Concerns
Ferrous Minerals				
Chromium (chromite)	Rep. S. Africa Rhodesia U.S.S.R. Turkey United States Greece	Phillipines Finland Canada Greenland India Yugoslavia	OPSM R&PUG	• air pollution related to processing
Cobalt	Zaire Cuba New Caledonia Zambia	U.S.S.R. Canada United States Morocco	(Recovered as byproduct of other metals) OPSM SUG	• same as concerns for major metals with which it is mined. (iron, copper, nickel)
Columbium	Brazil Canada U.S.S.R. Nigeria Uganda Tanzania Kenya	Zaire Norway Rwanda Malaysia Thailand Guyana United States	(Recovered principally as byproduct of tin) DSM OPSM SUG	• water pollution (sedimentation)
Iron	U.S.S.R. Canada Australia United States Venezuela Brazil Chile Peru	Liberia Morocco Mauritania Guinea Sierra Leone Angola India Rep. S. Africa	OPSM R&PUG	• water pollution (chemical) and thermal) • tailings disposal • pit reclamation • air pollution from dust and processing
Manganese	Rep. S. Africa U.S.S.R. Gabon United States	Brazil Australia India China	OPSM R&PUG LWGU SUG	• water pollution (chemical and thermal) • air pollution from dust and processing
Molybdenum	United States U.S.S.R. Chile Canada	Japan Norway Turkey Mexico	OPSM SUG	• reclamation of pits • tailings disposal • air pollution related to processing

TABLE 4 (Continued)

Minerals	Distribution of Known Major Deposits[1]		Primary Extraction Methods[2]	Principal Environmental Concerns
Nickel	Cuba New Caledonia U.S.S.R. Canada Indonesia	Philippines Australia Guatemala Dominican Rep. United States	SUG OPSM	• reclamation of pits • water pollution related to processing
Rhenium	United States U.S.S.R. Chile	Peru Mexico Zaire Canada	(Recovered as by-product with copper and molybdenum)	• minor except as related to processing of copper and molybdenum
Tantalum	Zaire Brazil Nigeria French Guiana U.S.S.R.	Mozambique Thailand Australia Canada United States	(Recovered as by-product of tin processing) DSM	• water pollution (sedimentation)
Tungsten	China United States South Korea Bolivia Burma	Brazil Malaysia U.S.S.R. Australia Canada Portugal	SUG OPSM	• minor
Vanadium	U.S.S.R. United States Rep. S. Africa Australia	India Finland Norway South-West Africa	(Recovered as coproduct with other metals, uranium, and phosphates)	• same as the specific coproducts involved
Nonferrous Minerals				
Aluminum (bauxite)	Australia Guinea Jamaica U.S.S.R. Ghana Surinam Yugoslavia Hungary China	Dominican Rep.&Hati Greece Guyana Fr. Guiana France India Malawi United States Brazil Turkey	OPSM R&PUG	• pit reclamation • waste disposal from processing • air pollution during processing • water pollution from tailings and processing

489

TABLE 4 (Continued)

Minerals	Distribution of Known Major Deposits[1]	Primary Extraction Methods[2]	Principal Environmental Concerns
Antimony	China Bolivia Rep. S. Africa U.S.S.R. Mexico Turkey United States Australia	(Usually mined as a coproduct with lead, silver, or gold, often in small shafts or adits) SUG	• same as the specific coproducts involved
Arsenic	United States Mexico France Japan Peru Sweden U.S.S.R.	(Recovered as a byproduct of product of processing other minerals, especially copper)	• highly toxic • often a component of smelter stack gas
Beryllium	United States (No data for other countries)	(Beryl is normally recovered as a coproduct with feldspar, mica, lithium, columbite, tantalite, or cassiterite in granite pegmatites) Small OPSM	• dust and fumes potentially toxic to susceptible individuals
Bismuth	Japan United States Mexico Peru U.S.S.R. Boliva Canada South Korea France Yugoslavia	(Recovered as a byproduct with lead, copper, tungsten and gold)	• same as the principal ores involved.
Cadmium	(Same as zinc distribution)	(Recovered as a byproduct of zinc processing	• Cadmium fumes are extremely toxic. Other concerns same as for zinc
Cesium	Canada Rhodesia South-West Africa Mazambique United States	(Surface mined as lucite or recovered as coproduct from granite pegatites)	• minor due to low consumption levels

TABLE 4 (Continued)

Minerals	Distribution of Known Major Deposits(1)	Primary Extraction Methods(2)	Principal Environmental Concerns
Copper	United States, Chile, U.S.S.R., Zambia, Peru, Zaire, Canada, China, Australia, Phillippines, Poland, Rep. S. Africa	OPSM SUG	• tailings and waste disposal • land use conflicts • air pollution as dust and smelter fumes • water consumption
Germanium	(Distribution parallels that of zinc, fluorspar, and some coals)	(Recovered as a minor byproduct from zinc ores)	• same as for zinc
Gold	Rep. S. Africa, U.S.S.R., Canada, Australia, United States, Colombia, Rhodesia	SUG OPSM DSM	• land use conflicts • tailings disposal • air pollution as dust and smelter fume • water pollution, especially with dredging
Lead	(Deposits of ore present in more than 50 countries) United States, Canada, Australia, Yugoslavia, U.S.S.R., China, Mexico, Morocco, Peru, South-West Africa	SUG R&PUG OPSM	• air and water pollution from smelters • toxicities to local biota • waste disposal
Magnesium	(Unlimited resources as dolomite, sea water, or well brines in almost all countries. List below based on magnesite reserves) China, North Korea, New Zealand, U.S.S.R., India, Czechoslovakia, Austria, United States	OPSM SUG	• air pollution from processing • possible fire hazards
Mercury	Spain, Italy, China, Yugoslavia, U.S.S.R., United States, Czechoslovakia, Japan, Mexico, Philippines, Turkey	SUG OPSM	• potential toxicities to employees and local populace • air and water pollution from processing

491

TABLE 4 (Continued)

Minerals	Distribution of Known Major Deposits(1)	Primary Extraction Methods(2)	Principal Environmental Concerns
Platinum and Related Minerals	Rep. S. Africa U.S.S.R. Canada Colombia United States Rhodesia Ethiopia	(Mined in small quantities as lode and placer deposits) SUG DSM (Also recovered as byprodcut from gold and copper ore)	• water pollution (dredging) • generally same concerns as for copper
Radium	Current demands are primarily met from existing stocks and secondary sources. Some primary production occurs as ore from Zaire is processed in Belgium.		• none related to present production • some health hazards exist at previous processing sites due to radon release from old tailings
Rare Earth Elements	United States India Australia U.S.S.R. Brazil Egypt Malagasy Rep. South Korea Canada Taiwan Malawi Sri Lanka	(Recovered on world wide basis from monazite and from bastnaesite within United States. Monazite is a common byproduct of titanium mining) DSM	• water pollution from dredging
Selenium	United States Chile U.S.S.R. Zambia Peru Zaire Canada	(Recovered as a byproduct of copper and lead refining)	• same as for copper
Silver	U.S.S.R. United States Mexico Canada Peru Australia Bolivia Honduras Rep. S. Africa	OPSM (Normally produced as coproduct or byproduct with copper, lead, or zinc)	• air pollution from processing • water pollution from tailings • waste disposal
Tellurium	United States Chile U.S.S.R. Zambia Peru Zaire Canada	(Recovered as a byproduct of copper refining)	• same as for copper • tellurium and related compounds are toxic at low concentrations

Best Available Document

TABLE 4 (Continued)

Minerals	Distribution of Known Major Deposits[1]		Primary Extraction Methods[2]	Principal Environmental Concerns
Thallium	Distributed similar to zinc reserves		(Recovered as a by-product of zinc processing)	• same as for zinc • thallium and related compounds are toxic and may accumulate in the body over a period of time
Tin	Thailand Malaysia Indonesia China Bolivia U.S.S.R. Zaire Nigeria Australia	Burma United Kingdom Canada France Japan North Korea South Korea Portugal Rep. S. Africa Tanzania	DSM OPSM SUG	• water pollution from dredging • air pollution from smelting • use of tin as a lining for cans hinders reprocessing of the cans for scrap iron
Titanium (Ilmenite ore	Norway U.S.S.R. United States Canada India Egypt Australia	Sri Lanka Spain China Japan Finland Malaysia Brazil	DSM OPSM	• water pollution from dredging • disposal of waste slimes • disposal of waste iron sulfate from processing
(Rutile ore)	Australia Sierra Leone Canada United States	Sri Lanka U.S.S.R. India		
Yttrium	India United States Australia Egypt Canada Brazil	U.S.S.R. Malagasy Rep. South Korea Malawi Taiwan Rep. S. Africa Sri Lanka	(Recovered from monazite-DSM, and as a byproduct from uranium processing-OPSM)	• water pollution from dredging and tailings disposal • radiological aspects when produced with uranium

493

TABLE 4 (Continued)

Minerals	Distribution of Known Major Deposits[1]		Primary Extraction Methods[2]	Principal Environmental Concerns
Zinc	Commercial grade deposits located in over 50 countries Major reserves in:			
	United States Canada Australia China U.S.S.R.	Ireland Mexico Morocco Peru South-West Africa Yugoslavia	SGU	• subsidence • dust and water pollution • disposal of waste rock and tailings • fumes from smelters
Zirconium (Ilmenite ore)	United States U.S.S.R. India Australia Sri Lanka	Rep. S. Africa Egypt Malagasy Rep. Brazil Thailand	DSM (Commonly mined with titanium)	• water pollution from dredging • disposal of waste slimes • disposal of iron sulfates from processing
(Rutile ore)	Australia Sierra Leone			
Nonmetallic Minerals				
Asbestos	Canada U.S.S.R. Rep. S. Africa Rhodesia China United States Italy	Swaziland Japan Cyprus Finland Yugoslavia Australia Bolivia	OPSM SUG	• health hazards are present throughout the processing and consumption cycle. Fibers are considered carcinogenic.
Barium (barite)	United States China U.S.S.R. West Germany Mexico Canada Japan Thailand Peru	Brazil Rhodesia Pakistan Algeria Liberia North Korea Morocco Chile Argentina	OPSM SUG	• tailings dust and disposal

TABLE 4 (Continued)

Minerals	Distribution of Known Major Deposits[1]	Primary Extraction Methods[2]	Principal Environmental Concerns
Boron	United States U.S.S.R. Turkey Argentina Chile	OPSM	• minor with respect to production
Bromine	United States U.S.S.R. France Israel Japan West Germany	(Primarily recovered from brines of saline lakes)	• objectionable odors and fumes from processing facilities
Calcium (Limestone, dolomite, chalk)	Abundant in most countries	OPSM SUG	• land use conflicts • reclamation of abandoned quarries • noise and dust near population centers
Clays (bentonite and kaolin, plus ball clay, fire clay, and fuller's earth)	Most types of clay are widely distributed around the world	OPSM	• noise, dust, and visual appearance of mines near population centers • land use conflicts • reclamation of pits • sedimentation to local streams
Corundum	U.S.S.R. Rhodesia Rep. S. Africa India Malawi Mozambique Malagasy Rep. Brazil Malaysia	OPSM	• noise and blasting near population centers
Emery	Turkey United States Greece West Germany U.S.S.R.	OPSM	• noise and blasting near population centers

495

TABLE 4 (Continued)

Minerals	Distribution of Known Major Deposits(1)		Primary Extraction Methods(2)	Principal Environmental Concerns
Diamonds	Zaire Rep. S. Africa Ghana U.S.S.R. Sierra Leone Angola	Guinea South-West Africa Tanzania Brazil Venezuela (Other African countries)	OPSM SUG	• land use conflicts • reclamation of abandoned pits • waste rock disposal
Diatomite	United States U.S.S.R. France West Germany Italy Algeria (Plus about 20 other countries)		OPSM	• reclamation of abandoned pits • disposal of waste rock
Feldspar	Abundant in most countries		OPSM SUG	• reclamation of abandoned pits • land use conflicts • disposal of waste rock
Fluorine (fluorspar)	Mexico U.S.S.R. Spain China Thailand France United States Italy	United Kingdom Rep. S. Africa West Germany Canada East Germany Mongolia South Korea North Korea Japan	SUG R&PUG OPSM	• disposal of waste rock • air and water pollution from processing
Garnet	United States U.S.S.R. India Australia Spain Argentina		OPSM DSM	• minor
Graphite	South Korea North Korea U.S.S.R. Mexico China Austria	Malagasy Rep. West Germany Sri Lanka Norway United States	SUG	• minor

TABLE 4 (Continued)

Minerals	Distribution of Known Major Deposits[1]	Primary Extraction Methods[2]	Principal Environmental Concerns
Gypsum	Abundant in most countries (Producing countries) United States, Italy, France, Spain, U.S.S.R., Iran, United Kingdom, India, Canada, Mexico	OPSM SUG	• reclamation of abandoned pits • dust from processing • disposal of waste rock
Lithium	United States, Rep. S. Africa, U.S.S.R., Argentina, Rhodesia, Mozambique, China, Uganda, South-West Africa, Australia	OPSM SUG and recovery from brines (often mined as coproduct with beryl, columbite, feldspar, mica, quartz, tantalite, etc.)	• potential water pollution from processing
Mica	Abundant on all continents (Producing countries) India, Malagasy Rep., Brazil, United States	OPSM	• disposal of mining and processing wastes
Perlite	United States, Ireland, Greece, Italy, Japan, Japan, Iceland, Australia, Scotland, New Zealand	OPSM	• reclamation of abandoned pits • disposal of waste rock and processing wastes • dust from processing
Phosphorus (phosphates)	Abundant on all continents (Major reserves) Morocco, China, United States, Algeria, U.S.S.R., Peru, Tunisia, N. Vietnam	OPSM	• land use conflicts • disposal of overburden and processing wastes • water and air pollution from procesing • reclamation of pits, waste dumps, and slime ponds • release of fluorine during processing

497

TABLE 4 (Continued)

Minerals	Distribution of Known Major Deposits[1]	Primary Extraction Methods[2]	Principal Environmental Concerns
Potassium (potash)	U.S.S.R. Canada East Germany West Germany Israel and Jordan United States France Spain Italy (plus numerous other countries)	SUG R&PUG SOL plus recovery from brines	• disposal of tailings • water pollution • water pollution from processing • land use conflicts • dust from tailings disposal areas
Pumice	Widespread abundance (Producing countries) Italy, West Germany, United States, Greece, France, Martinique, Chile, Spain, Austria, New Zealand	OPSM	• land use conflicts
Quartz crystal	Brazil (plus numerous other countries)	Mined by hand methods to preserve crystals	• overburden disposal • generally minor
Sodium (salt, soda ash)	Abundant on all continents (Producing countries) United States, China, U.S.S.R., West Germany, United Kingdom, India, France, Canada, Italy, Mexico, Poland, Netherlands	Rock salt - R&PUG Soda ash - R&PUG Brine salt - recovered by evaporation	• land use conflicts (brine recovery)
Strontium (celestite)	Reserves are worldwide but poorly documented United Kingdom, Spain, Mexico, U.S.S.R., Italy, Pakistan, Argentina, United States	Small scale OPSM	• minor

498

TABLE 4 (Continued)

Minerals	Distribution of Known Major Deposits[1]	Primary Extraction Methods[2]	Principal Environmental Concerns
Sulfur	Abundant worldwide	- wells (steam injection) - OPSM - recovery from processing of pyrites and from sour natural gas	• air pollution from processing • water pollution at points of consumption • water pollution from mining of sulfur bearing minerals such as coal.
	Japan, United States, U.S.S.R., France, India, Italy, China, Rumania, South Korea, Norway, Austria, Canada, Sweden, Rep. S. Africa (plus numerous other countries)	OPSM SUG	• air pollution (dust) from mining and processing • magnesium silicate in dust is health hazard to humans and livestock • reclamation of abondoned pits
Vermiculite	Rep. S. Africa, United States, Argentina, Brazil, India, Kenya, Tanzania	OPSM	• disposal of waste rock • reclamation of abandoned pits • dust from processing • disposal of processing waste (fines)

(1) These distributions are not inclusive, but rather show significant known reserves or documented production. Where possible, the countries were ranked according to size of known reserves (or production) starting with largest. Ranking is only meaningful for the first few countries in each list.

(2) R&PUG - room and pillar underground mining
LWUG - longwall underground mining
SUG - standard underground mining - shaft or stopping
ASM - area surface mining
OPSM - open pit surface mining
CSM - contour surface mining
DSM - dredge surface mine
ISR - in situ retorting
SOL - solution mining

499

BASIC CONTROL MEASURES AND MITIGRATION OF MINING IMPACTS

Controls for the primary environmental problems listed in the previous section may be categorized into controls of atmospheric emissions and particulates, controls of water pollutants, reclamation of disturbed areas, and approaches to minimizing land use conflicts. These categories are discussed individually below.

Control of Atmospheric Emissions and Particulates

Atmospheric pollutants generated during the excavation and mineral extraction activities tend to consist primarily of particulates while gaseous emissions assume a more important role during processing activities.

Generation of particulates around a mining operation can be substantially reduced by a few simple procedures including:

- Reduction in the area of land surface disturbed at any given time,
- Use of water or chemical dust suppressants on haul roads,
- Paving, where practical, of permanent roads,
- Reduction in the number of exposed transfer points for ore and waste rock, and
- Prompt and effective reclamation of abandoned mine areas and dump sites.

During mineral processing, a broader array of atmospheric pollutants are involved. These include not only ore and rock particulates from crushing, but also SO_2 in smelter fumes, fumes from processing reagents, and particulates of various process materials which may involve concentrations of trace elements and toxic compounds. Reduction or containment of atmospheric emissions at the processing stage commonly involves:

- Use of bag filters, electrostatic precipitators or wet scrubbers at crushing facilities and on smelter stacks,
- Use of scrubbers or other suitable SO_2 recovery techniques in the smelter process, and
- Substitution of refinery processes to minimize use and production of unessential toxic materials.

Control of Water Pollutants

Primary water pollutants in the excavation and extraction areas include sediments from disturbed areas and leachates from exposed ore and toxic waste materials. Control of such pollution should focus on the following:

- Avoidance of unnecessary surface disturbance,
- Prompt reclamation of exploration roads, abandoned mine areas, and waste dumps,

- Use of sediment ponds below areas of disturbance,
- Impoundment and removal of well drilling wastes including drilling muds, brackish water and oil,
- Burial of pyrite or toxic waste materials in spoil or waste dumps to prevent oxidation and leaching,
- Avoidance of disturbance to stream channels or use of channels as access roads, and
- Chemical treatment of acidic drainage.

Potential water pollutants from the processing facilities constitute an almost endless list depending upon the type of processing involved. In general, reduction of impacts is related to the following generic practices:

- Containment of spills and accidental discharges,
- Recirculation of cooling and process waters wherever possible to minimize quantity of discharges,
- Avoidance of use or production of toxic materials where possible,
- Discharge of process wastes into suitable burial sites or tailings impoundments instead of local drainages,
- Use of effective clay liner or other seal around tailings impoundments,
- Avoidance of flood prone drainages for tailings disposal sites,
- Protection of tailings pond dikes against erosion and failure by revegetation or suitable rip-rap, and
- Implementation of effective downstream or discharge monitoring programs to provide prompt detection of potential problems.

It is important to note that, in contrast to atmospheric emission where pollutant effects typically develop over a considerable period of time, a single release of toxic materials into a watershed may have drastic, far reaching, and long term implications.

Reclamation and Disturbed Areas

Reclamation has already been discussed in the context of reducing atmospheric and water-borne pollutants, but is also vitally important in returning the disturbed areas to other productive uses and in reducing the long-term aesthetic impacts of the mining operation. As environmental awareness becomes more pronounced, an increasing number of countries are beginning to consider mining as a temporary land use like any other industry. This is most apparent in several European nations where the reclamation planning and subsequent land use is a principal factor in mine design. While some types of mining operations are not conducive to reclamation in the sense of a return

501

to previous land uses, these areas may logically be developed for other uses if given adequate consideration at an early stage. Reclamation practices should include the following for excavation and extraction sites:

- Salvage, protection, and re-use of available topsoil where possible,
- Return of spoil, waste dumps and other disturbed areas to minimum practical slopes,
- Planting of vegetation species that are ecologically suited to the particular site and to anticipated subsequent uses of the area, and
- Steps to avoid contamination of local soils with waste chemicals and oil.

In addition to reclamation of disturbed areas, which considerably reduces long term visual impacts, simple procedures such as retention of wooded areas or natural hills around the mine or processing facility will help provide visual screening and noise reduction.

CONCLUSIONS

It is evident that mineral extraction is a vital and continual part of all modern societies. Thus, it has to occur and under economically tolerable conditions. At the same time, the recent history of several countries indicates that these societies are willing to pay some additional cost on mineral products to insure protection of environmental resources. The practices outlined in this paper to mitigate environmental impacts range from those which might be unacceptably expensive to implement (zero water pollutant discharge and total reclamation of open pit mines) to others which can be implemented at little or no additional cost. Certainly as many environmental problems arise in mineral extraction from carelessness and lack of forethought as from economic considerations. Some pollution resulting from economic constraints can be justified on a national priority basis in some developing countries; pollution resulting from carelessness and indifference cannot be justified anywhere.

BIBLIOGRAPHY

Down, C. C. and J. Stocks 1977. Environmental Impact of Mining. John Wiley & Sons, New York, 371 p.

Engineering and Mining Journal 1978. E/MJ International Directory of Mining and Mineral Processing Operations. MCGraw Hill, New York, 699 p.

Jones, M. J. (Ed.) 1975. Minerals and the Environment. Proceedings of a symposium sponsored by the Institution of Mining and Metallurgy. London, June 4-7, 1974. Institution of Mining and Metallurgy, London, 803 p.

Moore, R. T. and T. Mills 1977. An Environmental Guide to Western Surface Mining, Part Two: Impacts, Mitigation and Monitoring. FWS/OBS-78-04. U.S. Department of Interior, Fish and Wildlife Service. Washington, D.C., 482 p.

Nephew, E. A. 1972. Surface Mining and Land Reclamation in Germany. ORNL-NSF-EP-16 Oak Ridge National Laboratory, Oak Ridge, Tennessee, 105 p.

Streeter, R. G., R. T. Moore, J. J. Skinner, S. G. Martin, T. L. Terrel, W. D. Klimstra, J. Tate, Jr., M. J. Nolde. 1979. Energy mining impacts and wildlife management: which way to turn. p. 26-65 In: Transactions of the 44th North American Wildlife and Natural Resources Conference. Wildlife Management Institute, Washington, D.C.

U.S. Bureau of Mines 1970. Mineral Facts and Problems, 1970, Bulletin 650. U.S. Department of the Interior, Bureau of Mines, Washington, D.C. 1291 p.

U.S. Bureau of Mines 1973. Minerals Yearbook, 1971, Vol. III. Area Reports: International U.S. Department of the Interior, Bureau of Mines, Washington, D.C., 1111 p.

U.S. Bureau of Mines. 1975. Mineral Facts and Problems, Bicentennial Edition, Bulletin 667. U.S. Department of the Interior, Bureau of Mines, Washington, D.C. 1259 p.

U.S. Bureau of Mines. 1976. Mineral Industries of Africa, U.S. Department of the Interior, Bureau of Mines, Washington, D.C. 115 p.

U.S. Environmental Protection Agency 1973. Process, Procedures, and Methods to Control Pollution from Mining Activities. EPA-430/9-73-011. U.S. Environmental Protection Agency, Washington, D.C. 390 p.

U.S. Environmental Protection Agency 1974. State-of-the-Art, Uranium Mining, Milling and Refining Industry. EPA-660/2/74-308. U.S. Environmental Protection Agency, Washington, D.C. 113 p.

U.S. Secretary of Interior. 1979. Annual Report on Mining and Minerals Policy. U.S. Department of the Interior, Washington, D.C. 68 p.

504

RUSSELL T. MOORE

Section Manager

Professional Experience

Dr. Moore is responsible for developing and administrating a corporate section specializing in Mining Analysis and Reclamation at Environmental Research & Technology, Inc. (ERT). This responsibility entails: planning section objectives for a section of seven staff members, recruiting section personnel, serving as corporate liaison between section personnel and corporate management, marketing corporate services in the mining and reclamation field, supervising greenhouse and growth chamber projects and research. He serves as a corporate authority on surface mining and reclamation techniques and impacts, manages various individual mine related projects, and acts as a technical advisor to other projects in the fields of plant ecology and range management.

Dr. Moore has a wide range of experience which includes his work as a NDEA Fellow and research assistant. His research involved the ecology of a semi-desert grass species and gas exchange studies of transpiration and photosynthesis by two desert shrub species.

As a post doctoral research associate at California State University (San Diego), he was responsible for assembling and directing the operation of gas exchange equipment for measurements of photosynthesis and transpiration. The system was used for vegetation gas exchange and water relations studies in mangrove, alpine tundra, and chaparral communities.

Education

Ph.D. (Ecology) Utah State University
B.S. (Range Management) University of Idaho

Memberships and Honors

American Society of Plant Physiologists
Ecological Society of America
North Idaho Forestra Association Award
Phi Kappa Phi
Society of Range Management
Southwestern Association of Naturalists

Publications

Technical papers and publications in the fields of plant nutrition, water relations, reclamation, photosynthesis and range management.

GF-6/78

PRINCIPLES OF SOLID WASTE MANAGEMENT IN DEVELOPING COUNTRIES

William A. Duvel, Jr., Ph.D., P.E.

June 1980

International Environmental Management Institute
ENVIRONMENTAL RESEARCH & TECHNOLOGY, INC.
Concord, Massachusetts, USA

506

EXECUTIVE SUMMARY

A solid waste management system consists of a plan of operation or mechanism for the orderly control of the storage, collection, transport, processing, reuse, and final disposal of unwanted waste products. The principal objectives of the system are to protect the public health and to prevent environmental degradation. In developing countries the primary concern is with control and limitation of communicable diseases through proper containment and disposal of human body wastes. However, management of other waste sources -- household, commercial, institutional, industrial, agricultural, and mining -- are all important:

- to control the spread of communicable diseases by eliminating the feeding and breeding ground for disease vectors, e.g., rats, flies, mosquitos;
- to prevent air pollution resulting from open burning and wind-borne dust;
- to prevent the generation of foul odors and unaesthetic appearance associated with uncontained and/or uncollected garbage;
- to prevent the degradation of streams and lakes associated with uncontrolled dumping into surface waters;
- to prevent contamination of useable groundwater by leachate arising from solid waste; and
- to prevent uncontrolled disposal of hazardous materials into the environment, thereby reducing exposure of humans to these materials.

The five major steps to be taken in deciding on a system are described below.

1. Define the source of the waste. Determine how much you have, where it is coming from, how much is produced at each location, what is in the waste, and what its physical and chemical characteristics are. This information is necessary to properly select from available storage, transport, processing, and disposal options.

2. Determine the alternatives available for what to do with the waste within each element of the disposal system. Storage options include open piles, pits, ponds, and lagoons, or closed containers. Collection is a critical problem for urban systems. A variety of methods are used depending largely on the density of population. Methods range from individual house-to-house collection to pick-up of centrally located bulk containers serving apartment houses and

tenements. Industrial and mining residues are usually generated continuously so no special collection is necessary. Continuous transport of these wastes can be provided by a combination of chutes, belt and bucket conveyors, pneumatic and slurry pipe lines, trucks, and railroads.

A wide range of processing alternatives is available to condense and compact the waste or change its properties, making it easier to handle. Processing alternatives include:

- Sorting - A combination of magnetic separation, air flotation, pulping, thickening, dewatering and other methods to accomplish separation of different waste components.

- Mechanical processing - May include shredding, baling, and compaction to achieve volume reduction.

- Thermal processing - Incineration or pyrolysis to achieve waste destruction and volume reduction.

- Biological processing - Digestion and composting used to reduce "activity" and volume of the waste

- Chemical processing - Includes neutralization, precipitation, and others to reduce waste hazard and improve handling quality.

Disposal options are limited to landfill, land farm, and ocean disposal. Landfilling, the controlled burial of wastes, is popular because it is cheap, flexible, safe, and permanent. Landfarming is popular for the same reasons but also incorporates the recycle/reuse concept. Ocean disposal is only suitable for selected wastes.

3. Set the evalutation criteria by which you determine whether the elements of the system are appropriate for your situation. Overall the system must be realistic, relevant, flexible, acceptable, affordable, suitable to local conditions, and safe. Four principal items to consider are the technical/operating factors, cost, health/safety/environment considerations, and institutional/political factors. Major criteria are:

- reliability - Provide extra storage and equipment redundancy to accommodate all the waste all the time. Use rugged, heavy duty, standard equipment.

- flexibility - Avoid overly specialized equipment. Use versatile rather than single purpose vehicles. Design the system to operate in all kinds of weather.

- simplicity - Do not make the equipment or system complex. Keep it understandable.

508

- availability of labor and materials - These are typically lacking. Use local labor, equipment, materials, and fuel whenever possible.

- security - Protect equipment, materials, and fuel from theft and vandalism.

- Cost - Balance capital costs against operational costs but assume maintenance will be poor. Buy the equipment requiring the least maintenance and repair.

- objectives - Make sure you have the equipment and labor to achieve the objectives - protection of public health and the environment.

- acceptability - Choose a method that will be acceptable to local users and will not radically contravene long-standing customs and beliefs. Choose a system that people can understand and use.

4. Evaluate the alternatives in the context of the selection criteria established above. Use a matrix method or other technique to systematically consider all the relevant factors.

5. Develop the management controls needed to govern and operate the system. A variety of alternatives have been utilized for ownership and operation of municipal systems: government operation or licensing, special authorities, non-profit corporations, cooperatiaves, special districts, and inter government agreements. Other alternatives are available. Whatever the system selected, someone or some group of individuals must be accountable for making the system work and be given the authority and responsibility to carry out that mission.

Finding financing and operating revenues for municipal systems constitute another set of problems. Capital financing can be secured from internal government sources (e.g., oil or mineral revenues, taxes) or external sources such as grants and loans from the World Bank or foreign countries and corporations. Operating revenues can come from government revenues, special taxes, or user charges.

Industrial and mining operations do not have the same institutional or revenue problems as government systems providing services to individuals. In industrial and mining enterprises, the solid waste disposal system is a necessary cost of doing business and should be accounted for in the same manner as other essential services.

All systems (municipal, industrial, etc.) must have and maintain additional management controls which need to be considered: staffing requirements, equipment maintenance requirements, manpower management, accounting, record keeping, and monitoring. All these management controls should be considered along with the technical aspects of the solid waste system.

These basic precepts are the same regardless of context - municipal, industrial, mining, or agricultural. The application of these principles should be tailored to meet the particular constraints of climate, resources, culture, economics, institutions and other factors unique to conditions in each developing country.

510

PRINCIPLES OF SOLID WASTE MANAGEMENT IN DEVELOPING COUNTRIES

By: William A. Duvel, Jr., Ph.D., P.E.

Introduction

The principles of solid waste management in developing countries are not so very different from the principles in "developed" countries. Actually the principles of solid waste management are the same; the application of the principles is different because of different constraints of climate, resources, culture, economics, and other factors. Thus, this paper sets out some general elementary definitions and guiding principles of solid waste management and shows how they can be applied in developing countries.

What is Solid Waste?

What do we mean by solid waste? What are we talking about? We are simply talking about the solid residues, leftovers, and unwanted by-products of an activity. A more formal definition puts it this way:

> "Solid waste means any garbage, refuse, sludge from a waste treatment plant, water supply treatment plant, or air pollution control facility and other discarded material, including solid, liquid, semisolid, or contained gaseous material resulting from industrial, commercial, mining, and agricultural operations, and from community activities...."[1]

This more formal definition includes the concept of source; that is, solid wastes are typically characterized by where they come from. This characterization is important because it often determines how those wastes are managed and where they go.

As shown in Table 1, there are 7 broad categories of solid waste. Each of these categories is composed of different kinds of materials generated from different activities. Domestic, institutional, and commercial sources typically consist of garbage and rubbish. Garbage is the waste resulting from the handling, storage, sale, preparation, and cooking of food. Rubbish consists of such

---

[1]From regulations developed for the Resource Conservation and Recovery Act of 1976, Federal Register, Vol. 44, No. 179, September 13, 1979 p. 53461.

TABLE 1

SOURCE CATEGORIES OF SOLID WASTE

- Domestic Sources
  - Single family homes
  - Multi-family homes
  - Apartments & condominiums
- Institutional Sources
  - Schools
  - Government offices
  - Hospitals
- Commercial Sources
  - Stores
  - Offices
  - Service stations
  - Warehouses
- Industrial Sources
  - Process industries
  - Non-process industries
  - Utilities
- Mining Sources
  - Extraction
  - Processing & beneficiation
- Agricultural Sources
  - Farm operations
  - Crop production
  - Livestock production
- General Municipal Sources
  - Demolition
  - Construction
  - Street cleaning & maintenance
  - Landscaping
  - Park and beach operation
  - Catch-basin cleaning
  - Water & sewage treatment solids

512

items as paper, cartons, barrels, yard trimmings, furniture, cans, glass, ash, tires, appliances and other similar articles. These wastes along with those from the general municipal sources are sometimes referred to collectively as "municipal solid waste" or "municipal refuse." This term is used because in many urban areas their collection and disposal is provided by (or at least regulated by) the municipal government.

Industrial waste represents the residues from diverse industrial operations. In general the process industries such as petroleum refining, chemicals and plastics, food processing, metals refining and finishing, textile production and finishing, and paper and wood products operations generate significant quantities of solid waste, some of which is hazardous. Electric utilities, particularly those using coal or wood, are also significant industrial sources. The non-process industries such as electronics and metal fabricating for the most part do not generate significant quantities of wastes and have less difficult problems than do the process industries.

Mining, mineral extraction, and benefication typically generate enormous quantities of solid wastes. In many cases a large proportion of these wastes are inert residues which can be returned directly to the earth. However, some materials such as drilling muds and processing residues are difficult to dewater and pose serious management problems.

Agricultural operations, both crop and livestock production, are also important major sources of waste. Management of many of these wastes is simplified by the enhanced opportunity for direct recycling and reuse of the waste products.

What is Solid Waste Management?

Simply put, solid waste management is the controlling, handling, or supervision of the fate of solid wastes. Management involves exercising some degree of influence over these primary elements of the system:

- storage
- collection
- transport
- processing
- reuse/recycle
- disposal

A solid waste management system is a plan of operation or mechanism for the orderly control and disposition of solid waste. A management system can be very simple or very complex, depending upon the quantities and characteristics of the waste, the number and variety of wastes involved, general economic conditions, and a spectrum of other factors which vary with the particular case. Not all of these elements are found in all systems. Consider, for example, the very simple case of a latrine. Here human fecal matter

(one type of solid waste) is deposited directly into a pit in the ground which serves as both the storage and final disposal point. There is no collection, transport, or processing of the waste.

A typical municipal management system in the United States represents a complex case. Here, storage by individual homeowners is provided in trash cans which are placed at the curb. These cans are emptied once or twice a week into specially designed collection trucks which go to a transfer station. At the transfer station the wastes are compacted (the processing step) into large packer trucks and then transported to a landfill on the outskirts of the town. The landfill serves as the final disposal point.

While these examples appear to be quite varied, the important point is that the same fundamental principles apply for both the simple case and the complex case. The same principles apply to the case of government control or private control.

Why is Management Important?

Why is it necessary to go to the effort to develop a management system? Why not just leave the wastes unmanaged? There are two compelling reasons for properly managing solid wastes: health and environment.

The primary concern in solid waste management is for protection of public health. Historically the first concern is for control of human fecal matter through good personal sanitation practices. Control and limitation of communicable diseases (see Table 2) through proper containment and disposal of human body waste has been decisively documented and should be a primary goal for developing countries. Animal fecal waste is also of concern for, as shown in Table 2, it too contains disease producing organisms.

Household, commercial, and institutional wastes are also sources of pathogens. However, the public health hazard associated with these materials is somewhat less direct. Garbage and rubbish provide excellent habitat for disease vectors. Garbage and refuse provide food and harborage for rodents (e.g., rats and other similar vermin); breeding grounds for flies, mosquitos, and other insects; and a feeding ground for birds. Table 3 shows the principal diseases which can be transmitted to humans and animals from the three primary offenders -- flies, mosquitos, and rats. Proper control of municipal solid waste is universally essential if these vectors and related diseases are to be curtailed.

TABLE 2

DISEASES ASSOCIATED WITH FECAL MATTER

Diseases Associated with Human Fecal Waste

- Bacterial infections
  - Typhoid fever
  - Paratyphoid fever
  - Cholera
  - Shigellosis (bacillary dysentery)
- Viral infections
  - Poliomyelitis
  - Coxsackie infection
  - Infectious hepatitis
  - (very many other enteric viruses exist)
- Protozoal infections
  - Entamoeba histolytica
- Helminthiasis
  - Fish tapeworm
  - Beef tapeworm
  - Pork tapeworm
  - Pinworm
  - Roundworm
  - Whipworm
  - Hookworm

Diseases Associated With Animal Fecal Waste

- Salmonellae
- Infection from pig intestinal protozoan (Balantidium coli)
- Helminthiasis
  - Pig sacaris
  - Animal tapeworms
  - Hydatid worm

Source: Wilson, 1977

TABLE 3

DISEASES ASSOCIATED WITH VARIOUS VECTORS

Rodent-Borne Diseases	Fly-Borne Diseases	Mosquito-Borne Diseases
Echinostomiasis	Typhoid	Dengue
Hemorrhagic septicemia	Bacillary dysentery	Encephalitis
Histoplasmosis	Amoebic dysentery	Filariasis
Lymphocytic choriomeningitis	Diarrheas	Malaria
Plague	Asiatic cholera	Yellow Fever
Rat-bite fever	Helminth infections (worm)	Tularemia
Rat-mite dermatitis	Myiasis	Lymphocytic choriomeningitis
Rat-tapeworm infection	Loiasis	Melioidosis
Rocky Mountain spotted fever	Onchocerciasis	Rift-Valley fever
Salivary-gland virus infection	Ozzard's filariasis	
Salmonellosis	Leishmaniasis	
Schistosomiasis	African sleeping sickness (trypanosomiasis)	
Bilharziasis	Yaws	
Sporotrichosis	Tularemia	
Swine erysipelas	Bartonellosis	
Trichinosis	Cararrhal conjunctivitis	
Leptospirosis	Sandfly fever	
Leishmaniasis		
Relapsing fever		
Tularemoa		
Rickettsial pox		
Murine ryphus		

Source: Wilson, 1977

Agricultural and food processing wastes are much the same as garbage and create the same problems. Residues from many industrial process operations such as petroleum refining, chemicals and plastics manufacturing, metals refining and finishing, and tanning, utilize and/or produce hazardous materials. Residues from the production or use of these materials may be corrosive, explosive, toxic, carcinogenic, mutagenic, teratogenic, or otherwise directly injurious to people who come into contact with them. Table 4 shows some representative hazardous substances found in various industrial waste streams. Control of these hazardous industrial residues is also essential to protection of the public health.

There is an additional set of potential hazards which may result from improper storage, handling, and disposal of solid wastes.

- Spontaneous combustion and resulting fire are potential threats in all organic wastes subject to rapid bacterial action. Spontaneous combustion, long recognized in storage of hay, wood chips, coal, and grain can be a problem in municipal waste storage. Bacterial action within a pile of refuse can sometimes generate sufficient heat to ignite combustible materials in that pile. The resulting fires can cause property damage, air pollution, personal injury, and death.

- Gas production can also come about through bacterial action within the waste. Buried wastes (including those in controlled landfills) containing putrescible matter breaks down in the absence of air to form CO_2, H_2S, N_2, and CH_4. The latter can form explosive mixtures with air if allowed to accumulate in confined spaces.

The second major concern in solid waste management is for protection of the environment. Improper management of municipal and industrial residues can seriously degrade the air, water, and land. For example:

- Open burning of solid waste can contribute to air pollution and associated adverse health and aesthetic effects;

- uncontained and/or uncollected garbage and refuse will generate foul odors and an unaesthetic appearance;

- solid wastes allowed into surface waters (lakes, rivers, and streams) can degrade the appearance and quality of water making it unsuitable for drinking, fishing, bathing, and other beneficial uses;

- water coming into contact with solid wastes (even buried wastes) will leach out soluble components of the waste which may degrade groundwater quality so that it is no longer useable as a source of potable water.

TABLE 4

REPRESENTATIVE HAZARDOUS SUBSTANCES WITHIN INDUSTRIAL WASTE STREAMS

	Hazardous Substances										
Industry	As	Cd	Chlorinated hydrocarbons*	Cr	Co	Cyanides	Pb	Hg	Miscellaneous organics+	Se	Zn
Mining and metallurgy	X	X		X	X	X	X	X		X	X
Paint and dye	X	X		X	X	X	X	X	X	X	
Pesticide	X		X			X	X	X	X		X
Electrical and electronic			X		X	X	X	X		X	
Printing and duplicating	X			X	X		X		X	X	
Electroplating and metal finishing		X		X	X	X					X
Chemical manufacturing			X	X	X			X	X		
Explosives	X				X		X	X	X		
Rubber and plastics			X			X		X	X		X
Battery		X					X	X			X
Pharmaceutical	X							X	X		
Textile				X	X			X			
Petroleum and coal	X		X				X				
Pulp and paper								X	X		
Leather				X					X		

* Including polychlorinated biphenyls.

\+ For example, acrolein, chloropicrin, dimethyl sulfate, dinitrobenzene, dinitrophenol, nitroaniline, and pentachlorophenol.

Source: U.S. Environmental Protection Agency. 1974. Disposal of hazardous wastes: report to Congress. Environmental Protection Publication SW-115.

5/8

The last two points mentioned above are particularly relevant to developing countries in which provision of an adequate supply of fresh water is important for domestic purposes (drinking, cooking, and washing) and for food production through irrigation.

Some countries may believe they cannot afford the luxury of environmental protection when they are faced with the difficulty of providing essential human services -- food, water, housing, and health care. These countries should not be concerned. If the solid waste can be managed in such a way as to protect human health, most of the environmental protection is achieved at the same time and at no extra cost.

In lesser developed countries, there is properly a focus (at the government level) on management of household, commercial, and institutional wastes because it is perceived as an essential human service. It is closely linked with provision of clean water, proper wastewater disposal, basic health care and other similar services. However, industrial waste disposal should not be ignored. In some ways industrial residue disposal is easier to deal with because:

- it is usually physically in remote areas away from the general public;
- there is a better financial base from which to operate;
- better maintenance and equipment are likely to be utilized; and
- you do not need to change the behavior patterns of large numbers of people to make the system work.

Selecting a Management System

To develop effective solid waste management, a system or framework is needed in which to operate. If a system can be developed, then you may be able to manage it. As stated previously the elements of the system include storage, collection, transport, processing, reuse, and disposal. An orderly method for selecting and developing a system is described here. It is not possible in this short space to consider all possible situations. However, the fundamental method is the same regardless of what the waste is (municipal, industrial, agricultural, etc.) or what institution manages it (local government, family, private company, etc.). The basic steps to selecting the system are these:

1. Define the source
2. Define the alternatives

3. Set the evaluation criteria

4. Evaluate the alternatives

5. Develop the controls

The steps are outlined in more detail in the following sections.

Define the Source

Defining the source simply means determing what you have.

- How much waste is there?
- Where is it produced?
- How much is produced at each location?
- What is in the waste?
- What are its physical and chemical characteristics?

Answers to these questions are fundamental to system design. The information is needed to evaluate alternative storage, transport, and disposal options, to develop manpower and equipment needs, and to determine system costs. The more information you have about the waste, the better your chances of success for the system. However, common sense should dictate how much information to get and what level of information is required. For example, with municipal waste it is sufficient to know that this will be composed of garbage and rubbish. Nearly anyone can determine what is in the waste quantitatively just by looking. It is rarely necessary to have information on the exact chemical composition (e.g., carbon, nitrogen, and water). It is often more useful to have a general idea of composition -- glass, paper, food scraps, etc. On the other hand, for industrial residues it is often important for safety reasons to have the chemical composition of the waste determined. Workers will rarely know just by looking what is in a waste, so a compositional analysis is usually very helpful. However, a compositional analysis is not always required. For example, it is well established that fly ash and bottom ash from coal burning operations are not usually hazardous. Unless you are considering reuse of the fly ash for building materials, it is not necessary to know the composition. It is sufficient to know that you can spread the material with a bulldozer but the material must be moist or you will have dust everywhere.

Define the Alternatives

After you have determined what you are dealing with, you can begin to determine the alternatives available for what to do with the waste. Defining the alternatives seems a bit complicated at first because there are a large number of factors to consider. However, the

520

process can be simplified by an orderly development of ideas. As stated previously, there are six principal elements making up the system:

- storage
- collection
- transport
- processing
- reuse
- disposal

For each of these six elements, four fundamental questions must be answered.

- What are you going to do?
- How are you going to do it?
- Where are you going to do it? and
- Who is going to do it?

The spectrum of alternatives can now be identified for each element of the system. Table 5 shows in summary form the alternatives available for each element in the system.

For the storage options you can consider open piles, pits, ponds, and lagoons, or closed containers (e.g., drums and tanks). Inert residues which are not subject to wind and water erosion, such as bottom ash and mine process waste, can conveniently be stored in open stockpiles. Wastes subject to scavenging by humans, rodents, or birds should be stored in closed containers. Dusty wastes subject to wind erosion can usually conveniently be stored in closed containers (tanks and bins) or kept wet in pits, ponds, or lagoons.

Collection is most notably a problem in municipal systems where household wastes are picked up at hundreds of diverse points on a discontinuous basis and brought to some central facility for processing and/or dispsoal. In apartment houses, institutions, and commercial establishments and in densely populated areas, a large bulk container (usually 1 to 4 m^3) is used to store refuse deposited there by the inhabitants. The container is then periodically emptied into a specially designed truck.

TABLE 5

SOLID WASTE DISPOSAL ALTERNATIVES

	What to do	How to do it	Where to do it	Who to do it
Storage	• open piles • pits, ponds, lagoons • open rigid container (e.g. drums, tanks) • closed rigid container • flexible container (e.g. bag)	Use materials constructed of: • plastic • metal • concrete • stone • brick • wood	• at source • at processing location • at disposal site	• generator • collector/transporter • disposer • owner • municipality • contractor
Collection	• bring waste to processing point • bring waste to disposal point	Use: • bags/buckets/crocks • carts/wheelbarrows • wagons/trucks • chutes • pipeline • conveyor Collect continuously Collect intermittently	• from source to central point • from source to disposal point	• generator • owner • disposer • municipality • contractor
Transport	• bring waste to disposal point	• individuals • pack animals • trucks/wagons • pipeline • conveyors • railroad	• from processing to disposal point	• generator • owner • disposer • municipality • contractor
Processing	• hand processing • mechanical processing	• sorting • dewatering • compaction • baling • shredding • pulping • flotation	• at source • at central facility • at disposal point	• generator • collector/transporter • disposer • municipality • contractor
	• thermal processing	• incineration • pyrolysis		
	• biological processing	• composting • digestion		
	• chemical processing	• neutralization • precipitation • fixation		

828

TABLE 5 (Continued)

	What to do	How to do it	Where to do it	Who to do it
Reuse	• direct recycle • separation and recycle	• complete recycle • partial recycle • energy recovery • materials recovery	• at source • at disposal point	• generator • disposer • owner • contractor • municipality
Disposal	• landfill • landfarm • ocean disposal	• excavation • fill existing hole • build new mountain • surface spreading • plowed under • deep sea	• final waste repository	• generator • collector/transporter • owner • municipality • contractor

523

In suburban areas, house to house collection is commonly used. Here the waste from each household is placed into a packer truck which is specially designed to compress the waste into the body of the truck. In rural, sparsely populated areas, often times no collection is provided. Rural residents are usually closely allied to agricultural activities, and most of the household wastes are disposed of on-site or can be recycled directly along with agricultural residues. In other cases, at least in the U.S., residents bring their wastes directly to a central disposal facility. In some cases, residents bring their refuse to centrally located bulk containers. These containers are then periodially emptied into large trucks which take the refuse to a central disposal facility.

Commercial, institutional, and demolition waste is often stored in large roll-off containers up to $20m^3$ capacity. When these containers are full, they are rolled onto a truck body and hauled to the disposal point. Sometimes a stationary compactor is used in combination with the roll-off container so that more waste can be accomodated in one container.

Waste collection from industrial and mining operations pose problems different from those of municipal collection. Industrial and mining residues are typically generated continuously and from a central location or from a relatively small number of locations. Thus, collection and transport are basically the same. Industrial and mining operations use chutes, belt and bucket conveyors, pneumatic and slurry pipelines for continuous transport. They also use trucks and, to a much lesser extent, railroads for hauling waste.

There is a wide assortment of waste processing alternatives available. The use of these alternatives should be tailored to the particular circumstances or resources available to the waste management system. The simplest type of processing which can be employed is hand sorting. Sorting can also be accomplished with one or a combination of steps involving:

- magnetic separation - separating iron and steel products or magnetic ores from non-magnetic materials.
- pulping - a wet grinding process resulting in a paste-like material.
- air flotation - a pneumatic process used to separate heavy materials (like cans and glass) from light materials (like paper).
- thickening or dewatering - an aqueous process used to separate heavy materials (like sand) from water or oil.

524

Other types of mechanical processing such as shredding, baling, and compaction are sometimes used to reduce the volume of waste and/or make it easier to handle and dispose of. These operations are common with all types of waste.

Thermal processing via incineration or pyrolysis (controlled burning under high pressure and low temperature) is commonly employed in industrial operations such as refineries, chemical manufacturing, and pulp and paper manufacturing where the residues are combustible and have a significant heat content. This is an important alternative for energy recovery and waste volume reduction. Biological processes such as digestion and composting are used on wastes subject to bacterial action and putrefaction (such as biological waste treatment plant sludges, food processing residues, tannery residues, and paper mill sludges). Chemical processing is also popular to neutralize, consolidate, and reduce the volume and or hazard of industrial and mining residues.

Reuse, recycle, and recovery of materials and energy (the 3 R's of solid waste management) are important concepts to consider in the development of a solid waste management system. If conservation of natural resources is a primary national goal, then optimizing the three R's is a key step to achieving that goal. The concepts are not new and in lesser developed countries they are probably utilized more than in developed countries. Those countries with a "higher standard of living" tend to waste resources and throw away things which would not be thrown away in other countries. Here developing countries have a unique opportunity to maintain an old and worthwhile standard (i.e., no waste) while undergoing an industrialization and economic development process.

Solid waste disposal alternatives are essentially limited to landfilling, land farming, and ocean disposal. Landfilling is widely used for all types of waste, including municipal, industrial, mining, and agricultural. Landfilling is in effect the <u>controlled</u> burial of waste products. It typically consists of placing the wastes on the ground (commonly, but not necessarily in a natural or excavated pit or depression), spreading and compacting the waste to a uniform thickness (from about one to five meters), and then covering with an inert material (usually soil). The method is popular because it is cheap, flexible, safe, and permanent.

Landfarming is a combination processing and disposal method. It involves placing the waste on the ground and/or plowing wastes into the ground at a shallow depth (less than one meter), allowing natural microbial action to breakdown the wastes, and eventually incorporating the waste into the soil matrix. This type of waste disposal is used commonly worldwide for dispsoal of human body waste (night soil), animal waste (manure) and crop residues (mulch). To a lesser extent it is used for disposal of some industrial residues such as petroleum refinery wastes and food processing and canning wastes. The advantages of landfarming are much the same as landfilling.

The potential liabilities of both landfarming and landfilling are the same.

- They must be operated properly or they will revert to an open dump.
- They require substantial land area.
- Leachate may contaminate groundwater supplies.
- Operation may be weather dependent - you cannot operate in extreme cold or extreme wet periods.
- Runoff may contaminate surface water supplies.
- Production of methane gas may constitute a fire or explosion hazard.

The degree of risk associated with each of these liabilities is a function of the materials being disposed of and the way in which a facility is oeprated. In all cases mitigating measures can be employed to insure that the risks are minimized or eliminated.

Finally, disposal into the ocean is an alternative. In many areas the ocean is a convenient dumping ground. However, it has been conclusively demonstrated that this alternative is suitable for only selected types of wastes - principally those which will disperse and degrade without causing adverse environmental effects or those bulky wastes which will remain intact and will be absorbed into the ocean ecosystem. Because many countries depend on the sea for their livelihood or foodsource, ocean disposal is not recommended except in special cases and under controlled conditions.

Set the Evaluation Criteria

Collectively the evaluation criteria are the cornerstone of selection of the system. The criteria are the yardsticks by which you determine whether the components of the system (i.e., storage, collection, etc.) and the system itself is appropriate for your situation. Before talking about specific criteria, it is important to emphasize that solid waste disposal systems in developing countries must be realistic, relevant, flexible, acceptable, affordable, suitable to local conditions (e.g., climate, customs, economics, etc.), and safe. In one sense these are the overriding criteria and can be used collectively to determine the suitability of a system. Above all, the system developer must take into account local conditions so that it is appropriate for the situation. It must not be assumed that technologies such as packer trucks, or shredders, which are used in the U.S. and other developed countries are appropriate to lesser developed countries. In many instances these technologies are "over developed"; they cannot be absorbed by local forces and hence become useless. It is often more appropriate to use less sophisticated equipment, materials, and labor.

326

The overall criteria can be broken down into the specific factors shown in Table 6. Technical and operating factors are very important. The system and components must be sufficiently reliable to accommodate all the waste generated all the time. If the equipment or labor can not be relied upon to provide continuous service, then you must provide extra storage at various points to accommodate the waste being generated while the down component is brought back into service. Alternatively you must provide backup, substitute (so called, redundant) equipment or labor to take over when the regular component goes out. For example, if you are collecting waste from point A in a truck and the truck breaks down, in order to keep the solid waste collection system going you must either (a) provide extra storage at point A or (b) provide an alternate truck. In general, providing extra storage capacity is preferrred because it is inexpensive and increases the overall flexibility of the system.

Overall sytem flexibility is a second major criterion. This is usually achieved by incorporating flexibility into each component of the system. In general you should use standard equipment with interchangeable parts so you can take maximum advantage of a spare parts inventory. Avoid overly specialized equipment, particularly specialized pumps and trucks. Generally, motorized equipment is too expensive in developing countries to reserve for a single isolated activity. For example, it is often more appropriate to utilize open body trucks capable of hauling dirt, ash, tree stumps, people, and other bulky items as well as capable of hauling solid wastes. With this type of vehicle, you can handle different sizes and loads with the same vehicle. As noted previously, allow for extra storage at all collection points in the system so that equipment or labor shortages will not curtail use and function of the system.

Develop the collection, processing, and disposal system so that it can operate in all kinds of weather and under all kinds of conditions. One of the reasons that landfilling is a popular disposal method is that it is flexible. Landfills can accommodate wide variations in the quantity and chracteristics of wastes and can function well (usually) even in adverse weather conditions.

Simplicity is another very important criterion. Developing countries typically do not have access to a highly skilled labor force trained to service complex electrical and mechanical equipment. It takes time and money to train experienced mechanics, electricians, and other repair people. Therefore, at least initially, the system and its components should be simple enough to run with minimum training. While such a system may not appear to be the most efficient use of resources, it will at least allow the system to get started. You can improve and upgrade the system after you get going.

TABLE 6

CRITERIA FOR EVALUATION OF
SOLID WASTE MANAGEMENT SYSTEMS

1. Technical/Operating Factors
   a. reliability/certainty
   b. flexibility
   c. time frame for implementation
   d. land availability
   e. simplicity/complexity
   f. availability of labor
   g. availability of materials
   h. permanance

2. Cost Factors
   a. capital cost
   b. operating and maintenance costs
   c. affordability

3. Health/Safety/Environment Factors
   a. health aspects
   b. safety
   c. environmental acceptability
   d. resource conservation

4. Institutional/Political Factors
   a. political feasibility
   b. public acceptability
   c. worker acceptability

528

Availability of labor and materials are also fundamental criteria. As noted above, developing countries typically lack skilled labor. Components of the system should be designed so that local labor can be used with minimal training. This is particularly true for urban collection systems in which you are relying on a work force that does not receive close on-the-job supervision. Garbage collection has never been a glamorous job so it is work commonly taken by unskilled, uneducated, and often illiterate people. In many cases these workers are not highly motivated; that is, they are not interested in their work. The work itself is not intrinsicly interesting and the workers may be looked down on by the rest of the community. Therefore, you must provide strong, clear incentives to get the job done. These are either passive incentives (e.g., loss of pay, lowering of seniority, loss of priviledges) or positive incentives (e.g., bonuses, time off, promotion). You must provide clear instructions and simplified training so the workers understand what to do. You must also provide clear and close supervision until the worker understands what is expected.

The problem of labor availability is also relevant to industrial operations but with some differences. Industrial operations are not typically far-flung geographically. The workers, although perhaps illiterate and/or untrained, will ordinarily receive much closer supervision and better on-the-job training.

Availability of replacement parts, equipment, materials, and fuel should all be considered. Substituting local materials, such as stone or brick, for storage containers, may make more sense than trying to use steel or concrete which may not be available.

In the United Staes, paper and plastic bags and rigid plastic as well as galvanized steel cans are typically used for storage of household wastes. In many developing countries these materials may be unavailable or inappropriate. It would be more useful to use stone containers, clay pots, woven baskets, or other containers made from local materials which are readily available.

If motorized trucks are not available or you have trouble getting parts, why not utilize something like goat carts or ox carts until such time as you can get trucks? These "primitive" means seem inefficient, but they do work and they can be implemented with local talent and equipment. Set up the system with these items and then work toward adding the mechanical means later when you have more experience and money. This philosophy is particularly useful for dealing with agricultural wastes in farming areas where pack animals are typically available and in urban poor areas where crowded conditions and/or poor roads make motorized transport impractical.

In developing countries there is sometimes a sense of urgency to do things the "modern" way with up-to-date equipment. Such equipment is available (in other countries) but not in the developing country. It will take time to develop the import mechanism or local manufacturing to supply the equipment, to develop the transportation network (roads, railroads, etc.) to deliver the equipment where it is needed, to develop the distribution network which can be relied upon to stock replacement parts and to supply fuel, to educate the local work force in how to operate and maintain that equipment, and to change from the "old way" of looking at the problem to the "new way". While all this is taking place, you should proceed to develop the solid waste management system using local items which are available now, while at the same time, continuing development of the more mechanized way of doing things.

Where mechnical equipment is available it is generally advisable to get the "best" equipment. The best equipment is usually very heavy duty equipment which requires the least amount of maintenance under rugged and continuous service.

Security is a very important criterion to consider. You must provide measures and develop a system that will be safe from theft and vandalism of tools and equipment by workers or the local community. Security measures preventing theft and vandalism can include:

- surveillance or guarding of unattended equipment
- central warehousing or stockpiling of supplies and equipment with controlled access by fencing and locked gates
- periodic inventory of supplies and equipment
- check-out/check-in of supplies and equipment
- education and training in the value and use of equipment
- strong punitive measures for stealing or vandalism

Land availability is sometimes a limiting factor and generally relates to the disposal component of the management system. In crowded urban areas, there may not be sufficient land nearby to develop a landfill for municipal or industrial residues. In these cases some method of processing (e.g., incineration, baling) can be utilized to reduce the volume of waste required for disposal. In rural, undeveloped areas, land availability is typically not a constraint and you may consider shallow lagoons which take up large areas for waste disposal. This is particularly valid for industrial developments such as refineries, paper mills, chemical plants, and similar ventures. These facilities are often located well outside metropolitan areas and can take advantage of having large land areas available.

In many cases, cost factors constitute the overriding criteria. The principal aspects are capital cost (i.e., the initial investment or purchase) and the operating and maintenance costs (e.g., maintenance, service, spare parts, and fuel). In general it is better to get and use good equipment which will last a long time and will require little maintenance than to use cheap equipment which is constantly breaking down. However, this is not always possible because the better equipment is typically more expensive and therefore not "affordable." You must make the decision based on knowledge of local money availability, but over a longer period of time, it is usually preferrable to purchase the better equipment because reliable maintenance and repairs are usually not available.

It has already been stated that the reason for developing the solid waste management system is for protection of public health and the environment. These factors then become major criteria for selecting a system which:

- protects the public health:
- is safe for workers and the general public; and
- does not contribute to environmental degradation.

By failing to meet these criteria you have not achieved the primary purpose and the whole exercise is a wasted effort.

For example, if you do not provide closed containers for household garbage to prevent contact with disease vectors then you have not adequately protected public health. Similarly, if you allow toxic industrial sludges to accumulate in unlined lagoons in an area where ground water is or could be used for drinking water or irrigation, then you have not adequately provided for protection of the public health and you are contributing to environmental degradation. In the same vein, you must also provide a setting for individual workers so they are protected from accidents and personal injury either by use of equipment or exposure to hazardous materials.

Finally, you must consider institutional, political, and public acceptability factors. You must secure political acceptability; that is, the system must have the approval of the local political entity. This is particularly true in areas where local autonomy (e.g., state governments, municipal governments, tribal groups) is very important and strong. Without this acceptability, imposition of an unwanted system may result in covert or overt hostility and eventual system failure.

You must also win individual public acceptability. If people will not use the system, then what good is it? Getting people to use the system is often a difficult task because it requires changing local customs and beliefs and getting people to do things differently. Gaining public acceptance often becomes a matter of intensive and continuous training and instruction. Winning public acceptance can often be accelerated if people can see the benefits of the system and why it is advantageous to them. Thus, a program of public education should emphasize highly visible results. In selecting a system, consider whether or not you can achieve public acceptance and to what level.

Evaluate the Alternatives

Evaluating the alternatives is a complicated process which means simultaneously looking at all the alternatives reasonably available in light of all the criteria discussed above. Usually, three or four principal alternatives can be identified early by a quick screening of all the alternatives and the criteria. Once these have been identified it is appropriate to systematically evaluate each alternative in light of the criteria. The simplest way to do this is with an evaluation matrix. The matrix is not amenable to a strict numerical evaluation because a large number of value judgments must be made. Actually, any method can be used. The important concept is that all the evaluation criteria should be considered.

Develop Management Controls

The final activity in developing the management system is to determine and institute the controls which will be used to govern and operate the system. The primary decision is who will own and operate the system. For municipal collection and disposal systems there are any number of alternatives available for public and private ownership or a mixture of ownerships, each with advantages and disadvantages (see U.S. EPA 1976 for more detail). The alternatives typically available include:

- Public - Provide services through a governmental department.
- Private - Private firms contract with the governmental unit to provide services.
- Private - Private firms openly compete for service to individual homeowners with governmental unit providing licenses.
- Mixture - Provide some services by governmental unit and others by contract with private firms.

532

In developing countries, the private sector is usually not prepared to offer collection and disposal services. That is, no one is in the collection and disposal business because it is a new idea. Therefore, local governments must typically assume leadership and institute the collection and disposal system.

In the United States a variety of mechanisms is used to own and operate public systems for municipal collection and disposal. A municipal entity (e.g., city, town, borough, township, incorporated village, or county) can provide services for its own constituency. However, other mechanisms have been set up to meet local conditions. Among these alternatives are:

- Authorities - A special board, commission, or authority set up (elected or appointed) expressly for the purpose of organizing, operating, and financing a solid waste management system.

- Non-profit public orporation - An entity formed by the local governmental unit to provide the needed services in the manner of a private company.

- Multicommunity cooperative - Several communities get together and pool resources to provide servicen to all the communities

- Special districts - A subdivision or grouping of residents not following political boundaries who have gotten together to provide their own solid waste collection and disposal services.

- Governmental agreements - A simple but formal agreement between contiguous towns to pool resources and cooperate in providing services.

This is by no means an exhaustive list. There are any number of other arrangements which could be developed. The important factor in all these systems is that there must be a financial base - some way to pay for the services provided - and there must be recognized authority and responsibility - someone or somebody of individuals must be accountable for making the system work.

Getting the money to finance municipal systems is typically a major stubling block in developing countries. In all cases some sort of backing is required to get the system up and running. In petroleum rich developing countries, government revenues may be tapped to pay for the capital equipment, training, and education necessary to implement the system. Other countries may need extended loans or grants from the World Bank, foreign counties or foreign corporations.

Operating revenues are another problem. The principal alternatives are government funding (as may be possible in petroleum rich countries with government control of oil sales), taxes (property tax, sales tax, municipal utility tax, or special levies), or user charges. all of these have advantages and disadvantages which must be considered based on local conditions.

Industrial and mining operations typically do not have the same set of problems as governmental units. The costs of developing, implementing, and operating a solid waste disposal system are usually an integrated element of the development of the industrial operation when it is initiated. The solid waste disposal system is a necessary cost of doing business and should be accounted for in the same manner as the cost of procuring raw materials or development of water supply, electric utility, or other essential service.

Within the overall operating framework for either municipal, industrial, mining, or agricultural operations there are other managment controls which need to be considered. These are:

- Staffing requirements - determine the number of individuals required at different skill levels and when you will need them (e.g., day shift, night shift, seasonal variation).

- Equipment maintenance requirements - set up a schedule for routine overhaul and maintenance of all mechanical equipment. Set up a schedule for replacement. Keep a spare parts inventory. Keep accurate records of what maintenance was done and when it was done.

- Manpower management - Develop procedures for supervising and maintaining the labor force. Consider training requirements, especially for emergencies.

- Accounting - Develop the mechanisms for purchasing, payroll, recording cash flows, and other similar financial management procedures.

- Record keeping - Maintain accurate records on the type, quantity, flow rate, method of transport, and disposition of all solid waste streams.

- Monitoring - Monitor processing and disposal operations to detect adverse environmental degradation (e.g., uncontrolled air emissions, ground water contamination).

All these management control systems should be considered along with the technical aspects of the solid waste system. The management control system is the means by which the technical aspects are achieved, so the two aspects should be considered together.

Conclusion

A solid waste management system consists of a plan of operation or mechanism for the orderly control of the storage, collection, transport, processing, reuse, and final disposal of unwanted waste products. The principal objective is to protect the public health and prevent environmental degradation. Developing a management system is the same in any context - municipal, industrial, mining, or agricultural. The five major steps in deciding on a system are defining the source to quantify what you are dealing with, defining the alternatives to establish what avenues are open, establishing the evaluation criteria, evaluating the alternatives in light of the evaluation criteria, and, finally, developing the controls utilized to implement and operate the system. The application of these principles should be tailored to meet differing constraints of climate, resources, culture, economics, and other factors. However, in all cases the system chosen must be realistic, relevant, flexible, acceptable, affordable, suitable to local conditions, and safe.

SELECTED REFERENCES

D. G. Wilson. 1977. Handbook of Solid Waste Management. Van Norstrand Reinhold Company. New York.

An excellent, all encompassing general reference text covering all the technical alternatives for collection, processing, and disposal. Primary emphasis is on municipal refuse, but major sections are devoted to managing industrial, agricultural, and forest product wastes. This volume is packed with useful tables and figures.

G. Tchobanoglous, H. Theisen, and R. Eliasson. 1977. Solid Wastes. Engineering Principles and Management Issues. McGraw Hill. New York.

An excellent, reasonably current engineering college textbook. Primary focus on municipal refuse but several useful sections cover industrial residues. Provides realistic example problems and solutions.

American Public Works Association. 1970. Municipal Refuse Disposal. Public Administration Service. Chicago.

Although a bit outdated, this is a valuable standard reference text providing excellent resource information on municipal refuse disposal.

D. J. Hagerty, J. L. Pavoni, and J. E. Heer, Jr. 1973. Solid Waste Management. Van Nostrand Reinhold Company. New York.

A good, solid introductory textbook. Primary emphasis is on municipal wastes. Basic principles are covered but more recent developments in technology are not included.

J. L. Pavoni, J. E. Heer, Jr., and D. J. Hagerty. 1975. Handbook of Solid Waste Disposal. Materials and Energy Recovery. Van Nostrand Reinhold Company. New York.

A companion text to the reference cited above. Covers composting, incineration, sanitary landfill, materials recovery, and energy recovery.

C. L. Mandell. 1975. Solid Wastes: Origin, Collection, Processing, and Disposal. John Wiley & Sons. New York.

A comprehensive but not particularly well-organized document. General principles are covered adequately. Considerable attention is devoted to industrial waste disposal practices. A good starting point for learning about waste disposal in different industries.

U.S. Environmental Protection Agency. 1976. Decision-Makers Guide in Solid Waste Management. Publication SW-500. Washington, D.C.

An excellent concise summary of all relevant factors to be considered in a municipal solid waste system. Short summary tables and figures make this volume particularly readable. Considerable attention given to financing alternatives.

537

WILLIAM A. DUVEL, JR.

Senior Program Manager

Professional Experience

At Environmental Research & Technology, Inc. (ERT), Dr. Duvel is responsible for the development and supervision of major environmental programs. He has over ten years of diversified experience in wastewater treatment, stream pollution surveys, environmental impact statements, facility siting, water quality management planning, and solid/hazardous waste disposal. For the last seven years, Dr. Duvel has been a project manager in the consulting field, with much of his work centering on the pulp and paper, chemical processing, electric utility, and coal mining industries. A synopsis of relevant experience follows.

SOLID/HAZARDOUS WASTE MANAGEMENT: Environmental audits of inactive industrial hazardous waste disposal areas; technical and cost evaluations of proposed RCRA regulations; investigations of groundwater contamination from disposal of solvent residues and leachate from municipal landfills; evaluations of hazardous materials migration from orphaned sites; site selection, design and permitting of landfills; evaluation of disposal alternatives for industrial residues; and preparation of a design manual for FGD sludge disposal.

WATER QUALITY MANAGEMENT: Major aquatic ecology impact evaluation studies at various locations in the southeast; wastewater technology assessment studies in the Ohio Valley; water quality engineering studies of acid mine drainage and coal pile runoff.

OTHER ENVIRONMENTAL STUDIES: Environmental site evaluation for a new 1800 tpd paper mill; an EIS for a 500-Mw power plant in Minnesota; an environmental analysis of stream channelization projects in Pennsylvania; and a study of coal sources, transportation costs, and transloader siting for a new 3,300-Mw power plant in Virginia.

Before entering the consulting field, Dr. Duvel was Assistant Professor of Civil Engineering at the University of Pittsburgh. In that position he taught courses in the environmental engineering program and was responsible for operating and maintaining the environmental engineering laboratories of the School of Engineering.

Registration

Registered Professional Engineer in Pennsylvania

Education

Ph.D. (Environmental Sciences) Rutgers University
M.S. (Environmental Sciences) Rutgers University
B.S. (Biology) Tufts University

Memberships

American Society of Civil Engineers
American Water Resources Association
New England Water Pollution Control Association
Sigma Xi
Water Pollution Control Federation

ENVIRONMENTAL MODELING

Air Modeling

Bruce Egan

Vice President and General Manager
Air Quality Center
Environmental Research & Technology, Inc.

June 1980

International Environmental Management Institute
ENVIRONMENTAL RESEARCH & TECHNOLOGY, INC.
Concord, Massachusetts, USA

539

EXECUTIVE SUMMARY

Presentation Outline

I. Technical basis for Air Quality Modeling

A. Scales of Atmospheric Motions and their Relation to Air Pollution Problems.

1. "Global" Scale Motions (1000-10,000 km in horizontal; 10km in vertical). Possible long-term build-up of CO_2, CO, SO_2, Ozone, Particulates, etc.

2. "Synoptic" Scale Motions (100-1000 km in horizontal; to 10 km in vertical).

   a. Regional differences in meteorology.

   b. Long-range transport and transformation of pollutants.

3. "Mesoscale" Motions (10-100 km in horizontal; to 3 km in vertical).

   a. Urban-heat island flows

   b. Sea/lake breeze flows

   c. Regional air quality studies

4. "Microscale" Motions (10m to 100 km in horizontal; 10 to 1000 m in vertical).

   a. Industrial plant impact studies

   b. Nuclear siting studies

B. Atmospheric Dispersion Processes and Air Quality

1. Effects of Meteorological Parameters

   a. Wind speed and direction

   b. Turbulent mixing rates and atmospheric stability

   c. Mixing depths

   d. Time variations of meteorological parameters

2. Effects of Source Emission Rates and Geometry

   a. Isolated sources (point)

   b. Mobile sources (line)

   c. Land use sources (area or shallow-volume)

540

3. Chemically Reactive Pollutants

   a. Time scale of reactions vs. dispersion time scales

   b. Effect of different "mixes" of pollutants

   c. Reactivity as a function of meteorological conditions

4. Combinations of Meteorological and Emission Conditions of Special Importance to Air Quality Levels.

   a. Low wind speeds and low level sources

   b. Fumigation phenomena

   c. Prolonged atmospheric stagnation

   d. Rough terrain influences

C. Atmospheric Modeling Techniques

1. Tracer equation

2. Gaussian plume models

   a. Basic model

   b. Modifications

3. Numerical Simulation Models

   a. Eulerian

   b. Lagrangian

4. Meteorological Inputs

   a. Frequency of occurrence data

   b. Sequential data

   c. "worst case" inputs

5. Output Analysis

   a. Concentration fields

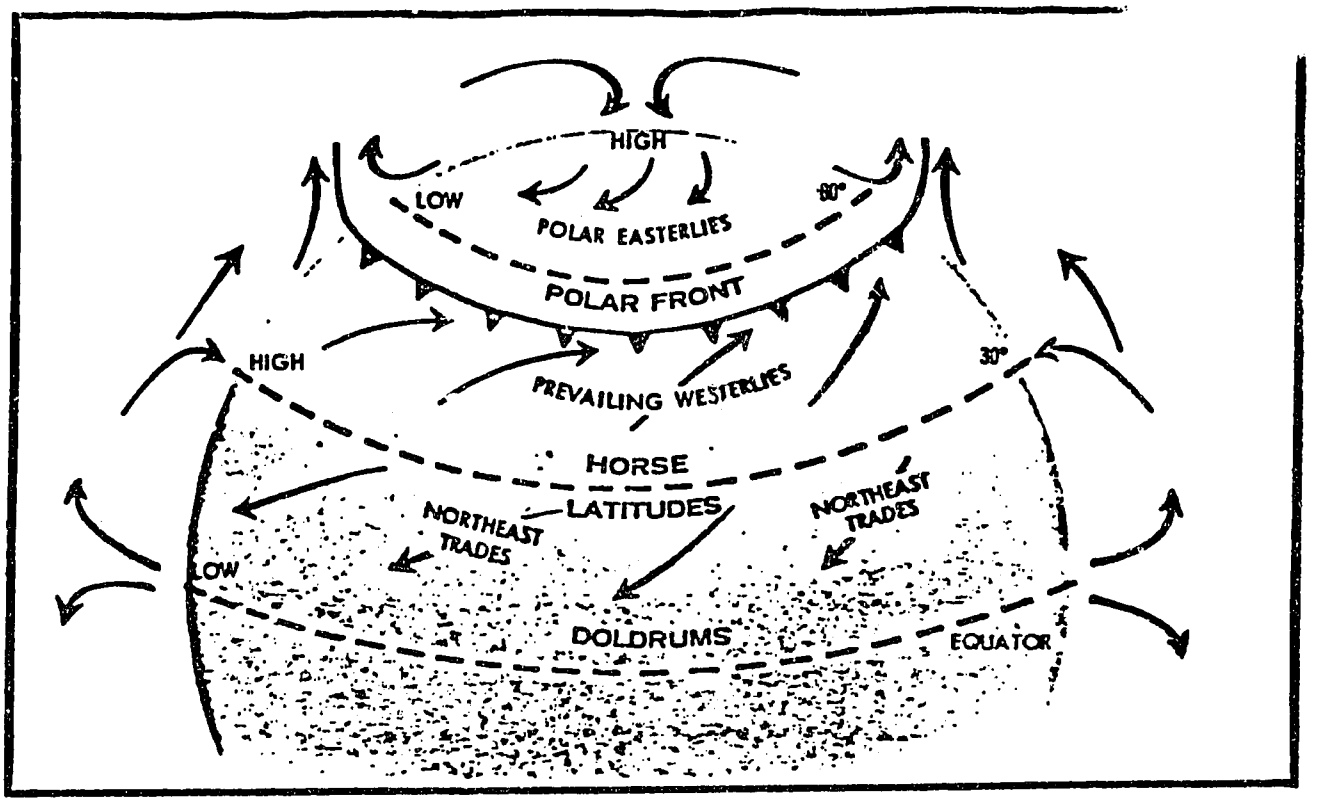
   b. Statistical presentations

   c. Model accuracy

   d. Sensitivity analyses

D. Use of Physical Modeling Techniques

541



On a rotating earth with a uniform surface, the general circulation of the Northern Hemisphere would be composed of the northeast trade winds, prevailing westerlies, and polar easterlies.

Source: Fire Weather... A Guide for Application of Meteorological Information to Forest Fire Control Operations, by Mark J. Schroeder and Charles C. Buck, Agriculture Handbook 360, Forest Service, U.S. Department of Agriculture, May 1970.

542

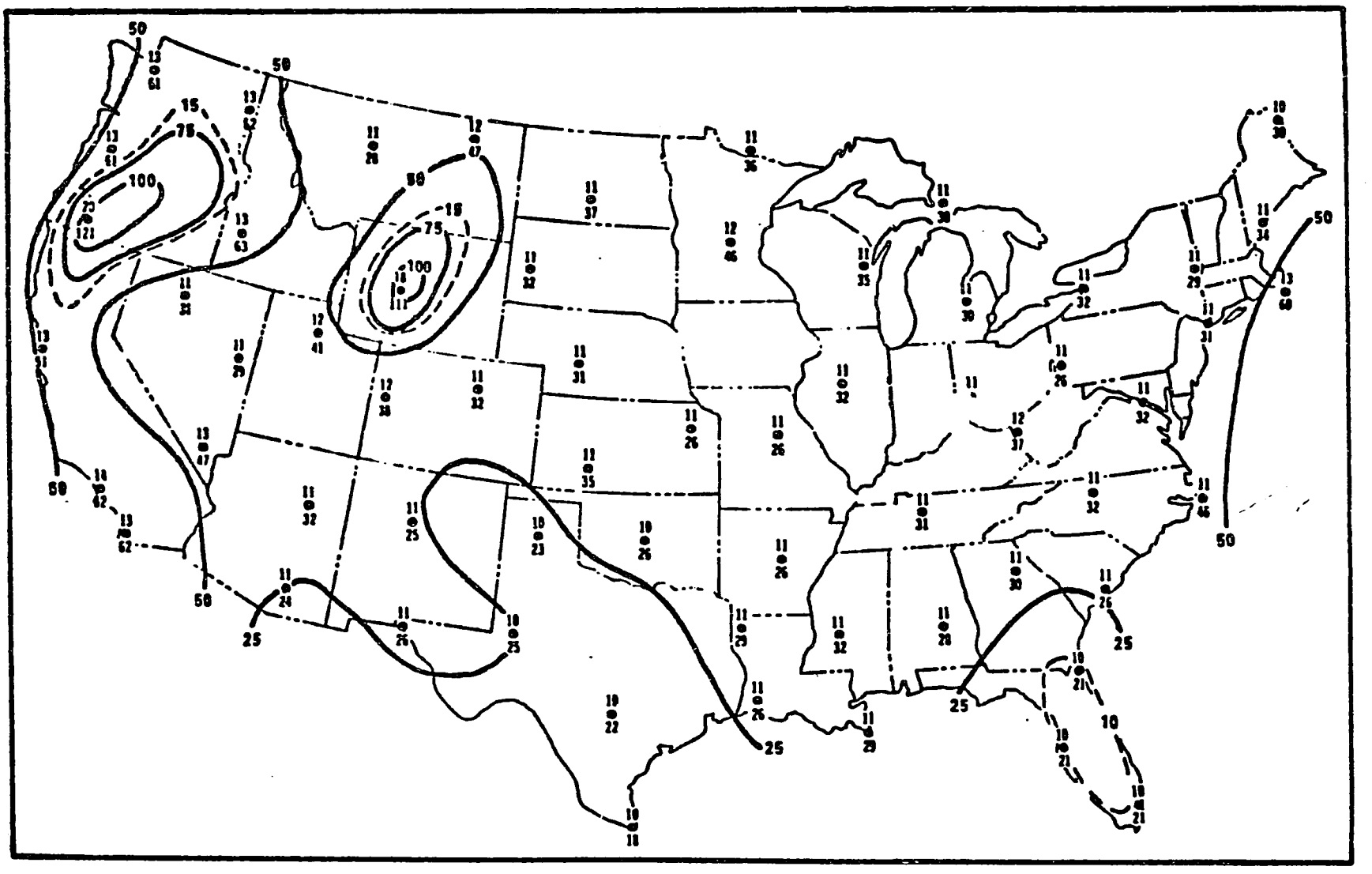
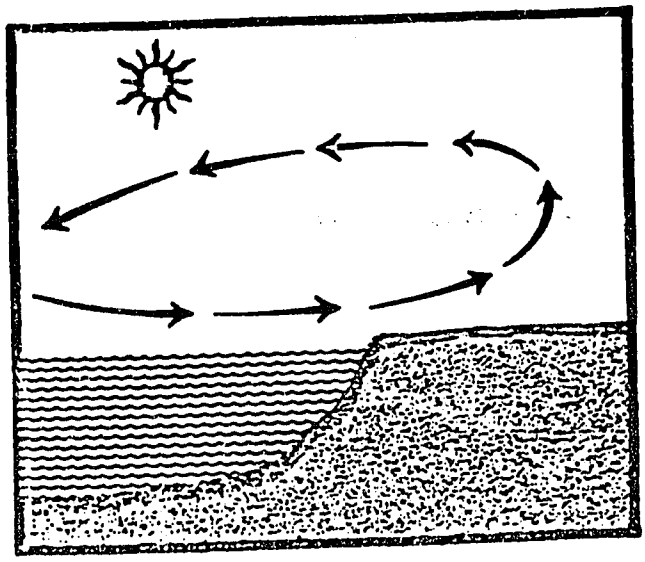
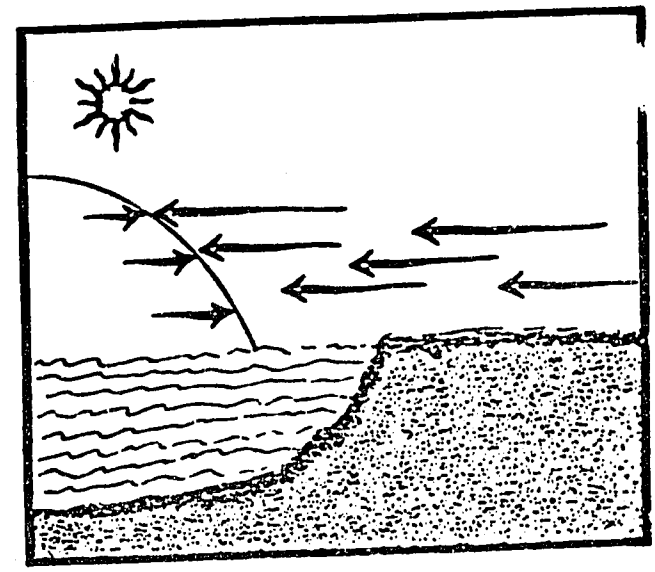


Figure 50. Data and isopleths (sec m^{-1}) of upper decile autumn afternoon $\bar{\chi}/\bar{Q}$ values (see text) for 10- (upper numerals and dashed isopleths) and 100-km (lower numerals and solid isopleths) city sizes.

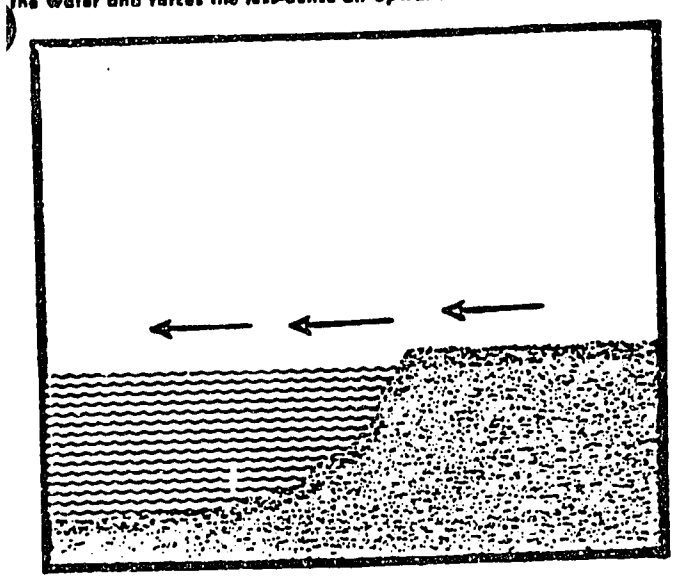
Source: Mixing Heights, Wind Speeds, and Potential for Urban Air Pollution Throughout the Contiguous United States, by George C. Holzworth, Division of Meteorology, Office of Air Programs, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, January 1972.



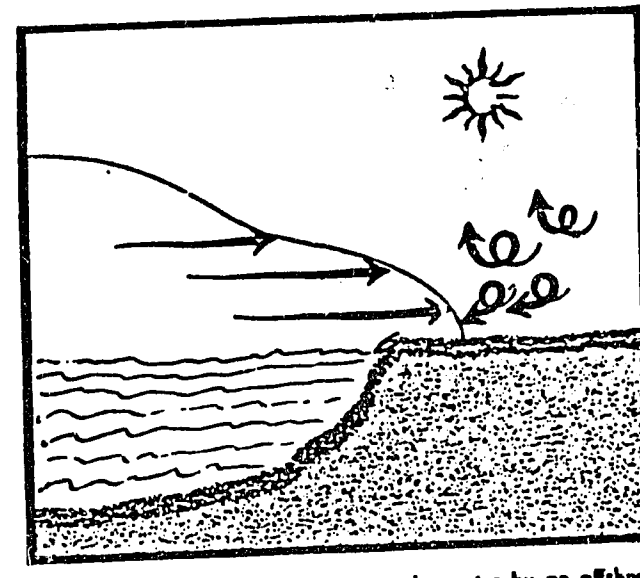
As land surfaces become warmer than adjacent water surfaces during the daytime, and air over the land becomes warm and buoyant, the denser sea breeze begins to flow inland from over the water and forces the less-dense air upward.



A general wind blowing toward the sea operates against the sea breeze and, if strong enough, may block the sea breeze entirely.

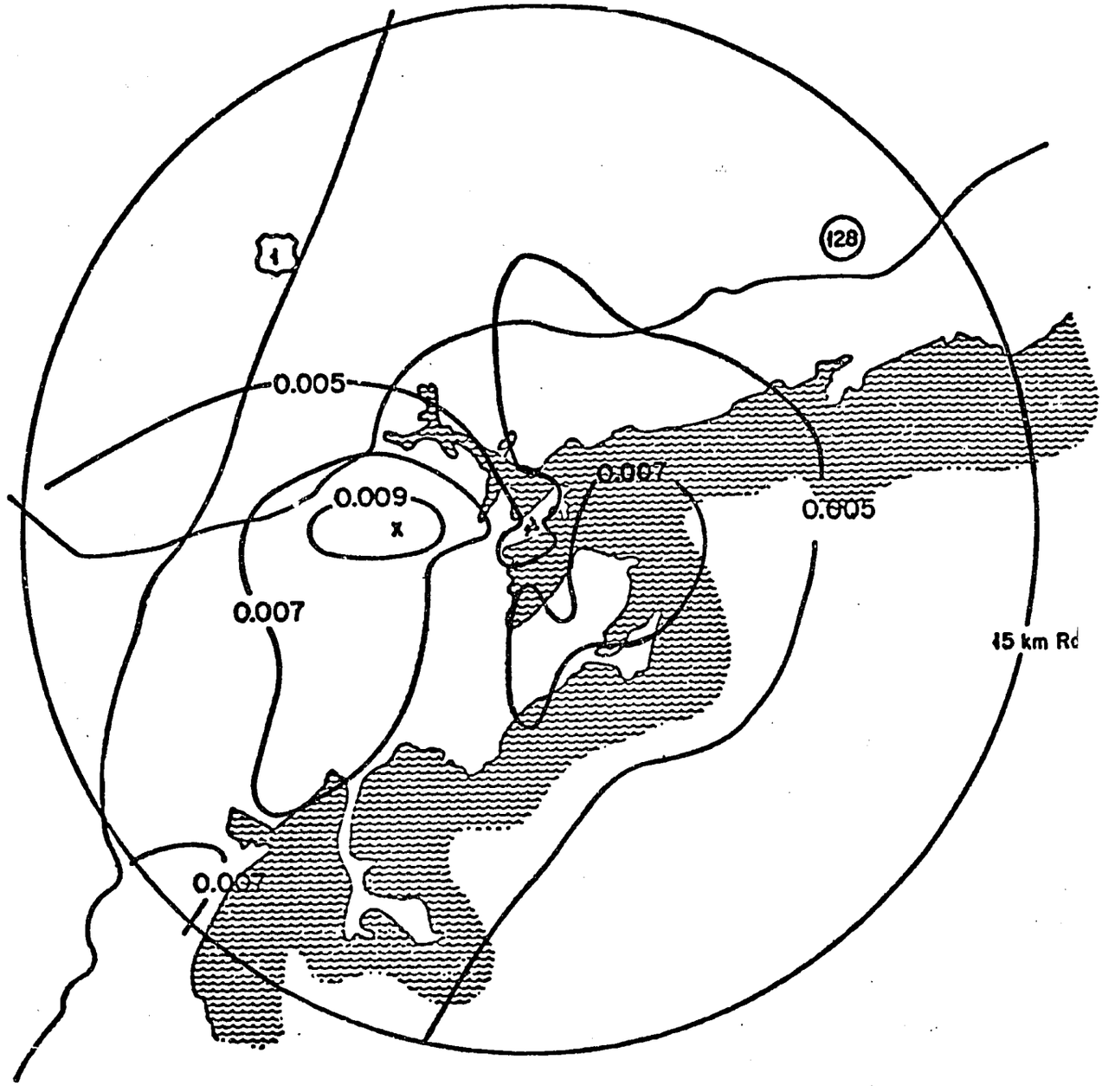


At night, land surfaces cool more quickly than water surfaces. Air in contact with the land becomes cool and flows out over the water as a land breeze, displacing the warmer air.



If marine air has been piled up over the water by an offshore wind, it may rush inland like a small-scale cold front when the local pressure difference becomes great enough.

Source: Fire Weather... A Guide for Application of Meteorological Information to Forest Fire Control Operations, by Mark J. Schroeder and Charles C. Buck, Agriculture Handbook 360, Forest Service, U.S. Department of Agriculture, May 1970.

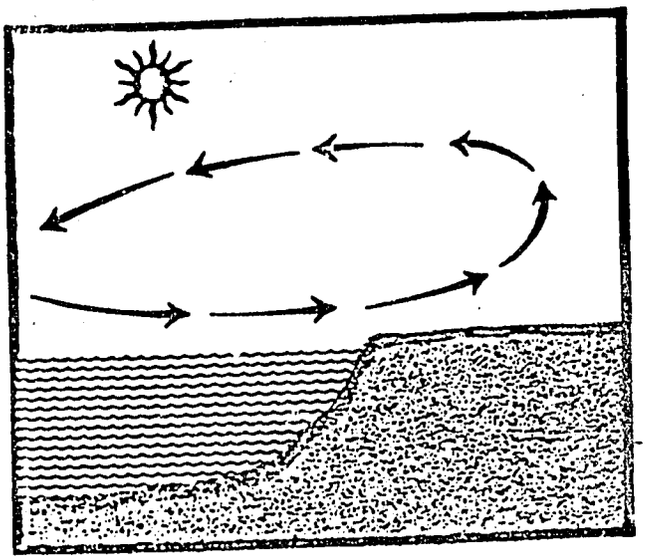


SCALE 0 1 2 3 4 5 KILOMETERS

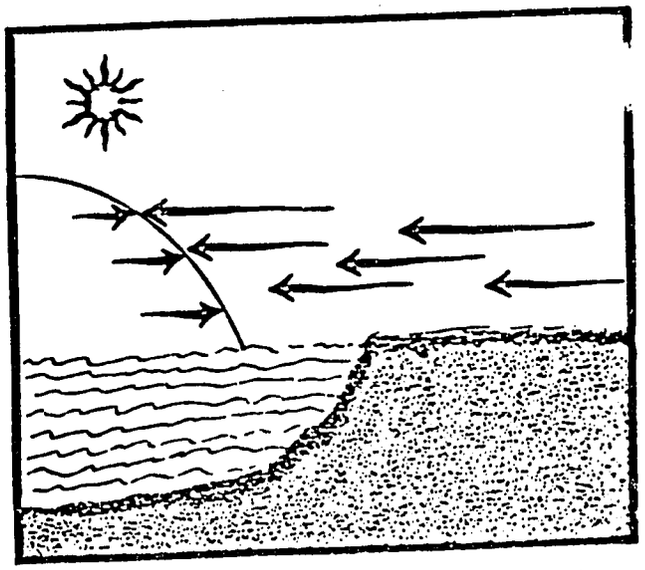
▲ SALEM HARBOR POWER PL

x PEAK ANNUAL SO_2 CONCENTRATION 0.012 ppm

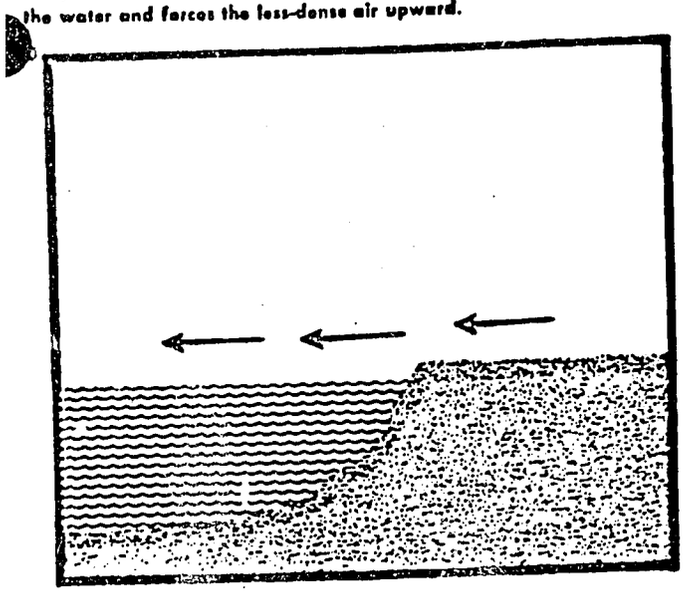
545



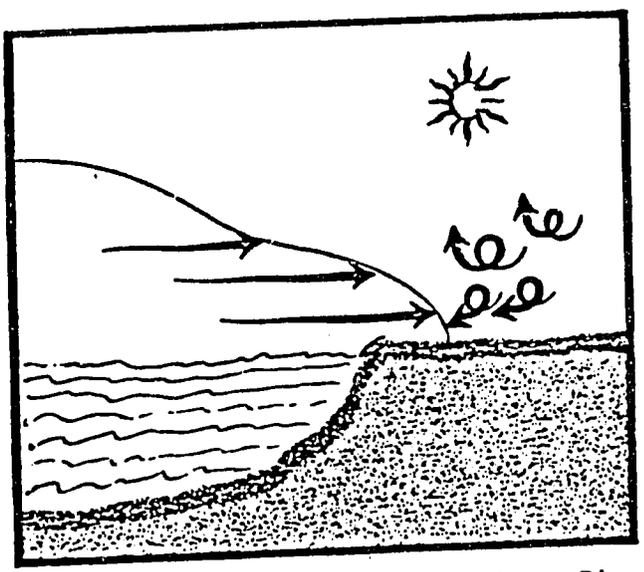
As land surfaces become warmer than adjacent water surfaces during the daytime, and air over the land becomes warm and buoyant, the denser sea breeze begins to flow inland from over the water and forces the less-dense air upward.



A general wind blowing toward the sea operates against the sea breeze and, if strong enough, may block the sea breeze entirely.



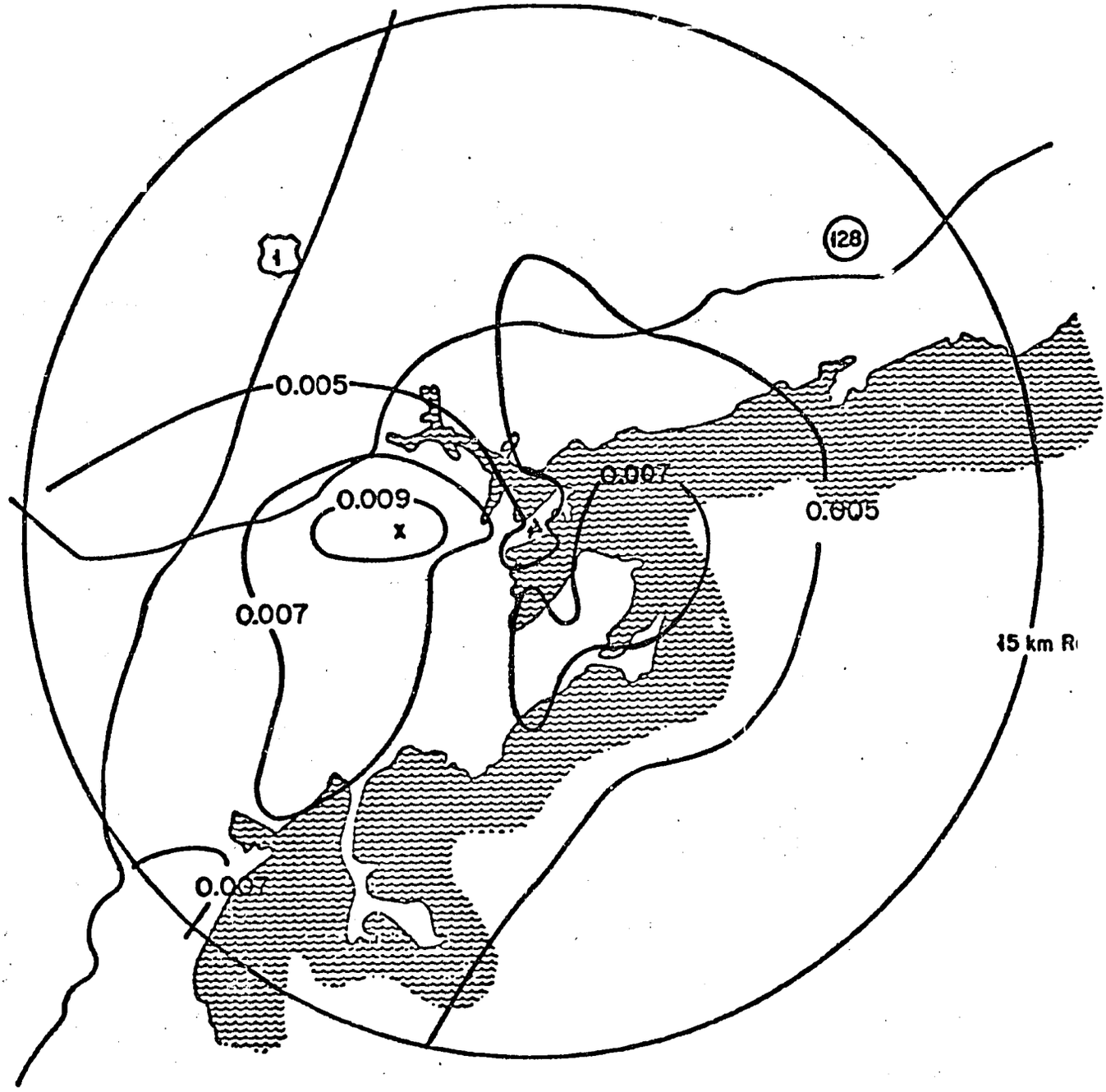
At night, land surfaces cool more quickly than water surfaces. Air in contact with the land becomes cool and flows out over the water as a land breeze, displacing the warmer air.



If marine air has been piled up over the water by an offshore wind, it may rush inland like a small-scale cold front when the local pressure difference becomes great enough.

Source: Fire Weather... A Guide for Application of Meteorological Information to Forest Fire Control Operations, by Mark J. Schroeder and Charles C. Buck, Agriculture Handbook 360, Forest Service, U.S. Department of Agriculture, May 1970.

546



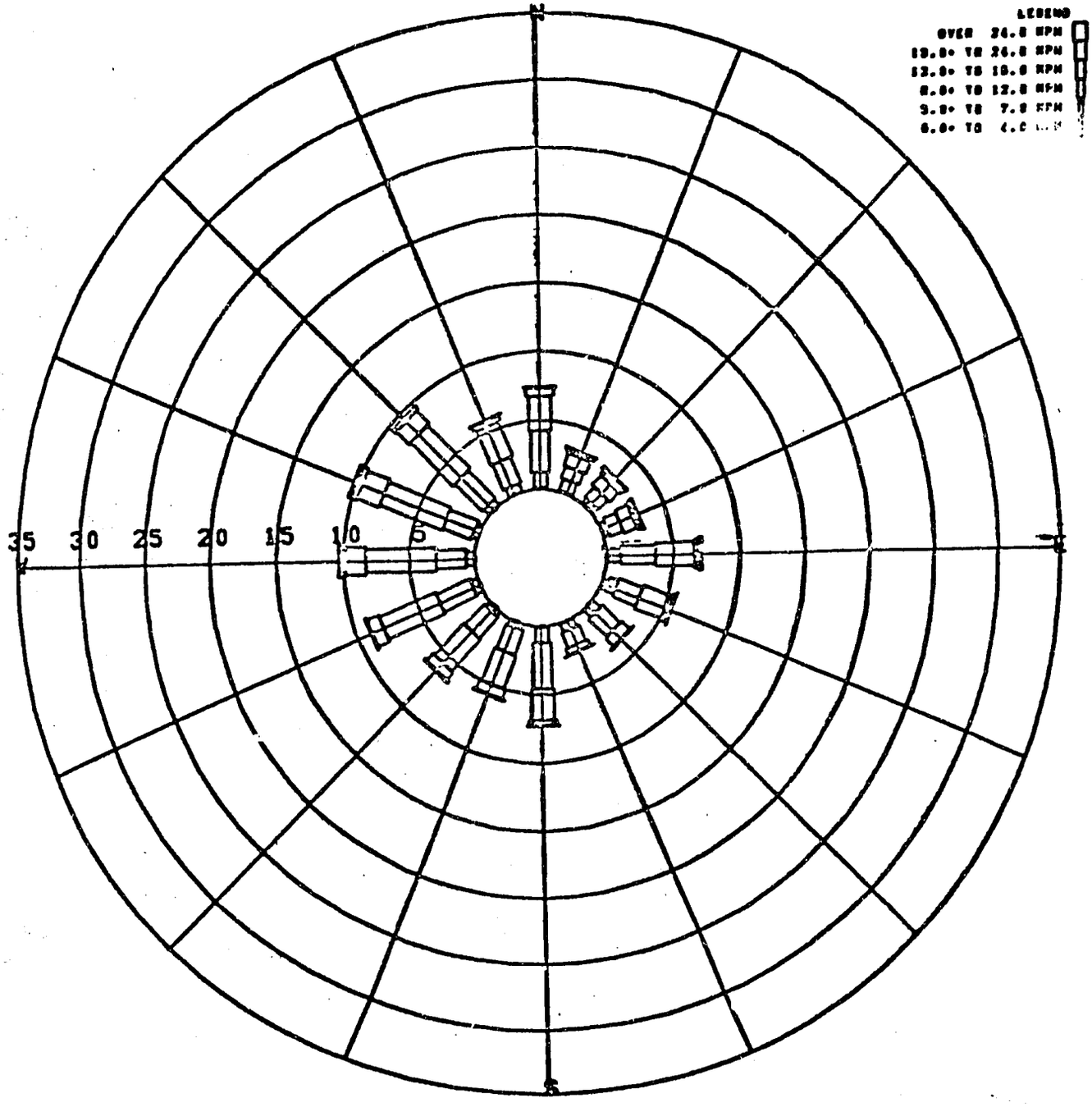
SCALE 0 1 2 3 4 5 KILOMETERS

▲ SALEM HARBOR POWER P

x PEAK ANNUAL SO_2 CONCENTRATION 0.012 ppm

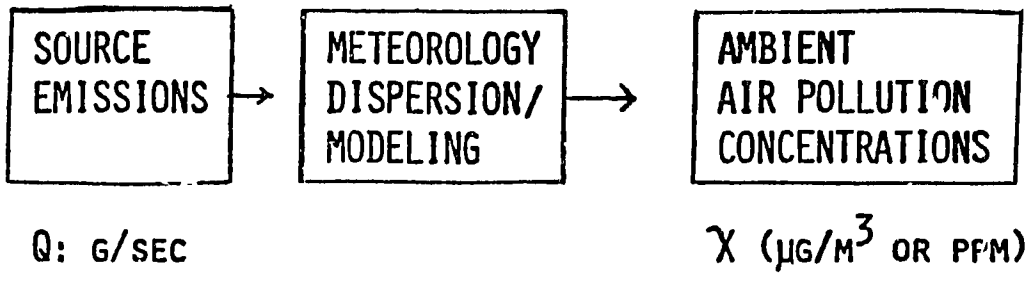
547

ENVIRONMENTAL RESEARCH + TECHNOLOGY LEXINGTON, MASSACHUSETTS 02173
BOSTON WIND ROSE 1965 - 1969
GRID VALUES REPRESENT WIND DISTRIBUTION IN PERCENT



Five-Year (1965-1969) Average Annual Wind Rose for
Logan Airport, Boston, Massachusetts

548


SOURCE EMISSIONS
METEOROLOGY DISPERSION/ MODELING
AMBIENT AIR POLLUTION CONCENTRATIONS
Q: G/SEC
χ (μG/M3 OR PPM)

549

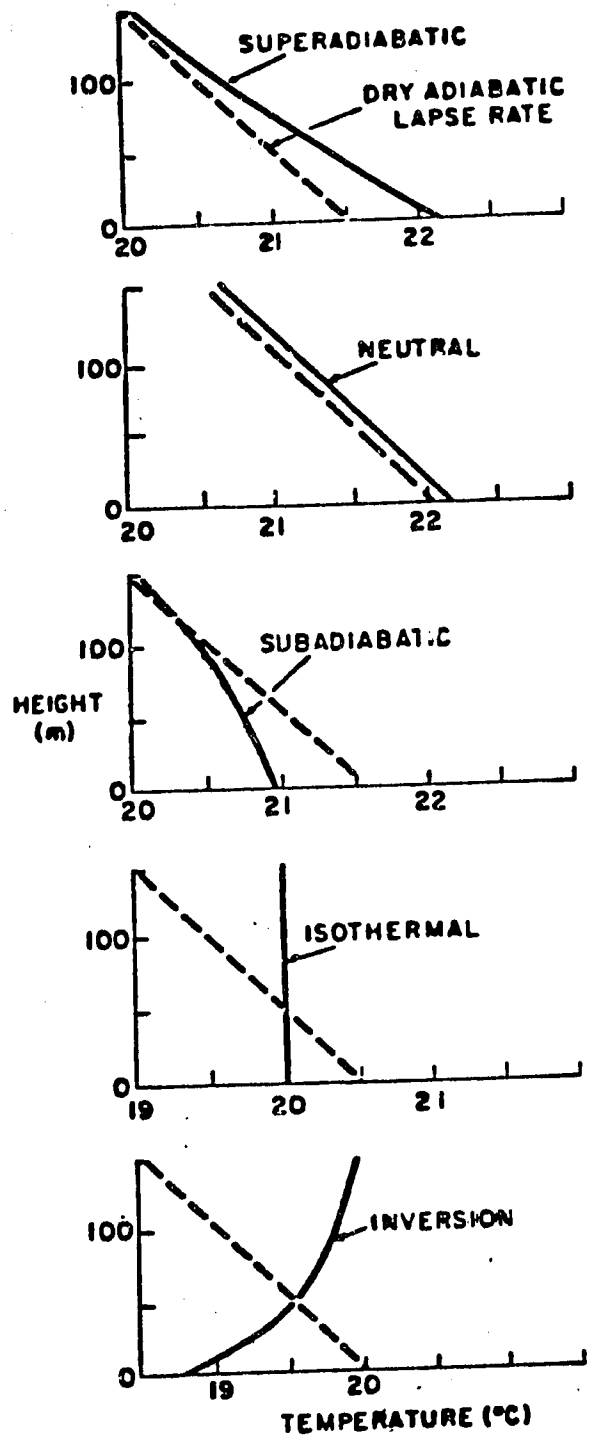


FIG. 1.5 TYPICAL ENVIRONMENTAL LAPSE RATES.
Typical examples of vertical temperature profiles are shown in comparison with the dry adiabatic lapse rate (−1C/100 m) which serves as a reference for distinguishing unstable from stable cases. The position of the dashed line representing the adiabatic lapse rate is not important; it is significant only as far as its slope is concerned.

Source: Recommended Guide for the Prediction of the Dispersion of Airborne Effluents, John R. Martin, Ed., Third Edition, The American Society of Mechanical Engineers, United Engineering Center, 345 East 47th Street, New York, NY 10017. Reproduced with permission.

Best Available Document

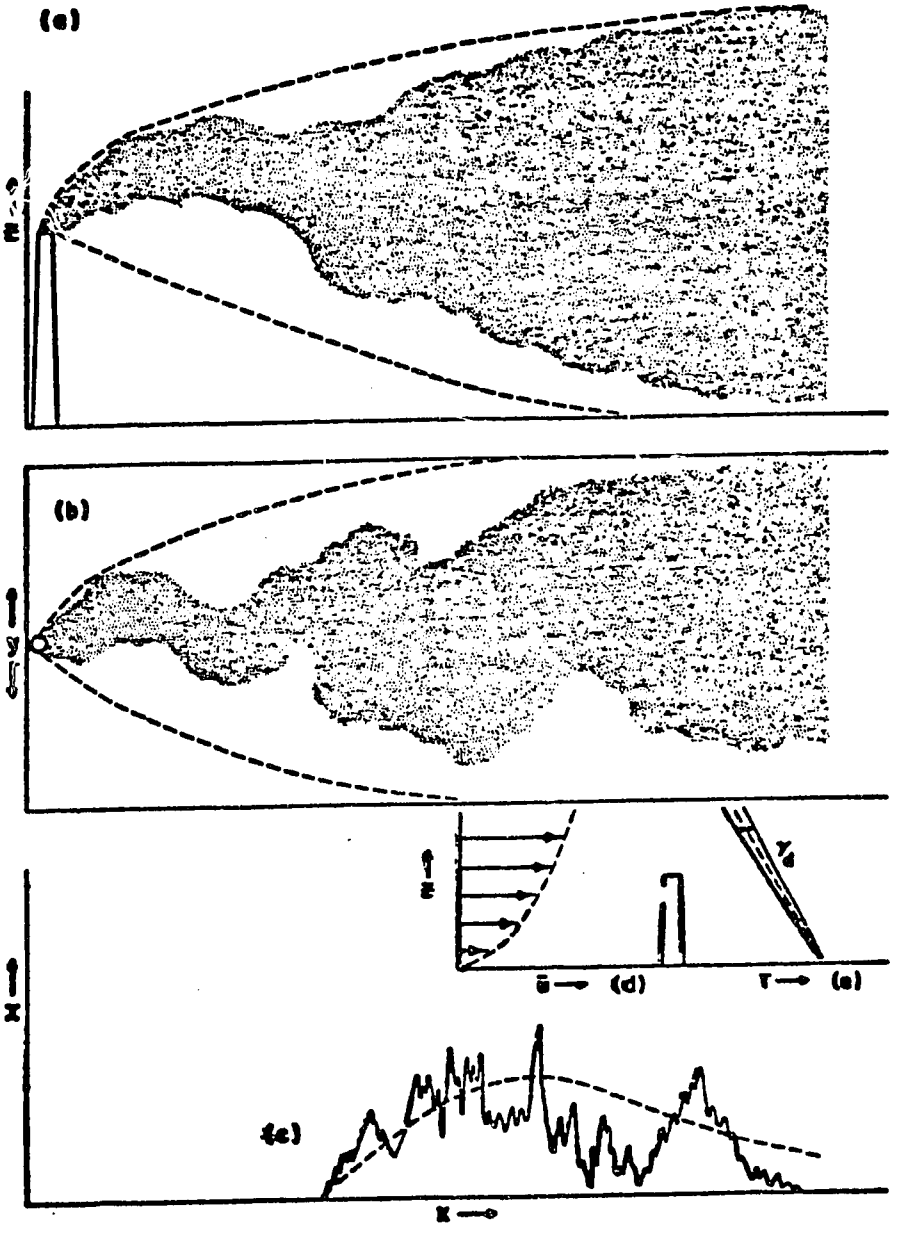


FIG. II-2 NEAR NEUTRAL ("CONING")

Source: Recommended Guide for the Prediction of the Dispersion of Airborne Effluents, John R. Martin, Ed., Third Edition, The American Society of Mechanical Engineers, United Engineering Center, 345 East 47th Street, New York, NY 10017. Reproduced with permission.

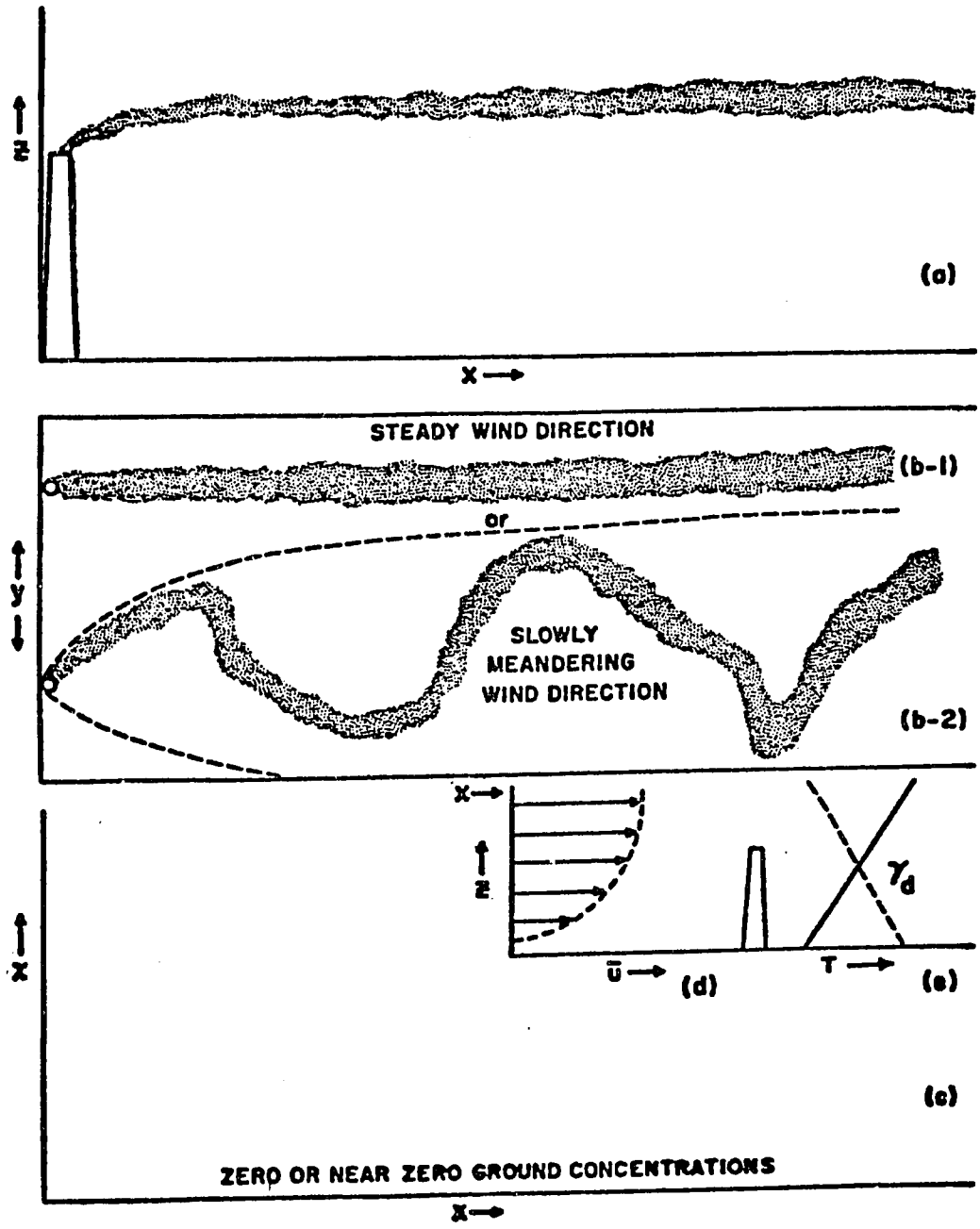


FIG. 11-3 SURFACE INVERSION ("FANNING")

Source: Recommended Guide for the Prediction of the Dispersion of Airborne Effluents, John R. Martin, Ed., Third Edition, The American Society of Mechanical Engineers, United Engineering Center, 345 East 47th Street, New York, NY 10017. Reproduced with permission.

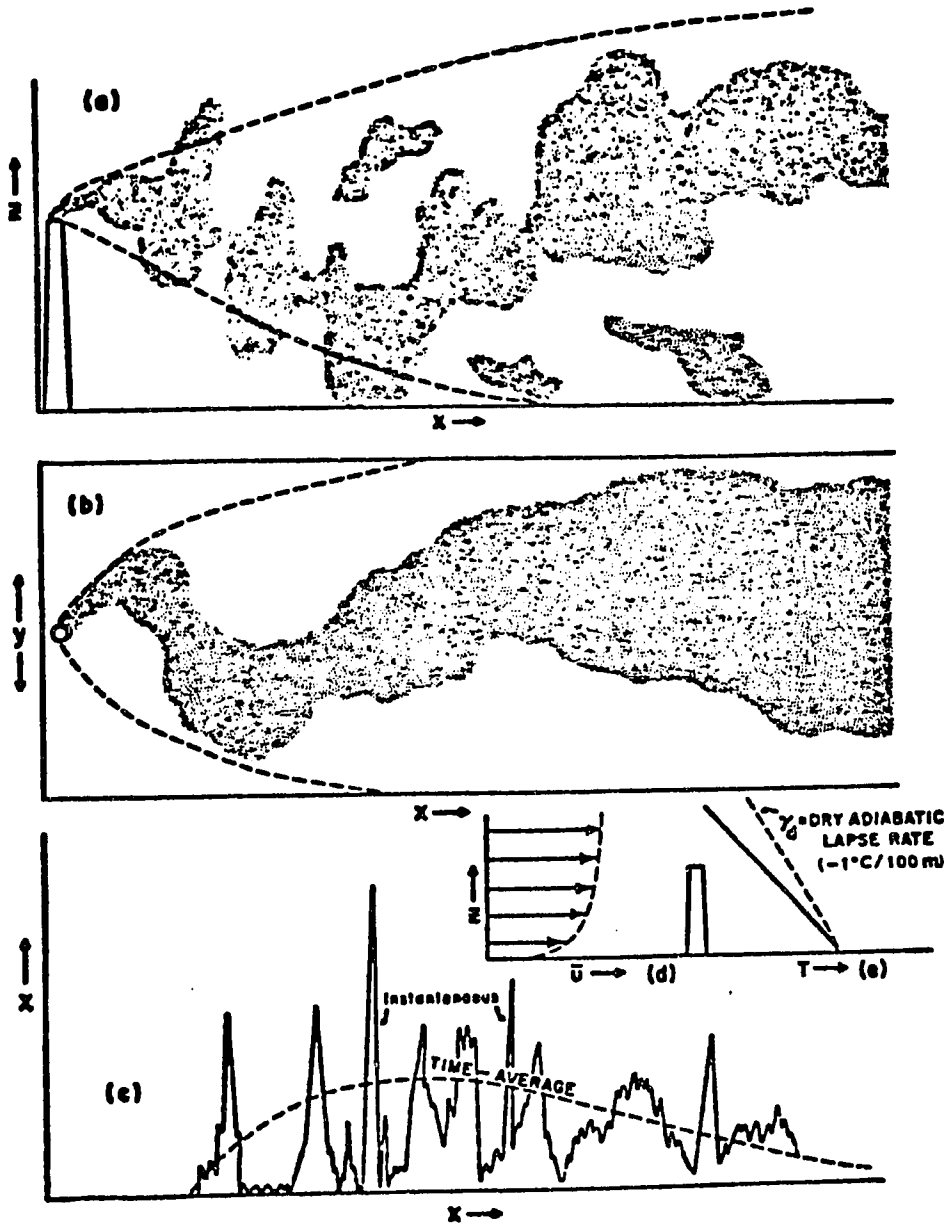


FIG. II-1 STRONG INSTABILITY ("LOOPING")

FIGS. II-1–II-5 PLUME DISPERSION. These five figures represent all of the major factors in different dispersion conditions. Sections (a) and (b) show elevations and plan views of dispersing plumes, in which stippled areas represent an "instantaneous" view and the dashed lines the hourly mean plume outlines. Section (c) shows plots of ground-level concentrations downwind, and (d) and (e) are plots of profiles of wind and temperature, respectively.

Source: Recommended Guide for the Prediction of the Dispersion of Airborne Effluents, John R. Martin, Ed., Third Edition, The American Society of Mechanical Engineers, United Engineering Center, 345 East 47th Street, New York, NY 10017. Reproduced with permission.

553

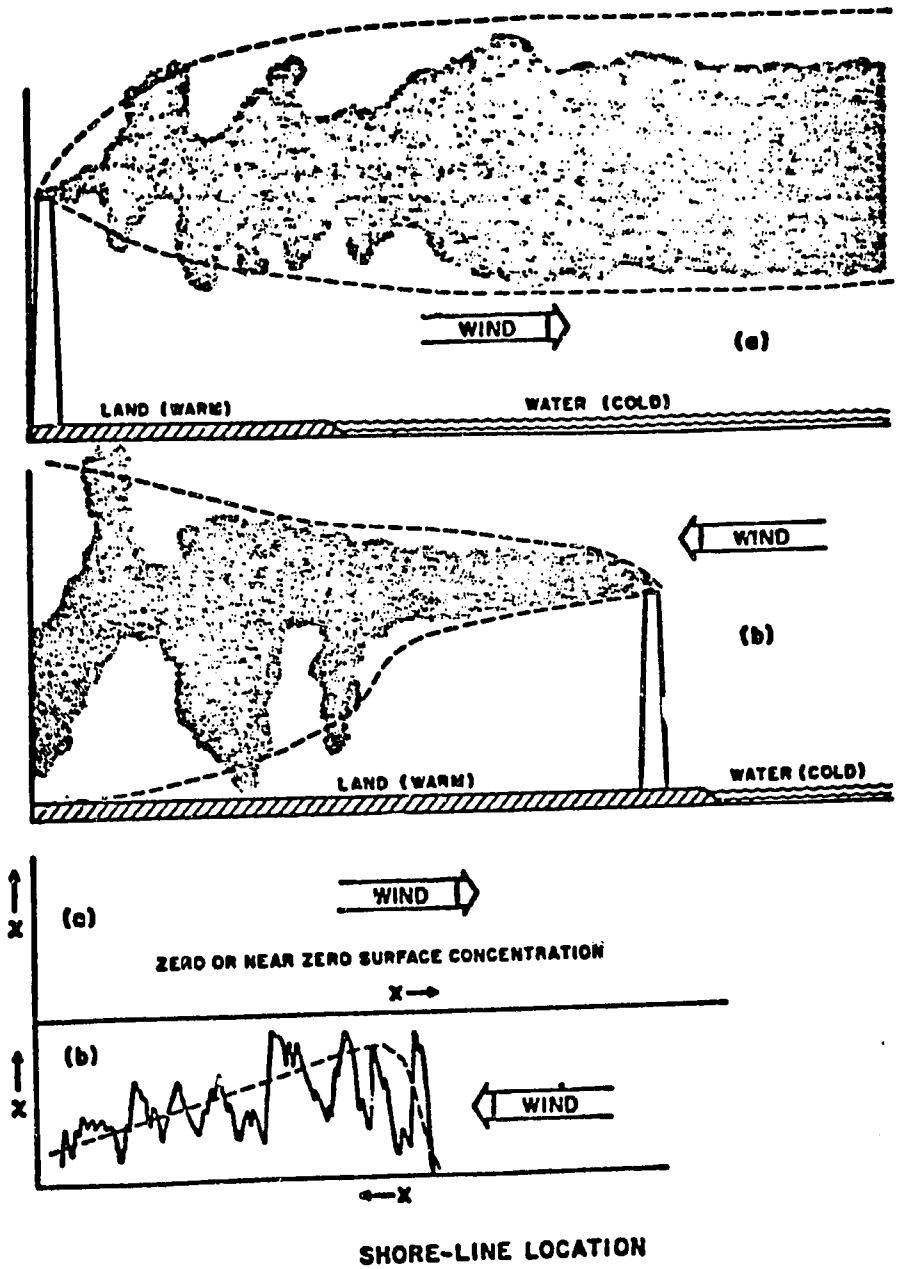


FIG. II-9 PLUME DISPERSION AT A SHORE-LINE LOCATION. A plume moving from warm land over cold water will lose its unstable characteristics and take on those of a stable plume. The converse occurs with the typical sea-breeze where the plume moves inland from cold water to warm land.

Source: Recommended Guide for the Prediction of the Dispersion of Airborne Effluents, John R. Martin, Ed., Third Edition, The American Society of Mechanical Engineers, United Engineering Center, 345 East 47th Street, New York, NY 10017. Reproduced with permission.

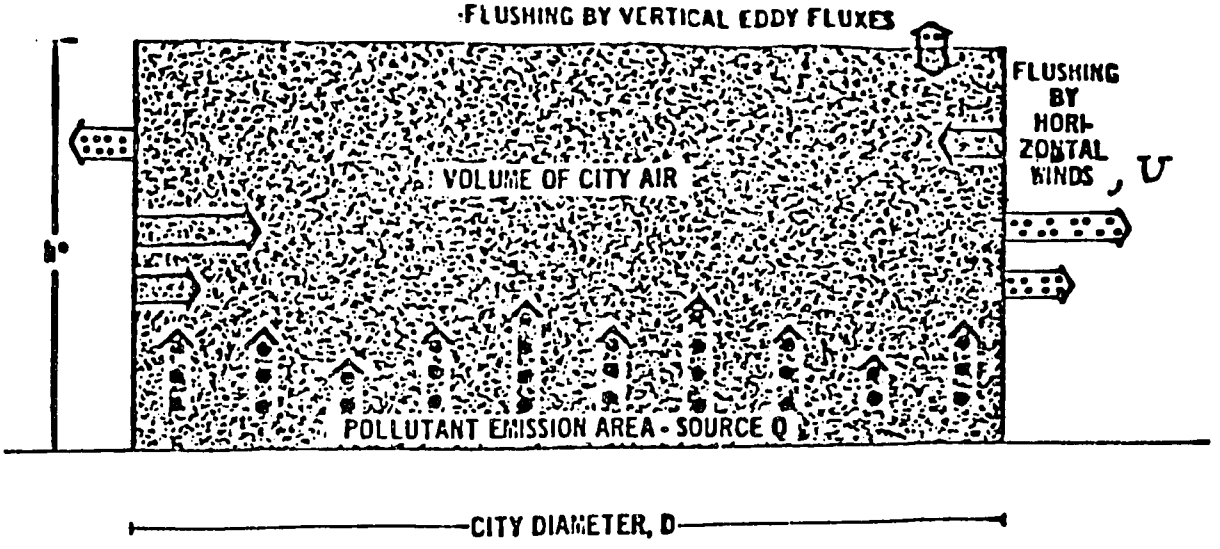


Figure 2-2. Schematic illustration of box or scalar model of urban diffusion.

$$C = \frac{Q}{UH^{*}W}$$

C = CONCENTRATION AT DOWNWIND END OF BOX (G/M^3)

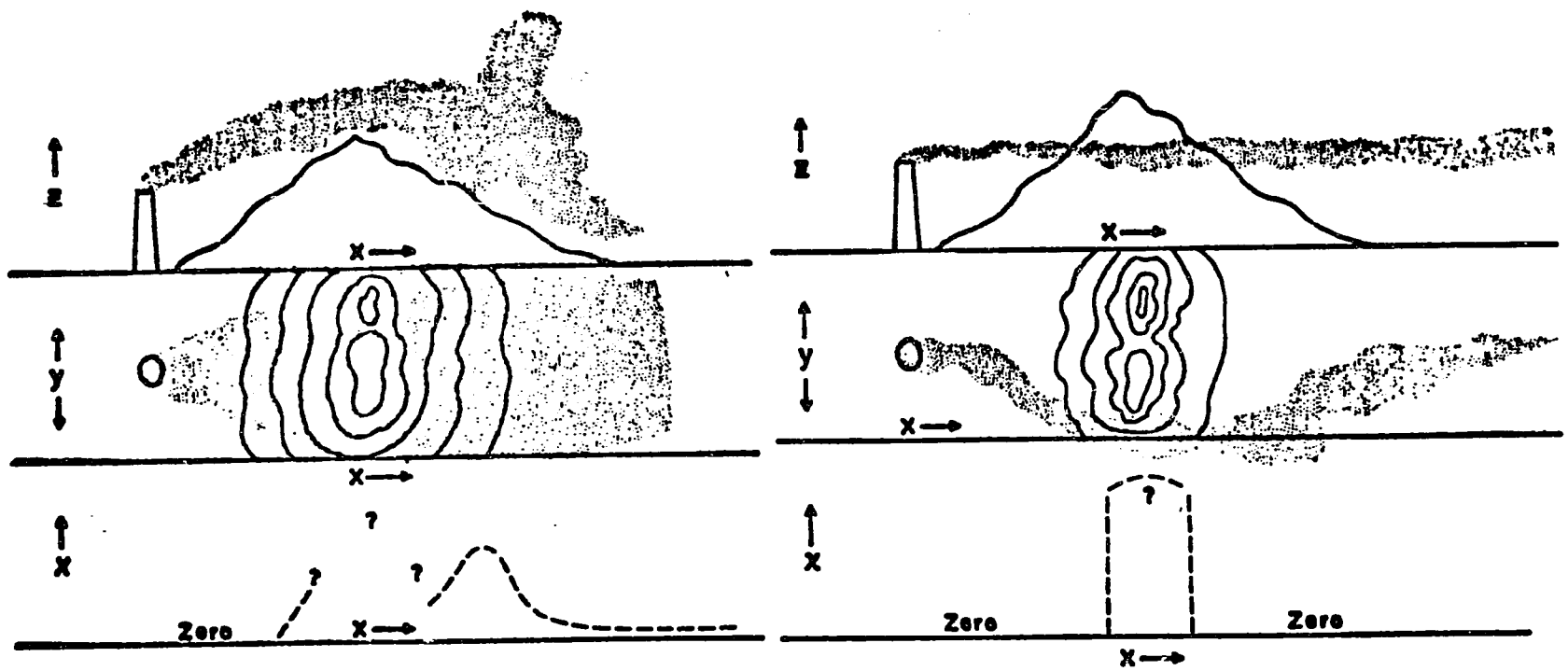
Q = TOTAL EMISSION RATE (G/SEC)

U = HORIZONTAL VELOCITY

H^* = MIXING DEPTH (M)

W = WIDTH OF BOX (M)

555



(a) HILL DOWNWIND-UNSTABLE LAPSE RATE

(b) HILL DOWNWIND-STABLE LAPSE RATE

FIG. II-17 PLUME DISPERSION NEAR VERY LARGE OBSTACLES. Very large and prominent landforms may affect the flow patterns somewhat differently than would be true of small buildings or hills. The entire plume may rise over a large hill in unstable conditions, possibly contacting the surface to some degree. In stable conditions, the air flow (and the plume) may be diverted around the obstacle.

Source: Recommended Guide for the Prediction of the Dispersion of Airborne Effluents, John R. Martin, Ed., Third Edition, The American Society of Mechanical Engineers, United Engineering Center, 345 East 47th Street, New York, NY 10017. Reproduced with permission.

656

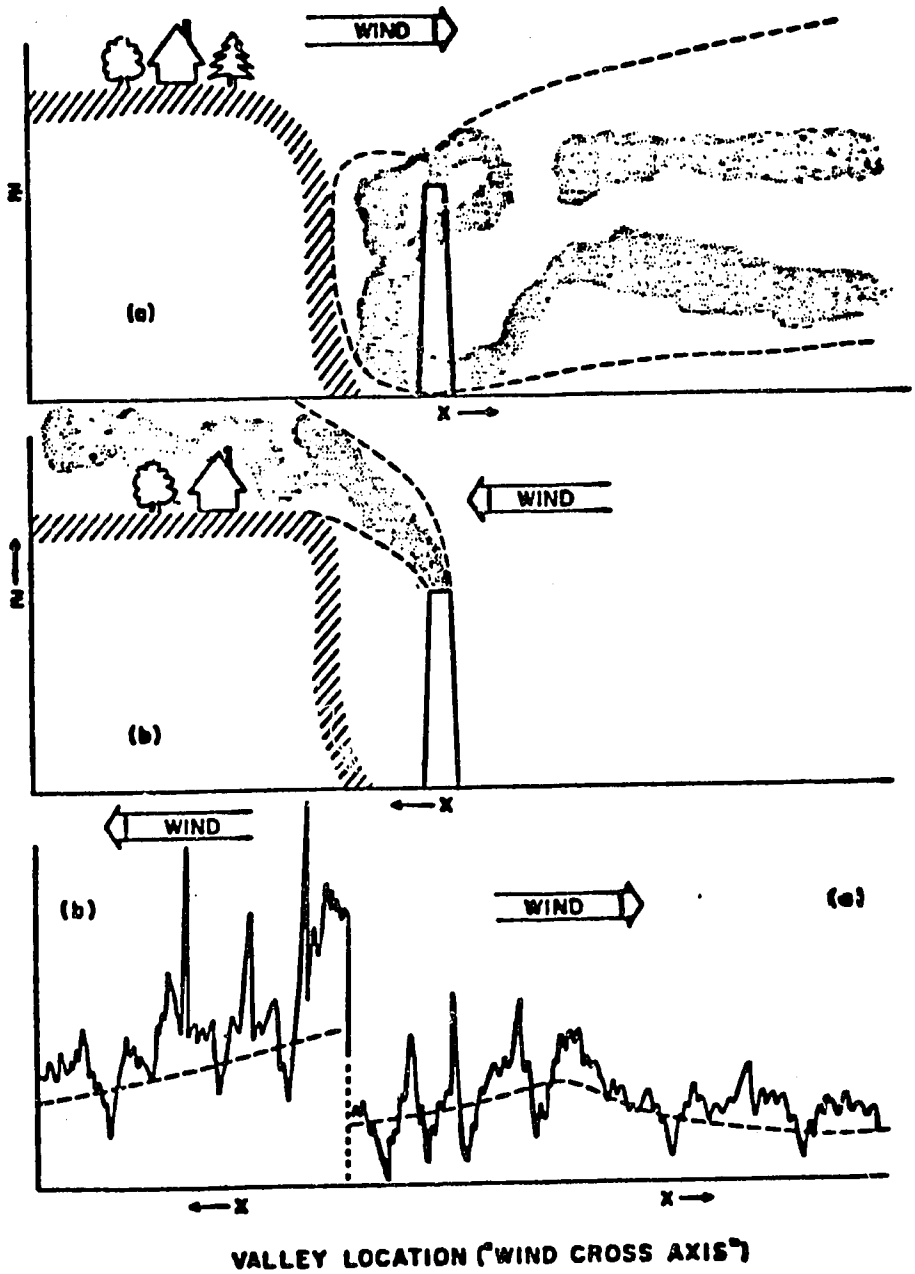
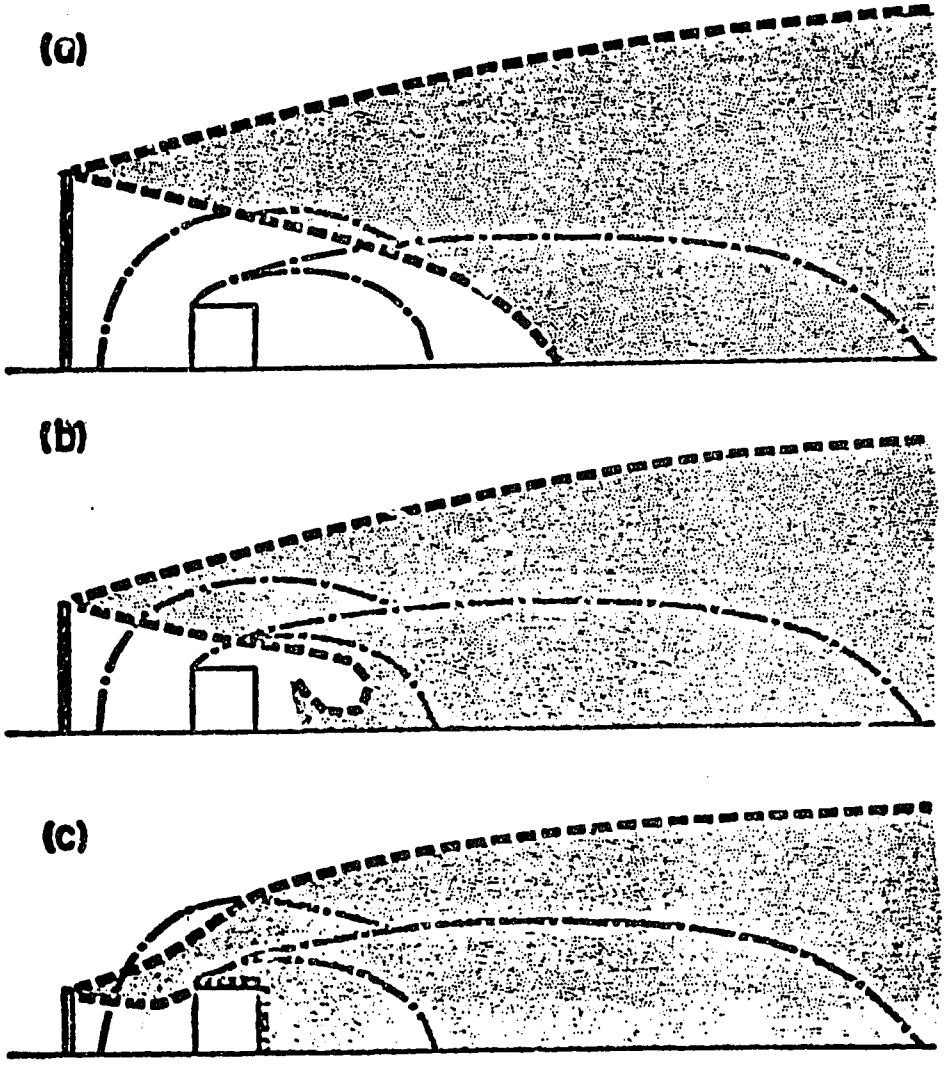


FIG. II-15 PLUME DISPERSION IN A DEEP VALLEY. With a wind from left to right, as in Section (a), the plume may be brought quickly to ground-level by aerodynamic eddies. Wind from the opposite direction may create high concentrations on the plateau.

Source: Recommended Guide for the Prediction of the Dispersion of Airborne Effluents, John R. Martin, Ed., Third Edition, The American Society of Mechanical Engineers, United Engineering Center, 345 East 47th Street, New York, NY 10017. Reproduced with permission.

557



Source: Recommended Guide for the Prediction of the Dispersion of Airborne Effluents, John R. Martin, Ed., Third Edition, The American Society of Mechanical Engineers, United Engineering Center, 345 East 47th Street, New York, NY 10017. Reproduced with permission.

558

REFERENCES

1. D.B. Turner, Workbook of Atmospheric Dispersion Estimates, Office of Air Programs Publication No. AP-26. US Environmental Protection Agency, Research Triangle Park, North Carolina. 84 pp. 1970.

2. J. R. Martin (ed.), Recommended Guide for the Prediction of the Dispersion of Airborne Effluents. American Society of Mechanical Engineers, 345 East 47th Street, New York, New York 10017. 85 p. 1979.

3. Environmental Protection Agency, Guideline on Air Quality Models. Guideline Series OAQPS No. 1.2-080. Research Triangle Park, North Carolina 1977.

4. American Meteorological Society, Preprints of Joint Conference on Applications of Air Pollution Meteorology, Nov. 29 - Dec. 2, 1977. Salt Lake City, Utah. American Meteorological Society, 45 Beacon Street, Boston, Massachusetts 02108. 413 pp. 1977.

5. D.A. Haugen (editor), Lectures on Air Pollution and Environmental Impact Analyses. American Meteorological Society, 45 Beacon Street, Boston, Massachusetts 02108. 296 pp. 1975.

6. F. Pasquill, Atmospheric Diffusion, 2d ed., Halstead Press, New York, New York. 429 pp. 1974.

7. D.B. Turner, 1979: Atmospheric Dispersion Modeling - A Critical Review. Journal of the Air Pollution Control Association (APCA) Vol. 29, Number 5, May 1979 pp. 502-519, APCA, 4400 Fifth Avenue, Pittsburgh, Pennsylvania 15213.

559

BRUCE A. EGAN

Vice President and General Manager, Air Quality Center

Professional Experience

Dr. Egan leads the Air Quality Center, the group within Environmental Research & Technology, Inc. (ERT) responsible for providing air quality consulting services nationwide and for the development and application of air pollution transport and dispersion models. At ERT, he has directed a number of projects, including a large air pollution monitoring model development and model validation program for the prediction of air quality levels in the vicinity of urban freeways, a multiphased program involving the development and validation of a plume rise model for gas turbine emissions, the development and application of dispersion models for the prediction of air quality in regions of complex terrain and the development of modeling techniques for the prediction of long-range transport of sulfates. Dr. Egan also manages other developmental and application programs involving air pollution impact emissions from both stationary and mobile sources. He has written a number of technical journal articles in the areas of air pollution meteorology and air quality modeling.

Dr. Egan is experienced in mechanical engineering, meteorology and air pollution technology. For two years, he was Engineer-in-charge of the Undergraduate Mechanical Engineering Laboratories at Harvard University, where he was primarily responsible for the design and development of laboratory experiments and apparatus for engineering courses in fluid dynamics and thermodynamics. Subsequently, he became Associate Director of the National Committee for Fluid Mechanics Films, in association with Educational Development Center, Inc., where he was responsible for the development of experiments used in an extensive educational film series on fluid mechanical phenomena. Dr. Egan has taught part-time at Boston University, and is presently appointed as a Visiting Lecturer at Harvard University. Dr. Egan has provided expert witness testimony on a number of occasions. He is a Certified Consulting Meteorologist, certified by the American Meteorological Society.

Dr. Egan's experience also includes the following professional activities:

- (1975) Invited by the American Meteorological Society to prepare and present a comprehensive review entitled "Turbulent Diffusion in Complex Terrain," Boston, Massachusetts.

- (1975 to Present) Member of the American Meteorological Society Committee on Meteorological Aspects of Air Pollution (Chairman 1976, 1977).

- (1975) Consultant to the Office of Technical Assessment to review the EPA 5-Year Plan for Research and Development, Washington, D.C.

- (1976) Invited participant in the DOE/ERDA sponsored Workshop on Research Needs for Atmospheric Transport and Diffusion in Complex Terrain, Alburquerque, New Mexico.

- (1976) Participant in the USA-USSR Working Group on Air Pollution Modeling, Instrumentation and Measurement Methodology, Leningrad, USSR.

- (1977) An invited participant in the EPA sponsored Specialists Conference on the EPA Modeling Guideline, Chicago, Illinois.

- (1977) Invited participant in the AMS Workshop on Stability Classification Schemes and Sigma Curves, Boston, Massachusetts

- (1977) Program Chairman for the AMS/APCA Joint Conference on Applications of Air Pollution Meteorology, Salt Lake City, Utah.

- (1977 to Present) Member of the General Committee of the Air Pollution Control Division of the American Society of Mechanical Engineers.

- (1979) Panel leader at the EPA Workshop to Develop Recommendations on Atmospheric Dispersion Models in Complex Terrain, Raleigh, North Carolina.

- (1979) Member of the National Commission on Air Quality Atmospheric Dispersion Modeling Panel, Washington, D.C.

- (1979 to Present) Member of the Steering Group of the AMS/EPA Cooperative Agreement.

Education

Dr. Egan received his A.B., S.M., and Sc.D. degrees in Engineering and Environmental Health Sciences from Harvard University.

Memberships

Air Pollution Control Association
Air Pollution Control Division, American Society of Mechanical Engineers
American Meteorological Society
Harvard Engineering Society
Sigma Xi (past chapter President)

GF-5/80

ENVIRONMENTAL MODELING

Water Modeling

Dominic DiToro

Associate Professor
Environmental Engineering and Science Program
Manhattan College

Consultant
Environmental Research & Technology, Inc.

June 1980

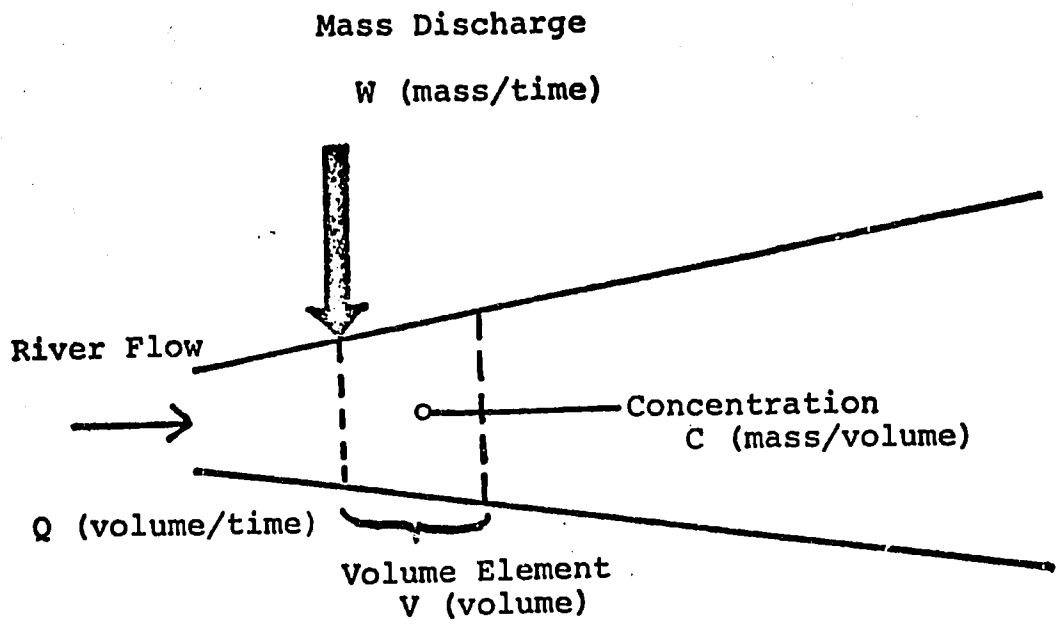
International Environmental Management Institute
ENVIRONMENTAL RESEARCH & TECHNOLOGY, INC.
Concord, Massachusetts, USA

562

1. INTRODUCTION AND OVERVIEW

Water quality modeling is a branch of Environmental Engineering which seeks to evaluate the consequences of the discharge of materials into natural or man-made bodies of water. The general questions to be answered are: what are the causes of presently existing water quality conditions and what can be expected to occur if remedial or other actions are taken. The methods used are quantitative rather than descriptive. They are based on numerical and mathematical methods that are characteristic of all engineering disciplines, rather than qualitative and descriptive methods that are more common to the natural biological sciences. The essential issue is that of causality: to relate the observed effects in a body of water to the natural and man-made causes. It is, therefore, not significantly different from other engineering disciplines in its aims, methods, and goals.

The calculations are based on the principle of mass balance. In its simplest terms one simply accounts for all the sources of materials of concern that enter the body of water, and all the sinks of this material within the water body, and all mass that exists. An example is shown in Figure 1. A mass discharge rate of magnitude W with units (mass/time) enters a river with flow rate Q (volume/time). A volume element of the appropriate size relative to the space scale is considered and an accounting is made of the mass entering the volume; the mass leaving the volume due to the river flow; and the mass leaving the volume due to the reactions occurring within the volume. For this example it is assumed that only one reaction is occurring and it removes mass at a constant fraction per unit time at a rate, K. It is further assumed that the time scale of the problem is such that all the quantities in the calculation are constant in time. The result of the mass balance is that the concentration of mass in the volume element, c (mass/volume) is given by: $c = W/(Q+KV)$. This result illustrates the components of water quality modeling: (1) the appropriate time and space scale are used; (2) the mass discharges are known; (3) the transport regime is specified; and (4) the kinetic structure is approximated. As shown subsequently these requirements can only be satisfied if adequate and appropriate receiving water and mass discharge measurements are made.



Mass Balance

Mass In	=	Mass Lost in V	+ Mass Out
W	=	KcV	+ Qc
(Inputs)	=	(Reactions)	+ (Transport)

Figure 1 Water Quality Monitoring: The Framework

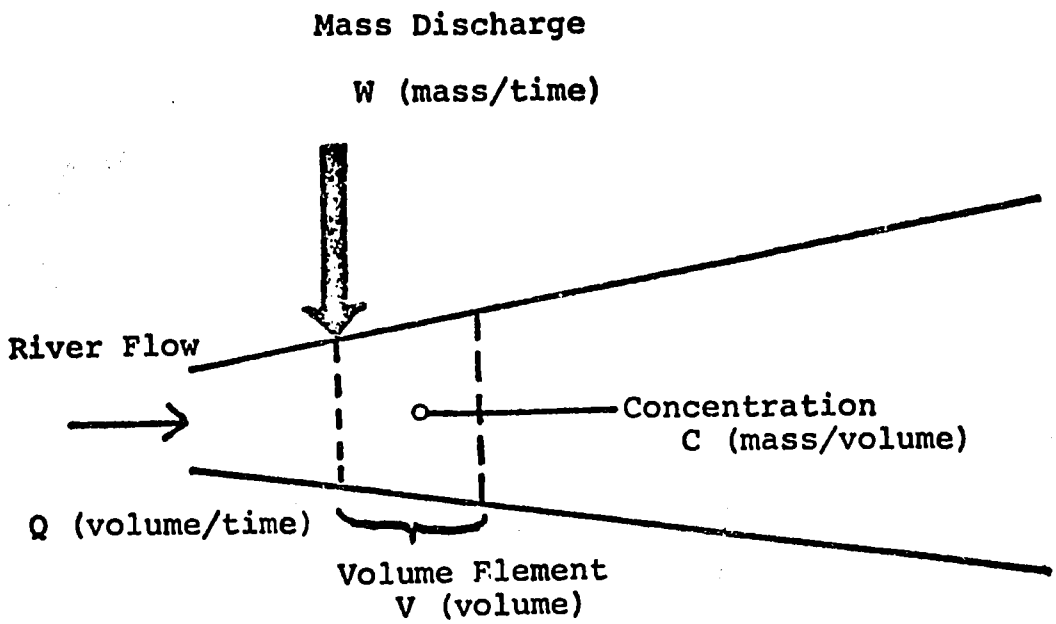
564

1. INTRODUCTION AND OVERVIEW

Water quality modeling is a branch of Environmental Engineering which seeks to evaluate the consequences of the discharge of materials into natural or man-made bodies of water. The general questions to be answered are: what are the causes of presently existing water quality conditions and what can be expected to occur if remedial or other actions are taken. The methods used are quantitative rather than descriptive. They are based on numerical and mathematical methods that are characteristic of all engineering disciplines, rather than qualitative and descriptive methods that are more common to the natural biological sciences. The essential issue is that of causality: to relate the observed effects in a body of water to the natural and man-made causes. It is, therefore, not significantly different from other engineering disciplines in its aims, methods, and goals.

The calculations are based on the principle of mass balance. In its simplest terms one simply accounts for all the sources of materials of concern that enter the body of water, and all the sinks of this material within the water body, and all mass that exists. An example is shown in Figure 1. A mass discharge rate of magnitude W with units (mass/time) enters a river with flow rate Q (volume/time). A volume element of the appropriate size relative to the space scale is considered and an accounting is made of the mass entering the volume; the mass leaving the volume due to the river flow; and the mass leaving the volume due to the reactions occurring within the volume. For this example it is assumed that only one reaction is occurring and it removes mass at a constant fraction per unit time at a rate, K. It is further assumed that the time scale of the problem is such that all the quantities in the calculation are constant in time. The result of the mass balance is that the concentration of mass in the volume element, c (mass/volume) is given by: $c = W/(Q+KV)$. This result illustrates the components of water quality modeling: (1) the appropriate time and space scale are used; (2) the mass discharges are known; (3) the transport regime is specified; and (4) the kinetic structure is approximated. As shown subsequently these requirements can only be satisfied if adequate and appropriate receiving water and mass discharge measurements are made.

565



Mass Balance

Mass In	=	Mass Lost in V	+ Mass Out
W	=	KcV	+ Qc
(Inputs)	=	(Reactions)	+ (Transport)

Figure 1 Water Quality Monitoring: The Framework

266

2. PRINCIPLES AND METHODOLOGY

2.1 Time and Space Scales

The framework of analysis begins with a specification of the appropriate time and space scales. These are intervals of time and space within which the concentrations of the materials of concern can be assumed to be constant or over which an averaging of the concentration fluctuations is reasonable. These are determined primarily by considering: (1) the reactivity of the substances; (2) the characteristic mixing and flushing time and space scales of the receiving water; (3) the time and space scale at which impacts are important. Figure 2 illustrates the orders of magnitude for various classes of materials. The range reflects the different receiving water types. Highly reactive materials, such as coliform bacteria and the reactions affecting dissolved oxygen are analyzed on hourly to weekly time scales and local to regional space scales. Suspended solids, nutrients, and algal growth have weekly to yearly time scales and local to regional space scales. Acute toxic effects on receiving water biota are short time and space scale phenomena, whereas long term toxic effects are cumulative and depend on the residence time of the material in question.

2.2 Mass Discharges

Adequate estimates of the mass inputs to receiving water are required. For point sources the issue is usually one of representative sampling for the appropriate time scale: for example, industrial effluents can change quantity and quality abruptly. The more severe difficulties are related to non-point sources: atmospheric inputs; distributed inputs related to overland and groundwater inflow to the water body; and inputs from stormwater and combined sewer drainage. For situations in which these are likely to be important, specialized sampling programs and estimation methods are required. In water quality modeling there is no substitute for reliable mass discharge information based on direct measurements at the appropriate time and space scale.

2.3 Transport

Adequately characterizing the transport is not straightforward because the receiving water geometry and hydrodynamics are fixed by natural circumstances and tend to be complex. There are very few perfectly uniform streams or circular flat-bottomed lakes. As a consequence the transport regime usually is estimated from the distribution of tracer substances. Detailed numerical calculations of circulation, if they are necessary, are also compared to observations of water motion and tracer distributions. Therefore, data are central to the estimation of the transport regime.

567

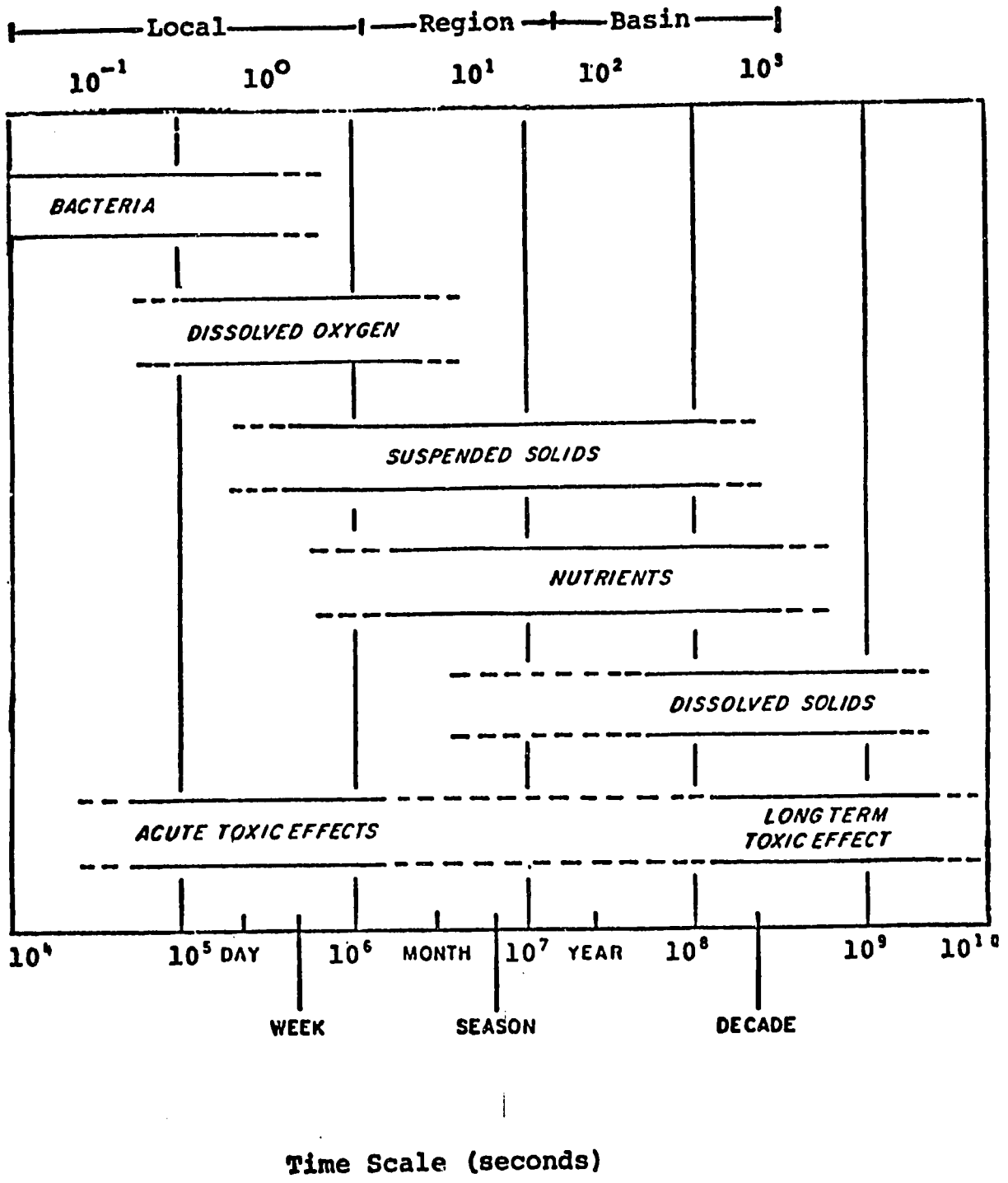

SPATIAL SCALE (km)
Local
Region
Basin
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
BACTERIA
DISSOLVED OXYGEN
SUSPENDED SOLIDS
NUTRIENTS
DISSOLVED SOLIDS
ACUTE TOXIC EFFECTS
LONG TERM TOXIC EFFECT
10^{4}
10^{5} DAY
10^{6} MONTH
10^{7} YEAR
10^{8}
10^{9}
10^{10}
WEEK
SEASON
DECADE
Time Scale (seconds)

Figure 2

568

It is usually necessary and always advisable to simplify the problem by reducing the spatial dimensionality to either one or two dimensions as appropriate. Whether this is reasonable is determined by the water quality observations, the spatial detail reqired for the analysis, and the spatial scale. Figure 3 illustrates common simplifications that are employed. Advection refers to the unidirectional velocities averaged to the appropriate time and space scale, and dispersion refers to the mixing induced by the circulations and velocity fluctuations that are not incorporated into the time and space averaged velocity field.

2.4 Kinetics

The most complex issues arise from the reactions which occur in natural waters. Chemical and biological reactions are both involved and they must be characterized realistically and quantitatively. In other engineering disciplines, for example chemical engineering, the important chemical reactions can be investigated in laboratory reactors and the results are directly applicable to the prototype. In natural waters this is not the case. The difficulty is that most reactions of interest are either explicitly biological, such as the growth and death of algae, or are the result of the interactions of microorganisms and the substance of interest, such as the oxidation of organic carbon compounds. These reactions are influenced by the nature of the water body being analyzed in complex and uncertain ways. The type of drainage area, the hydrology, the geomorphology of the receiving water, the type and composition of the sediment, the quantity and characteristics of suspended particles and other dissolved materials, all influence the biological régime, and contribute to the reaction kinetics. Laboratory experiments in highly simplified and idealized settings are not adequate analogues of the natural body of water, although they can add important information for certain isolated reactions.

It is primarily this lack of direct laboratory analogues that has forced the development of methods in water quality modeling that rely on observed data directly as an integral part of the analysis. The use of these methods in a wide variety of water bodies has lead to the accumulation of empirical information from which it is possible to establish realistic models for certain of the important reactions and to establish probable ranges of the important parameters.

The historical sequence of development of analysis frameworks for water quality problems is illustrated in Figure 4. The analysis of dissolved oxygen in streams due to the oxidation of the organic component of wastewater (BOD) by bacteria was the first water quality modeling framework and is still employed today with some major modifications: the inclusion of benthal oxygen demand and algal photosynthesis and respiration. The oxidation of reduced nitrogenous

569

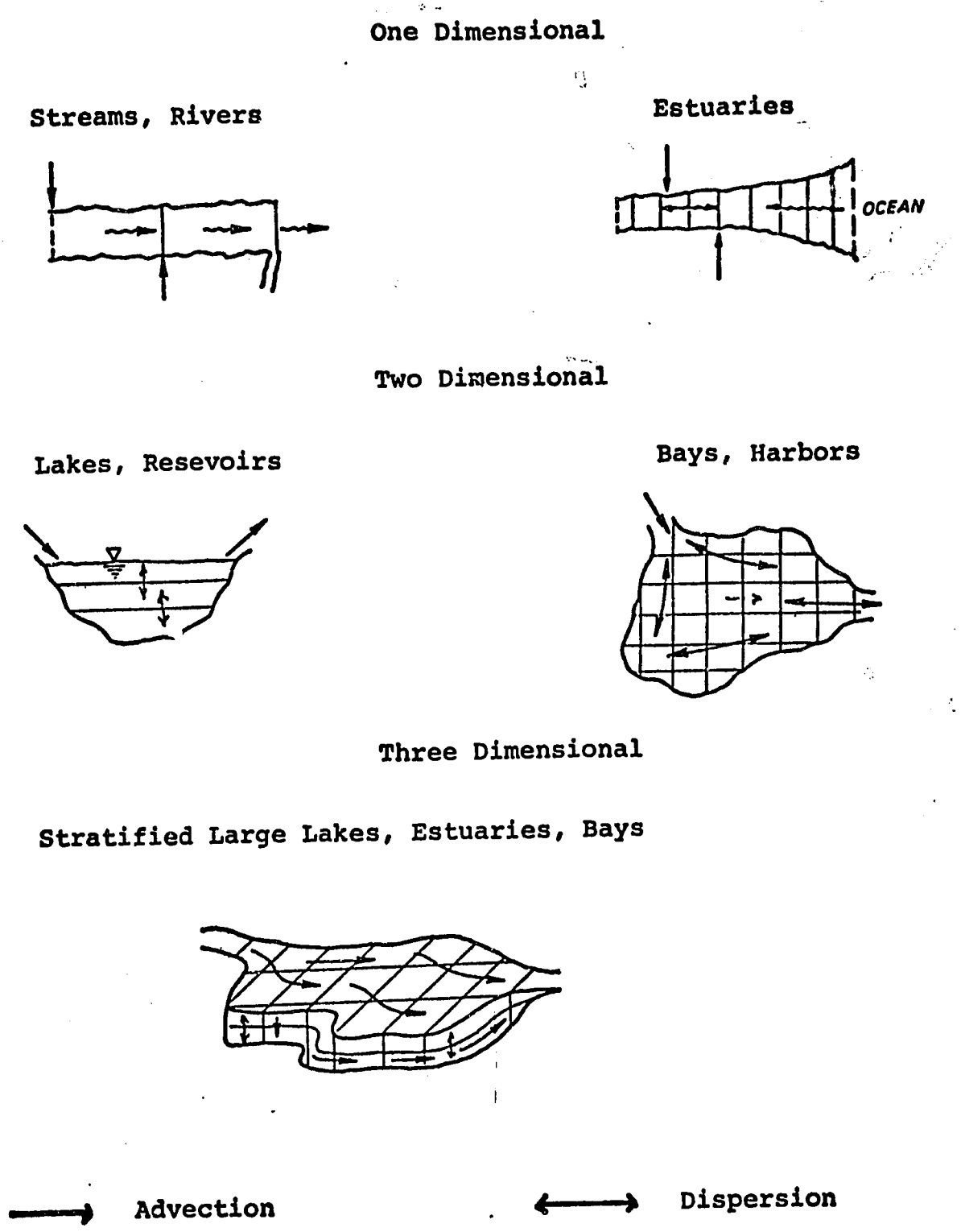


Figure 3 Transport Regimes

570

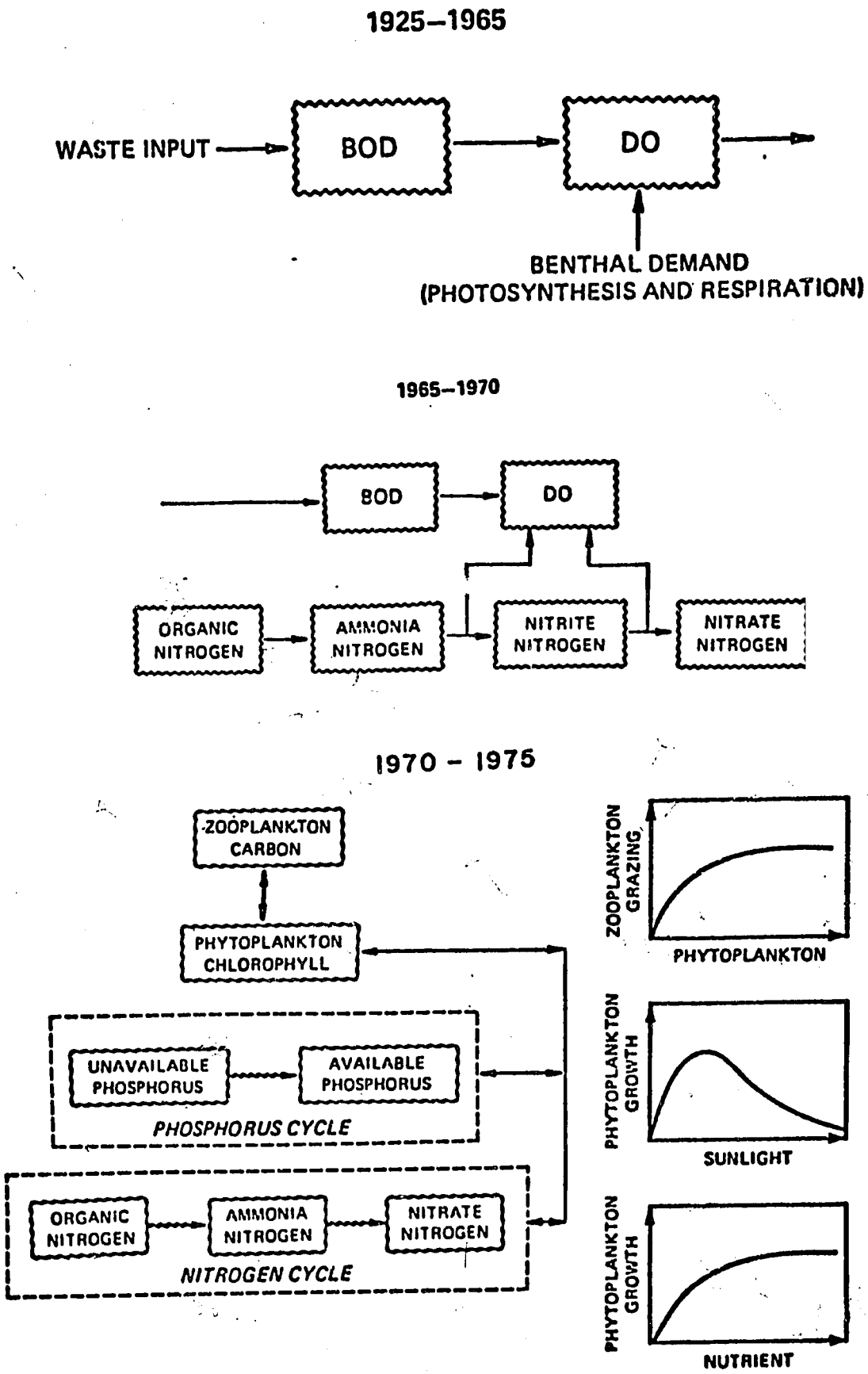


Figure 4 Kinetic Structures

571

compounds, which is usually important, as shown in a case study, was then incorporated into the kinetic framework used for dissolved ogygen.

The complex kinetic structures that describe the growth and death of planktonic algae have more recently been developed. They differ from the more empirical kinetics described above in that they attempt to relate the physiological responses of the organisms to the effects of temperature, sunlight, and nutrient concentrations. Inorganic chemical reactions which determine pH have been included and these are affected by the biological reactions. Reactions which are characteristic of the interstitial waters of sediments have been investigated and included in refined computations of dissolved oxygen and nutrient balances. This increased realism increases the complexity of the numerical calculations, the quantity of the data required, and the interpretation of results that are obtained. This is illustrated subsequently in the case studies.

An important current area of development in water quality modeling is the analysis of the behavior of toxic chemical compounds. There are complications in specifying both the appropriate transport regime and kinetic structure. The transport of most toxic chemicals considered to date is strongly coupled to the transport of fine grained suspended and bed sediments, an area which is not well understood in spite of a long history of investigation. The kinetics of biological interactions are also not well understood. However, progress is being made and developments are expected in the near future.

For the kinetic frameworks and transport structures discussed above the state of the science is not well developed when compared to other engineering disciplines. Therefore judgment and experience play an important role in formulating the inevitable idealization and simplifications which are required for successful model building. Water quality modeling is as much an empirical engineering art as it is an engineering science.

Nevertheless, quite a range of water quality problems can be analyzed successfully within these limitations. It is the purpose of the remainder of this paper to present a few case studies that illustrate the applications of the principles discussed above.

Case Study - The Delaware Estuary

The analysis of the dissolved oxygen distribution in the Delaware Estuary was performed using the kinetic framework that incorporates nitrification as well as carbonaceous BOD. The transport regime was one dimensional advection dispersive. Figure 5 includes a location map and two dissolved oxygen deficit profiles comparing observations to computation for two quite dissimilar periods: low flow high

temperature, and higher flow and low temperature. The agreement indicates that the model properly accounts for temperature and flow variations.

The components of the calculation are shown in Figure 6. The mass discharges of carbonaceous and nitrogenous BOD are used to compute the BOD_5, ammonia and nitrate distributions. The comparisons to observations are used to calibrate the kinetic parameters of carbonaceous oxidation and nitrification. The oxygen consumed by these reactions produces the dissolved oxygen deficit shown in Figure 5.

The use of the model in evaluating treatment and other alternatives is illustrated in Figure 7. For conventional secondary treatment the maximum deficit is projected to be lowered from 7 mg/l to between 5 and 6 mg/l. This relatively small effect for a 60% reduction in total mass discharged is due to the nitrification reaction. If the effluents are nitrified in the treatment plants, the deficit is sharply reduced. The effects of increasing freshwater flow during low flow periods from new flow augmentation reservoirs is shown to be ineffective since the dispersion is the dominant transport mechanism. Displacing the location of the mass discharges downstream of their present locations is effective but quite expensive when compared to treatment.

Case Study - Lake Erie

The water quality conditions in Lake Erie have been the subject of analysis for a long period of time. A number of different water quality variables have been investigated, and these provide examples of differing kinetic and transport structures.

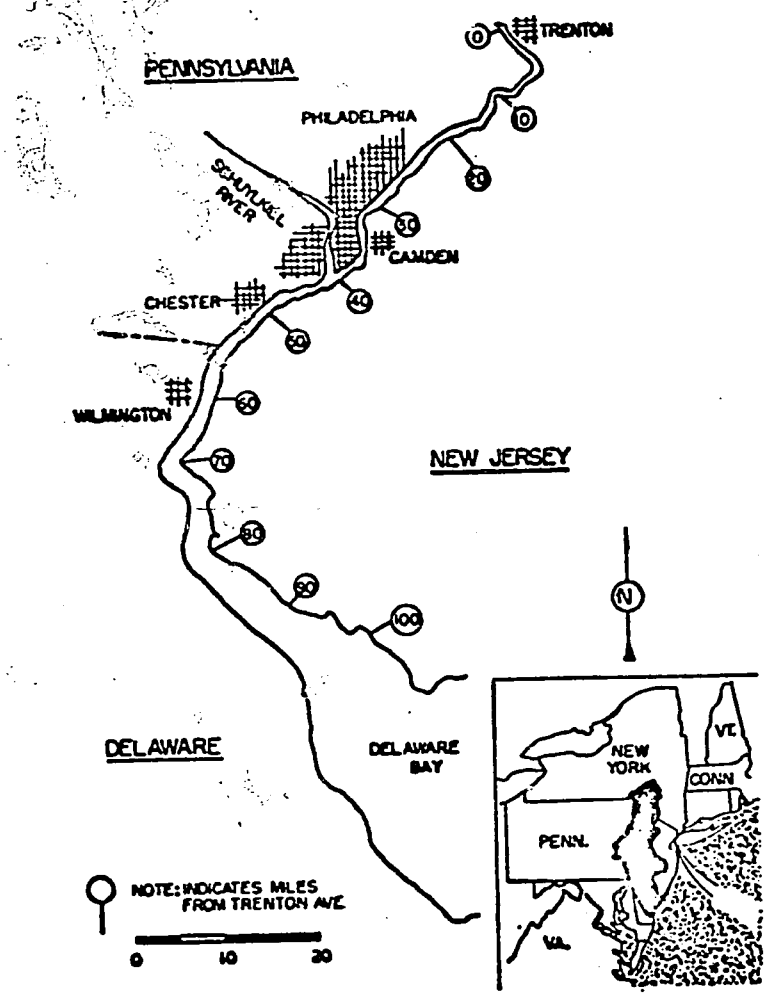
The coliform distribution in the Western Basin of Lake Erie is due to mass inputs from its major tributaries, the Detroit and Maumee Rivers. The organisms are transported into the Western Basin where their natural mortality and the transport field combine to sharply reduce their concentration, as shown in Figure 8. The transport field is estimated from numerical circulation models and the chloride distribution. Bacterial mortality kinetics are assumed to be first order.

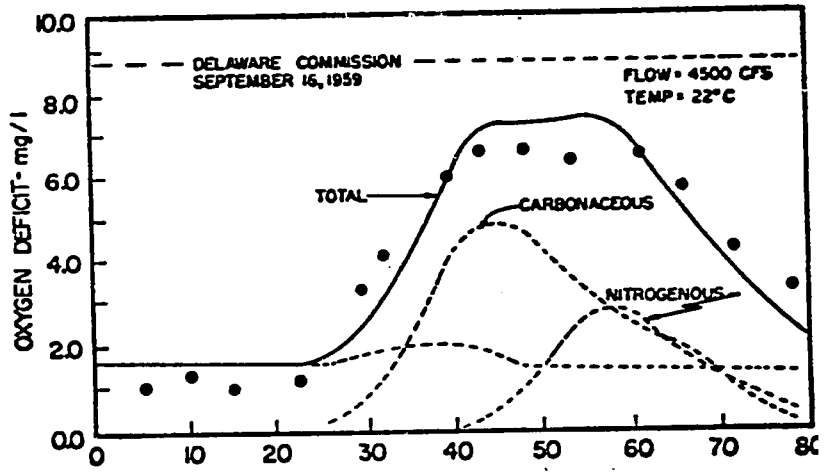
The principle water quality problem in Lake Erie is the anoxia that develops in the Central Basin Hypolimnion. This is caused by the algal respiration, the oxidation of detrital organic carbon (which is primarily of algal origin), and the oxidation of sedimented algae and organic carbon. The increased algae over the years is due to increased nutrient input into the Lake.

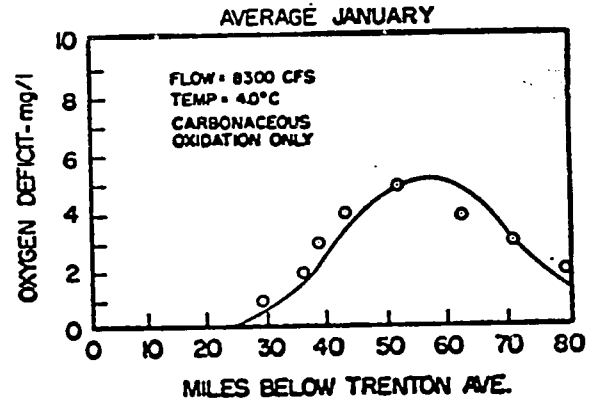
The computation is done for each basin epilimnion, hypolimnion, and surface sediment layer. The model calibration with 1970 is shown

573

LOCATION MAP OF DELAWARE RIVER ESTUARY

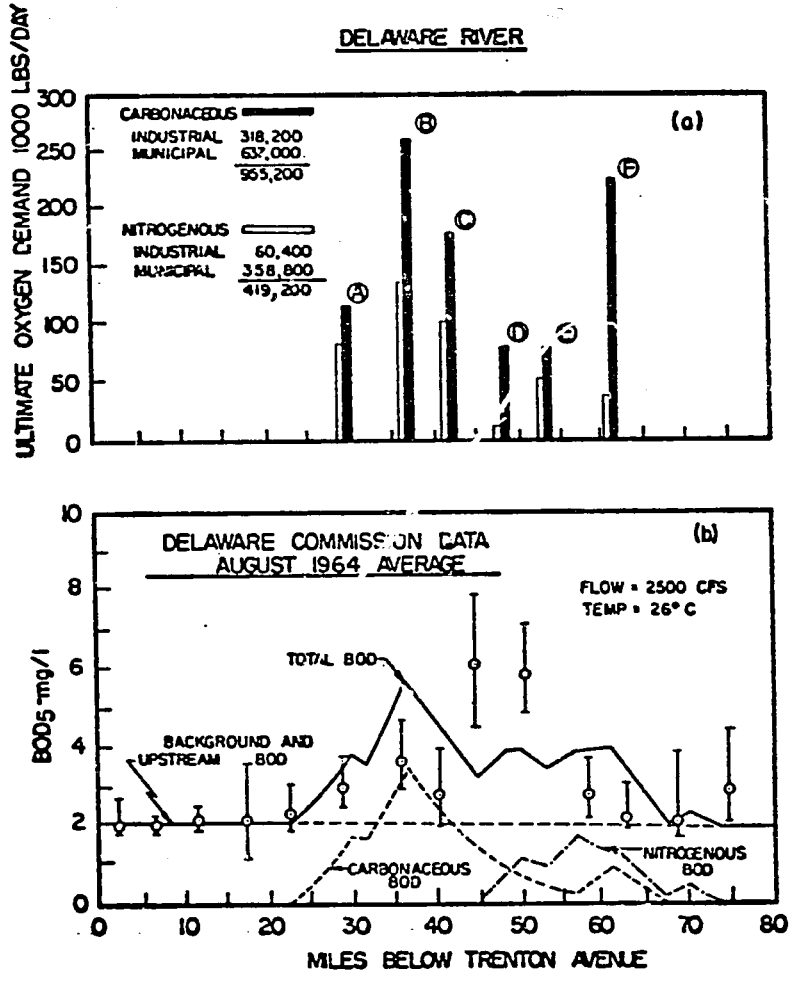




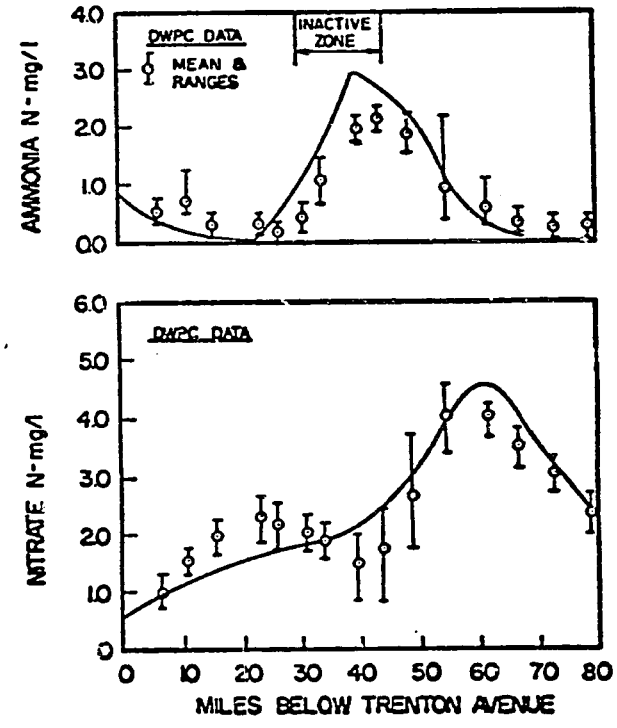


OBSERVED AND CALCULATED OXYGEN DEFICIT DISTRIBUTIONS

Figure 5

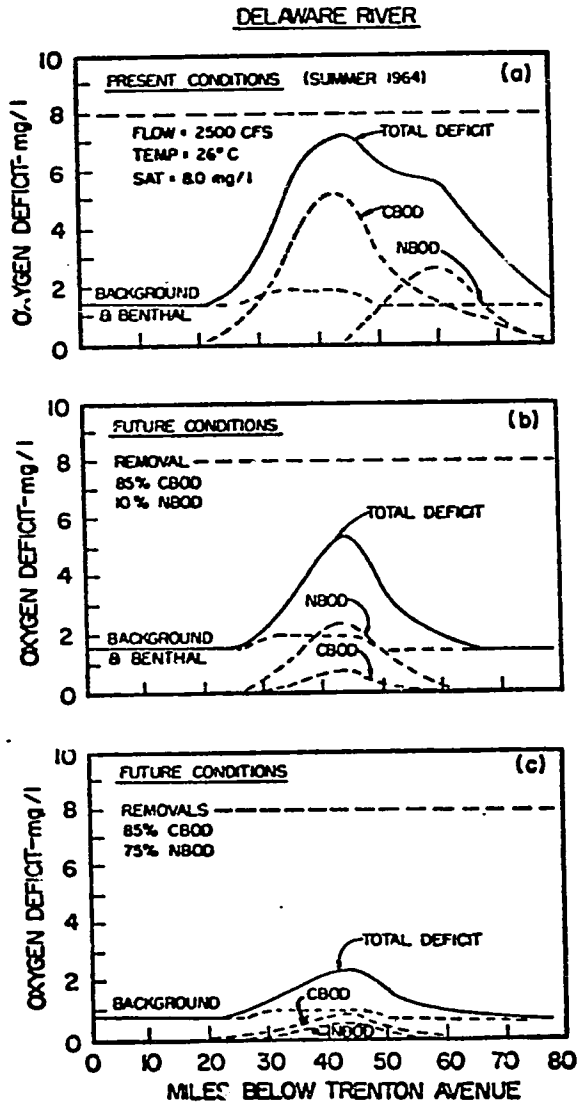


BOD LOADING DISTRIBUTION AND PROFILE



NITROGEN LOADING DISTRIBUTION AND PROFILES

Figure 6



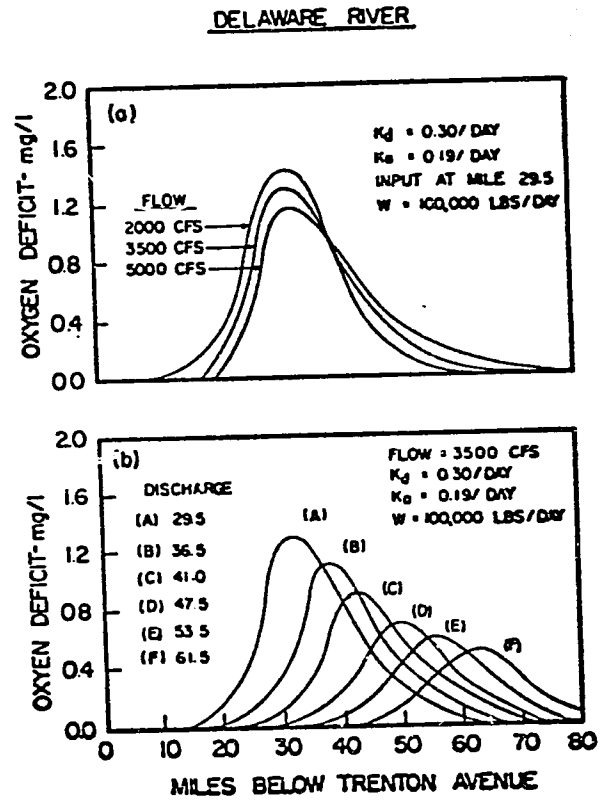
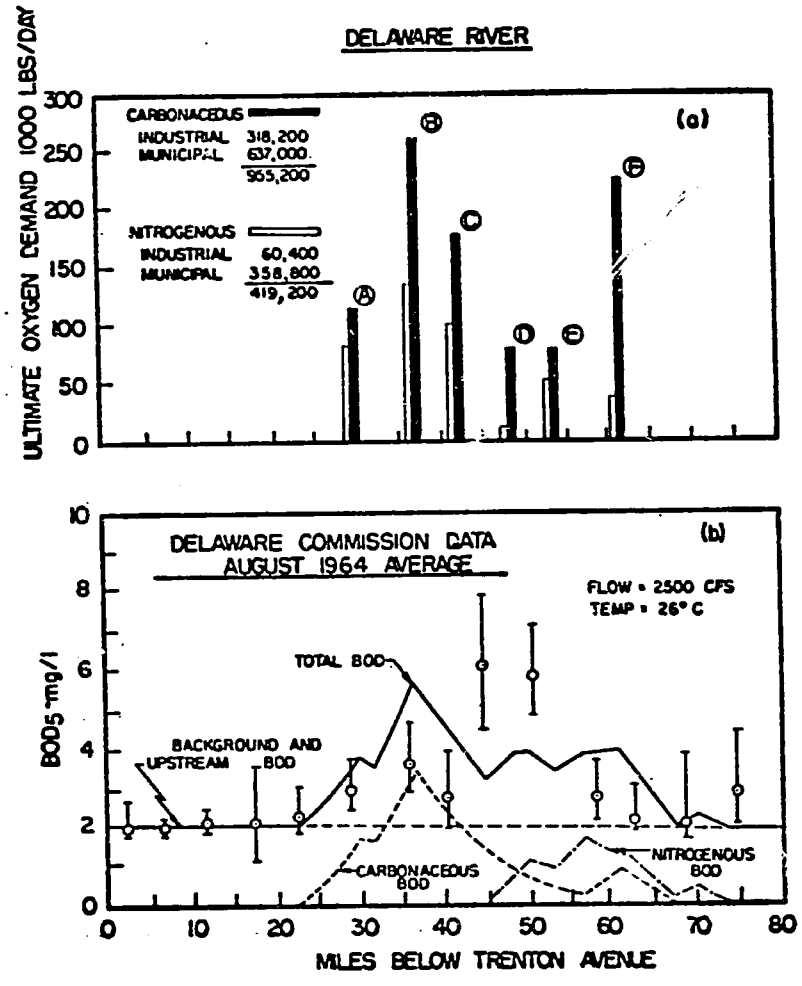


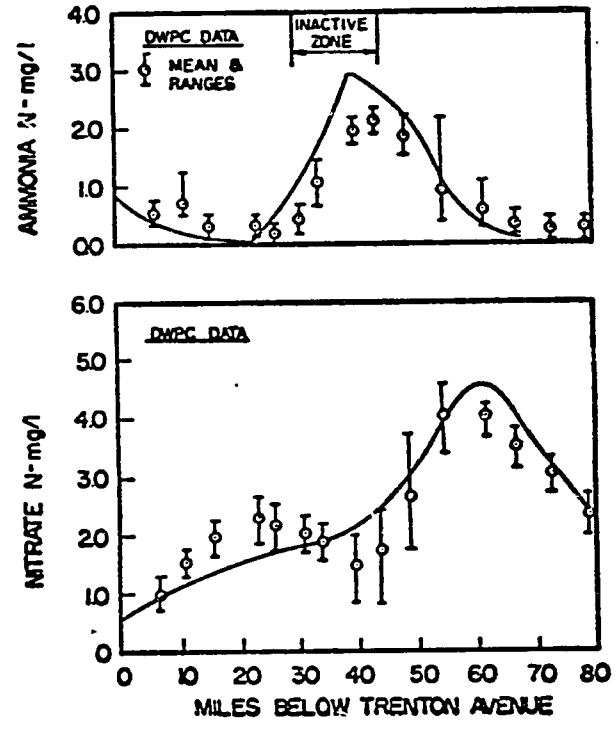
FIG. 10.—EFFECT OF WASTE TREATMENT ON THE TOTAL DEFICIT DISTRIBUTION

Figure 7

576

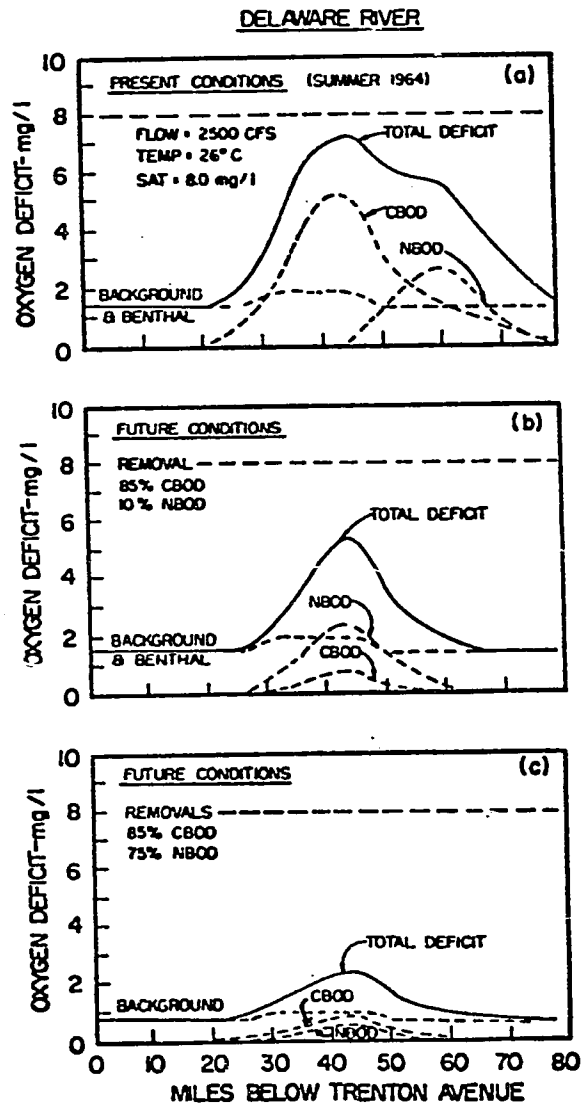


BOD LOADING DISTRIBUTION AND PROFILE



NITROGEN LOADING DISTRIBUTION AND PROFILES

Figure 6



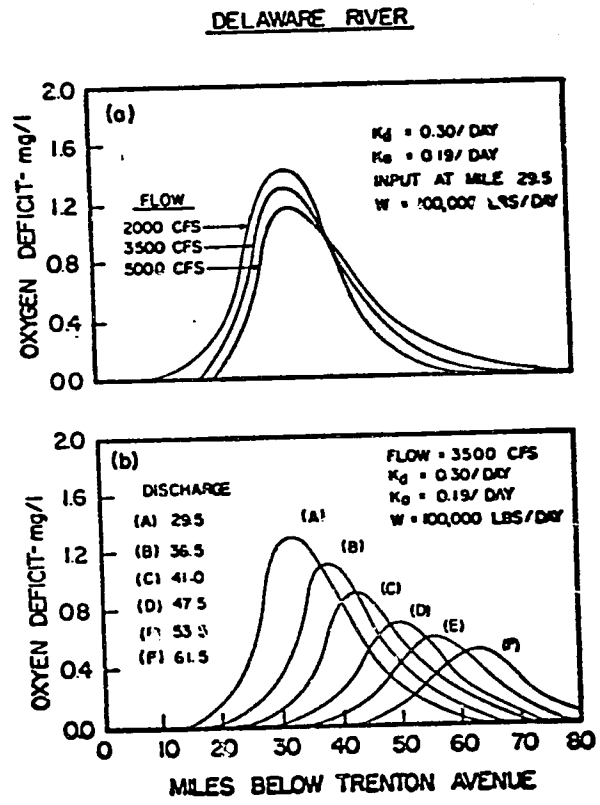


FIG. 10.—EFFECT OF WASTE TREATMENT ON THE TOTAL DEFICIT DISTRIBUTION

Figure 7

578

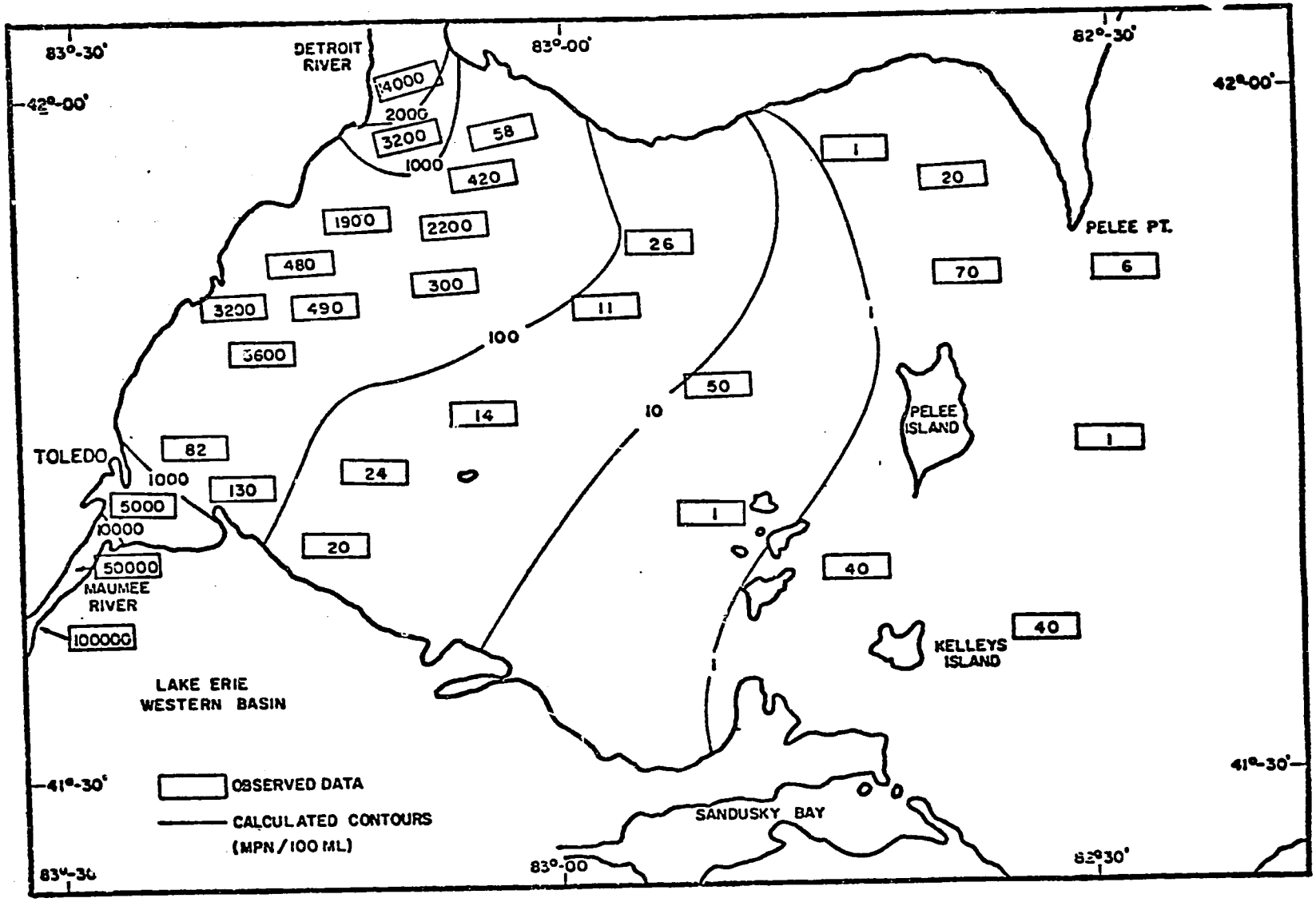


Figure 8 Coliform Bacteria - Model Results and Observed Data

in Figure 9 for chlorophyll, primary production and total phosphorus, in the epilimnia of the basin and in Figure 10 for the dissolved oxygen, pH and chlorophyll in the Central Basin. In fact, twelve variables in all segments are used in the calibration. A verification of the dissolved oxygen distribution was performed for 1975 when no anoxia developed. The model compared quite well with the year's data.

An example of the type of toxic chemical models which are being developed is shown in Figure 11. The structure uses the phytoplankton model kinetics in order to estimate the uptake rate in those compartments. The remainder of the kinetics are linear. A calibration to observed ranges of data in various compartments is shown. Although these models are not well developed, in the sense that a large amount of experience has been accumulated, it is clear that the framework will be further developed and refined as concern for toxic chemicals in natural waters increases.

580

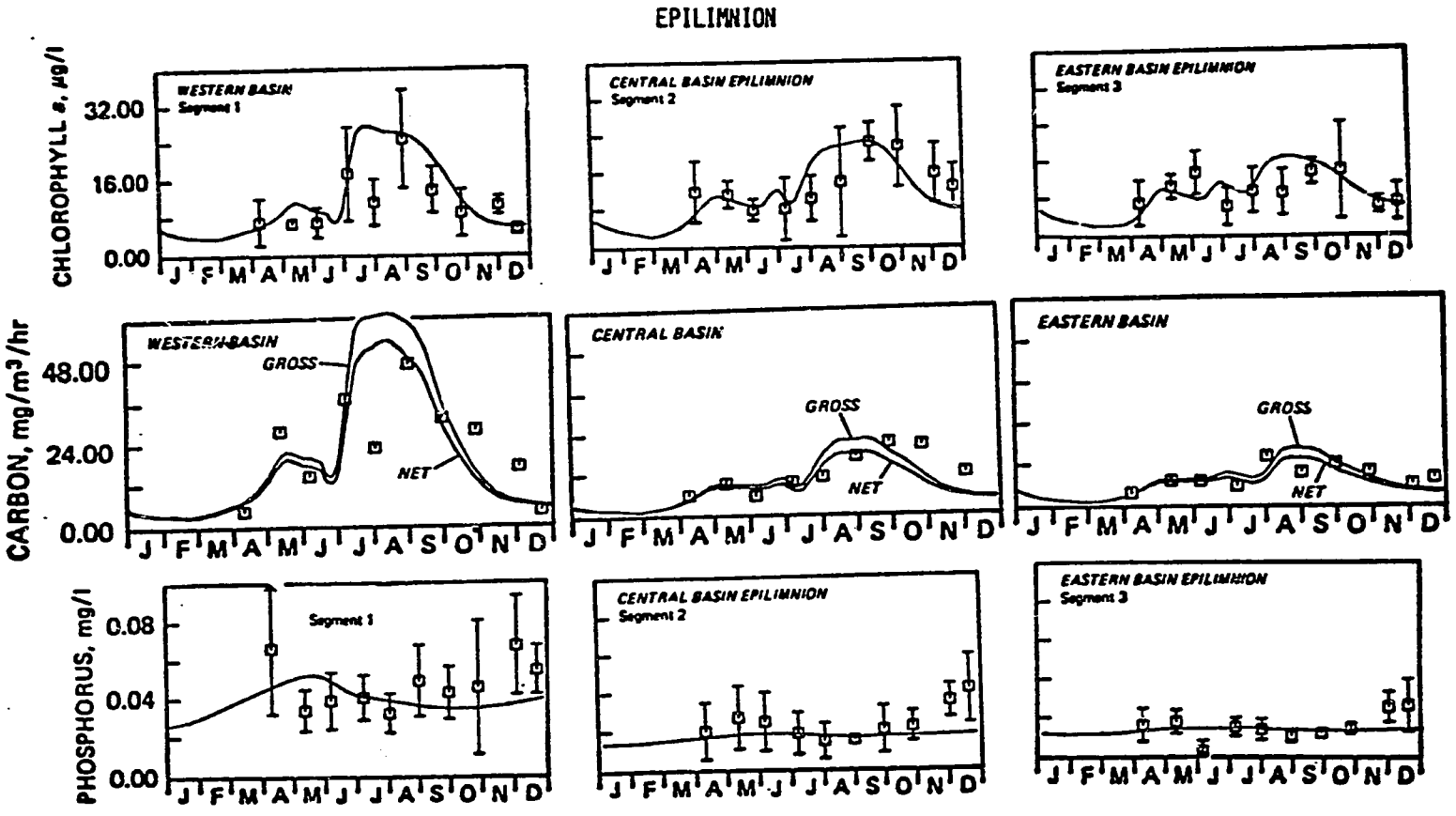


Figure 9 Lake Erie Calibration, 1970

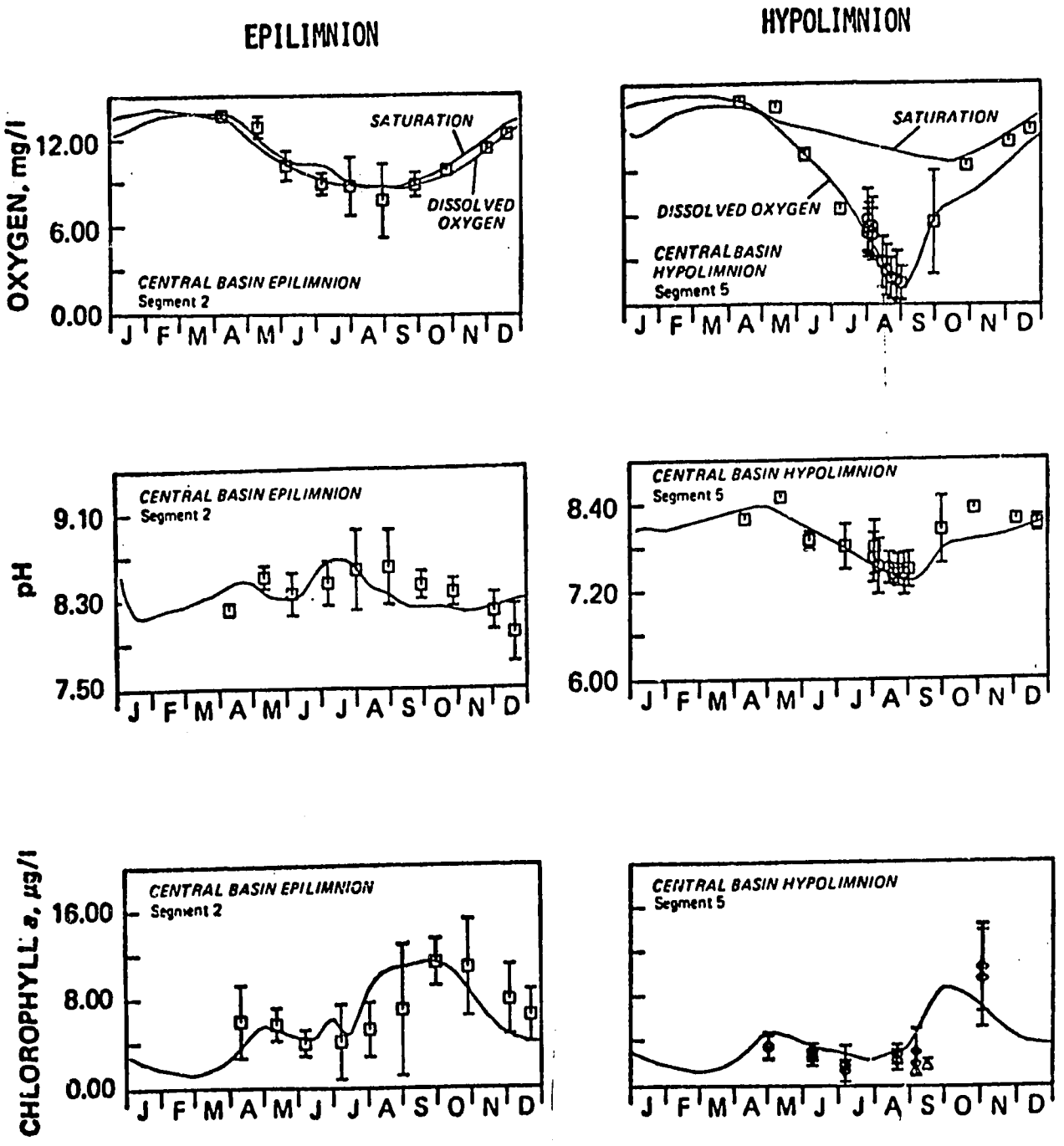
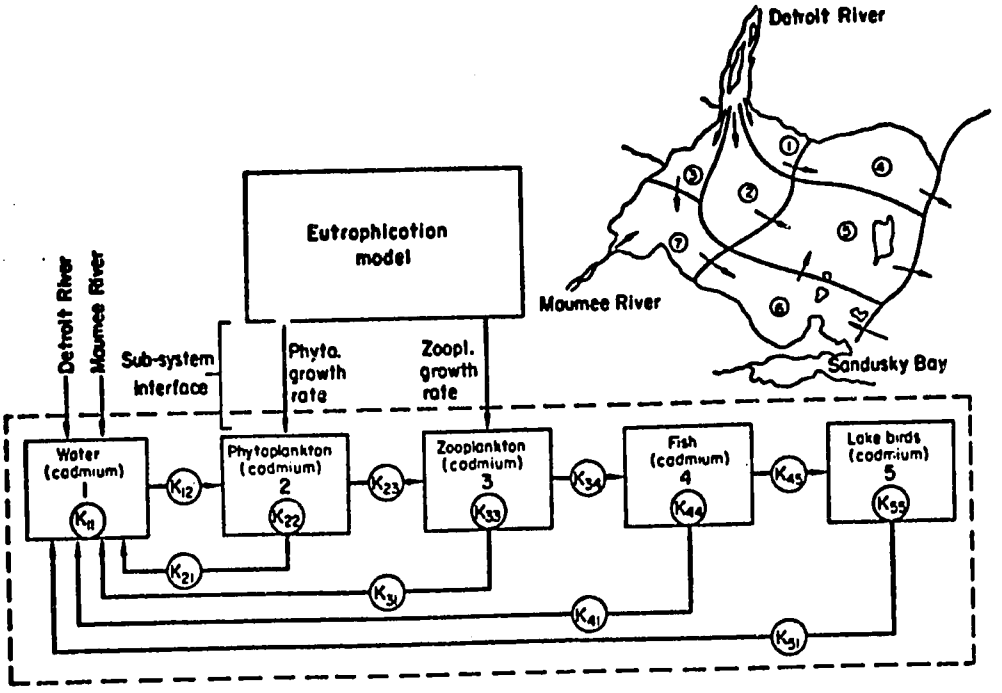
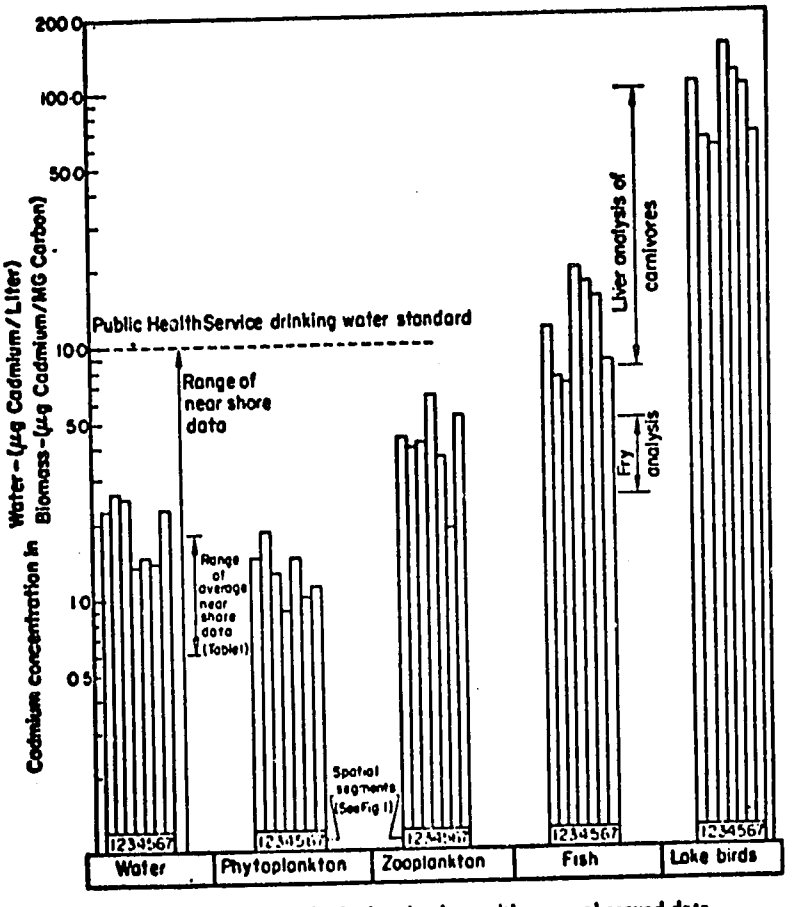


Figure 10 Lake Erie Central Basin Calibration, 1970

582



Basic structure of food chain model.



Comparison of calculated values with some observed data.

Figure 11

583

REFERENCES AND BIBLIOGRAPHY

Delaware Estuary Case Study

O'Connor, D. J., J. P. St. John, and D. M. DiToro. "Water Quality Analysis of the Delaware River Estuary." Proc. ASCE, J. Sanit. Engr. Div., Vol. 94, No. SA6, Dec. 1968.

Contains the details of the analysis presented in Figures 5 through 7, and references to the earlier estuary literature.

Lake Erie Case Study

DiToro, D. M., D. J. O'C onnor, R. V. Thomann, and J. L. Mancini. "Phytoplankton-Zooplankton Nutrient Interaction Model for Western Lake Erie" in Systems Analysis and Simulation in Ecology, Vol. III, ed. B. Patten, Academic Press, 1975.

Contains the details of the transport field for the Western Basin and an earlier analysis of phytoplankton chlorophyll.

DiToro, D. M. and J. Connelly. "Mathematical Models of Water Quality in Large Lakes, Part II." Lake Erie EPA Ecological Research Report Series (in press) 1979.

Contains the details of a state-of-the-art phytoplankton, dissolved oxygen and sediment calculation, a portion of which is shown in Figures 9 and 10.

Thomann, R. V., D. S. Szumski, D. M. DiToro, and D. J. O'Connor. "A Food Chain Model of Cadmium in Western Lake Erie." Water Research, Vol. 8, 1974.

Contains the details of the calculation illustrated in Figure 11.

General

Thomann, R. V. Systems Analysis and Water Quality Management, McGraw Hill, 1972.

The only textbook in the field of water quality modeling.

"Estuarine Modeling: An Assessment." EPA Water Pollution Control Reseach Series. 16070 DZV 02/71, EPA Water Quality Office, Washington, D.C., 1971.

A series of papers which give the state-of-the-art as of 1971.

584

DiToro, D. M., R. V. Thomann, D. J. O'Connor, and J. L. Mancini. "Estuarine Phytoplankton Biomass Models Verification Analyses and Preliminary Applications." In The Sea: Ideas and Observations on Progress in the Study of the Sea, ed. E. Goldberg, John Wiley, Inc. 1977.

A review article presenting the state-of-the-art in phytoplankton modeling in estuaries, with references to previous literature.

O'Connor, D. J. "The Temporal and Spatial Distribution of Dissolved Oxygen in Streams." Water Resources Res., Vol. 3(1), 1967.

Contains a review of dissolved oxygen modeling in streams with emphasis on different geometries, temporal patterns of photosynthesis and flow variation.

585

ADVANCED ENVIRONMENTAL INFORMATION SYSTEMS

Case Study: Hydrologic Information Service

James Huston

General Manager
Satellite Information Services
Environmental Research & Technology, Inc.

June 1980

International Environmental Management Institute

ENVIRONMENTAL RESEARCH & TECHNOLOGY, INC.

Concord, Massachusetts, USA

586

INFORMATION SYSTEM OPERATION AND SERVICES

1. System Description

The Hydrologic Information Service is provided by means of a data sensing, collection, processing and dissemination system. This system includes sensors and Data Collection Platforms (DCPs) placed at selected sites of various environmental exposures and geographic diversities. These DCPs sample data from water stage sensors in the vicinity of the sites and then transmit this information through a satellite system to a receive earth station. Specialized equipment at this receive earth station time-tags the data and forwards it to a computer processing center where it is processed into an information structure specified by the customer. This information is then disseminated to the customer through a distributed intelligent communication network.

The structure of the hydrologic information system consists of the following subsystems:

- Sensors
- Data Collection Platforms
- Satellite Communications
- Receive Earth Station
- ENVIRONET Information Center
- User Interface Subsystem
- USGS Computer System (Customer Furnished Equipment)

Figure 1 shows a functional block diagram of these subsystems.

1.1 Sensors

Each DCP is connected to a water height sensor. Standard sensors (float-pulley type) are used at most sites. At some sites, experimental sensors which have electronic measuring equipment are used. Figure 2 shows hydrologic stage sensors.

The standard sensors are electromechanical devices which contain a float, pulley, and an electronic encoding module. As the float bobs on the water surface, the pulley is rotated. The position of the rotation is read by the electronic encoder which returns the value to the DCP. This is an analog-to-digital conversion; i.e., the continuous variable position of the float-pulley is converted to a binary number by the use of mechanical gears. The float is installed in a stilling well in order to minimize instantaneous fluctuations in the water surface due to wind or current effects.

The all-electronic experimental sensors are installed and tested at selected sites. These sensors measure the water height from above by "strobing" an acoustic pulse down a tube and measuring the return time of the reflected pulse. This sensor is designed to be more accurate and reliable than standard sensors. Those sites with the experimental sensors are closely watched in order to determine their performance characteristics relative to the standard sensors.

587

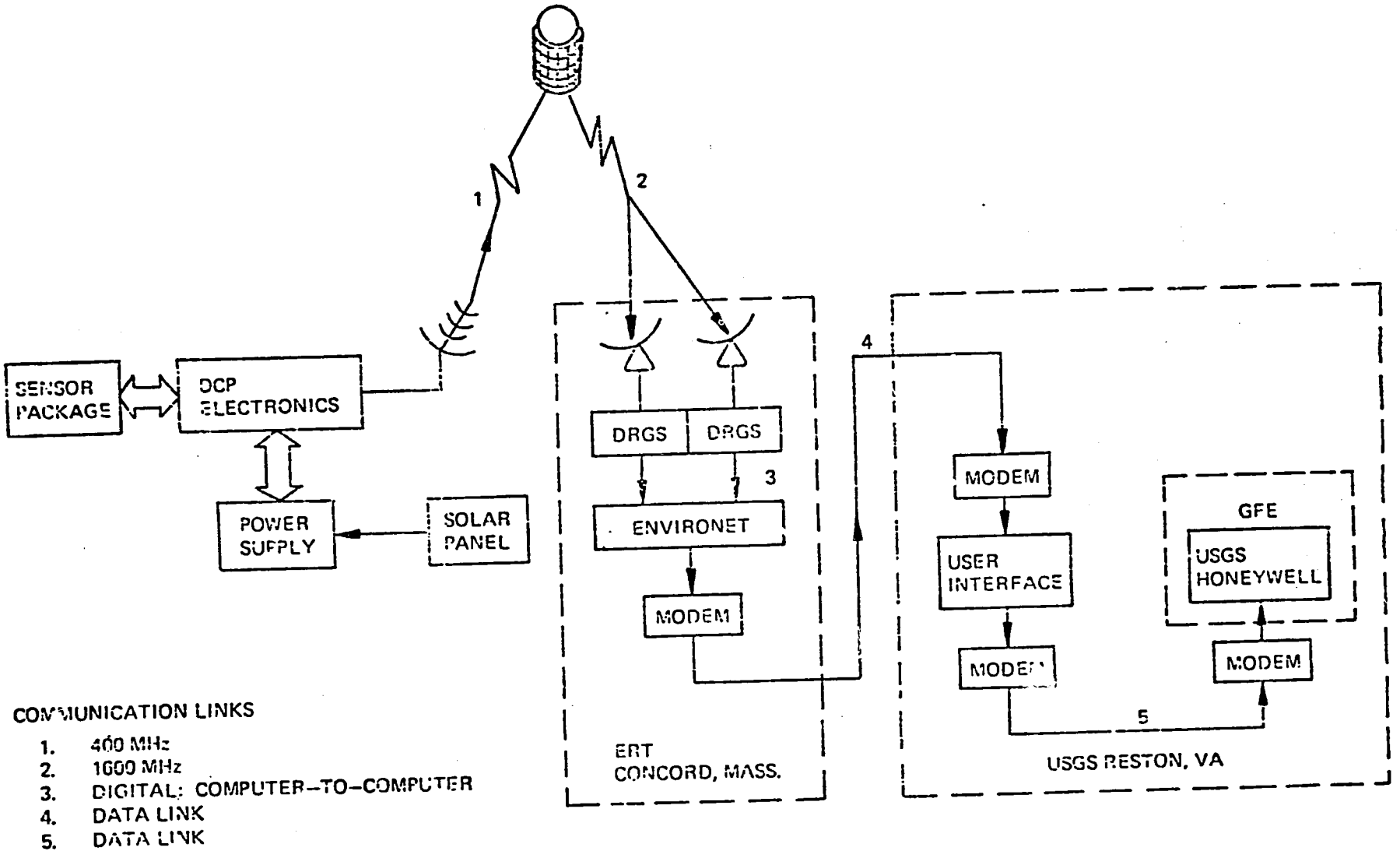
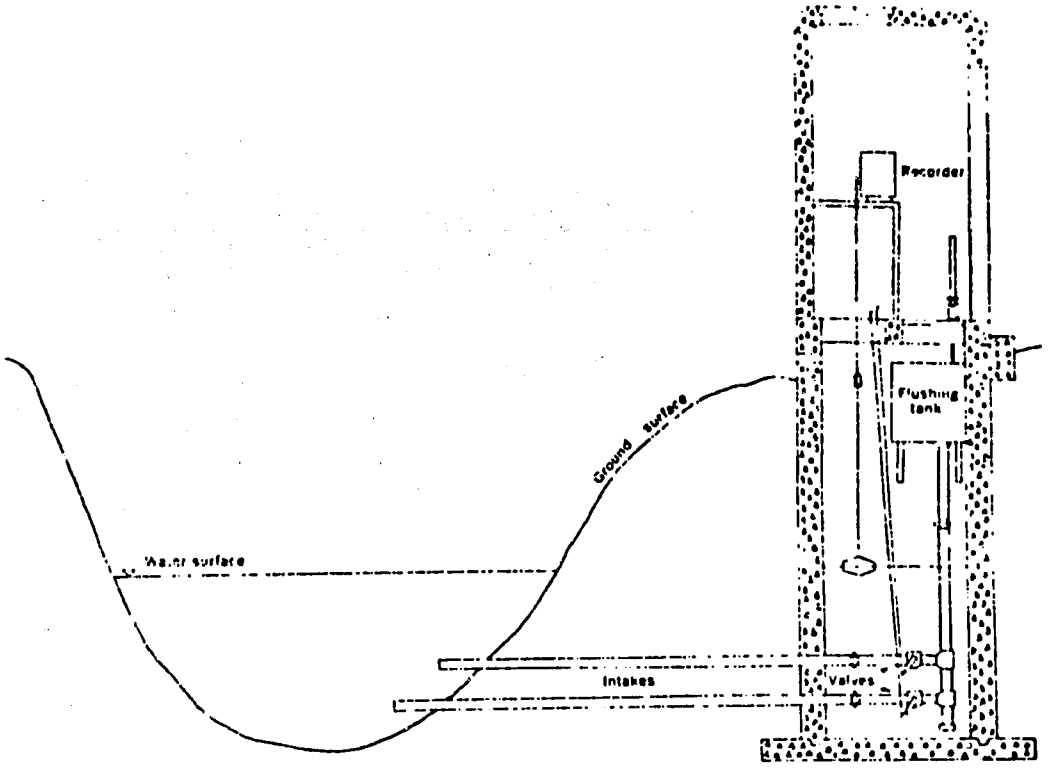
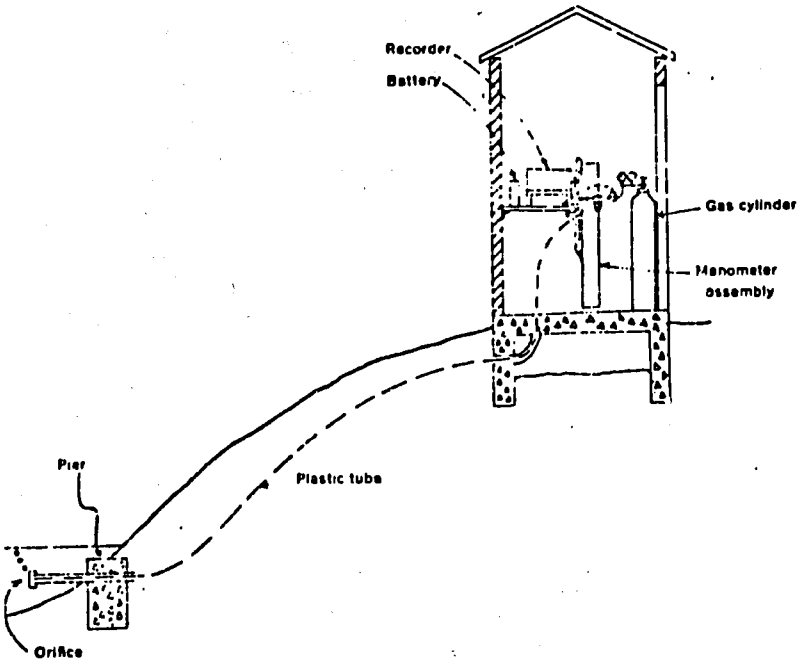


Figure 1 Environmental Information System.

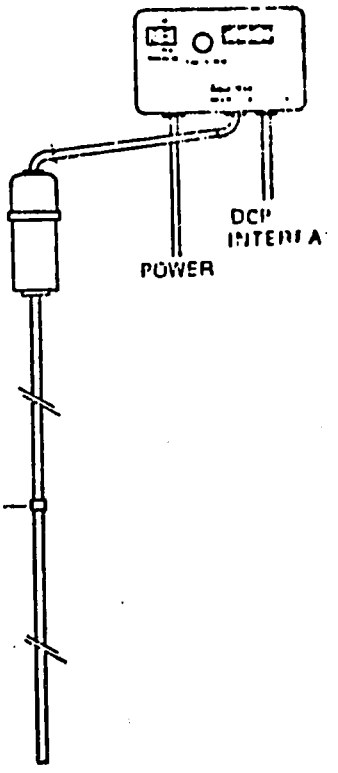
585



a) FLOAT–GAGE INSTALLATION (Buchanan & Somers, 1968)



b) BUBBLE–GAGE INSTALLATION (Buchanan & Somers, 1968)



c) ACOUSTIC SENSOR

igure 2 Hydrologic Stage Sensors

589

At some sites, additional sensors may be placed. This is to further demonstrate and experiment with remote satellite data collection techniques.

1.2 Data Collection Platform

A DCP is an electronic device which (a) causes the hydrologic stage sensor to activate, (b) reads the digital representation of the water height as measured by the sensor, and (c) transmits a message containing the hydrologic measurements to a communication satellite.

The DCP functionally consists of the following modules:

A. The Controller Radio Set Transmitter

The controller module contains the components which affect the operational performace of the DCP. The controller is a microprocessor which periodically samples the sensor, formats a message, and transmits the message. The radio set equipment consists of an RF transmitter which modulates a carrier at the appropriate UHF frequency. The transmit frequency is controlled by setting micro-switches internal to the controller/radio set transmitter.

B. Antenna

The antenna consists of a five element crossed Yagi type which is designed to perform at UHF frequencies.

C. Batteries

There are six (6) cells, two (2) volts each, packaged together in series to provide a twelve (12) volt battery pack. The batteries are of the rechargeable Gel-Type which are expected to last a least one year without service.

D. Solar Panel and Voltage Regulators

At most sites, a 400 milliampere (at 14 volts) solar panel is installed to charge the batteries. In the northern sites, 650 milliampere solar panels are installed. Both types have a voltage regulator which prevents battery overcharge.

E. Cables

To connect the antenna to the DCP, a shielded RF cable with male TNC connectors at each end is used. This battery and stage sensor will be connected to the DCP through a second cable.

Figure 3 shows the DCP site configuration.

590

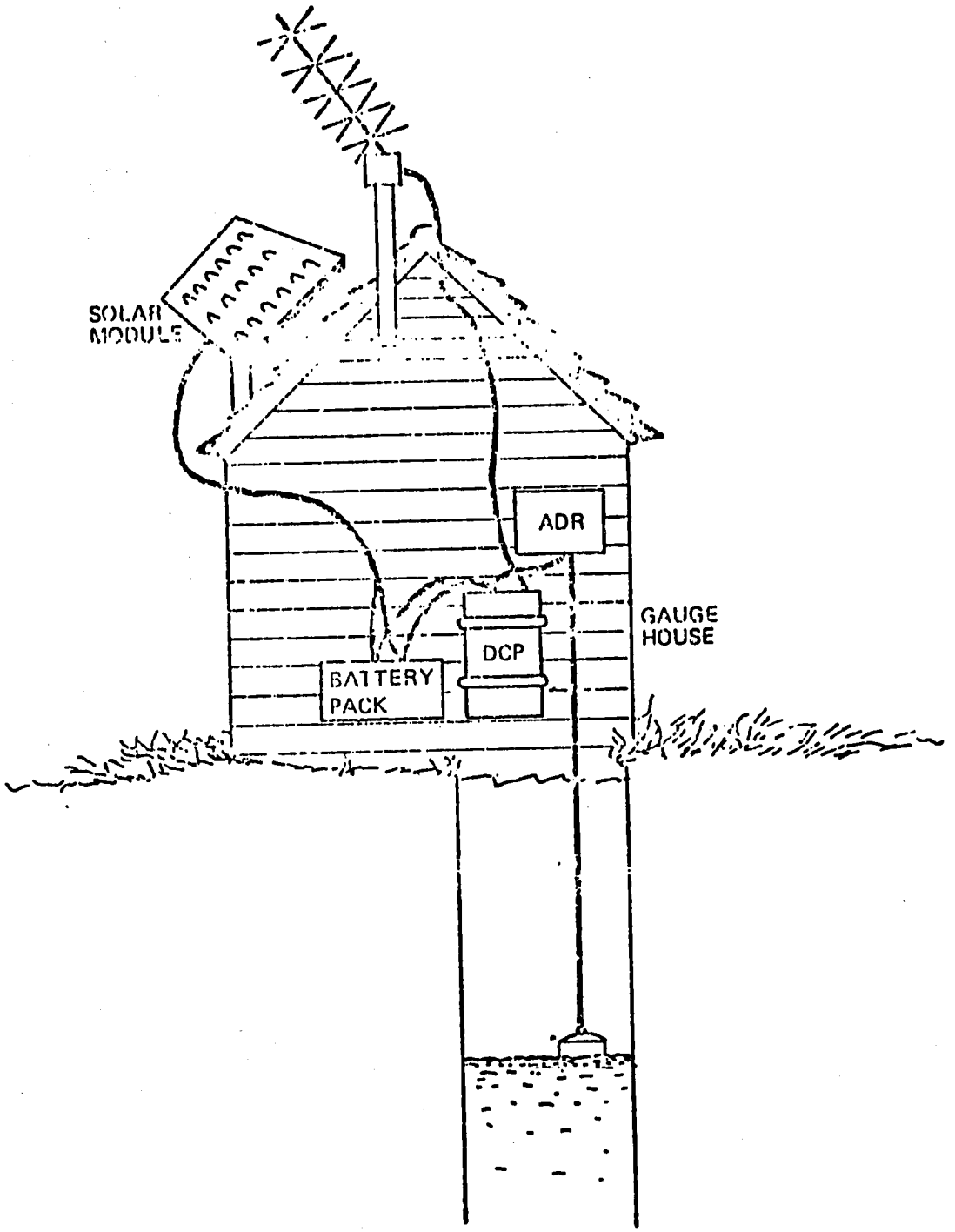


Figure 3 DCP Site Installation

1.3 Satellite Communication

The COMSAT General/ERT Hydrologic Information System uses a U.S. Government Geostationary Operational Environmental Satellite (GOES). This satellite system is operated by the National Oceanic and Atmospheric Administration/National Environmental Satellite Service (NOAA/NESS). The GOES satellite receives DCP messages at 400 MHz frequency and translates it to 1600 MHz frequency for retransmission to the receive earth station. All initial COMSAT General DCPs will utilize the GOES Work satellite.

Figure 4 shows the coverage area of the GOES satellites and the look angles from the DCP to the satellite.

1.4 Receive Earth Station

The Receive Earth Station is designed to perform the following functions:

- Receive the DCP messages
- Time tag the messages
- Verify the messages for errors
- Forward the messages to the ERT Data Processing Center
- Store the messages to guard against loss
- Monitor the performance of the DCP (frequency offset, transmit power, and bit error rate)

The receive station equipment will be installed at the ERT facility in Concord, Massachusetts. This equipment will be duplicated to ensure that there is no single failure point which can cause a major loss of data. Both of these stations will operate simultaneously with selection of data based on the best performing station.

2. ERT ENVIRONET Information Center

The ERT ENVIRONET Information Center receives the data from the Receive Earth Station. The Center then adds value to the data stream by centralization, organization, validation, archiving, reformatting and combining the independent raw data into useful logical information.

The data processing subsystem is an ERT computer system based on the Data General M600 Eclipse computer. For backup to the M600, ERT will use either a Data General S.250 or a Data General C/330 Eclipse.

The data from the Receive Earth Station to the ERT computers is transmitted over a computer-to-computer line. The ERT computers archive the input data, evaluate the contents of the input data, format an output message, and transmit the converted record downstream to the USGS/WRD Interface Subsystem.

Figure 5 shows the block diagram of the ERT computer system; Figure 6 shows the processing flow of the DCP messages.

592

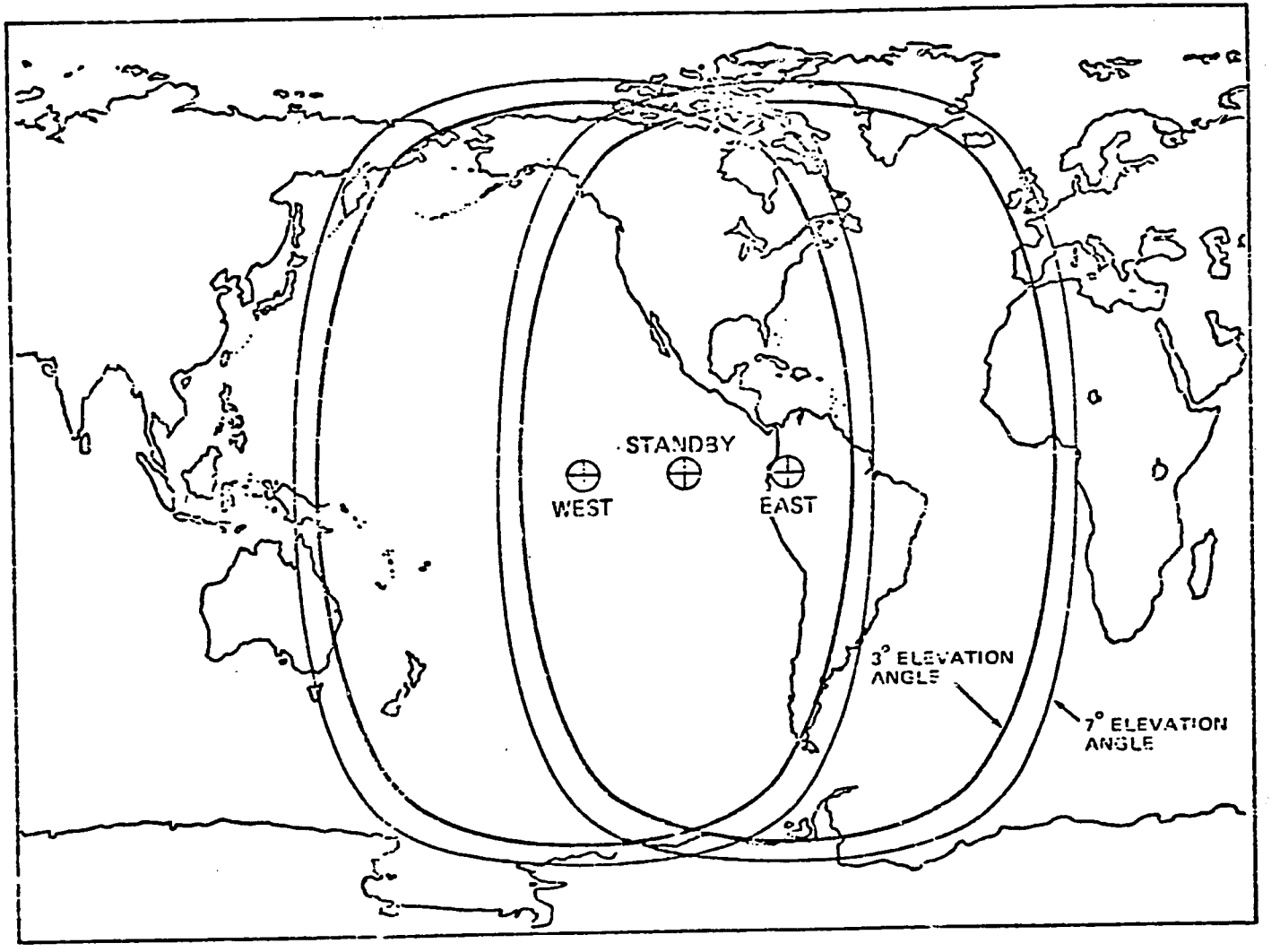


Figure 4 SMS/GOES Coverage

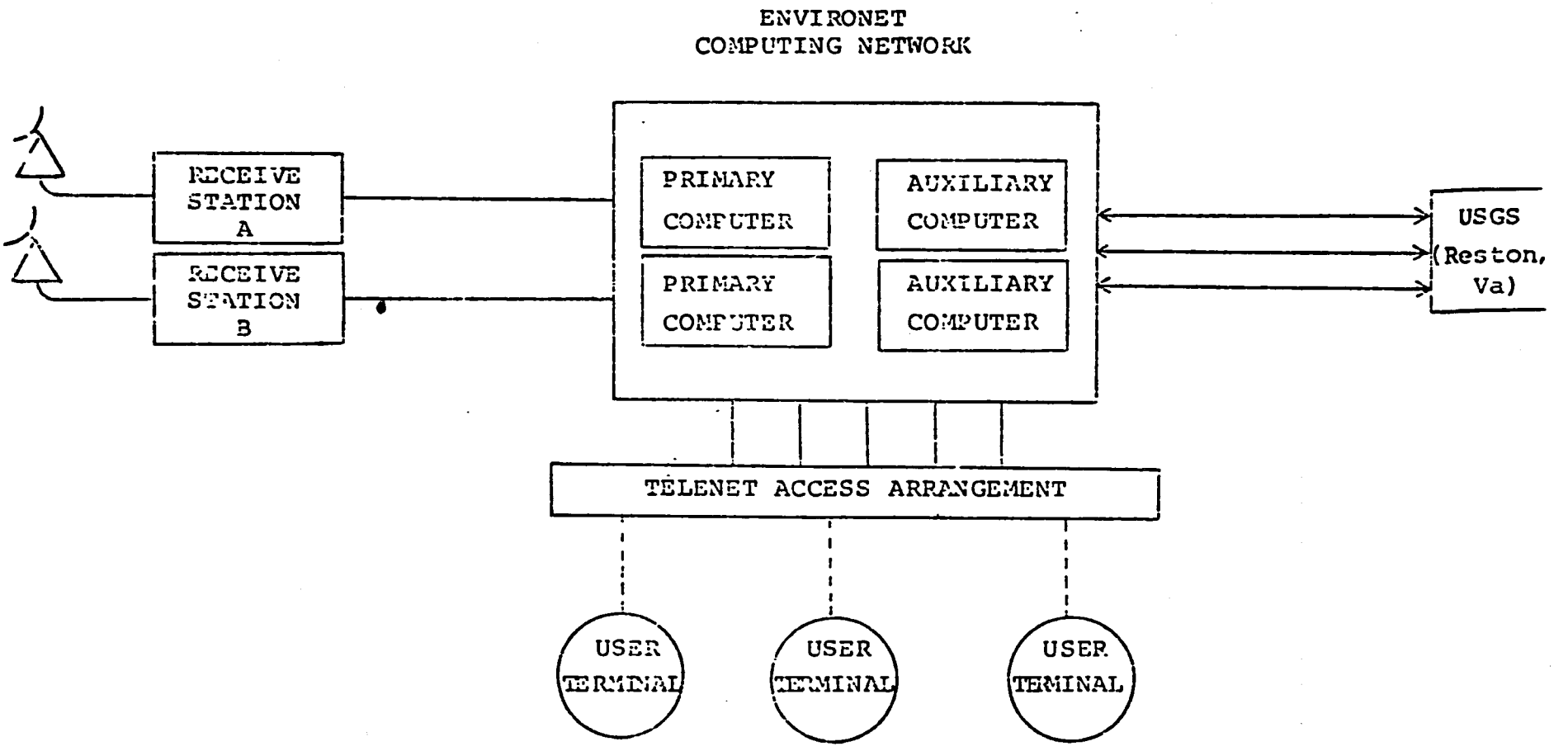


Figure 5 ERT ENVIRONET Information Center

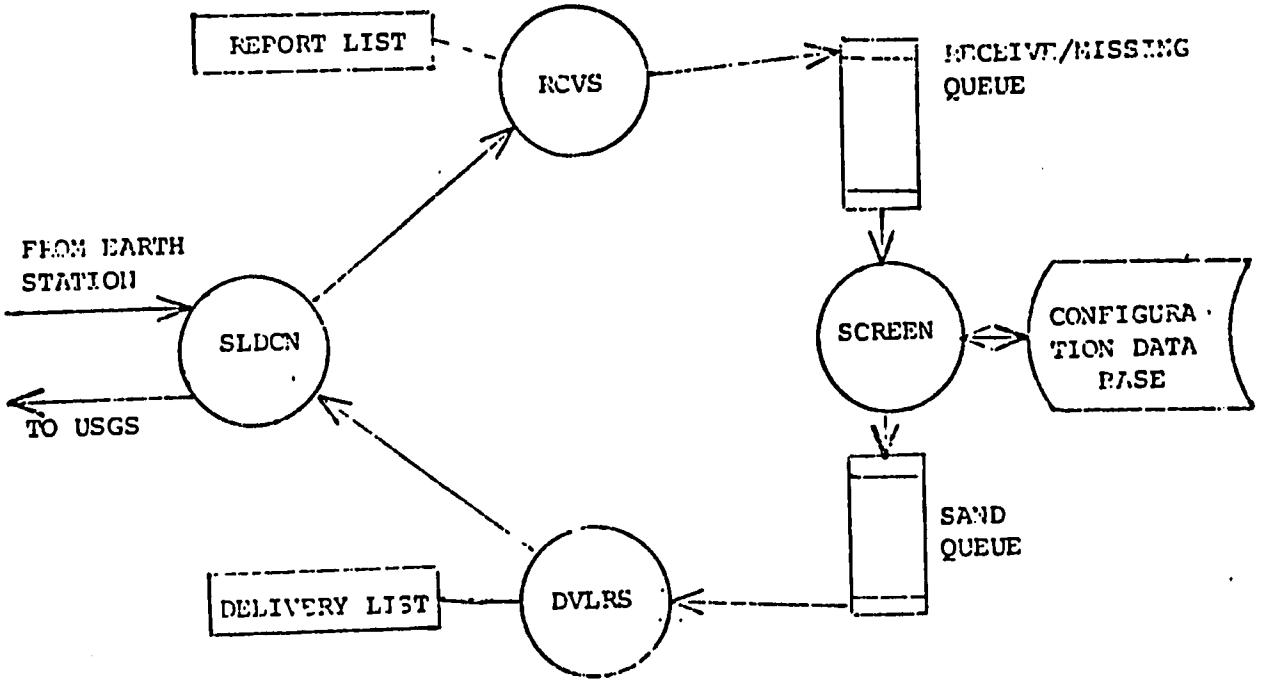


Figure 6 DCP Message Processing Flow

ADVANCED ENVIRONMENTAL INFORMATION SYSTEMS

Case Study: Hydrologic Information Service

James Huston

General Manager
Satellite Information Services
Environmental Research & Technology, Inc.

June 1980

International Environmental Management Institute

ENVIRONMENTAL RESEARCH & TECHNOLOGY, INC.

Concord, Massachusetts, USA

596

INFORMATION SYSTEM OPERATION AND SERVICES

1. System Description

The Hydrologic Information Service is provided by means of a data sensing, collection, processing and dissemination system. This system includes sensors and Data Collection Platforms (DCPs) placed at selected sites of various environmental exposures and geographic diversities. These DCPs sample data from water stage sensors in the vicinity of the sites and then transmit this information through a satellite system to a receive earth station. Specialized equipment at this receive earth station time-tags the data and forwards it to a computer processing center where it is processed into an information structure specified by the customer. This information is then disseminated to the customer through a distributed intelligent communication network.

The structure of the hydrologic information system consists of the following subsystems:

- Sensors
- Data Collection Platforms
- Satellite Communications
- Receive Earth Station
- ENVIRONET Information Center
- User Interface Subsystem
- USGS Computer System (Customer Furnished Equipment)

Figure 1 shows a functional block diagram of these subsystems.

1.1 Sensors

Each DCP is connected to a water height sensor. Standard sensors (float-pulley type) are used at most sites. At some sites, experimental sensors which have electronic measuring equipment are used. Figure 2 shows hydrologic stage sensors.

The standard sensors are electromechanical devices which contain a float, pulley, and an electronic encoding module. As the float bobs on the water surface, the pulley is rotated. The position of the rotation is read by the electronic encoder which returns the value to the DCP. This is an analog-to-digital conversion; i.e., the continuous variable position of the float-pulley is converted to a binary number by the use of mechanical gears. The float is installed in a stilling well in order to minimize instantaneous fluctuations in the water surface due to wind or current effects.

The all-electronic experimental sensors are installed and tested at selected sites. These sensors measure the water height from above by "strobing" an acoustic pulse down a tube and measuring the return time of the reflected pulse. This sensor is designed to be more accurate and reliable than standard sensors. Those sites with the experimental sensors are closely watched in order to determine their performance characteristics relative to the standard sensors.

597

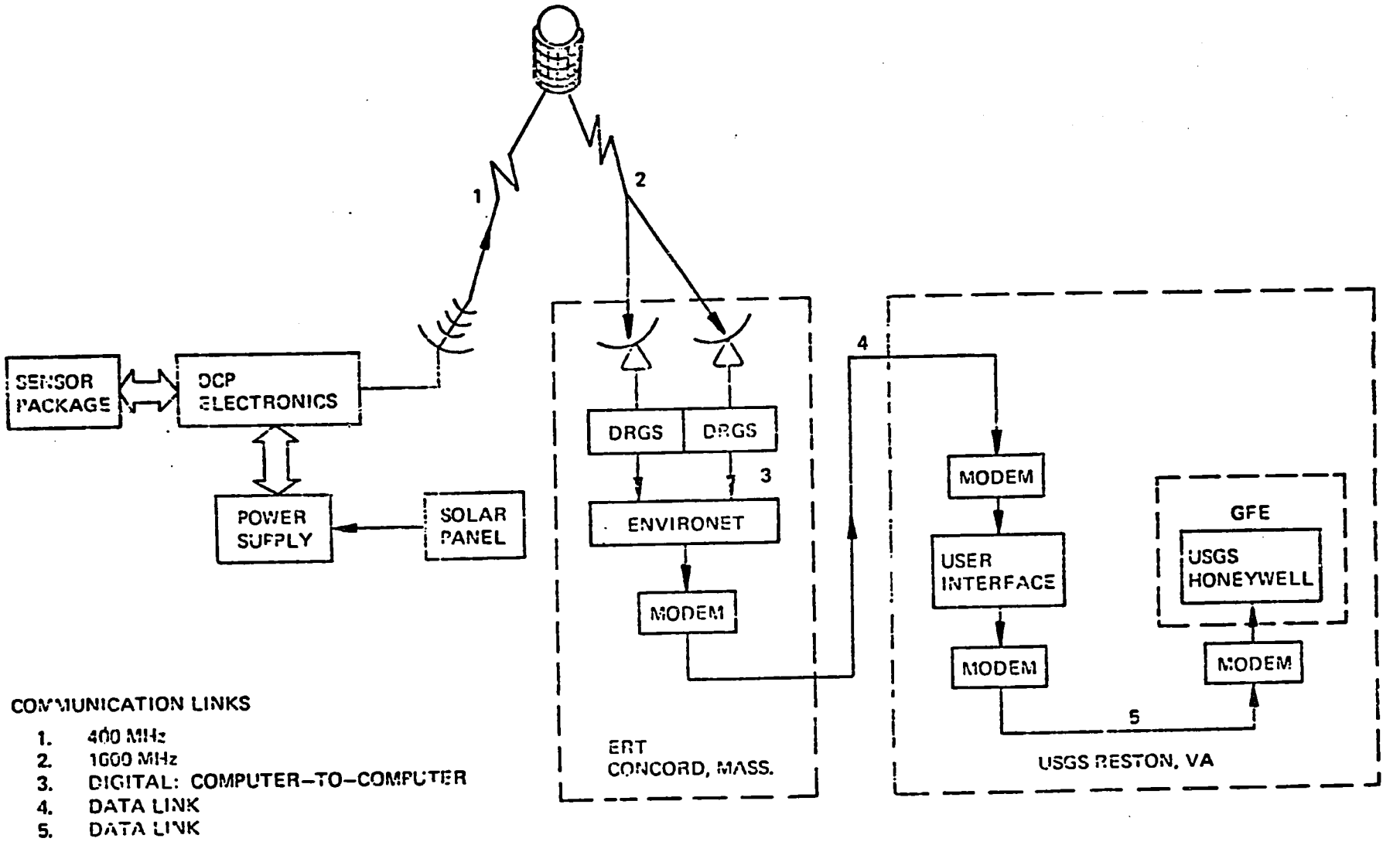
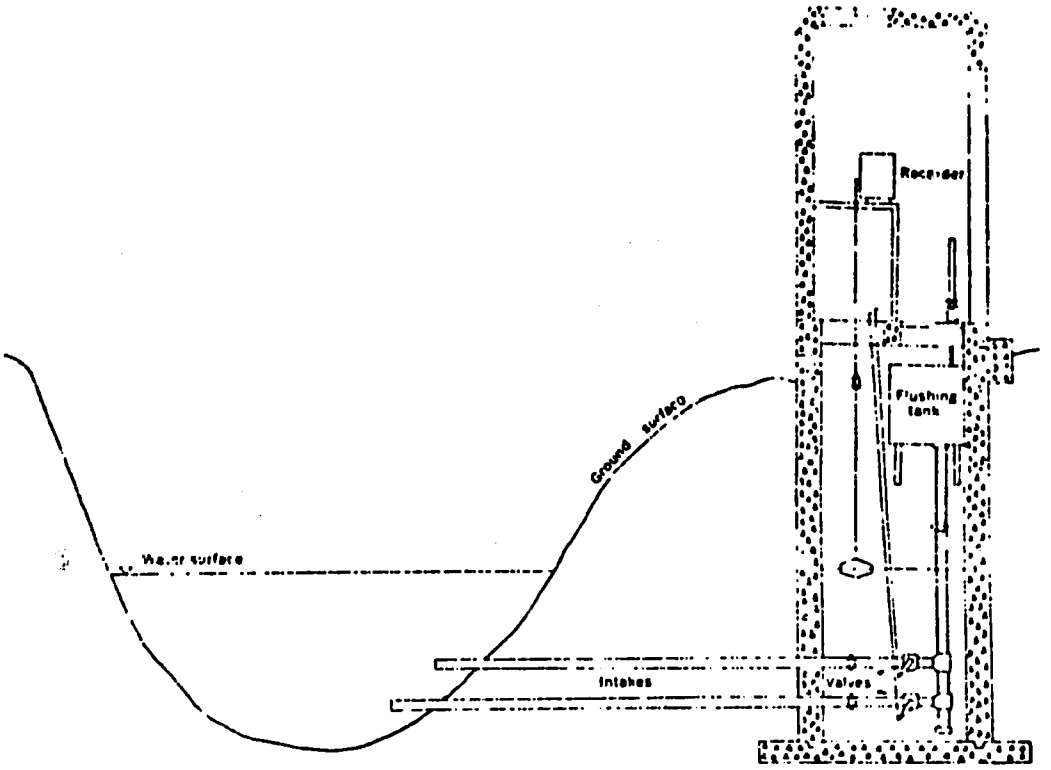
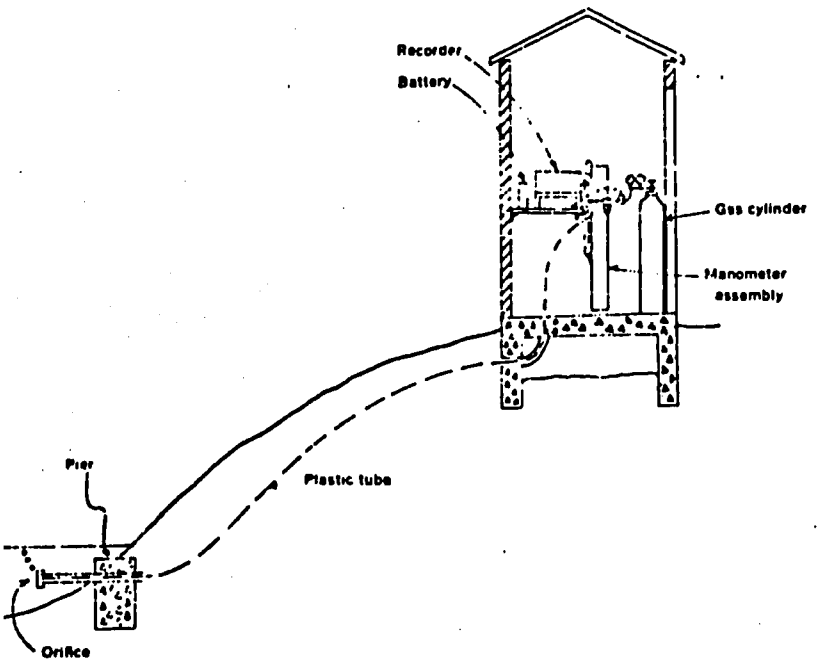


Figure 1 Environmental Information System

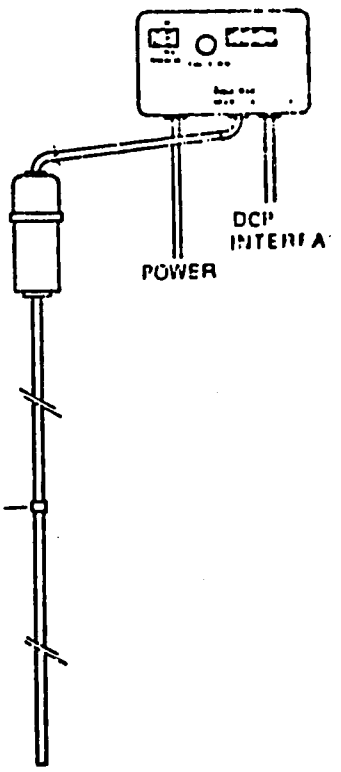
398



a) FLOAT–GAGE INSTALLATION (Buchanan & Somers, 1968)



b) BUBBLE–GAGE INSTALLATION (Buchanan & Somers, 1968)



c) ACOUSTIC SENSOR

Figure 2 Hydrologic Stage Sensors

599

At some sites, additional sensors may be placed. This is to further demonstrate and experiment with remote satellite data collection techniques.

1.2 Data Collection Platform

A DCP is an electronic device which (a) causes the hydrologic stage sensor to activate, (b) reads the digital representation of the water height as measured by the sensor, and (c) transmits a message containing the hydrologic measurements to a communication satellite.

The DCP functionally consists of the following modules:

A. The Controller Radio Set Transmitter

The controller module contains the components which affect the operational performace of the DCP. The controller is a microprocessor which periodically samples the sensor, formats a message, and transmits the message. The radio set equipment consists of an RF transmitter which modulates a carrier at the appropriate UHF frequency. The transmit frequency is controlled by setting micro-switches internal to the controller/radio set transmitter.

B. Antenna

The antenna consists of a five element crossed Yagi type which is designed to perform at UHF frequencies.

C. Batteries

There are six (6) cells, two (2) volts each, packaged together in series to provide a twelve (12) volt battery pack. The batteries are of the rechargeable Gel-Type which are expected to last a least one year without service.

D. Solar Panel and Voltage Regulators

At most sites, a 400 milliampere (at 14 volts) solar panel is installed to charge the batteries. In the northern sites, 650 milliampere solar panels are installed. Both types have a voltage regulator which prevents battery overcharge.

E. Cables

To connect the antenna to the DCP, a shielded RF cable with male TNC connectors at each end is used. This battery and stage sensor will be connected to the DCP through a second cable.

Figure 3 shows the DCP site configuration.

600

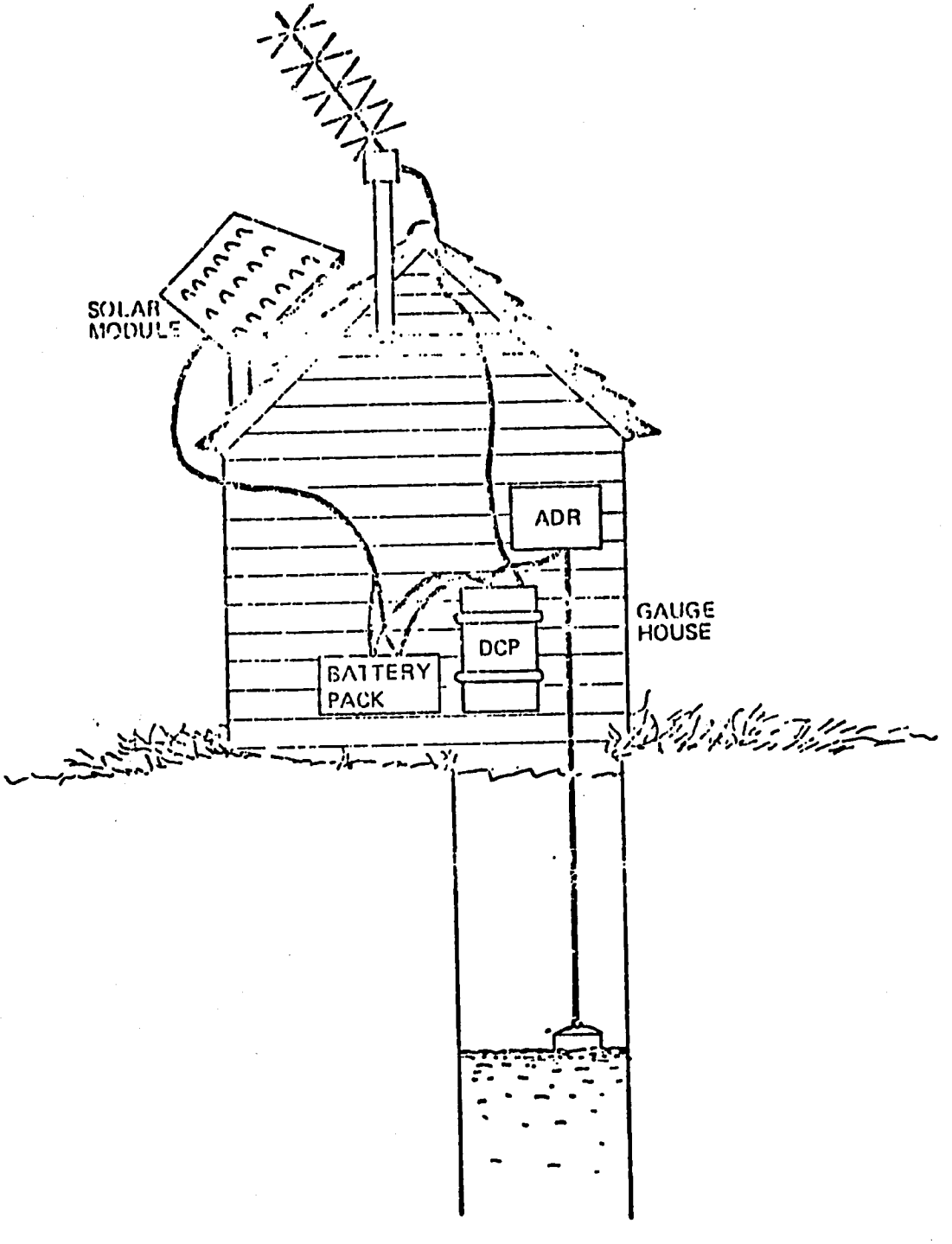


Figure 3 DCP Site Installation

601

1.3 Satellite Communication

The COMSAT General/ERT Hydrologic Information System uses a U.S. Government Geostationary Operational Environmental Satellite (GOES). This satellite system is operated by the National Oceanic and Atmospheric Administration/National Environmental Satellite Service (NOAA/NESS). The GOES satellite receives DCP messages at 400 MHz frequency and translates it to 1600 MHz frequency for retransmission to the receive earth station. All initial COMSAT General DCPs will utilize the GOES Work satellite.

Figure 4 shows the coverage area of the GOES satellites and the look angles from the DCP to the satellite.

1.4 Receive Earth Station

The Receive Earth Station is designed to perform the following functions:

- Receive the DCP messages
- Time tag the messages
- Verify the messages for errors
- Forward the messages to the ERT Data Processing Center
- Store the messages to guard against loss
- Monitor the performance of the DCP (frequency offset, transmit power, and bit error rate)

The receive station equipment will be installed at the ERT facility in Concord, Massachusetts. This equipment will be duplicated to ensure that there is no single failure point which can cause a major loss of data. Both of these stations will operate simultaneously with selection of data based on the best performing station.

2. ERT ENVIRONET Information Center

The ERT ENVIRONET Information Center receives the data from the Receive Earth Station. The Center then adds value to the data stream by centralization, organization, validation, archiving, reformatting and combining the independent raw data into useful logical information.

The data processing subsystem is an ERT computer system based on the Data General M600 Eclipse computer. For backup to the M600, ERT will use either a Data General S.250 or a Data General C/330 Eclipse.

The data from the Receive Earth Station to the ERT computers is transmitted over a computer-to-computer line. The ERT computers archive the input data, evaluate the contents of the input data, format an output message, and transmit the converted record downstream to the USGS/WRD Interface Subsystem.

Figure 5 shows the block diagram of the ERT computer system; Figure 6 shows the processing flow of the DCP messages.

602

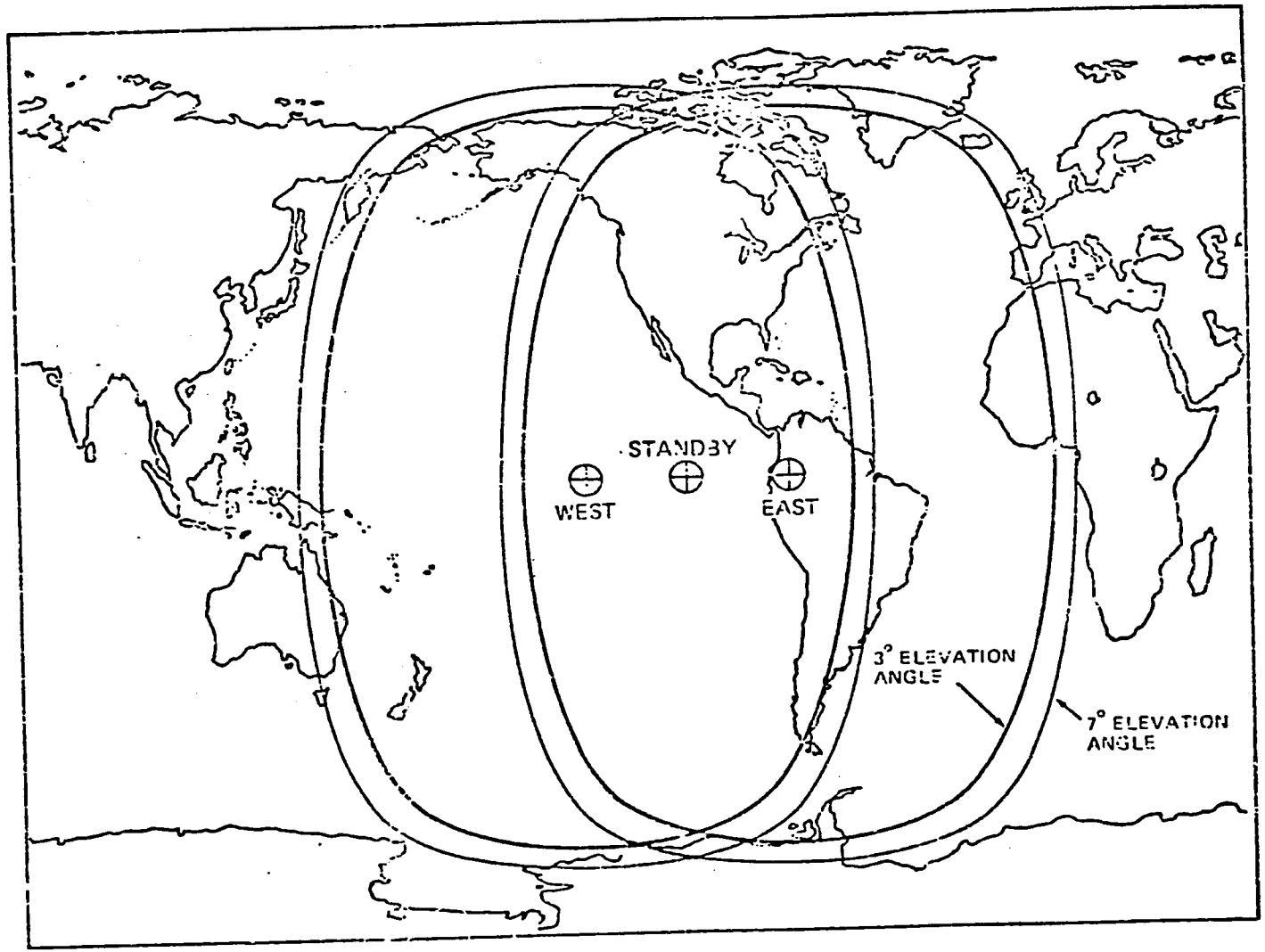


Figure 4 SMS/GOES Coverage

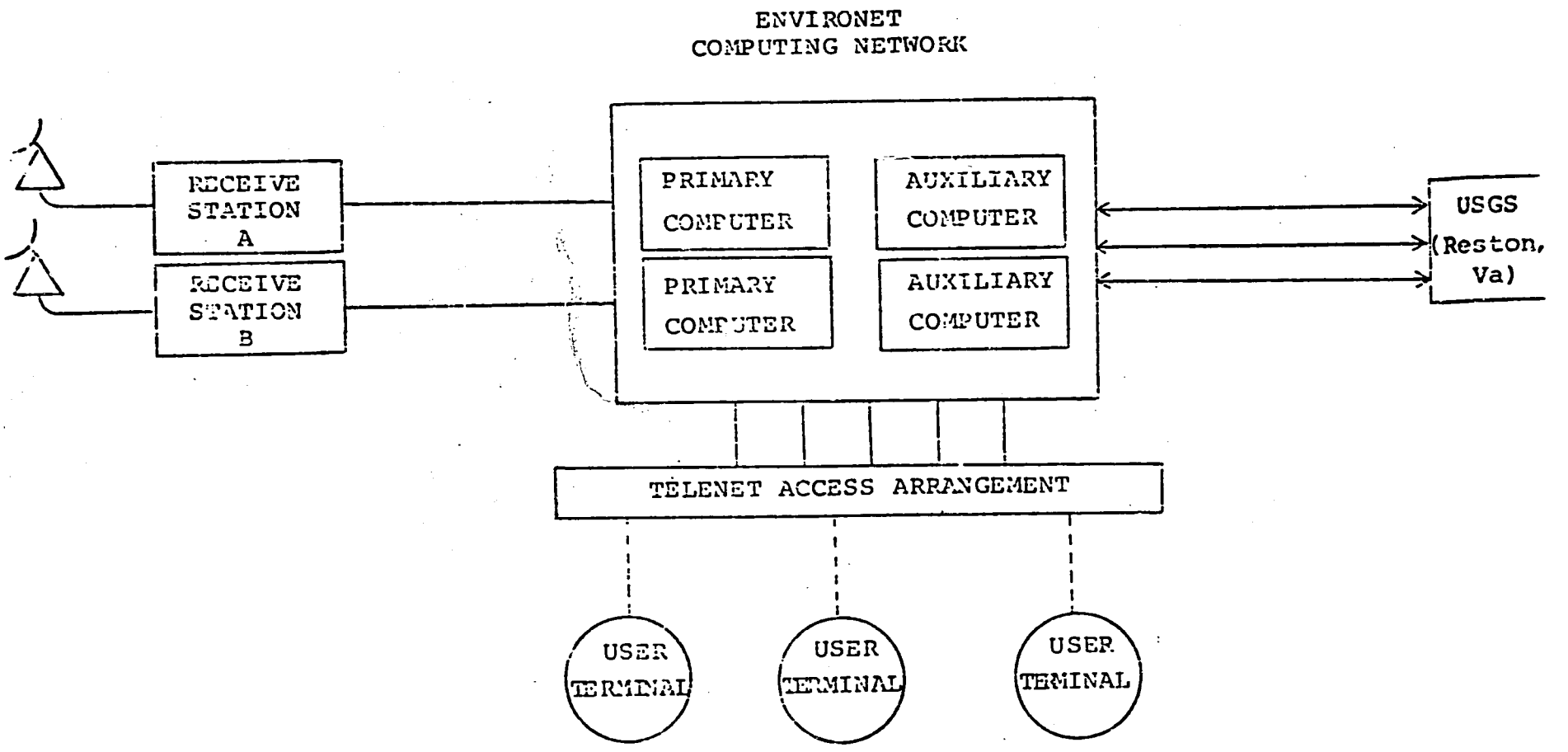


Figure 5 ERT ENVIRONET Information Center

604

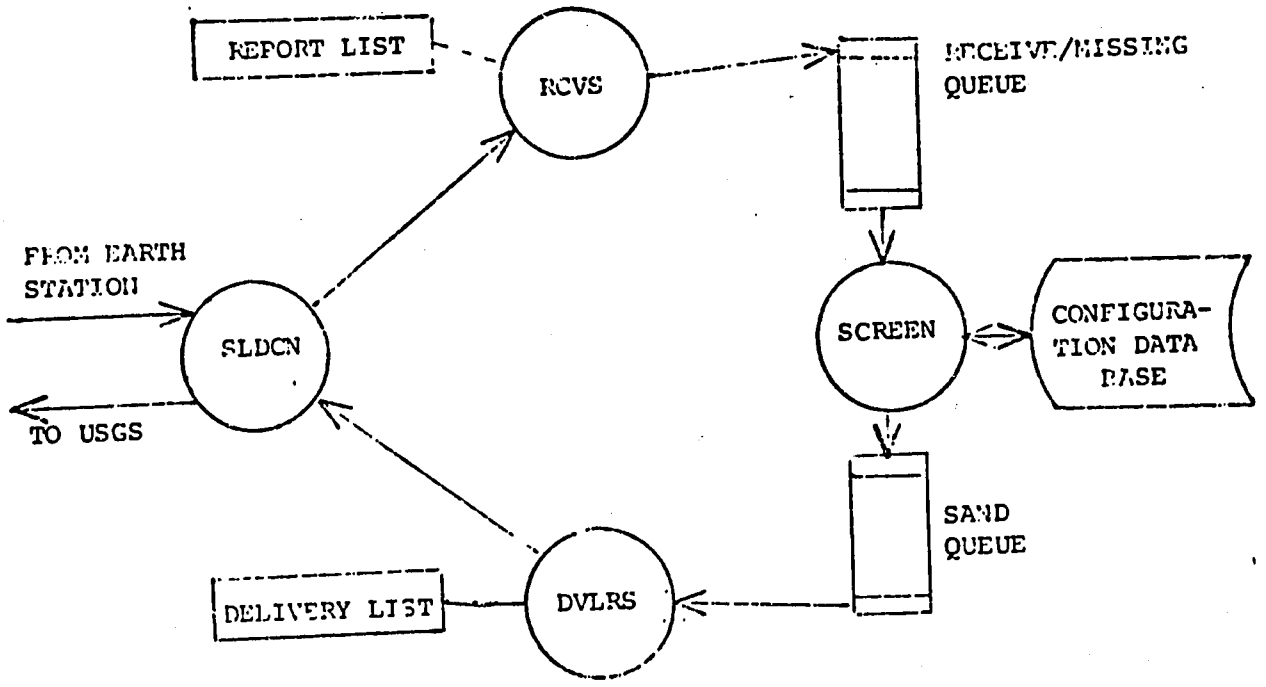


Figure 6 DCP Message Processing Flow

605

ENVIRONMENTAL EDUCATION AND TRAINING

John Whitman

Director
International Environmental Management Institute
Environmental Research & Technology, Inc.

June 1980

International Environmental Management Institute
ENVIRONMENTAL RESEARCH & TECHNOLOGY, INC.
Concord, Massachusetts, U.S.A.

606

1. Introduction

The need for environmental education and training has never been as stong and widespread as it is today. This need extends through nearly all segments of the population, including policy makers, administrators, scientists, technicians, equipment operators, children in and out of school, and the general public.

The target populations for environmental education, as recommended by the UNEP/Unesco Intergovernmental Conference on Environmental Education, are as follows:

- Education of the general public: this education should be provided at every age and at all levels of formal education, for pupils and teachers and in the various non-formal education activities for young people and adults, including the handicapped. In this education, voluntary organizations may play an important role.

- Education of specific occupational or social groups: this education is focused on those whose activity and influence have an important bearing on the environment, for instance, engineers, architects, administrators and planners, industrialists, trade unionists, policy-makers and agriculturalists. Various levels in formal and non-formal education should contribute to this training.

- Training of certain professionals and scientists: this training is for those working on specific problems of the environment, such as biologists, ecologists, hydrologists, toxicologists, soil scientists, agronomists, foresters, landscape architects, oceanographers, limnologists, meteorologists, and sanitary engineers. It is important that the training of scientists include an interdisciplinary component.

This paper is concerned with applying educational strategies to solve environmental problems. The founding principle is that education has a major role to play in responding to environmental issues, and that education can be a critical means by which to implement technological solutions, institutional and social changes, and policy options for environmental management.

The need for environmental education is present wherever there are environmental problems whose solutions require information, knowledge, and skills. While the need exists in countries of all types and levels of economic development, different educational programs must be designed to solve different environmental problems.

In many developing countries, the need for environmental education is as basic as the bare necessities of life, and this is a call for public education programs that deal with health and sanitation, food and

water, shelter, including protection from natural disasters, and even literacy.

In countries experiencing infrastructure and industrial development, the need for environmental education and training calls for programs to develop environmentally sound planning, siting, management and operations of projects and industries.

Some countries following legislative or other compelling requirements demand that environmental impact assessments preceed certain projects and that polluting utilities, industries, and other operations meet national air and water quality standards. These requirements have founded a major market for environmental skills and technologies, including control and monitoring systems technologies, all of which, in turn, require specialized environmental education and training. As such technologies transfer to other countries, there is a corresponding need for training in the recipient countries.

In the United States there is even legislation that specifically calls for environmental education. The Environmental Education Act of 1970 authorizes the Commissioner of Education "to establish education programs to encourage understanding of policies, and support of activities, designed to enhance environmental quality and maintain ecological balance."

The need for environmental education and training is, therefore, strong and widespread. It is also diverse and requires appropriately designed and implemented strategies sensitive to different social, political, economic, cultural, and technical realities from country to country.

A quick review of worldwide trends in environmental education will assert the need for action among policy makers and practitioners alike.

2. Worldwide Trends in Environmental Education

The need for effective and rapid environmental education and training results most directly from a combination of fast population growth and a disproportionate distribution of resources to accommodate such growth.

Today, the physical size of the world is obvious and well known. Not so well known is how fast the world's population is growing, and what the implications of this are to everyone in developing and developed countries alike.

The following trends will help sharpen an appreciation for world population growth:

608

- It took from the origin of mankind, over a million years ago, to the early 1800s for the world to reach a human population of 1 billion.
- The next billion was reached in about 100 years, by 1930.
- The third billion was reached in 30 years, by 1960.
- The fourth billion in 15 years, 1975.
- Today, in 1980, the world's population is about 4.5 billion.
- Today's population size is expected to double in about 30 years, and the population is most likely to peak between 8 and 11 billion, reaching about 6 billion by the year 2000.

Numbers of people alone are not the issue. The availability and distribution of resources necessary for life combine with the sheer size and concentration of the population to cause increasing stress on social, political, and economic stability. These stresses are not to be placed aside for future generations; they are present throughout the world today and they underscore the need for very rapid and effective education -- education for basic needs and education for wise management in a time of difficult choices.

Although the principles of living in harmony with nature have long appeared in customs and religions, the need for environmental education and training has only relatively recently become recognized as an important area for local, regional, national, and international action. The world's first intergovernmental meeting at the ministerial level was held on the subject in October 1977, when delegates from 66 countries around the world met in the Soviet Union and endorsed 41 recommendations for action in environmental education and training.

This meeting, called the Tbilisi Conference, was jointly sponsored by the United Nations Environment Program (UNEP) and the United Nations Education, Scientific, and Cultural Organization (Unesco). UNEP and Unesco also jointly coordinate an Office of Environmental Education based at Unesco headquarters in Paris. The mission of the office is, in part, to develop and implement a worldwide approach to environmental education and training. The office also publishes a newsletter, CONNECT, which provides a summary of selected world events and activities in environmental education and training of concern to UNEP and Unesco.

The Tbilisi Conference produced a final report, which includes a declaration, a statement on the role, objectives, and guiding principles of environmental education, and strategies for the development of environmental education at the national level.

609

The UNEP/Unesco Office of Environmental Education has funded the design and development of a small number of pilot projects in regions around the world. These are reported in various issues of CONNECT.

More recently, in February 1980, a number of international financial institutions signed a declaration pledging funds for environmental projects, specifically those for education and training. These institutions include:

- African Development Bank
- Arab Bank for Economic Development in Africa
- Asian Development Bank
- Caribbean Development Bank
- Inter-American Development Bank
- World Bank
- Commission of the European Communities
- Organization of American States
- United Nations Development Program
- United Nations Environment Program

These trends, giving recognition and funding to needs for environmental education, are promising, but not adequate. There is much initiative required by national governments, non-governmental organizations, private corporations, community groups, and individuals.

These trends assert the need for action among policy makers and practitioners to apply educational strategies as a key management tool in solving environmental problems. The next section presents some design considerations useful in developing a specific educational program.

3. Design Considerations

In general, there are four elements of an educational program (including training) that deserve careful consideration:

- Need and Target Population
- Goals and Objectives
- Implementation Techniques and Schedule
- Evaluation Techniques

3.1 Need and Target Population

The need for education is an urgent one among all ages of the population and across a wide array of occupations. However, specific needs will differ from group to group.

In many developing countries, the needs for education are so great and obvious that there is little sense in spending time and resources to conduct a needs assessment. It would perhaps be more worthwhile to apply whatever resources are necessary and available to responding to known needs.

Within organizations, the situation may be different. A newly developed Ministry of the Environment, for instance, would do well to undertake an analysis of position requirements for the next five years to determine specific needs for trained human resources. Once the positions are quantified and associated with job descriptions, the organization will be in a better position to determine training needs. A five year plan for training can be developed that takes advantage of traditional sources of education, such as universities, as well as newly developed programs, which the organization can undertake under contract or by utilizing internal trainers.

Regardless of how obvious a need for education or training is, it will be helpful, if not critical, to document and describe the need accurately and with justification. Such a description may help convince decision makers, including funders, to agree to implement a program.

A good statement of need also will help determine how best to evaluate the program's success.

3.2 Goals and Objectives

The goals and objectives of specific educational efforts also will vary among groups, depending on the needed outcomes. These outcomes may range from an increased general awareness of environmental issues; to sanitary handling of food and water; to formulating effective environmental standards and regulations; to assessing the environmental effects of development projects; to designing engineering controls; to operating and calibrating pollution monitoring instruments; and so forth.

Each program should have a clearly defined goal and set of objectives. The entire design of the program and the evaluation strategy should reflect this statement. The success of the program will be measured against the statement and the program itself will be judged accordingly.

3.3 Implementation Techniques and Schedule

The implementation, or educational techniques required to accomplish a program's goals and objectives also will vary, depending largely on

611

the age and occupation of the target group. Some techniques may involve parent-child interaction; others may require a large-scale media broadcast; others may be tied to on-the-job training; yet others may involve individualized, programmed instruction. The range of techniques to choose from is nearly as large as all possible means of communication.

Scheduling is a critical element of educational programming. Events should follow each other logically and according to a plan of action. Timing, too, is important, but sometimes overlooked. Imagine a television broadcast for teenage males and females timed for 7:00 pm on a Saturday night. Nearly every teenage person among the target group might be out on a date that night, doeming the message and wasting time and money.

3.4 Evaluation Techniques

Evaluation is one of the most important, but largely ignored or poorly treated components of an educational program. The evaluation designs necessary to know whether the educational effort will be or has been effective also will differ depending on the circumstances and resources available.

In one case, a simple examination following a course on how to operate a piece of equipment may suffice. In a case involving changing public behavior in favor of more sanitary handling of food and water, a test for a lower incidence of physical impairment or disease may be highly desired as an indicator of success, but may simply not be possible, especially in areas where epidemiological data are not available. In such cases, perhaps selective interviews and observational studies may prove the best evaluation techniques.

A very few new educational programs are beginning to use effective evaluation techniques to measure success and to correct for program defects during implementation.

3.5 Additional Considerations

It is especially helpful to consider first the ultimate goal or purpose of the program. This can guide the selection of the most appropriate implementation procedure. For instance, one category of programs may attempt to achieve environmental literacy -- the teaching/learning of fundamental concepts, principles, and methodologies for thinking, communicating, and acting in an environmentally sound way. Such teaching and learning naturally begins at home, as part of a person's general upbringing and socialization process. Later such learning may find its best place in schools, universities, and other formal educational systems, or in community organized activities, such as religious programs, scouting groups, and so forth among the various informal educational systems.

Environmental literacy need not require newly designed and heavily funded courses or programs; rather, existing curricula in the sciences,

612

technology, and the professions, such as engineering, law, business administration, and public policy easily can be revised to include environmental concepts, material, and discussion focusing on environmental topics and issues. After all, it is the students of these curricula who likely will be engaged in life-long professions that have an environmental impact and toward whom we will turn for environmental solutions.

Another category of educational programs deals directly with the teaching/learning of specific skills required for particular jobs. This kind of program may find its best place within the various development sectors that require environmentally sound operations and that demand people trained in specific environmental disciplines or with special skills. In such programs, the necessary education and training costs should be borne by that sector, and not by the public.

Time is a critical dimension to be considered in the design of an education program. Does the program require a very rapid, short-term payoff? Can the goals wait for a long-term payoff?

As in all educational programs, there is a time lag between inception and results. Formal educational programs tend to have a long-term payoff, meaning an extended time period during which the human resources being educated are generally unproductive. Formal education includes primary and secondary school and higher education. Calculate at least twenty years, ages 1 to 20, before an educational system can turn out a crop of higher educated citizens.

Informal or non-formal education can have a short-term payoff. Such education can be undertaken through the media, community outreach programs, such as family planning and health care programs, and in work-related training, such as vocational training, extension work, and on-the-job training. Media broadcasts can enlighten a listening or viewing public in a matter of minutes; on-the-job training can produce experts in weeks or months.

Policy makers and practitioners would do well to consider carefully these various components of a program: needs and target population; goals and objectives; implementation techniques and schedule; and evaluation techniques. There is little time to study needs and experiment with programs that do not have a sound evaluation design. These are reasons to turn to educational experts for advice and direction in helping to solve specific environmental problems.

4. Funding Sources

Venerable national and international institutions gravely concerned with the environment and environmental education will point you to the following sources of money for your project:

613

- Government agencies
- Non-governmental organizations
- International agencies
- Foundations
- Universities

It is likely that the person guiding you will agree that your project is of exceedingly high importance. It is also likely that this person will be in one of the above organizations. In other words, do not depend on the traditional sources of funding for environmental education programs. The logical sources often simply do not have the money.

There are other sources of funds that are beginning to show more or new support. These include the international financial institutions (development banks) and private corporations. Additionally, church federations and foreign governments (especially those among developed countries and OPEC) should be considered.

There are several points that may be helpful in securing funding. First, a program with a sound evaluation design that will show results should deserve funds over those without such evaluation. Programs with proven effectiveness should be replicated and funding sources would do well to support them.

Second, it may be futile to wait forever for funding. Instead, consider developing the program with whatever resources are available, donated, or borrowed. If a program begins to show success, further support may be forthcoming. Community organizers would do well to initiate programs and use their on-going success to attract attention and funding.

Third, anticipating a program's results in terms of money saved can show an effective justification for funding the program. For instance, Project Burn Prevention was designed to use educational strategies "to increase knowledge, change attitudes, alter burn-safety-related behavior, and thereby reduce the number and severity of burn injuries among various groups of the public" in the United States. Over two million Americans are burned by hot liquid, flame, electricity, and other burn sources each year. It can cost over $50,000 per patient to treat severe burns requiring plastic surgery. A cost analysis of the possible savings such a program could produce led to the funding of an experimental public education program at a cost of $1 million. The experimental program is now complete, showing favorable results (the program was rigorously evaluated), and the program is now being disseminated nationwide.

In the longer term, those sectors having environmental impacts should bear the cost of protection, including the costs of education and training. Meanwhile, imagination, nerve, and some aggressive qualities may be required to supplement funds from the usual sources.

5. Selected Suggestions

The following are additional considerations that may help to create and design environmental education programs and policies:

- Environmental education policy should have clearly defined goals and objectives. These must relate directly to your country's goals for development and achieving a certain standard of living.

- Environmental education must have the commitment of the government, both in principle and in terms of providing sufficient resources to achieve goals for environmental education.

- Environmental education should be designed to correspond to economic and income incentives in the private and public sectors. There must be jobs for graduates in environmental fields, and environmental education must be a qualification for other jobs that have environmental implications.

- Environmental education should be used in public information and awareness efforts to ensure an informed public capable of intelligently challenging or supporting policies that will have environmental consequences. The public must be able to recognize environmental issues and choose options.

- Environmental education policy must anticipate and plan for future needs and a rapidly changing set of circumstances brought about, in large measure, by rapid population growth. Goals of environmental education should be relevant in the future as well as today.

- Environmental education opportunities should be linked directly to other sectors of development, with regulations and incentives guiding responsibilities for environmental protection in each sector.

- Environmental education opportunities should be identified for each development project, so that when a road, dam, power plant, airport, school, or irrigation project is planned, the planners should include opportunities to educate workers at all levels of the project regarding the environmental aspects of the project.

- Development banks and other development institutions should educate their managers and planners in the environmental aspects and implications of development.

615

- Environmental managers should not wait for funding or the results of plans in order to get started with environmental education programs. They should use whatever resources are currently at their disposal, which, if modified, could begin the process of education. Success can then help to justify needed funding.

- Environmental managers probably know already the needs for environmental education, and should probably get started implementing programs with sound evaluation techniques.

- Environmental education should not be limited to the public sector. The private sector should, by incentive or regulation, also contribute to the environmental education effort.

- Incorporate environmental messages in national literacy programs. This is a way to reach large numbers of people early in their development.

- Mobilize volunteers for scientific research projects. Much basic data and samples can be collected by capable people if appropriately organized.

- Make the private sector include environmental content in its advertising. For instance, design soft drink advertisements to include environmentally sound messages.

- Create opportunities for women in development; educate accordingly.

- Use indigenous training resources.

- Tap non-governmental sources of credibility, such as scientists and religious leaders. They can help convey environmental messages to the public and decision makers.

- Challenge and change unsound policies, especially those that threaten the quality of life. Educational programs can be designed to involve the public in ensuring environmentally sound policies. They also can help to correct unsound policies.

This paper has provided an overview of world trends in environmental education, presented several critical components of educational programs, discussed briefly sources of funding, and set forth selected suggestions regarding environmental education action. References that follow will be helpful in pursuing further information on environmental education programs and the design, development, and evaluation of educational programs in general.

616

6. References

In the broadest sense, the concept of "environmental education" can refer to any activity that falls within the intersection of the concepts of "environment" and "education," both of which are very broad concepts indeed. The following few references will not do the subject justice; however, they provide a range from general issues that deserve attention as candidates for educational programs, to specific texts on educational objectives and evaluation.

1. Barbara Ward, Progress for a Small Planet, W.W. Norton & Company, New York, 1979.

   A readable and up-to-date book describing critical environmental issues for environmental management. Appropriately designed educational programs should be considered among the problem-solving tools required by these issues.

2. International Union for the Conservation of Nature and Natural Resources, World Conservation Strategy: Living Resource Conservation for Sustainable Development, Morges, Switzerland, 1980.

   Recent compendium of selected needs for conservation along with recommendations for management, including education and training recommendations.

3. United Nations Environment Program/Unesco, Intergovernmental Conference on Environmental Education, Final Report, Tbilisi, USSR, 14-26 October 1977, Unesco, Paris, 1977.

   Results of the first ministerial level conference on environmental education and training. Includes recommendations for action, as well as a declaration and set of goals and objectives.

4. The World Bank, Education, Sector Working Paper, December 1974.

   Overview of trends in education and development to 1970, a statement of the Bank's education development strategy for the 1970s, and a description of the Bank's education lending policy.

5. Mats Hultin, Guidelines for Education Sector Work, Office Memorandum, The World Bank, 3 April 1978.

   A description of the Bank's sector work in education, including guidelines for undertaking education sector surveys and identifying projects.

6. Economic Development Institute, Seminar on Teaching Project Analysis, Readings, compiled by Robert Youker, The World Bank, December 1977.

   An eclectic collection of readings on learning theory, the process for developing a training program, teaching methods and

617

techniques, the case study method, evaluating training, and developing a course schedule and calendar.

7. John Whitman, Internet Teacher Guide, Strategic Environmental Planning, 1977.

Teacher guide for one of the larger UNEP/Unesco pilot projects in environmental education. Contains source documents including the Environmental Education Act of 1970, a publication titled, Fundamentals of Environmental Education, other copies of environmental legislation, and news reports on environmental issues.

8. Benjamin Bloom, ed., Taxonomy of Educational Objectives: The Classification of Educational Goals, David McKay Company, Inc., New York, 1956.

The principal text dealing with the nature and types of educational objectives. Includes two handbooks, one on the cognitive domain, the other on the affective domain.

9. Donald T. Campbell and Julian C. Stanley, Experimental and Quasi-Experimental Designs for Research, Rand McNally College Publishing Company, Chicago, 1963.

The prevailing text on how to set up a program for the purpose of evaluating its effectiveness for research.

10. Carol H. Weiss, Evaluation Research: Methods of Assessing Program Effectiveness, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1972.

Useful considerations of applying research methods to the evaluation of social programs, including those in education, social work, health, job training, and other non-formal efforts to apply and evaluate educational strategies.

618

JOHN R. WHITMAN

Director - International Environmental Management Institute

Professional Experience

Mr. Whitman is Development Manager and Director of the International Environmental Management Institute of ERT. Mr. Whitman is responsible for developing educational and training programs in management and technical areas to facilitate technology transfer and to strengthen environmental management and operations skills in the developing world. Mr. Whitman has been with ERT since June 1978.

Mr. Whitman conducts an annual two-week international Seminar on Principles of Environmental Management in Developing Countries, which, in 1979, included fifty-five participants from twenty-six countries. The seminar is designed to acquaint top-level decisionmakers in governments, industries, and international organizations with an integrated approach to environmental management. Government ministers, government agency and department heads, and representatives from industry comprise the group of participants.

Prior to joining ERT, Mr. Whitman was a consultant to the School and Society Programs division of Education Development Center, Inc., one of the world's largest non-profit educational research and development corporations with extensive experience in developing innovative programs for developing countries. There, Mr. Whitman designed a variety of educational programs dealing with issues such as reducing the socio-economic effects of earthquakes, reducing the economic hardship of increasing energy costs on the elderly, and involving large networks of volunteers in scientific research.

Mr. Whitman is founder of Strategic Environmental Planning, a private consulting group responsible for developing a major international environmental education program in cooperation with Unesco and United Nations Environment Program, and a worldwide oil spill reporting network for the U.S. Environmental Protection Agency.

Mr. Whitman served for seven years with the Smithsonian Institution National Museum of History and Technology, Museum of Natural History, and Center for Astrophysics, principally developing international environmental programs.

Mr. Whitman has served on a variety of international expert panel workshops dealing with issues such as oil spills, pollution monitoring, and environmental education.

Education

Ed.M.	Harvard University (Administration, Planning, and Social Policy)
A.B.	Boston University (Philosophy)

WILLIAM D. RUCKELSHAUS AND THE ENVIRONMENTAL PROTECTION AGENCY

On December 2, 1970, William D. Ruckelshaus took on a new job, Administrator of the Environmental Protection Agency. EPA was merely an idea embodied in words on a piece of paper. The job remained to turn that idea into a reality. The existing facilities, programs and people, their work and their tools had to be brought together both physically and organizationally. For the first time their efforts had to be realigned into some kind of coordinated program that reflected the interdisciplinary nature of environmental pollution. William D. Ruckelshaus, then Assistant Attorney General in charge of the Civil Division of the Justice Department, was chosen by President Nixon to be the first EPA administrator on October 31. Others within the Nixon Administration had been offered the job, but turned it down. "Day One" for EPA was less than 5 weeks away--December 2, 1970.

The EPA, the first new line agency formed by the Nixon Administration, was established under a Presidential Reorganization Plan that took effect in October 1970 when it was not disapproved by either House of the Congress. Recommended by the President's Advisory Council on Executive Organization (PACEO) chaired by Roy Ash, the rationale behind the new agency was to coordinate an attack on pollution.

The state of the environment was gaining momentum as an issue of popular concern in 1970. Membership in both old conservation groups such as the Sierra Club and younger, more militant groups like the Friends of the Earth was increasing. In response to mounting public concern, Congress established the Council on Environmental Quality in 1969, lodging it in the Executive Office of the President. The CEQ had set out an extensive environmental agenda for the Administration by early 1970. In February 1970, President Nixon delivered a message on the environment which laid out 37 separate goals he wanted to achieve that year. Senator Edmund Muskie, the leading contender for the 1970 Democratic presidential nomination, was also trying to capitalize on the environmental groundswell. He was the major congressional spokesman for the environment and chairman of the Senate Public Works Subcommittee on Air and Water Pollution. Muskie sponsored some of the early pollution acts, as well as the Resources Recovery Act of 1970 and the Clean Air Act Amendments of 1970. He was an outspoken proponent of Earth Day. "Earth Day," April 22, 1970, was a great public relations success. Widespread media coverage created the impression that millions of Americans were up in arms about environmental degradation.

This case was prepared by Ms. Peggy Wiehl under the supervision of Professor Joseph L. Bower as the basis for class discussion rather than to illustrate either effective or ineffective handling of an administrative situation. It is based on a case study prepared by Mr. Gregory B. Mills. Funds for the development of this case were supplied by the Alfred P. Sloan Foundation.

Copyright © 1974 by the President and Fellows of Harvard College

Distributed by the Intercollegiate Case Clearing House, Soldiers Field, Boston, Mass. 02163. All rights reserved to the contributors. Printed in the U.S.A.

620

The creation of EPA brought together in one agency a variety of research, monitoring, standard-setting, grant-making, technical assistance, and enforcement activities formerly scattered through several departments and agencies. As noted, its designers sought to provide a governmental structure for approaching pollution control problems that treated the total environment as a single, interrelated system.

EPA inherited 5,743 employees from 15 agencies. Exhibit 1 shows the division of the employees and the budget. These resources were to be used for dealing with six basic types of pollution under a variety of legislative mandates. A description of some of the programs and problems inherited by the agency follows. They constituted the new material for Ruckelshaus' agenda.

Water pollution: The Federal Water Quality Administration had been moved from HEW to the Interior Department, and then to EPA. Charged with the control of pollutants which impair water quality, FWQA was broadly concerned with the impact of degraded water quality. It performed a wide variety of functions, including research, standard-setting and enforcement, and provided construction grants and technical assistance. Progress against water pollution had been slow, however, in spite of large expenditures of cash. Federal enforcement was limited under the 1965 Water Quality Act to only interstate cases, and there had been only intermittent attempts at enforcement. Another difficulty was that as known pollutants were becoming controlled, more were discovered. The mercury scare of early 1970 is an example.

Also joining EPA was the Bureau of Water Hygiene from HEW. The BWH's responsibility was to monitor drinking water quality, but it had no enforcement powers.

Air pollution: The National Air Pollution Control Administration was transferred intact from HEW. NAPCA was responsible for motor vehicle and stationary pollution control and had concentrated on research for pollution control methods--without much luck. Its regulatory functions were similar to the FWQA's, and the 1963 Clean Air Act provided limited enforcement powers. NAPCA had not been an active enforcement agency: it had taken only one polluter to court. Yet air pollution was an area of strong public and governmental concern due to the periodic occurrences of heavy smog and scientific warnings of health hazards. Pressures from the automotive and manufacturing interests charged environmentalists with advocating unreasonable, costly, and technically impossible measures.

Solid waste: HEW's Bureau of Solid Waste Management moved intact to EPA. It concentrated its efforts on R & D projects and hence the bureau's activities would be able to expand under the 1970 Resource Recovery Act sponsored by Muskie. This act authorized $460 million over the next three years for construction of local disposal facilities, federal research on waste recycling, and expanded personnel.

Pesticides: EPA inherited three pesticide units. One of these units, the Pesticides Regulation Division, with responsibility for registering and labeling all commercially-used pesticides, was transferred intact from the Agriculture Department. The transfer was opposed by farm interests who feared chemicals would be considered as pollutants rather than as aids to production. According to Ralph Nader's Water Wasteland, the division traditionally had a close working relationship with pesticide companies.

The EPA received 275 of the 475 employees in FDA's Office of Pesticide Research. It set and enforced standards limiting pesticide residues in food. The FDA, however, retained its authority to remove food with excess pesticide residues from the market.

The Interior Department's research projects on the effects of pesticides on fish and wildlife were also moved to EPA. Actually this involved only one laboratory.

Radiation: Controversy over the adequacy of federal radiation standards had been growing. Scientists and environmentalists were calling for an immediate stiffening of the standards. The Atomic Energy Commission's authority to set standards and emission limits for radioactivity was transferred to the EPA, although AEC retained responsibility for the implementation and enforcement of radiation standards.

EPA received over half of another HEW agency--the Bureau of Radiological Health. Its function was to monitor the radiation in the air and precipitation and to conduct research into the biological effects of radiation.

Noise: The Reorganization Plan established the Office of Noise Abatement and Control within the EPA. This involved a one-year study of the noise problem.

The New Administrator's View of the Job

Faced with a wide range of publicly visible problems and a confusion of agencies, organizations, and laboratories, Ruckelshaus commented to the researcher on why he took a job others rejected:

> What can you expect to accomplish? I think the chance of accomplishing something with a brand-new agency like this, where you have a problem that has a lot of legitimacy to it and high public visibility, and therefore the political support that you need to move forward very fast--the chances of succeeding are enormous.
>
> I felt there was a chance here, in this area, to try to turn that situation around. To try to start because, number one, there was a lot of public support to do something about it, and there was a real chance to take this process and use it as effectively as possible, and thereby convince people that government was willing to do something about the problem.
>
> I was convinced then that in spite of all of the faddism that was associated with the problem, there is enormous legitimacy to the issue itself.
>
> Also, the fact that a new agency like this comes along once every fifteen years in the federal government, and a chance to be in on the formation of such an agency was something you just don't get very often.

Ruckelshaus

William Ruckelshaus is a native of Indiana. After receiving his law degree from Harvard in 1960, he joined his father's law firm. Shortly thereafter a family friend appointed him deputy attorney general of Indiana. There he drafted the state's air pollution control law and in 1963 he represented the state board of health in water pollution abatement actions. In 1966, Ruckelshaus was elected to the state legislature and named majority leader one year later. In 1968, he opposed Birch Bayh in the U.S. Senatorial election, but lost. Recruited to the Justice Department, Ruckelshaus was the liaison to college campuses. Although the tough assignment involved responsibilities such as quelling student demonstrations in Washington over Cambodia, he became known as one of the more outgoing and accessible members of the Administration. In spite of his good reputation at Justice, Ruckelshaus' appointment drew criticism. Environmentalists were apprehensive about having a confidante of Attorney General Mitchell heading EPA, especially since he lacked outstanding environmental credentials.

When Ruckelshaus was presented at a White House news conference in November 1970, the national news teams, including Walter Cronkite, came rolling in the door at 20th Street where Ruckelshaus and company had made a home. Even though there was not even a legal agency yet, everyone expected full-blown competence, articulate EPA spokesmen, and the ability to do things as if they had been in operation for five years.

Ruckelshaus was forceful and dynamic, the image was one of momemtum of exciting things happening. The TV cameras focused on a little door sign that read "Environmental Protection Agency"; the press felt the symbol was important, that the public should perceive that something new was in place. Ruckelshaus was in his own new setting, not on somebody else's historical ground. He and EPA had their own identity, but getting the EPA to function effectively would be a challenging task.

The Early Moves

Although coordinating the various agencies EPA had acquired would be difficult, an EPA task force[1] had been established in July to prepare the ground work for the agency's start up. The group examined the structure most appropriate to allow for a strong top management which they felt EPA would need. It also selected key immediate tasks that the administrator would have to deal with.

A special OMB team was assigned to prepare EPA's budget for FY 1972. During its first 7 months, the agency would be operated from the allocations left in the inherited budgets for FY 1971 (Exhibit 1). So it was important for the administrator to get involved in upcoming legislation and the budgeting process. Getting a permanent headquarters in Washington was essential in establishing EPA's image. Although the agency had been given a half floor in one building, it would be better to have a location that could house all

[1]The team consisted of about 15 members from such agencies as NASA, Department of HEW, Department of Transportation, and CEQ. Its work was primarily directed by Howard Messner, an OMB management analyst on special assignment.

of the 2,000 EPA employees, facilitating administrative control. Ruckelshaus also had to select his top and middle management. Constraints in the number of top civil service positions (such as heads of divisions) allocated to EPA complicated the task.

While the task force aided Ruckelshaus with start up problems, the administrator was confronted with two major issues. He had to keep the various agencies EPA had inherited running while a new organizational structure was being developed. And, he had to generate sufficient activity to convince the public and other interest groups that EPA was serious about cleaning up the environment. These problems interacted and were potentially conflicting. On the one hand, Ruckelshaus needed to minimize disruption during the transition period so that he would have time to create a new organizational structure. The urgency of the attack on pollution demanded that vital on-going programs not be disturbed or delayed by the realignment. Certain statutory deadlines had been set that the new EPA would have to meet. The concomitant directive to "keep doing things the way you always have," however, meant in some cases to continue to do nothing, or to keep doing things the wrong way. On the other hand, Ruckelshaus recognized that he had to act quickly and dramatically to capture the constituency he needed to make a successful agency. But if the agency continued "to do things the way you always have," dramatic action was impossible. Yet if Ruckelshaus seized the initiative from these agencies, he would only contribute to the disruption and dissatisfaction he was struggling to avoid. To make matters more complicated, Ruckelshaus had to consider how to deal with the fragmented policies and people now in his charge, at the same time that he pondered what the goals of EPA should be.

> I realized very rapidly that I was going to have to grit my teeth for a while with this structure we had chosen in the beginning so that I could absorb enough of this information, sort of through the pores, to get a feel for what we ought to do. I had to go around to all of these regions and to the major laboratories that we had; sit down and listen to these people and just get a feel myself, personally, for what was going on.
>
> There was a need to establish for the agency some clear goals that everybody could identify with. I went around and talked to a lot of them in the agency. There were all kinds of different opinions as to what those goals ought to be, including a strong recommendation that there wasn't enough authority. I looked at the two most recent examples of agencies like EPA: OEO and NASA. I looked at them in terms of what their statutory goals were. NASA's had been very narrowly defined, in terms of "let's get to the moon in ten years" and they achieved it--in the process, almost did themselves out of business. OEO, on the other hand, had a very amorphous goal: "let's do something about poverty." Some would say that is what they were doing: <u>something</u> about poverty. This was the kind of progress that is very difficult to measure.
>
> I felt that <u>we</u> had to be very careful that EPA did not go to either of those extremes. So, we defined our initial

goal as pollution abatement. This was fairly narrow, in the environmental sense, but nevertheless it was identifiable enough, understandable enough, to let us know what we were doing, so that we could move towards the goal. To the extent that we were successful in achieving that goal, a relatively narrow goal, I felt that the larger responsibilities in the environment would much more naturally gravitate toward that agency than they would if we tried to fight for them at the outset.

Internal Difficulties

The physical separation of facilities created identity and communication problems. The initial move of agencies into EPA was largely done on paper, leaving most of the employees sitting at their old desks. In some cases even personnel within the same division were physically separated. Employees complained that they did not feel a part of EPA. The first pesticide headquarters office, a small room in a shabby office building, was moved three times within five months. The director, Raymond E. Johnson, spent most of his time on the phone trying to keep in touch with employees located in three other buildings while fending off industry representatives anxious to register their concerns. Johnson logged some 600 phone calls in the first six weeks.

Said Ruckelshaus:

> I tried to establish initially, with all the key people that we had inherited in the agency, a feeling of mutual trust. I didn't believe that because people had been coming in here telling me what a bum they were, that that was necessarily true. If I didn't trust them and believe in them, there was no way for them to do the same for me. I found that by and large, that works. Human beings respond to that. It is clear to me that you are not going to get loyalty just because you demand it. You have to earn it.
>
> [The key officials] reported directly to me, and I would have Dominick and Middleton [Commissioners of the Office of Water Programs and the Office of Air Programs, respectively] come in at least once a week for a major reporting session. I tried to call them every chance I got to keep them involved in what I was doing and what was going on. I wasn't so interested about the Pesticide Office and the Solid Waste Office. You could kind of put them aside because there wasn't the same kind of pressure in that area to do something as there was in Water and Air.

Further problems stemmed from the uncertainty--which persisted months after the agency was in operation--as to what actually belonged to EPA. This confusion resulted from the unwillingness of some "donor" departments to give up valuable facilities and personnel. In a number of places the Reorganization Plan had failed to specify precisely what was to be transferred to EPA. Consequently, high EPA officials had to spend time negotiating with the various departments which were supposed to provide EPA with its structural components. Perhaps the worst example of this bureaucratic power struggle was the decision made concerning HEW's Twinbrook Research Laboratory in Rockville, Maryland.

The first settlement provided for joint ownership of the laboratory with a result that research teams were split down the middle, half belonging to EPA and half to HEW. Both agencies were dissatisfied. As Ruckelshaus commented:

> While we were deciding how to form the ultimate structure, the turf fighting that was going on at this time was just ferocious--people vying over who was going to get what piece.

Ruckelshaus had to work out the most effective way of dealing with these difficulties. Another organizational issue had to be considered as well.

Organizing the Structure[2]

The existing bureaucracies were structured by categorical programs. Both the EPA task force and the PACEO felt a functional organization where the agency subunits were responsible for such areas as research, standard-setting, and enforcement was the most appropriate structure. They devised an evolutionary strategy where the agency would maintain its programmatic orientation under a "Commissioner System." On "Day One" only research and management would be fully functionalized. The rest of the functionalization would occur in stages.

The Nixon Administration's "New Federalism" called for decentralized federal administration and strong regional authority. Moving quickly to delegate responsibility to the regional offices was problematic for several reasons: (1) the need for immediate enforcement action required early centralized control; (2) there was little knowledge of the capabilities of regional personnel; (3) the delegation of authority to the regions was strongly resisted by EPA headquarters bureaucracy; (4) the selection of regional administrators required time.

Consequently, Ruckelshaus delayed action on the regions. He left the field offices intact, and assigned an interim coordinator for each of the ten regions in an order dated December 4, 1970.

Early Staffing Decisions

At Ruckelshaus' request, four members of the task force stayed on to help EPA through the early months. While reorganization was occurring at the top, Ruckelshaus was highly dependent on the existing leadership of the inherited units. Neither he nor his assistant administrators were capable of stepping in and running them. To fill the deputy and assistant administrator positions, Ruckelshaus worked with a White House executive search team. Although this could have resulted in clashes over whose nominee would get the job, the joint effort proved successful. An early selection was the Assistant Administrator for Enforcement: John Quarles. A member of Interior Secretary Hickel's staff, Quarles was highly recommended and in office on "Day One."

As noted earlier, Ruckelshaus wanted to "hit the ground running," to

---

[2]For a full discussion of this issue see Design for Environmental Protection (C16-74-026).

show his willingness to "take polluters to the mat." It was Quarles, who would orchestrate the enforcement actions. He recalled that Ruckelshaus

> . . . was concerned with establishing the credibility of the agency. I remember that he mentioned this to me--he emphasized it at about the first meeting we had in November, in advance of his being confirmed. We were talking about what the agency would do at the beginning, and he was very anxious to identify some strong enforcement actions that we could take right at the start.

Past Enforcement

Hitting the ground at anything beyond a crawl was a serious problem for Ruckelshaus and Quarles. Federal agencies had made little headway in combatting pollution. In part this was because of ineffective federal and state laws and unwieldy enforcement provisions. The "conference" procedure was one of the major vehicles used. It began with the covening of federal and state officials to discuss the problem. If no action was taken in 6 months, the hearings could be held. After another 6 months' waiting period, the case could be taken to court. Before the creation of the EPA, only one polluter (of water) was taken to court.[3] The difficulty--aside from the time involved--was that the procedure required accusing a state of failure to act before the federal government could go to court.

The Water Quality Act of 1965 was passed to strengthen water pollution enforcement but it applied only to interstate waterways. (The technical difficulties were similar to the conference restraints--the government had to prove that the welfare of specific individuals was endangered, and how much the water quality was affected. Then the polluters were allowed 6 months to take corrective action.) According to a Nader report, these standards ignored the most effective standard: effluent controls. FWQA showed little willingness to move against industries and municipalities which were not complying. By December 1970 only 30 states possessed fully approved standards and compliance schedules, although the deadline had been June 30, 1967.

The rediscovery early in 1970 of the Refuse Act of 1899 finally gave water pollution enforcement its broadest mandate. Originally passed to keep navigable waters free of shipping obstructions, it forbade discharges into navigable waters and their tributaries without a permit from the Army Corps of Engineers. The penalty was up to $2,500 per day and up to one year in jail for the responsible executive. Polluters could be prosecuted in criminal suits to enjoin further pollution, and industries could be compelled to treat dumpings into streams. Civil suits were another tool that gave some power for enforcement. In March 1970 the Justice Department moved against Florida Power and Light, and in July 1970, it filed 10 civil suits over the mercury discharges.

---

[3]This involved sewage discharges from St. Joseph, Mo. into the Missouri River. The conference was convened June 11, 1957, and a court order issued October 31, 1961. For the next six years no attempt was made to monitor the discharges. By the end of 1970, one-fourth of the city's sewage was still being discharged raw into the river.

As in the water area, little enforcement action had been taken in the area of air pollution. The Clean Air Act of 1967 established a federal policy for stationary polluters. It required NAPCA to designate air quality control regions and establish air quality criteria and emission control techniques. States were to then establish their own ambient air standards and propose implementation plans. In October 1969, however, only 25 of the expected 90+ regions were designated by NAPCA. By March 15, 1970, 57 regions were designated, five criteria reports completed, two control technique documents prepared. By December 1970, none of the plans had been adopted.

Although HEW was authorized to issue maximum levels for auto emissions for 1968 model cars, they were not effective. The certification procedure was dubious. Prototype vehicles the auto manufacturers submitted to HEW labs were often pampered. To impose the $1,000 fine allowed for violation of federal standards, NAPCA had to show each car was in violation--hardly useful for nationwide compliance.

The pending Clean Air Act amendments of 1970 brought what little enforcement there was to a halt. If passed, NAPCA would be required to set national ambient air quality standards--instead of approving the regional standards. It would also change federal policy on auto emissions. So, little could be done until the fate of the amendment was decided.

Thus, while the major organizational changes were occurring, Ruckelshaus had to begin to formulate a strategy for dealing with enforcement. Enforcing the pollution laws involved a wide spectrum of groups and issues the EPA and Ruckelshaus would have to deal with. The administrator had to decide how fast he should act, and against which polluters. Any EPA action had to consider the reactions of the main interest groups: the environmentalists, the press, the White House, Congress. Ruckelshaus did not want to undermine the EPA's image by making large, costly mistakes in the beginning.

Since the past enforcement of pollution laws had been sporadic at best, and the policy and legislative goals set by the White House were weak, it was unclear what the EPA could actually accomplish. Ruckelshaus stated that he was concerned about the actual White House commitment to the environmental issue.

> I could see some enormous difficulties if they were going to give lip service, as everybody was doing at that stage, to the problems of the environment, and then try to get the administrator of that agency to act as a front man for that lip service when in fact he wasn't implementing these acts or doing what he was supposed to do. I thought that would be just disastrous.
>
> I think this was pretty clearly perceived in the White House as the President's agency. It was his plan that had gone up there, and they saw fairly strong vested interest in seeing the thing succeed. I do not think that perception was nearly as accurate among many as it should have been. Because while there was some pressure in the White House against strict enforcement of these standards, that didn't necessarily mean that they didn't want this <u>agency</u> to succeed. They really did.

Ruckelshaus decided that the first major consideration was how to deal with enforcement action. This was important for two reasons: (1) to generate public interest and support for EPA, and (2) to put other polluters on notice that EPA was serious about enforcement. He decided to litigate as quickly as possible.

As a way to build a constituency out of the few materials he had, Ruckelshaus decided to act immediately. To meet the need for immediate, visible action he instituted a series of lawsuits against major polluters.

During EPA's first week, Ruckelshaus brought suit against three cities--Atlanta, Detroit, and Cleveland -- for violating the Federal Water Pollution Control Act. Recognizing the need for maximum media coverage, Ruckelshaus took advantage of a December 10 speech invitation from the Mayor of Atlanta to announce these suits. As Ruckelshaus recalls:

> I called him up just before I made the speech and told him just exactly what I was going to say, and did he still want me to come, and he said he'd already been elected for the present, so he had no problem.

Then, on December 17 the EPA asked the Justice Department (under the Refuse Act) to prosecute both Jones and Laughlin Steel for discharging pollutants into the Cuyahoga River, and US Plywood-Champion Papers for polluting the Great Ohio River. EPA revoked the conditional certification for two heavy duty trucks manufactured by Ford which did not meet the emissions standards. (Ford was required to stop sales of the engines and modify any still on its hands before they could be sold.) The agency also sought prosecution against ITT-Rayonier for its pulp mill operations on Puget Sound. The Lake Superior enforcement conference dealing with Reserve Mining's taconite wastes was reconvened. Other companies singled out for enforcement actions were Armco Steel, US Steel, Union Carbide, Du Pont, and General Motors. In its first two months EPA brought five times as many enforcement actions as all of its inherited agencies combined had initiated in any previous two-month period. Media coverage was heavy, and the agency quickly acquired the activist image Ruckelshaus sought.

While Ruckelshaus saw these early actions as vital to the agency's credibility, they were also risky moves. They made EPA vulnerable to attack from conservative congressmen and the White House. A number of the affected industries publicly called the agency "irresponsible." While such general broadsides were unlikely to do damage, there was always the danger that EPA might not be able to back up particular claims.

A lot of adverse publicity could conceivably force large industries to comply voluntarily; however there were many variables associated with compliance. The laws on pollution were changing, making it difficult for the companies to set up a permanent strategy. And the publicity would have to be kept up for a long time to have any real effect. The case by case approach (citing one company's violations) finds the headlines for a few months, then fades into the background.

While these prosecutions were being initiated, new environmental issues and legislation arrived. The removal of phosphates and NTA from detergents had been a battle between public health officials, environmentalists, and the manufacturers. On December 19, 1970, the Surgeon General and Ruckelshaus announced that major soap manufacturers had agreed to remove NTA from their detergent products due to alleged potential hazards. A Shell Oil platform in the Gulf of Mexico caught fire in the beginning of December. After a two-year ban due to the Santa Barbara disaster, the Interior Department approved offshore leasing. Ruckelshaus was bombarded with protesting telegrams, for by that time (mid-December) the Shell fire was still blazing and an oil slick three miles long and one mile wide had settled on the water. He announced that EPA was concerned with the safety of offshore operations. On December 23, the Justice Department filed charges against four oil companies for their failure to maintain safety devices on oil rigs in the Gulf of Mexico.

EPA's enforcement tools were altered with the passing of new legislation. On December 23, 1970, President Nixon signed the Refuse Act Permit Program into law. It was to be a joint effort by EPA and the Army Corps of Engineers "to regulate the discharge of pollutants or other refuse matters into the navigable waters of the U.S." The Corps would have administrative responsibility for the permits; the EPA would submit opinions on matters of water quality. Each industrial polluter had to apply for a permit by July 1, 1971. The EPA had to be prepared to advise the Corps on permit requests it would be deluged with.

In still another field, pesticides, a Federal Court in January 1971 ordered the EPA to decide whether it should suspend production of DDT and prohibit its interstate transport. The agency decided to impose a 60-day deadline on itself to decide the issue and to request comments from the public on DDT's hazard. In addition to pacing the EPA's litigation and focusing on certain polluters, Ruckelshaus had still other deadlines to face.

The Clean Air Act Amendments, passed December 31, 1970, required EPA to promulgate national primary and secondary ambient air quality standards by January 31, 1971. As mentioned earlier, this Act changed the entire approach to air pollution. These were to be the basis on which emission standards would later be established. Ruckelshaus had to evaluate whether meeting the deadline was more important than using careful judgment. He recognized this as a crucial decision since,

> The ability we had to review and analyze the standards at that time was almost non-existent. We inherited almost no analytic capacity. We just didn't have a very good assessment of what the options were; no analysis of what the real choice was as far as the statute was concerned, any secondary or tertiary effects. We had no real analysis of this.

But based on the need for public support, Ruckelshaus decided to meet the air standards deadlines. The problem was not so much that of creating public interest as it was harnessing existing concerns. He thought that once public support started to diminish slightly, congressmen and the Administration would receive a lot of complaints about the EPA's actions. And the commitment of many legislators was only as strong as public opinion. Ruckelshaus noted that.

> For purposes of agency credibility it was important to meet those deadlines [of the Clean Air Act] at the beginning of the agency. I think that in achieving some of them we may have made some mistakes by doing things faster than we were ready to move wisely, but that had to be weighed against the fall-out of not meeting the deadline, which could have been deadlier to the agency. Once we got established and had to implement the Water Bill [in 1972], I felt we were strong enough as an agency to be able to slip those deadlines if it was unreasonable to meet them and we weren't ready to act.

Securing an Independent Constituency

Through the early months, Ruckelshaus was riding the crest of a wave of public concern over environmental degradation. Ruckelshaus perceived that wave as enabling him to resist pressures from Congress, the White House, industry, or others who might seek to interfere in EPA's activities. The stronger the environmentalist pressure, as long as it did not lead to unreasonable demands, the more autonomy Ruckelshaus would have in his leadership of EPA.

One problem faced by Ruckelshaus was the tendency for environmentalists to view public officials as either friends or enemies of the environment; one was either "tough" or "soft" on polluters. This polarity was reinforced by media coverage of environmental news. Environmentalists had easy access to the press and had the ability to call the public tune on what was "tough," and therefore "good." As Ruckelshaus put it: "We couldn't afford even the appearance of being soft."

The key to Ruckelshaus' ability to maintain public support would thus be his direct relations with the national environmental groups and his dealings with the national media. Ruckelshaus had to consider the best way to communicate with these two groups. How to approach them and how frequently to meet with them were important decisions. There were numerous requests for speaking engagements; Ruckelshaus had to decide where he could get the most exposure. What issues should be dealt with first, through which medium, and to which groups were key decisions.

There were several special interest groups whose opposition might prove disastrous to EPA. The farmers were one such group, especially powerful because of their ties to Rep. Jamie Whitten and other influential congressmen from rural districts. Ruckelshaus had to assuage their fears that EPA would underplay agricultural concerns. He noted:

> One of the things that occurred to me very quickly was that farmers were going to be scared to death and also the agricultural organizations, because we inherited the pesticides from Agriculture and Interior and HEW. One of the agencies we inherited was created to regulate what another was created to promote. They were both all of a sudden under the same roof. The agriculture organizations were just terrified. There were these environmentalists who were fooling around with their pesticides. Those guys could have an impact on Congress, going in there and screaming about this nutty organization that is going to dry

> up all the pesticides in the country. We had to make sure that they didn't perceive this agency's role as putting them out of business.

To combat this possibility Ruckelshaus hired a friend with strong ties to the agricultural industry as a consultant. In this capacity, he flew over the country reassuring the farmers that the EPA recognized their position.

Congress

Despite Ruckelshaus' pleas, the responsibility for EPA's authorizing legislation remained fragmented among several committees, of which Muskie's and Whitten's were most important. As Ruckelshaus desired, appropriations were consolidated to treat EPA's budget as a whole. In February 1971 House Appropriations chairman George Mahon (D-Tex.) assigned EPA to the newly-created Appropriations Subcommittee on Agriculture, Environment, and Consumer Protection. Chairman of that subcommittee was Jamie Whitten of Mississippi. Ralph Nader's staff, in their Water Wasteland report, called Whitten "the virtual czar of the federal farm bureaucracy."

The urgency of the environmental issue in the public eye and Senator Muskie's personal stakes in the matter meant that Ruckelshaus enjoyed no "honeymoon."

Whitten and Muskie presented different problems for Ruckelshaus. Whitten could be effectively neutralized by a high level of constituent pressure for strong environmental policy; Whitten's fear of defeat on the House floor of any appropriations bill served to check his power. The [illegible] cultivating environmental concern was that Ruckelshaus might simply enable Muskie to seize the issue, while criticizing EPA for its inactivity. This conflict created the need for both grass roots support and "public sanity."

So as not to antagonize either Whitten or Muskie, EPA's decisions and actions had to be "above the table" and defensible.

> It was just that wherever you got some charge that some industry was in there fiddling around the Administration, trying to get a standard lifted or something, this is the kind of thing that Muskie would land on, and in my opinion, it would destroy that agency if they ever showed it.
>
> Given the whole tenor of the way the press viewed this Administration as favoring big business, we had to just be constantly careful. Not only about whether we were doing the right thing or not, but did we give them the appearance, did we give them something to hold onto to make us look awful--and you didn't need much!

The budget was another issue that had to be dealt with. Circumstances were such that Ruckelshaus dealt with relatively liberal authorizations committees and a conservative appropriations committee. He noted that:

> We had a political problem in that the authorization committees authorized enormous sums of money for all of these programs with no way in the world for us to spend all of it. Any suggestion that the Administration came up with below that

> authorizing figure would be attacked as inadequate. We had to defend that budget from both sides. We would go in to Whitten, and he would say it was too much; then we would go to the authorizing committee and they would say: "Why didn't you spend all the money we gave you?". They would never come down and testify in front of Whitten's committee and say we need more money. It was really a game. And after a while I found the easiest way to deal with that was to call it a game, to say, "We know what you are doing. If you want to give us more money, go on down there and testify."

Dealing with the White House

The pressures exerted on EPA from the White House were greatly determined by President Nixon's personal view toward environmental protection and his calculations of political support. While Nixon had no strong personal interest in environmental policy *per se*, he saw the political need for at least the appearance of governmental response to pollution problems. The opposition of environmental groups was a potential thorn in his side, particularly if Senator Muskie could marshal them effectively in his presidential bid. Nixon wanted the EPA to succeed as an effective regulatory agency for it was "his baby." However, the President saw the need for "balance"--ecological concern should not endanger the health of the domestic economy. Thus, in February 1971 Nixon assured industrialists that they would not become scapegoats of the drive for cleaner air and water.

The attitude of the White House toward EPA's policy of cultivating its own independent constituency was not clear. Ruckelshaus noted that:

> [John] Ehrlichman [Assistant to the President] understood the dilemmas we were facing and the problems that we had. As long as I was in communication with him it was all right. I think [Nixon] sees [the development of an independent constituency] and he is ambivalent about it. On the one hand, he recognizes what is happening, as in the case of the people in his cabinet who had constituencies independent of their association with him — like Hickel or Romney or Volpe -- who had been politicians themselves. On the other hand, he definitely perceives from time to time the need to have people like that around. I think it is directly proportionate to the amount of public support he personally has.

During early 1971 Nixon's popularity, as measured by the Gallup Poll, was declining. In November 1970 the "Nixon approval index" stood at 57%, the 1970 average. By April 1971 it dipped for the first time below 50%, to 49%. The Cambodian invasion, among other things, contributed to this trend.

To Ruckelshaus, there were advantages and disadvantages to provoking White House disapproval:

> I felt that to a certain extent the desires of the White House and my feelings that we needed public support were antagonistic. From time to time to get whacked by the White House probably

> wasn't a bad thing--in order to gain more public support to do something about the issue. I didn't consciously go out and try to antagonize them into slamming at me. But when it did happen, as it did occasionally, I didn't feel that it had hurt the ability of the agency to move forward.

On the other hand, he added,

> Every time I was pitted against the White House it was, in my opinion, a very bad thing. I know that from the point of view of some environmental organizations, if they believe that, it might enhance me somewhat in their eyes. In fact, what happens is that it makes the White House mad. So when you go over there and you are talking about budget items or which direction we ought to go in, the really important policies we are dealing with, they are already mad at you. They think you are out there stimulating that publicity.

Fortunately for Ruckelshaus, early circumstances did not require decisions involving substantial tradeoffs between environmental and economic interests, he admitted that:

> I would have been in some jeopardy if we had had to start making some very tough decisions as opposed to just saying I'm for clean air and clean water.

The Problem for the Future

In the first six months, Ruckelshaus had created the public activist image he desired for himself and for EPA. The obvious executive and legislative pressures had been carefully calculated and dealt with. Now that the hectic start up demands had subsided somewhat, Ruckelshaus had to consider EPA's future course in enforcing pollution control. In spite of the initial flurry of suits and actions against polluters, EPA's effectiveness was being challenged.

The Justice Department and conservationists were criticizing EPA's approach, accusing the agency of failing to move vigorously against polluters. They charged that since the enforcement procedure was so cumbersome, EPA depended on negotiation and the conference with publicity as the primary abatement tool. Quarles responded that EPA had changed the federal policy to a more balanced approach, that previously the emphasis had been totally on voluntary compliance. Now "we stand ready to go to court if necessary . . . and are developing the technical capability to do so. . . . What counts is being willing to go to court if that is required . . . and we have gone to court."

Two critical deadlines were coming up. The manner in which Ruckelshaus chose to deal with them had implications for EPA's future enforcement policy. He had pledged vigorous use of the Refuse Permit program. But cooperative or not, some industry leaders feared they would not be able to meet the July 1 permit program deadline--even if the agencies provided applications and other documents immediately. It would be impossible for some companies to analyze their discharges in time to file complete applications. (One firm, for instance, had ordered monitoring equipment April 12 and was told it could not be delivered until September 1.) There was also a question of the program's legality. Businessmen for the Public Interest, on behalf of conservation

groups, filed suit in Chicago against the EPA and the Army. It attempted to block permit issuance to Lake Michigan industries until stricter regulations for lake pollution were established.

The other key decision involved the automobile emission standards set out in the Clean Air Act Amendments. Auto manufacturers had to file applications on January 1, 1972 for a suspension of the 1975 emission standards for hydrocarbons and carbon monoxide. Such an extension could be granted by the administrator only if "all good faith efforts have been made to meet the standards." It was generally accepted that the auto companies would request such suspensions, after which the administrator had 60 days to decide on the request.

Ruckelshaus commented on the importance of his action on automobile exhaust:

> The automobile emission problem is obviously something we are going to have to deal with. There is going to come a time in '71 and they [the auto companies] are going to come ask me for some more time [to comply with the emission standards]. I am going to have to decide whether or not they have made a "good faith" effort. If this whole situation isn't going to be completely farcical, the first thing I have to do is to convince the automobile industry that we are serious about enforcement. That has been completely clear to me. Otherwise, there will be no way two years hence, or whenever they ask for an extension of time, I could conceivably make a judgment that they have made this good faith effort. So, we have to figure out how we are going to convince them that we are serious.

Exhibit 1

The EPA "Inheritance"

Major units	Previous agency	# of personnel	Fiscal '71 budget (millions)	Administrator
Federal Water Quality Administration	Interior	4,070	1,000	David D. Dominick
Bureau of Water Hygiene	HEW	160	2.3	James McDermott
National Air Pollution Control Administration	HEW	1,100	110	John T. Middleton
Bureau of Solid Waste Management	HEW	180	15	Richard D. Vaughan
Pesticides Regulation Division	Agriculture (Agric. Research Service)	425	5.1	G. G. Rohwer
Office of Pesticides Research	HEW (Food and Drug Administration	275	10.7	
Research on effects of pesticides on wildlife and fish	Interior	9	0.216	Raymond E. Johnson
Bureau of Radiological Health (Environmental Exposure Division)	HEW	350	9	John C. Villforth
Federal Radiation Council	Interagency	4	0.144	
Division of Radiation Protection Standards	Atomic Energy Commission	3	0.075	

636

DEVELOTECH SITING COMMISSION: (A)

Jordan Philips had recently been appointed as Deputy Minister of the Environment, and he planned to do what seemed appropriate. In fact, he planned to what many, if not most people in his situation had done before and probably would continue to do. Mr. Philips was on his way to visit the U.S. Environmental Protection Agency for advice, with the hopes that EPA would agree to send a team of experts from the United States to his country to make recommendations on critical environmental problems, proposed environmental standards, and necessary actions to ensure environmental protection during the country's growing economic development. For Mr. Philips, the trip meant several thousands of miles by air and about a week away from home. Mr. Philips settled deep into the back of his seat, gazed out over the earth, and thought about how far his country had come in such a short time.

His Country

Mr. Philips' country is situated on the coast of one of the largest continents. Eventually explored by Europeans less than one hundred and twenty-five years ago, the country in fact could boast of possessing the skull of the earliest known man on earth, and the country's seemingly ageless culture was rich with customs that prized the value of nature and the balance between earth, man, and the gods. Some of the country's tribal religions were central to the way nomadic groups learned to cope with a shifting, sometime tumultuous, but always fickle nature, which mostly was kind and providing, but could be unexpectedly harsh with drought one season, floods the next, and occasional volcanic eruptions or jarring earthquakes. The scales of balance had always been set by nature, but were now to be tipped by human activities.

Philips smiled to himself as his country's profile flashed before his mind:

EQUATORIAL REPUBLIC

LAND:

114,536 Km^2, 32% arable (under cultivation), 21% forested, 30% desert and mountainous, 9% urban, 8% unreported, probably waste.

This case was prepared by John Whitman as the basis for analytical discussion of issues of environmental management. The case is a composite of fictitious but possible events, situations, people, and places. The case is not intended to refer to any particular country.

Copyright © 1980 by Environmental Research & Technology, Inc., 696 Virginia Road, Concord, MA 01742, U.S.A.

WATER:

Limits of territorial waters (claimed): 200 nautical miles
Coastline: 1,053 km

PEOPLE:

Population: 43,462,837 (January 1980), average annual growth rate (current) 2.7%
Literacy: est. 15%
Language: English official
Labor Force: 42% of total population, most unskilled

GOVERNMENT:

Legal name: Federal Equatorial Republic
Type: Republic; under military rule from October 1967 to May 1979
Capital: Star City
Legal system: Based on English common law; tribal law
Suffrage: universal adult suffrage
Political subdivisions: 17 counties

ECONOMY:

GDP: $22 billion (FY79 current prices), $506 per capita; 6.9% growth rate (1975-1979)

Agriculture: main crops -- cotton, rubber, cassava, sorghum, palm kernals, millet, corn, rice, livestock

Fishing: catch 503,265 metric tons (1979); imports $16.2 million (1978)

Major industries: extractive industries -- crude oil, natural gas, coal, copper; processing industries -- oil palm, cotton, rubber petroleum, wood, hides/skins; manufacturing industries -- textiles, cement, building materials, food products, chemicals

Electric power: 1,428,000 kW capacity (1978); 62 kWh per capita

Exports: $12.6 billion (f.o.b. 1978 est.); oil (94%)

Imports: $15.2 billion (c.i.f. est.); machinery and transport equipment, manufactured goods, food, chemicals

Major trade partners: U.K., European Communities, U.S.

638

COMMUNICATIONS:

Railroads: 3,206 km
Highways: 73,254 km
Inland waterways: 9,340 km consisting of Silton River, Flowing Lake, and small rivers and creeks

Ports: 2 major (deep water), 5 minor
Civil air: 25 major transport aircraft
Airfields: 46 total, 41 usable
Telecommunications: Above average system composed of radio-relay links, open-wire lines, and radiocommunication stations; 99,000 telephones; 14 AM, 3 FM, and 6 TV stations; 1 Atlantic Ocean and 1 Indian Ocean satellite station.

...The picture faded out as Philips turned his thoughts to his country's recent history.

Equatorial Republic had conducted its self-sufficient ways, based primarily on agriculture and fishing, until the early fifties, when U.S., British, and Dutch oil companies discovered oil off-shore and on-shore, centered in the country's prime fishing and agricultural regions. The exploitation of this mineral wealth led to a series of political and economic upheavals until 1967, when the military took control of the government. The military established domestic rule effectively, but the people felt the imbalance between favoritism toward foreign industries interested in making investments in the country, and poor management of such critical domestic affairs as providing basic health care, sewage and waste systems, clean water, and adequate housing for the fast-growing numbers of people moving off the land and away from the fishing areas to cluster around the cities and developing industrial areas. Self-sufficiency in agriculture and fishing, too, had been lost, partly as a result of the migration to the cities, and partly due to the loss of agricultural land to urbanization and industrial uses.

The change to civilian rule in 1979 was a planned event, but the new President had quickly to gain credibility with the general public, foreign investors, and surrounding countries, not to mention the military. One of the first objectives of the new government was to establish a Ministry of the Environment, but the ministry had to act quickly to gain its own credibility among the various interest groups that could so easily be affected by the ministry's policies. Because so many of the country's domestic problems could in the broadest sense be considered environmental problems, there was the vast expectation by the public that the new ministry would provide relief for its basic needs. Yet because of the heavy foreign investment in dirty industries, particularly oil and chemicals, there was considerable pressure felt by the ministry to formulate policies that would not detract from the country's economic priorities.

639

Mr. Philips thought back to the year before, when he attended the International Seminar on Principles of Environmental Management in Developing Countries. He remembered the case study on William D. Ruckelshaus and the Environmental Protection Agency, and winced. How, he wondered, would his own boss, the Minister, pull if off. He had promised her that he would do his best to ensure environmental protection, but not at the expense of industry and the country's economic plans.

The specific problem at issue was where to locate the planned $25 billion industrial complex, which would bring together a broad range of turnkey industrial development projects, including:

- a commerical harbor
- water desalination plant
- the National Petroleum Co.
- a cement company
- a packaging and plastics factory
- the Equatorial Fisheries Processing Center
- a refinery
- electrical power generation
- sea water pumping station
- a petrochemical industry processing plant for urea, ammonia, ammonia sulfate, and sulfuric acid production
- an industrial repair and maintenance engineering company

An estimated 14 million square meters would be required to accommodate the complex, not including the housing and settlement areas for some 240,000 workers and their families. The date of completion is 27 May 1984, exactly five years following the changeover to civilian rule.

The Develotech Siting Commission

In January 1980, the new President established the Develotech Corporation, a government-controlled entity responsible for all aspects of planning and coordinating the development of the industrial complex. In February, the corporation assembled the Develotech Siting Commission, a group of representatives from government ministries and industries selected to plan the location of the complex.

Members of the Commission include a representative of the President and individual delegates from the following Ministries: Agriculture; Commerce; Economic Planning; Environment; Health; Industries; Lands, Natural Resources, and Energy; Rural Development; Tourism; and Works and Public Housing. The Commission also includes representatives from the National Petroleum Company; the cement company; plastics company; Equatorial Fisheries Processing Center; the Equatorial Institute of Fisheries; and the Equatorial Institute of Science and Technology, which was concerned with the development of the desalination plant. The President's representative was appointed as Chairman of the Commission.

The Commission's ability to work together in a short period of time would prove critical to the proper selection of a site, a location that would hopefully minimize disruption of the current affairs and also fit well into plans for future use of the country's natural resources, including coastline areas.

Mr. Philips was appointed as the representative of the Ministry of the Environment. His responsibility was to provide guidance on the environmental aspects of the project, including the soundness of the implementation, operations, and termination phases associated with each of the industrial components and, of course, the complex as a whole.

Since construction was to begin on 1 September 1980, Mr. Philips squirmed with a feeling of near desperation. A great deal was riding on his effectiveness, not least of which was the credibility of the new government.

Jordan Philips

Mr. Jordan Philips was born in the Equatorial Republic, which at the time was part of the British Empire. He received a degree in engineering from the University of California and went on to study law in England. Following receipt of his law degree in 1960, Mr. Philips returned home to begin teaching at the national university in Star City and to consult regularly with the National Petroleum Corporation. Mr. Philips was the principal author of the agreement leading to the transfer of 60% ownership of all foreign oil operations to the government, and he cited frequently the list of adverse impacts foreign operators had on the local economies, populations, and environments of the various petroleum operations in the country.

Philips was bothered by the trade-offs inherent in many technological approaches to a higher standard of living. A particularly memorable anecdote on the subject was told by a well-known economist during a speech following the economist's return from the Soviet Union. The Soviets, he reported, were eager to import American transportation technology, especially automobiles, the big ones. While sympathetic with the hunger the Russians felt for luxurious commodities, the economist could not figure out why the Soviets were also seeming to desire the massive ribbons of concrete and asphalt, the time-wasting congestion of traffic jams, and the health-threatening smogs of choking emissions. The dilemma of wanting the best from the West and taking the worst with it stuck with Mr. Philips, and now was coming home to him in terms of his own country's choices. Indeed, traffic jams had become a way of life in Star City.

There was an additional feeling that gave Mr. Philips a twinge of personal concern. He knew that given his country's population growth and the corresponding demands for resources, the environmental policies he helped to develop today were in large measure going to determine his personal comfort following his retirement. Would there then be enough food, water, jobs, sanitation, literacy, and amenities to ensure social and political stability? Or would he retire to a situation of massive squalor?

Mr. Philips was still an hour away from JFK. In three more hours he would be arriving in another plane at Washington National Airport. The next day he would have to face the experts with his problem: "Where, and how, do I begin?"

International Environmental Management Institute April 1980

DEVELOTECH SITING COMMISSION: (A)

Study Questions

1. What is the most important task facing Mr. Philips? If you were Mr. Philips, how would you order your priorities for action?

2. Who are the various individuals and groups to whom Mr. Philips must account? What is he trying to deliver to them?

3. What does Mr. Philips need to know to provide guidance on the environmental aspects of the project?

4. What are the pros and cons of going to the U.S. EPA for help?

5. What should Mr. Philips ask members of the EPA? Should he talk to industry, too? If so, what should he ask industry? Should he also talk to other siting commissions?

6. How can Mr. Philips convince the other Commission members to agree on a site with the least environmental impact even if its cost is greater than another, environmentally degrading site?

7. How would you measure Mr. Philips' success after one year in office? How will those to whom he is accountable measure his success?

8. What are some of the other critical issues facing Mr. Philips?

G43

DEVELOTECH SITING COMMISSION: (A)

Jordan Philips had recently been appointed as Deputy Minister of the Environment, and he planned to do what seemed appropriate. In fact, he planned to what many, if not most people in his situation had done before and probably would continue to do. Mr. Philips was on his way to visit the U.S. Environmental Protection Agency for advice, with the hopes that EPA would agree to send a team of experts from the United States to his country to make recommendations on critical environmental problems, proposed environmental standards, and necessary actions to ensure environmental protection during the country's growing economic development. For Mr. Philips, the trip meant several thousands of miles by air and about a week away from home. Mr. Philips settled deep into the back of his seat, gazed out over the earth, and thought about how far his country had come in such a short time.

His Country

Mr. Philips' country is situated on the coast of one of the largest continents. Eventually explored by Europeans less than one hundred and twenty-five years ago, the country in fact could boast of possessing the skull of the earliest known man on earth, and the country's seemingly ageless culture was rich with customs that prized the value of nature and the balance between earth, man, and the gods. Some of the country's tribal religions were central to the way nomadic groups learned to cope with a shifting, sometime tumultuous, but always fickle nature, which mostly was kind and providing, but could be unexpectedly harsh with drought one season, floods the next, and occasional volcanic eruptions or jarring earthquakes. The scales of balance had always been set by nature, but were now to be tipped by human activities.

Philips smiled to himself as his country's profile flashed before his mind:

EQUATORIAL REPUBLIC

LAND:

114,536 Km^2, 32% arable (under cultivation), 21% forested, 30% desert and mountainous, 9% urban, 8% unreported, probably waste.

This case was prepared by John Whitman as the basis for analytical discussion of issues of environmental management. The case is a composite of fictitious but possible events, situations, people, and places. The case is not intended to refer to any particular country.

Copyright © 1980 by Environmental Research & Technology, Inc., 696 Virginia Road, Concord, MA 01742, U.S.A.

WATER:

Limits of territorial waters (claimed): 200 nautical miles
Coastline: 1,053 km

PEOPLE:

Population: 43,462,837 (January 1980), average annual growth rate (current) 2.7%
Literacy: est. 15%
Language: English official
Labor Force: 42% of total population, most unskilled

GOVERNMENT:

Legal name: Federal Equatorial Republic
Type: Republic; under military rule from October 1967 to May 1979
Capital: Star City
Legal system: Based on English common law; tribal law
Suffrage: universal adult suffrage
Political subdivisions: 17 counties

ECONOMY:

GDP: $22 billion (FY79 current prices), $506 per capita; 6.9% growth rate (1975-1979)

Agriculture: main crops -- cotton, rubber, cassava, sorghum, palm kernals, millet, corn, rice, livestock

Fishing: catch 503,265 metric tons (1979); imports $16.2 million (1978)

Major industries: extractive industries -- crude oil, natural gas, coal, copper; processing industries -- oil palm, cotton, rubber petroleum, wood, hides/skins; manufacturing industries -- textiles, cement, building materials, food products, chemicals

Electric power: 1,428,000 kW capacity (1978); 62 kWh per capita

Exports: $12.6 billion (f.o.b. 1978 est.); oil (94%)

Imports: $15.2 billion (c.i.f. est.); machinery and transport equipment, manufactured goods, food, chemicals

Major trade partners: U.K., European Communities, U.S.

645

COMMUNICATIONS:

Railroads: 3,206 km
Highways: 73,254 km
Inland waterways: 9,340 km consisting of Silton River, Flowing Lake, and small rivers and creeks

Ports: 2 major (deep water), 5 minor
Civil air: 25 major transport aircraft
Airfields: 46 total, 41 usable
Telecommunications: Above average system composed of radio-relay links, open-wire lines, and radiocommunication stations; 99,000 telephones; 14 AM, 3 FM, and 6 TV stations; 1 Atlantic Ocean and 1 Indian Ocean satellite station.

...The picture faded out as Philips turned his thoughts to his country's recent history.

Equatorial Republic had conducted its self-sufficient ways, based primarily on agriculture and fishing, until the early fifties, when U.S., British, and Dutch oil companies discovered oil off-shore and on-shore, centered in the country's prime fishing and agricultural regions. The exploitation of this mineral wealth led to a series of political and economic upheavals until 1967, when the military took control of the government. The military established domestic rule effectively, but the people felt the imbalance between favoritism toward foreign industries interested in making investments in the country, and poor management of such critical domestic affairs as providing basic health care, sewage and waste systems, clean water, and adequate housing for the fast-growing numbers of people moving off the land and away from the fishing areas to cluster around the cities and developing industrial areas. Self-sufficiency in agriculture and fishing, too, had been lost, partly as a result of the migration to the cities, and partly due to the loss of agricultural land to urbanization and industrial uses.

The change to civilian rule in 1979 was a planned event, but the new President had quickly to gain credibility with the general public, foreign investors, and surrounding countries, not to mention the military. One of the first objectives of the new government was to establish a Ministry of the Environment, but the ministry had to act quickly to gain its own credibility among the various interest groups that could so easily be affected by the ministry's policies. Because so many of the country's domestic problems could in the broadest sense be considered environmental problems, there was the vast expectation by the public that the new ministry would provide relief for its basic needs. Yet because of the heavy foreign investment in dirty industries, particularly oil and chemicals, there was considerable pressure felt by the ministry to formulate policies that would not detract from the country's economic priorities.

Mr. Philips thought back to the year before, when he attended the International Seminar on Principles of Environmental Management in Developing Countries. He remembered the case study on William D. Ruckelshaus and the Environmental Protection Agency, and winced. How, he wondered, would his own boss, the Minister, pull if off. He had promised her that he would do his best to ensure environmental protection, but not at the expense of industry and the country's economic plans.

The specific problem at issue was where to locate the planned $25 billion industrial complex, which would bring together a broad range of turnkey industrial development projects, including:

- a commerical harbor
- water desalination plant
- the National Petroleum Co.
- a cement company
- a packaging and plastics factory
- the Equatorial Fisheries Processing Center
- a refinery
- electrical power generation
- sea water pumping station
- a petrochemical industry processing plant for urea, ammonia, ammonia sulfate, and sulfuric acid production
- an industrial repair and maintenance engineering company

An estimated 14 million square meters would be required to accommodate the complex, not including the housing and settlement areas for some 240,000 workers and their families. The date of completion is 27 May 1984, exactly five years following the changeover to civilian rule.

The Develotech Siting Commission

In January 1980, the new President established the Develotech Corporation, a government-controlled entity responsible for all aspects of planning and coordinating the development of the industrial complex. In February, the corporation assembled the Develotech Siting Commission, a group of representatives from government ministries and industries selected to plan the location of the complex.

Members of the Commission include a representative of the President and individual delegates from the following Ministries: Agriculture; Commerce; Economic Planning; Environment; Health; Industries; Lands, Natural Resources, and Energy; Rural Development; Tourism; and Works and Public Housing. The Commission also includes representatives from the National Petroleum Company; the cement company; plastics company; Equatorial Fisheries Processing Center; the Equatorial Institute of Fisheries; and the Equatorial Institute of Science and Technology, which was concerned with the development of the desalination plant. The President's representative was appointed as Chairman of the Commission.

The Commission's ability to work together in a short period of time would prove critical to the proper selection of a site, a location that would hopefully minimize disruption of the current affairs and also fit well into plans for future use of the country's natural resources, including coastline areas.

Mr. Philips was appointed as the representative of the Ministry of the Environment. His responsibility was to provide guidance on the environmental aspects of the project, including the soundness of the implementation, operations, and termination phases associated with each of the industrial components and, of course, the complex as a whole.

Since construction was to begin on 1 September 1980, Mr. Philips squirmed with a feeling of near desperation. A great deal was riding on his effectiveness, not least of which was the credibility of the new government.

Jordan Philips

Mr. Jordan Philips was born in the Equatorial Republic, which at the time was part of the British Empire. He received a degree in engineering from the University of California and went on to study law in England. Following receipt of his law degree in 1960, Mr. Philips returned home to begin teaching at the national university in Star City and to consult regularly with the National Petroleum Corporation. Mr. Philips was the principal author of the agreement leading to the transfer of 60% ownership of all foreign oil operations to the government, and he cited frequently the list of adverse impacts foreign operators had on the local economies, populations, and environments of the various petroleum operations in the country.

Philips was bothered by the trade-offs inherent in many technological approaches to a higher standard of living. A particularly memorable anecdote on the subject was told by a well-known economist during a speech following the economist's return from the Soviet Union. The Soviets, he reported, were eager to import American transportation technology, especially automobiles, the big ones. While sympathetic with the hunger the Russians felt for luxurious commodities, the economist could not figure out why the Soviets were also seeming to desire the massive ribbons of concrete and asphalt, the time-wasting congestion of traffic jams, and the health-threatening smogs of choking emissions. The dilemma of wanting the best from the West and taking the worst with it stuck with Mr. Philips, and now was coming home to him in terms of his own country's choices. Indeed, traffic jams had become a way of life in Star City.

There was an additional feeling that gave Mr. Philips a twinge of personal concern. He knew that given his country's population growth and the corresponding demands for resources, the environmental policies he helped to develop today were in large measure going to determine his personal comfort following his retirement. Would there then be enough food, water, jobs, sanitation, literacy, and amenities to ensure social and political stability? Or would he retire to a situation of massive squalor?

Mr. Philips was still an hour away from JFK. In three more hours he would be arriving in another plane at Washington National Airport. The next day he would have to face the experts with his problem: "Where, and how, do I begin?"

DEVELOTECH SITING COMMISSION: (A)

Study Questions

1. What is the most important task facing Mr. Philips? If you were Mr. Philips, how would you order your priorities for action?

2. Who are the various individuals and groups to whom Mr. Philips must account? What is he trying to deliver to them?

3. What does Mr. Philips need to know to provide guidance on the environmental aspects of the project?

4. What are the pros and cons of going to the U.S. EPA for help?

5. What should Mr. Philips ask members of the EPA? Should he talk to industry, too? If so, what should he ask industry? Should he also talk to other siting commissions?

6. How can Mr. Philips convince the other Commission members to agree on a site with the least environmental impact even if its cost is greater than another, environmentally degrading site?

7. How would you measure Mr. Philips' success after one year in office? How will those to whom he is accountable measure his success?

8. What are some of the other critical issues facing Mr. Philips?