EPA'S NATIONAL ECOLOGICAL EFFECTS RESEARCH PROGRAMS

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ENVIRONMENTAL PROTECTION AGENCY

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PREFACE

This paper was initiated and prepared largely by the Office of Health and Ecological Effects and its emphasis is on the research of the four ecology laboratories in that Office. However, there is important research on the transport and fate of pollutants and exposure assessment in EPA which is the responsibility of the Office of Air, Land, and Water Use and the Office of Monitoring and Technical Support. Those offices have contributed material in their respective areas.

The purpose of the paper is to outline the direction to be taken by EPA in ecological research over the five-year period beginning with Fiscal 1978. The discussion is on ecological research required to understand the problems caused by the increased pressures of man on his environment and to help provide solutions. Objectives are broadly stated, a rationale for defining the research program is given, and planned approaches for conducting the required scientific work is provided. Finally, temporal and resource considerations are presented. It is hoped that the paper will serve to highlight major components of EPA's future ecological research program.

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I. Introduction

Man has shown great ingenuity in altering his environment and affecting the ecological systems upon which he is dependent for survival. He has developed a tremendous capability for extracting resources from the earth and utilizing these for his existence and pleasure. In addition to natural resources, thousands of new substances are synthesized annually for use in man's ever advancing technology.

As a result of ignorance, carelessness and indifference, man's utilization of these natural and synthetic resources continues to gravely impact his ecosystem. Polychorinated biphenyls, used in electrical transformers and capacitors, have been found in human fat, having been transported from manufacturing plants to the dinner table via the aquatic ecosystem. The rash of oil spills during the winter of 1976-77 highlight the ecological hazards of shipping this needed energy resource. Kepone, polybrominated biphenyls, TCDD and asbestos are a few of the many toxic substances which have caused serious pollution incidents in recent years.

Man would lead a precarious existence if he relied on remedial solutions to pollution problems as they arose (in the form of kepone-style incidents). If he is to effectively assess, predict and prevent the destruction of the earth's ecosystems, it is imperative that man understand the complex biogeochemical relationships functioning in the environment. The "biogeochemical cycles" are the complex and interconnected circuits by which energy and chemical elements move throughout the biosphere (See Figure 1). The major cycles involve the movement and flow of energy, carbon, hydrogen, oxygen, nitrogen and minerals. Compounds (including pollutants) move within and between air, land

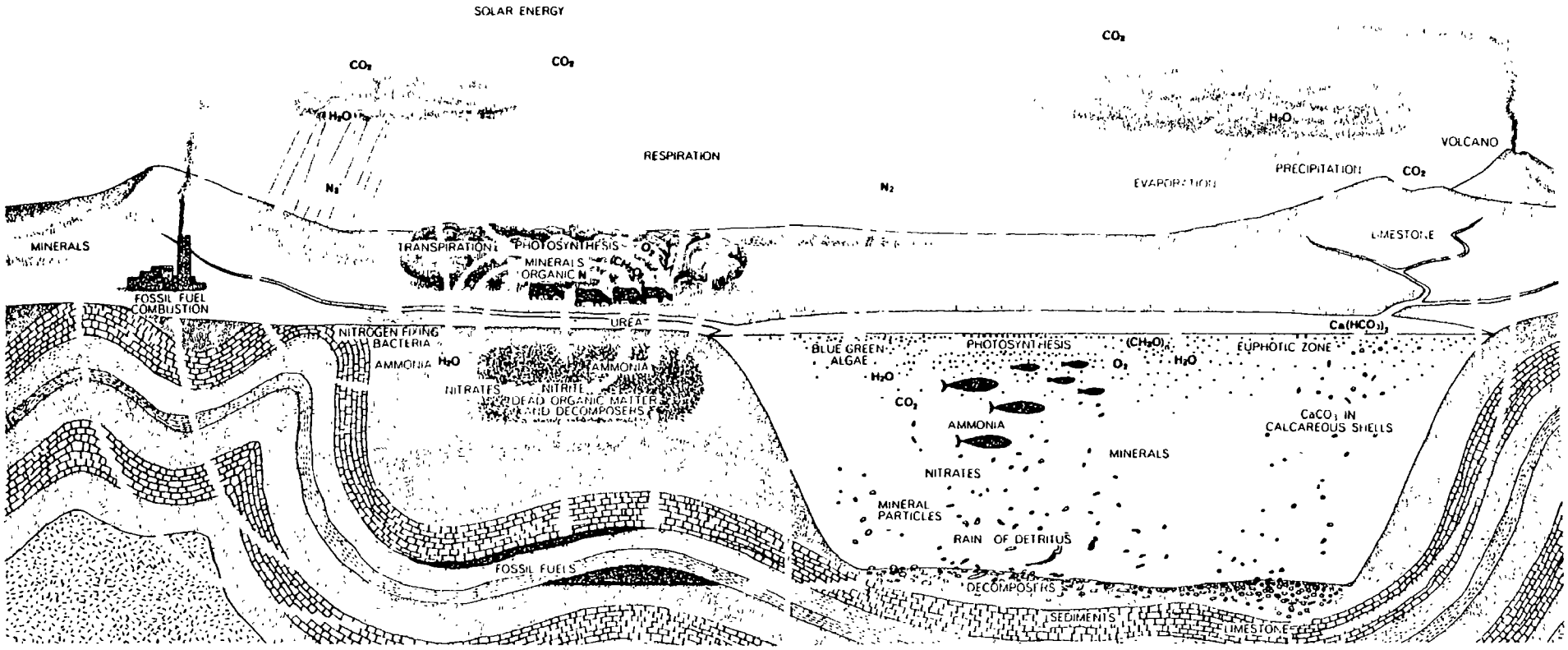


FIGURE 1 MAJOR BIOGEOCHEMICAL CYCLES OF THE BIOSPHERE

and water systems by physical and chemical processes (precipitation, evaporation, wind, leaching, etc.) and biological processes (photosynthesis, respiration, metabolism, movement by or accumulation in plants and animals, decomposition, etc.). Once introduced into the environment, some man-made pollutants may never be permanently removed from the biogeochemical cycle. For example, pollutants may be bound as relatively stable residues under sediment deposits for years only to be resuspended by a dredging operation.

Pollutants may have direct effects on organisms and their environment or they may be transferred into other chemical forms or physical states by chemical, physical or biological processes. These processes may increase or decrease the toxicity of the substances. For example, fresh #2 fuel oil when exposed to light becomes several times more toxic because certain fractions are transformed by photochemical action to very toxic peroxides.

Man's activities may affect individual organisms or may alter populations, communities or even whole ecosystems. Pollutants may impact specific organs or tissues in individual organisms as is the case with carcinogens which cause tumors in the liver. Some pollutants have greater toxicity for certain groups of organisms than for others. For example, warm-water, "rough" fish are frequently tolerant of higher concentrations of toxic substances than are cold-water sport fish. In the case of the ecological transport of a substance from prey to predator through the food chain, a pollutant may accumulate to toxic concentrations in the tissue of the final consumer (who may be man). Mercury poisoning of people in Minamata, Japan was a result of the bioaccumulation of mercury in seafood and ultimately in man. Pollutants may affect populations, communities and ecosystems as typified by

the bioaccumulation of DDT which causes the eggs of birds of prey to be very fragile. This results in reductions in birth rates which if sufficiently significant will alter the ecosystem.

Understanding biogeochemical processes like transport, transformation and bioaccumulation is a necessity for evaluating direct and indirect effects of man's activities on the environment. The study of these processes is integral to the scientific discipline of "ecology".

II. Human Activities Requiring Ecological Research

It is appropriate to EPA's responsibilities for the protection of the total environment, and it is in agreement with the present state of the science, for EPA to concentrate its activities in ecological research on the study of the effects of new or intensified human activities on the finite resources of air, land, and water. New and intensified activities include: industrial growth and diversification, growth of agricultural and forest productivity, transportation, land use, energy development, and recreational pursuits and demands. In addition to ecosystem impacts, economic considerations must be addressed. For the public and regulator to make sound assessments of ecosystem impacts, they must know the real costs and real benefits of maintaining or altering ecosystems, in terms of enjoyment, livelihood, and health.

Each activity has its own and somewhat unique pollution characteristics. For example:

- Industrial growth and diversification add new complex chemical compounds to the aquatic environment, even while meeting water quality and effluent standards. In the air, the principal pollutants are particulates and gaseous wastes that may undergo considerable physical, chemical and biological transformations in the atmosphere.

- o The increase in agricultural and forest productivity in recent years results, at least partially, from the application of agricultural chemicals, switching to more economic management practices, and irrigation.

  Non-point source pollutants from these activities - soil particles, dissolved minerals, nitrogen and phosphorus and some pesticides - adversely affect ecosystems at concentrations far below levels significant to the health of man.
- o Modern transportation systems contribute heavily to air pollution.
- o Land use activities of our mobile and expanding human population, have extensive impacts on ecosystems and human welfare. The siting of industrial centers, power plants, transportation corridors, etc. has a large influence on the environmental and health impacts of those activities.
- o Energy development incorporates the problems of industrial growth, transportation, and land use.
- o Finally, the increase in leisure time in economically developed countries is promoting a more mobile society with the resultant dispersion of pollutant sources and intensification of those involving transportation and recreation.

III. Ecological Research Objectives

If one considers a general framework depicting relationships between man's activities and the biogeochemical processes (figure 1), one begins to appreciate the interrelated nature of the environment. The determination and assessment of intermediate as well as ultimate ecological effects of man's activities requires a comprehensive research program.

The objectives of such research are: (1) To understand the structure and function of natural ecosystems. Such understanding will serve as a baseline against which changes can be measured and assessed; (2) To understand effects of pollutants, singly and in complex mixtures, on these ecosystems. Effects on individuals, populations, and communities may offer a basis for predicting effects on entire ecosystems. Understanding pollutant movements, transformations and fate is essential, so as to determine where effects will occur. Determination of rate of recovery of ecosystems from different stresses is necessary to understanding the significance of the pollutant effect; (3) To develop necessary methods for detecting and quantifying pollutants and determining their persistence; and for measuring ecological effects of these pollutants; and (4) To determine, in terms of human well-being and desires (e.g., esthetic, recreational considerations, life support, etc.) the significance of changes in ecosystems. Only when this is done can priorities be established for actions to ameliorate environmental changes.

The ecological research objectives of the Environmental Protection Agency must be defined consistently with the federal legislative authorities under which the Agency operates. The EPA has been given broad authorization for the conduct of ecological research in several major pieces of legislation. Overlapping these broad authorizations and other authorizations provide for research on specific problems (e.g., pesticide persistence and alternatives, effects of sediment on estuarine fish and wildlife). In addition to these explicit authorizations, there are mandates which derive from implementation dates for major environmental protection standards and regulations.

The legislative authority for EPA's ecological research program comes primarily from six separate Acts: The Clean Air Act (CAA), The Federal Water Pollution Control Act Amendments (FWPCA), the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA), The Marine Protection, Research and Sanctuaries Act (MPRSA), the Energy Reorganization Act of 1974 (ERA), and the National Environmental Policy Act (NEPA). Research also will be required to implement the new Toxic Substances Control Act (TSCA) and the Resource Conservation and Recovery Act (RCRA).

Implementation to date of the research program under these authorizations has been focused on meeting rather specific, often immediate requirements of the Acts. The resulting research products have provided the basis for regulations, standards and criteria involving the air, water and land. This includes quantifying and predicting the responses of ecosystems to pollutants characteristic of man's activities. This is regarded as the first estimate in process which has been formalized in the Acts by requiring periodic review and revision of the research base supporting the regulatory program.

In addition to finding solutions to simpler short-range problems, it is the objective of the Agency to accumulate information on the more complex problems. Biogeochemical processes are important in determining the ultimate impacts of the introduction of pollutants into the environment, and long-term studies are required for understanding these processes. These studies should increase the Agency's predictive capability to solve evolving complex environmental problems and help bring "fire-fighting" research into proper context.

Section II of this document listed some of the major areas of human activities which can pose environmental management and protection

problems whose solutions require research. Since the resulting "research problems" are almost infinite in number, the EPA must set priorities in order to systematically select the most important problems to tackle. The following are among the major criteria which should be applied in the setting of priorities:

- Scientific and other evidence should be available to show that a problem is likely to exist; precious resources cannot be applied to irrelevant topics. In determining whether a problem exists, indications should be available to show that a particular activitity is resulting in the environmental presence of materials to which organisms or ecosystems are or may be exposed, resulting in possible adverse effects.
- The degree of severity of the problem should be considered in terms, for example, of the volume and distribution of the pollutants of concern, the significance and persistence of their potential effects on ecosystems, and the perceived value of potentialy impacted ecosystems and natural resources.
- The maximum length of time which the problem can be allowed to persist without being regulated must be estimated. This involves projecting the expected incremental impact of the problem over time and requires consideration of its temporal urgency.
- As a logical extension to the above, the timing requirements of the Agency, as well as its mandated responsibilities, for solving its priority problems must be taken into account.
- The users of the research products and how they will be used must be identified. This will ensure that the experimental design is appropriate and that the study will supply data

revelant to the problem.

- o The degree of public concern about the problem must be addressed.
- o Finally, consideration must be given to the estimated length of time and the cost required for obtaining a solution to the problem.

Once the problems have been ordered and it has been determined which ones will be addressed, the proposed research approach must be evaluated. In doing so, the following are some of the questions to be answered, with the assumption that all outputs will be legally defensible and have appropriate quality control and standardization of methodologies.

- o Is the existing or proposed approach the most scientifically valid one for addressing the problem(s) at hand?
- o Will the approach provide answers in a manner coincident with the known timing requirements?
- o Is the approach aimed at detecting or elucidating effects on environmental pressure points in terms of the most critical ecosystems and organisms?
- o Does the research contribute to an overall program containing a proper mixture of short-, medium-, and long-term efforts to satisfy environmental management and protection requirements of today and the future?

IV. Approaches to Ecological Research

The approaches to achieve the ecological research objectives of the Environmental Protection Agency may be considered in relation to biogeochemical cycles and the effects of human activities on the ecosystem. One approach for studying the impacts of man's activities is to

study the processes and effects on individual components of ecosystems, that is, one attempts to gain an understanding of effects on the whole through study of its isolated parts. This approach is exemplified by the laboratory study of single pollutant effects on single species. This involves, for example, modifying, standardizing, and validating existing tests for each species and each class of pollutants tested, and developing new short-term tests for screening hazardous materials. Other research is conducted on the biogeochemical processes which determine the fate of pollutants, i.e. transport accumulation and degradation.

Another approach to ecological research is that of modeling. Information gained from the testing of individual pollutants and individual processes and organisms is fed into computerized mathematical models in order to predict the fate and effects of pollutants in natural systems. A second modeling approach is the development of simulated ecosystems or microcosms which simplify the study of the fate and effects of pollutants by the ability to control all environmental characteristics.

The final approach to ecosystem research involves actual field observations to verify predictions; determine levels of pollutant residues actually in the environment; establish baseline data on unstressed ecosystems; and study ecosystems which have been or are being stressed by man.

A comprehensive research program should utilize all of these approaches. Data from a variety of environments and geographical regions should be collected and analyzed. The dissemination of the information should be in formats usable by decision-makers as well as researchers.

The EPA Office of Research and Development plays an important role in providing information in the form of technical support to other program offices and regional offices of the Agency. Approaches to meeting needs for technical support include publishing and disseminating

scientific papers and technical reports; providing scientific expertise at working groups, task force, seminars and symposia; and providing testimony at public and judicial hearings.

Another important approach to achieving ecological research goals is through coordination with other Federal agencies and international organizations with involvement in environmental issues. The ORD Office of Health and Ecological Effects is represented on numerous interagency committees including, but not limited to, the Federal Commission on Ecological Reserves; the USDA/EPA University Coordinating Committee on Agricultural Research; the USDA Combined Forest Pest Research and Development Program; the EPA/COE Executive Committee on Criteria for Dredged and Fill Materials; the Interagency Committee on Aquatic Contaminants; the National Response Team for Oil and Hazardous Material Spills; and the Interagency Technical Committee on the Argo Merchant.

Office of Health and Ecological Effects scientists represent the Agency on several international committees, among which are the UNESCO Programme on Man and the Biosphere (MAB Projects 8 and 14); the International Joint Commission between the United States and Canada on the Great Lakes; the Panel for International Program Cooperation in Oceanography; UNESCO Intergovernmental Oceanographic Committee, and its subcommittees on Global Investigation of Pollutants in the Marine Environment, and Interagency Oceanographic Data Exchange. Other Interagency cooperation is carried out in the form of Interagency Agreements (IAG's). Through IAG's, agencies with unique expertise of facilities conduct research for the other Federal agencies lacking these resources, thereby increasing the overall government efficiency. Among the agencies with whom the EPA has IAG's are the Department of Agriculture,

National Science Foundation, Department of Interior, U. S. Forest Service, National Cancer Institute, Energy Research and Development Administration, and National Aeronautic and Space Administration.

V. Program Areas and Laboratory Assignments

This section describes the integration of EPA's ecological effects program carried out by the four laboratories and Headquarters. The program is presented in terms of three major areas: Exposure/Effects Assessment; Measurement Methods Development; and Technical Support.

The program incorporates suggestions made in several studies of ecological research needs and EPA's research programs. These include (1) Assessment of the Scientific Quality of the Ecological Research Programs of the Office of Research and Development, SAB Ecology Advisory Committee, 1976, (2) Research Needs, in Water Quality Criteria 1972, NAS/NAE, 1973, (3) Organization and Management of EPA's Office of Research and Development, Committee on Science and Technology, U. S. House of Representatives 1976, (4) A Review of the EPA Environmental Research Outlook FY 1976 through 1980, U. S. Congress Office of Technology Assessment, 1976. All of these documents recommend increased emphasis on long-range research and in particular increased emphasis on pollution processes, transport, transformation, and ecological effects in the context of ecosystems.

Exposure/Effects Assessment includes evaluation of stress caused by environmental pollutants as well as pollutant burdens in animal and plant tissue. It includes the study of the effects of increasing stress on animals and plants, populations and ecosystems as a function of time and pollutant concentrations. The development of predictive models to link stress to environmental pollutant concentrations is a

logical extension of such work. Measurements of ecological effects of environmental pollutants acting singly or in combination on individual species, on communities of selected species, and on entire ecosystems are part of this area. Effort is included here which aims at identifying the species, life stages and ecological functions impacted by selected environmental pollutants. Socio-economic studies on the benefits of control of environmental pollutants are also included.

The second area, Measurement Methods Development, includes the testing and validation, as well as development, of appropriate bioassay and ecosystem investigative procedures. Sampling, sample handling, and analytical techniques are included, as are culture programs. A comprehensive quality assurance program is an integral part of this effort.

Technical Support includes the short-term scientific support provided to the rest of EPA and to state and local agencies on such matters as enforcement proceedings, provision of consultation, responding to crises, carrying out special unprogrammed research projects, etc.

Within each program area described below, each of the four ecology laboratories has its own special emphasis and expertise, as well as geographic location with its own unique study opportunities. In general terms, the Duluth laboratory is oriented toward freshwater research and the Narragansett laboratory toward marine research. In the Gulf Breeze laboratory, marine and estuarine activities predominate, particularly concerning pesticides. The Corvallis laboratory deals with aspects of both marine and freshwater ecosystems and with the terrestrial environment. The integrated pest management program is an extramural program carried out at Headquarters.

The following material describes in broad detail the work to be accomplished by the four ecological effects laboratories in the above program areas.

Exposure/Effects Assessment

This is the key function of EPA's Ecology research program. Measurement Methods Development is in support of exposure and effects assessment. The specific activities underway at each laboratory represent in part a reflection of previous assignments and organizational structure, including the agencies under which each lab was originally authorized, but in large part also reflect new activities supportive of EPA's responsibility for the total environment. In the discussion to follow, laboratories will not be specifically mentioned. However, Table 1 at the end of this section summarizes the individual laboratory assignments and specializations.

Ecosystem studies are a major or increasingly important component of the exposure and effects assessment program. Laboratory assignments attempt to cover the range of ecosystems facing major impact and within the reach of EPA regulatory authority. Specific attention is being focused on marine and estuarine ecosystems along the Atlantic, Gulf, and Pacific coasts. Inland, the Great Lakes, which constitute more than 95% of the nations surface freshwater, are receiving major attention, along with smaller lakes and riverine systems. Wetland ecosystems, the transition between the aquatic and terrestrial environments, are being examined to develop criteria for wetland protection. The unique problems of cold climate ecosystems, both terrestrial and aquatic, are being examined in relation to the impact of energy resource development. The effects of air pollution and energy resource development on terrestial ecosystems in general are being assessed. The effects of land use practices on other ecosystem components is being studied. Baseline data on the behavior of

relatively unstressed natural ecosystems is also being obtained.

In addition to field studies on large-scale ecosystems, an increasing level of effort is being devoted to the measurement of ecosystem-level effects of stresses on laboratory-scale model ecosystems and on semi-controlled outdoor stream channels, freshwater ponds, marine and estuarine systems, and terrestrial plots. The purpose of this effort is to develop experimental ecosystems which can be easily manipulated and to which controlled additions of pollutants can be made in an attempt to uncover principles which apply to all or to broad categories of ecosystems.

Along with this effort on natural and model ecosystems, mathematical modeling or simulation techniques are being developed and refined.

In addition to studies of the effects of pollutants on ecosystems, the transformations and ultimate fate of pollutants introduced into ecosystems is receiving emphasis in all laboratories, with the goal of a better definition of the assimilative capacity of terrestrial and aquatic ecosystems for the waste materials of human activities. The integrated pest management program deals with analysis of insect pest populations and their interactions within eight major crop ecosystems. Options being developed for control of these pests emphasizes non-pesticide methods wherever possible. The program goal is to reduce dependence upon pesticide chemicals and to reduce the environmental stress from these chemicals. Additional program areas deal with urban integrated pest management of insect growth regulators, insect pathogens, and development of models of the relationship between the crop, insect, and physical environment to permit development of accurate pest control decision strategies.

More traditional research activities concerned with the interactions between organisms, stresses, toxicants, and mixtures of toxicants is receiving attention. Water quality criteria continue to depend to a large degree on acute and chronic effects data for single toxicants or stresses, and the chemical and physical requirements and limits of organisms are inadequately known, especially those on organisms existing near the extremes of their tolerance ranges. Information on the effects of air pollution, and of land pollution from pesticide application or waste disposal, on terrestrial organisms is also being obtained.

Attempts are being made in the laboratory to assess the exposure of organisms to pollutants in the field, using indices such as residue levels in organisms or changes in enzyme activity.

Measurement Methods Development

Although better methods and techniques are frequently natural spinoffs of research, these techniques themselves are always of high priority since the quality of scientific information is dependent upon the methods used to obtain such information.

Methods are being developed to yield improved and more rapid measurements of the effects of stress on aquatic and terrestrial organisms and on the structure and functions of ecosystems. These stresses include single toxicants and complex mixtures, extremes of physical environmental factors, and excess nutrients. Emphasis is on the development of more rapid tests, screening tests, and on methods which yield an integrated measure of effect. Improved and standardized means of using aquatic and terrestrial microcosms for establishing criteria based on ecosystem-level effects are being actively pursued.

The availability of an adequate spectrum of experimental organisms for bioassay work is a limiting factor for the development of realistic criteria. This limitation is particularly acute in the marine environment, where a major effort is underway to develop and improve methods for culturing, holding and rearing experimental marine organisms.

Attempts are also being made to expand upon the set of response parameters which can be used to assess the effects of stress on organisms and ecosystems.

Technical Support

All four Environmental Research Laboratories provide support to the regulatory and standard-setting activities of the agency in the form of data compilation and analysis, preparation of testimony for administrative and judicial proceedings, analytical and technical advice to other R&D laboratories, and technical advice to EPA regions, state and local governments, and citizens.

The preceeding material provides descriptions of components of the EPA's ecosystem effects research program. Table 1 summarizes the information and should prove useful in demonstrating how the four laboratories cooperatively cover the three program areas. Appendix A lists some of the major outputs anticipated over the five year period, FY 1978-1982. These outputs are consistent with the programs described in this section.

TABLE I

PROGRAM AREAS AND LABORATORY CAPABILITIES

LABORATORY	EXPOSURE/EFFECTS ASSESSMENT	MEASUREMENT METHOD DEVELOPMENT	TECHNICAL SUPPORT
Narragansett	-Toxicant monitoring on marine environments -Toxicant effects on marine environments -Evaluation of petroleum by-products effects on marine organisms and ecosystems -Chemical/physical requirements and limits of marine organisms -Impact of stress on marine ecosystem stability and resiliency	-Development of culturing techniques -Acute and chronic bioassays -Development of response parameters for assessing stress effects on marine ecosystems -Development of marine microcosms	-Marine ecosystems -Impact of power plant on coastal ecosystems -Marine water quality criteria
Gulf Breeze	-Effects (transport, fate and transformations) of toxic organics including pesticides and inorganic on marine and estuarine organisms and ecosystems -Effects of halogenated biocides and their by-products on estuarine ecosystems -Effects of complex wastes on marine and estuarine organisms and ecosystems -Assess the impact of biological pest controls on marine and estuarine ecosystems	-Develop criteria to evaluate the impact of pollutants at the ecosystem level -Development of acute and chronic bioassays for marine and estuarine organisms -Development of genetically controlled marine test organisms and standard test conditions -Use of microcosms in criteria development -Analytical techniques for separation and measurement of toxicants -Screening development techniques of potential toxic substances in estuarine/marine ecosystems	-Effects of pesticides and toxic organics on marine and estuarine environments -Marine and estuarine water quality criteria -Ocean disposal regulations -Dredged material disposal guidelines

Program Areas and Laboratory Capabilities (Continued)

Laboratory	Exposure/Effects Assessment	Measurement Methods Development	Technical Support
Duluth	- toxicant monitoring in freshwater environments - toxicant effects in freshwater - complex effluent effects - chemical/physical requirements and limits for freshwater organisms - Great Lakes ecosystems effects - Freshwater ecosystem effects in smaller lakes and streams	- improve methods to measure effects of single toxicants and complex wastes on freshwater organisms - improve field measurement techniques for Great Lakes ecosystems - new and improved techniques for measuring freshwater ecosystem responses	- freshwater ecosystems, especially fish and insects - freshwater quality criteria
Corvallis	- nutrient and toxicant loading and effects on freshwater ecosystems - lake restoration - physical and chemical processes in marine water - ecosystems models - cold climate research - criteria for Western aquatic species - air pollution impact on terrestrial ecosystems - socio-economic assessment	- methods to assess pre-and post-ocean dump site conditions - methods for storing, preserving, and treating marine sediment samples - methods for analysing metals and toxicants in tissues, sea water, and surface films - development of terrestrial microcosms - development of a bioassay technique for determination of organic compounds in freshwater; using bacterial bioluminescence	- physical/chemical transport in aquatic ecosystems - ocean disposal regulations - terrestrial ecosystems - eutrophication processes and lake restoration - wetlands - freshwater quality criteria - secondary air quality criteria - economics - engineering

Appendix A

Major Program Outputs - 1978-1982

Program outputs for each laboratory are provided in the following tables. Separate tables are provided for Exposure/Effects Assessment and Measurement Methods Development. Research Areas correspond to those identified in the table of the previous section of this paper - Outputs describe specific accomplishments with arrows denoting expected completion dates by fiscal year. Milestone dates are estimated on the basis of presently anticipated resource levels. Both specific and general outputs are given. While these tables do not provide sufficient detail to comprehensively describe each laboratory's program, major goals are defined and it is hoped that the "flavor" of the laboratory missions is evident.

Exposure Effects Assessment - Narragansett Environmental Research Laboratory

Research Area	Output	Fiscal Year 78	79	80	81	82
Toxicant monitoring in marine environments	Mussel Watch - continuous environmental assessment of 100 field stations to assess body burdens for heavy metals, transuranics, petroleum hydrocarbons, and chlorinated hydrocarbons →					
Toxicant effects in marine environments	Complete heavy metal bioassays →					
Evaluation of petroleum byproducts effects on marine organisms and ecosystems	Complete oil and oil byproduct bioassays →					
Chemical/physical requirements and limits of marine organisms	Develop water quality criteria for selected marine organisms →					
Impact of stress on marine ecosystem stability and resiliency	Complete field assessment of sludge dumping sites →					
	Complete dredge spoil site assessments →					

Measurement Methods Development - Narragansett Environmental Research Laboratory

Research Area	Output	Fiscal Year 78	79	80	81	82
Development of culturing techniques	Develop standard laboratory clones of experimental biota →				►	
Acute and cronic bioassays	Develop benthic bioassays for dredge spoil disposal →	►				
	Develop standard bioassays including evaluation of response parameters and quality control methods →					→
Development of response parameters for assessing stress effects on marine ecosystems	Develop marine cytogenetic and mutagenic protocols →				►	
	Develop dredge spoil dump assessment methods →	►				
	Develop organic/inorganic chemistry methods for potential marine toxicants, especially transuranics,organics,and potential carcinogens →					→
Development of marine microcosms	Determine the uses and applicability of microcosms to determine the effect of pollutants on marine ecosystems →			►		

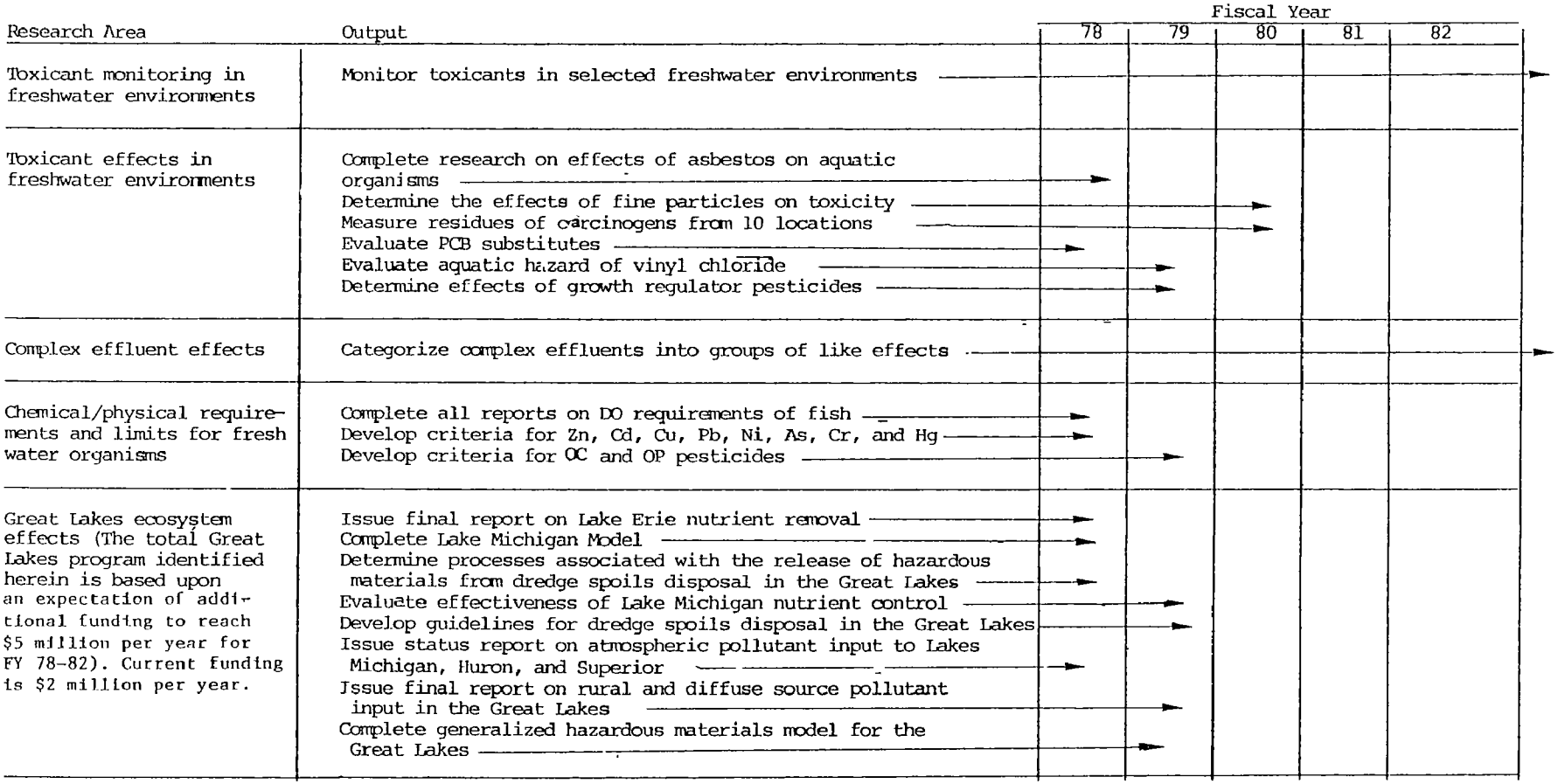
Exposure/Effects Assessment - Gulf Breeze Environmental Research Laboratory (Including Bears Bluff Field Station)

Research Area	Output	Fiscal Year 78	79	80	81	82
Effects (transport, fate and transformations) of toxic organics including pesticides and inorganics on marine and estuarine organisms and ecosystems	Document effects of specified chlorinated hydrocarbons on the marine environment and prepare testimony for the Office of Environmental and General Counsel and the Office of Pesticide Programs →					
	Document effects of specified organophosphate and carbamate pesticides on the marine environment →					
	An integrated assessment of the potential for carcinogens to reach man through the marine food webs →					
	Model effects (transport, fate and transformations) of specific pollutants in marine and estuarine ecosystems					
	James River - Kepone →					
	Escambia Bay - PCB →					
	Other systems →					
Effects of halogenated biocides and their by-products on estuarine ecosystems	Documentation of state-of-the-art knowledge of products from oxidative biocides and the ecological transfer and impacts →					
	Prepare a state-of-the-art report on the effects of chlorine, bromine, and other industrial biocides on the marine environment →					
Effects of complex wastes on marine organisms	Ecological assessment of the impact of selected offshore oil drilling mud constituents on Gulf of Mexico estuarine and marine organisms →					
	Assessment of effects of selected complex industrial waste →					
Impact of biological pest controls on marine and estuarine ecosystems	Document the effects of alternative methods of pest control such as the use of viruses, on marine ecosystems →					
	Extend techniques for elucidate interactions of chemo-responses or man-produced biocides with critical behavioral responses of marine organisms in natural communities →					

Measurement Methods Development - Gulf Breeze Environmental Research Laboratory (Including Bears Bluff Field Station)

Research Area	Output	Fiscal Year 78	79	80	81	82
Development of acute and chronic bioassays for marine organisms	Publish and up-date of Bioassay Methods for Ocean Dumping →		→			
	In vivo and in vitro mutagen/carcinogen bioassay methods for estuarine organisms →				→	
Development of genetically controlled marine test organisms and standard test conditions	Laboratory/Field Method For mutagenic, teratogenic carcinogenic, developmental impact potential upon marine vertebrate →					→
Use of microcosms in criteria development	Determine effects of toxic organics on marine ecosystems using microcosms and other experimental environments →			→		
Analytical techniques for separation and measurement of toxicants	Develop techniques for several rapid analyses of complex industrial wastes →		→			
	Publish methodologies on the use of incidence or neoplasia in marine and estuarine animals as an indicator of pollution by chemicals with carcinogenic properties →				→	

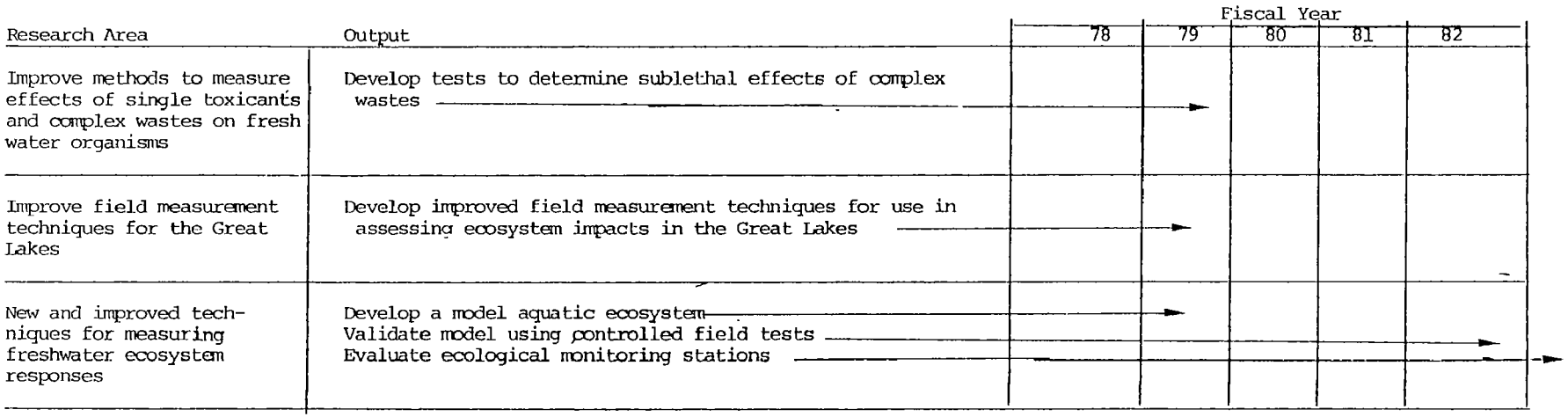
Exposure/Effects Assessment - Duluth Environmental Research Laboratory



Exposure/Effects Assessment - Duluth Environmental Research Laboratory (Continued)

Research Area	Output	Fiscal Year 78	79	80	81	82
Great Lakes ecosystem effects	Complete report on viruses in Great Lakes waters	→	→	→		
	Complete Saginaw Bay studies	→	→	→		
	Complete Lake Superior model	→	→			
	Issue final report on Lake Ontario nutrient control effectiveness	→	→	→	→	
	Issue guidelines for nutrient control in Lakes Ortario, Erie, and Michigan and Saginaw Bay - Lake Huron	→	→	→		
	Report on assessment of once-through cooling systems on the biota of western Lake Erie	→	→	→		
	Complete overall combined Great Lakes model	→	→	→		
Freshwater ecosystem effects in smaller lakes and streams	Develop a model for calculating permissible loading to achieve permissible levels in rivers	→	→	→	→	
	Assess the role of sediments as reservoirs of fat soluble organics in rivers and lakes	→	→	→	→	
	Complete validation of dredge spoil criteria	→	→			
	Determine benefits of toxicity removal:					
	(a) for 10 industry types	→	→	→		
	(b) for 10 additional industry types	→	→	→	→	→

Measurement Methods Development - Duluth Environmental Research Laboratory



Exposure/Effects Assessment - Corvallis Environmental Research Laboratory

Research Area	Output	Fiscal Year 78	79	80	81	82
Nutrient and toxicant loading and effects on freshwater ecosystems	Determine the response of lake systems to external loadings and within lake cycling processes →					
Lake restoration	Prepare reports on evaluation of various lake restoration techniques, starting with a methodology handbood (FY 78) →					
Physical and chemical processes in marine water	Develop information on the physical-chemical properties of estuarine ecosystems coupled with bioassay evaluation of their carrying capacity →					
	Develop information on the response of marine benthos to sediments →					
	Describe the ecosystem significance of shifts in phytoplankton dominance and biomass in regions impacted by waste discharges					
	Develop effluent and water quality criteria for toxic materials in ocean outfalls (e.g., municipal sewage discharges) →					
Ecosystem models	Modeling of ecosystems dynamics is fully integrated with, and supportive of, laboratory and field studies →					
Cold Climate Research	Develop information on bioaccumulation and/or dynamic response of ecosystem components to pollutants from petroleum production (FY 78), construction (FY 79), mining (FY 81), and industrial atmospheric emissions (FY 82) →					

Exposure/Effects Assessment - Corvallis Environmental Research Laboratory (Continued)

Research Area	Output	Fiscal Year 78	79	80	81	82
Wetland ecosystems	Develop vegetative criteria for delineating wetland boundaries and their relation to tidal datums	→				
	Determine the physiological requirements of vegetative indicator species	→	→			
	Determine the productivity and function of specific wetland types	→	→	→		
	Develop and demonstrate environmental assessment methods relating wetland value and function to overall ecosystem value	→	→	→	→	→
Criteria for Western aquatic organisms	Develop criteria for Cr, Cd, and Zn for Pacific Northwest fish	→				
	Develop criteria for selected organics and inorganic for Pacific Northwest aquatic species	→	→			
Air pollution impact on terrestrial ecosystems	Preliminary assessment of chronic regional effects of acid precipitation on forest and agricultural lands	→				
	Determine the effects of air pollutants on soil decomposer systems	→	→			
	Determine the effects of photochemical oxidants on a mixed conifer forest ecosystem	→	→	→	→	
	Develop protocols for determining the bioenvironmental impact of a coal-fired power plant	→	→	→		
Socio-economic assessments, including ecological responses	Determine the ecological benefits of non-point source sediment and nutrient control	→	→			
	Evaluate the sediment-bound behavior of toxicants	→	→	→	→	
	Determine the ecological effectiveness of non-point source controls for agriculture and mining (dissolved minerals and toxic substances)	→	→	→	→	→

Exposure/Effects Assessment - Corvallis Environmental Research Laboratory (Continued)

Research Area	Output	Fiscal Year 78	79	80	81	82
	Prepare reports on the socio-economic impacts of pollutants and their control					
	Develop methods for determining the economic losses associated with multiple air pollution stress on crops and forests					

Measurement Methods Development - Corvallis Environmental Research Laboratory

Research Area	Output	Fiscal Year 78	79	80	81	82
Methods to assess pre and post ocean dump site conditions	Evaluate biostatistical methods and field data collection techniques to assess pre-discharge and post-discharge effects of ocean dumping and ocean outfalls →	→				
Methods for storing, preserving, and treating marine sediment samples	Develop methods for field collection, preservation, handling and analysis of polluted marine sediments →	→	→	→		
Methods for analyzing metals and toxicants in tissue, sea water, and surface films	Develop methods for field handling, laboratory extraction and analysis of marine organisms →	→	→	→		
	Develop methods for analyzing metals and toxicants in sea water and surface films →	→	→	→		
Development of terrestrial microcosms	Evaluate terrestrial microcosms for application to substitute chemical test protocols →	→				
	Determine the characteristics and behavior of selected chemicals in terrestrial model ecosystems →	→	→			

VI. State of the Program to Date

Ecological research being conducted by EPA, other Federal agencies, and the overall scientific community ranges from studies of subcellular physiology to complete ecosystems.

Experiments involving single pollutant-single species have been an effective crash program for developing media criteria data that go a long way towards protecting the environment. This simplistic approach will no doubt have to continue to some extent in response to EPA needs and deadlines. But it is neither scientifically sound nor cost-effective for analyzing complex ecosystems.

Terrestrial ecology research supporting Federal environmental pollution control programs has since 1955 been associated with air pollution legislation. Knowledge developed has provided the scientific support for the establishment of national secondary (non-health) air quality standards and other pollution control strategies. Continuing work with "criteria" and other gaseous pollutants is being directed toward more representative simulation of ambient pollution exposures which are characterized by randomly varying concentrations over time and pollutant mixes as they may occur in the real world. The effects of these exposures on selected crops and tree species are being measured in terms of reduced yield and/or marketability of the product so as to provide damage function information for econonmic loss analysis.

Aquatic ecological research has provided the scientific basis for promulgation of water quality standards and has developed and tested techniques for restoring eutrophic lakes to higher levels of utility for recreation and water supply. The latter work is expanding to include the effects of extraneous organic and inorganic chemicals

on eutrophic processes and controls thereof. Continuing research on accumulation of pesticides and other toxic chemicals in edibles is supporting a strong waste effluent control position of the Agency. Such research includes both identification of toxicants in chemically complex waste streams and summary effects of these wastes on organisms significant to man.

The classical research which provides descriptions of ecosystem components and processes is being augmented by more sophicated research to describe the dynamics of material cycling and energy flow through ecosystems. This trend required identification and quantification of controlling variables and the relationship of biological activity to these variables. A considerable effort has been placed on predicting ecosystem behavior, but the utility of this research prediction has been limited because the results tend to be site specific and sensitive to controlling variables difficult to measure with accuracy. Better predictive success has been obtained by analyzing sub-units which describe only a segment of the total ecosystem structure and processes.

Further research on the "physiology" of whole ecosystems, including long-term sublethal effects, mechanisms and significance of cycling of metabolic materials, the effects and significance of natural environmental controlling variables versus man-induced stresses, and effects of randomly varying pollutant concentrations consistent with real world conditions will refine predictive techniques.

As discussed above, the state of knowledge for predicting ecosystem responses to man's activities is in its formative stages. Unfortunately, our ability to use ecosystem effects information to increase the quality of man's environment is even less well developed. While ecological

effects research has provided some tangible results in this area (e.g., development and application of techniques to restore culturally eutrophic lakes), the translation of these results into practical, useful management methodologies is lacking. The requirement for combining the results of ecosystems effects research with social and economic analysis of costs and benefits is also recognized.

Appendix A

Major Program Outputs - 1978-1982

Program outputs for each laboratory are provided in the following tables. Separate tables are provided for Exposure/Effects Assessment and Measurement Methods Development. Research Areas correspond to those identified in the table of the previous section of this paper - Outputs describe specific accomplishments with arrows denoting expected completion dates by fiscal year. Milestone dates are estimated on the basis of presently anticipated resource levels. Both specific and general outputs are given. While these tables do not provide sufficient detail to comprehensively describe each laboratory's program, major goals are defined and it is hoped that the "flavor" of the laboratory missions is evident.