UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

OFFICE OF
THE ADMINISTRATOR

Honorable Lee M. Thomas
Administrator
U. S. Environmental Protection Agency
401 M Street, S. W.
Washington, D. C. 20460

Dear Mr. Thomas:

The Science Advisory Board has initiated a series of scientific reviews of Agency research programs that have proven to be a highly useful means of assessing the quality and relevance of existing research, identifying research needs and involving the scientific community in the research planning process. Such reviews have also aided internal communication within the Office of Research and Development (ORD) and between ORD and the program offices.

The specific research programs SAB has reviewed since April 1985 include the following:

- o FY '87 ORD Research Plan
- o Total Human Exposure
- o Risk Assessment Methodologies
- o Ground Water
- o Forest Effects
- o Dioxins
- o Biotechnology
- o Extrapolation Modeling
- o Water Quality
- o Ecological Risk Assessment
- o Alternative Hazardous Waste Control Technologies
- o Superfund Innovative Technologies Evaluation

In addition, the Science Advisory Board had scheduled reviews for the integrated air cancer and indoor air research programs.

The purpose of presenting this information is to inform you that such reviews have focused both the SAB's and the Agency's thinking on research plans and needs to a degree never before achieved through preparation and review of the Five Year Research and Development Plan (Research Outlook). As you know, Congress has required that the Agency provide the SAB with the opportunity to review the Plan. The Board believes that its extensive research program reviews fulfill the spirit and intent of Congress for SAB oversight of the Agency's research program. Comments on specific issues in the five year plan have also been addressed in individual research program reviews.

Sincerely,

Norton Nelson
Chairman
Science Advisory Board

U.S. Environmental Protection Agency

Long-Range Research Agenda

1987 - 1991

INTRODUCTION

The primary goal of the U.S. Environmental Protection Agency is the reduction of risk to public health and to the environment. Within this context, the Office of Research and Development (ORD) provides the scientific information necessary to determine the extent of these risks and to develop and evaluate technology options to reduce, eliminate or prevent them. As part of this process ORD must anticipate the scientific questions that will arise so that appropriate data may be obtained and evaluated for the regulatory decision-making process.

The framework for this document is a series of scientific issues identified by EPA's six topical Research Committees: Water, Air and Radiation, Hazardous Waste, Interdisciplinary, Multimedia Energy (including acid deposition), and Pesticides and Toxics. These committees, composed of representatives of ORD, Agency Program (regulatory) Offices and the Regions, are jointly chaired by senior managers from ORD and the appropriate Program Office. The critical scientific issues for each committee were delineated in a joint strategy document by the Assistant Administrators of ORD and the appropriate Program Office. Thus, these issues reflect the perspectives of both the regulatory and research offices of EPA on determining where scientific uncertainties lie and how the Agency might reduce those uncertainties. The integration of the overall research program is, thus, a matrix of topically-oriented research committees and discipline-oriented offices.

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AIR AND RADIATION

Under the Clean Air Act (CAA), as amended in 1977, EPA is responsible for setting ambient air quality standards to protect the public health (primary standards) and welfare (secondary standards) from air pollutants emitted from both stationary and mobile sources. National Ambient Air Quality Standards (NAAQS) have been set for six "criteria" pollutants: ozone (O_3); carbon monoxide (CO); particulate matter (PM); sulfur dioxide (SO_2); nitrogen dioxide (NO_2); and lead (Pb). As required by law, these standards must be reviewed every five years and revised if necessary. Compliance with these standards is the responsibility of each state through the development and implementation of State Implementation Plans (SIPs) which limit emissions from existing sources, set time tables for compliance and establish monitoring procedures. The Agency is also responsible for setting New Source Performance Standards (NSPS) to limit criteria air pollutant emissions from new sources or from existing sources which have been modified based on the use of best demonstrated control systems. In areas where the air quality is better than that required to meet primary and secondary standards, emissions from new or modified sources are restricted under the Prevention of Significant Deterioration (PSD) program. In addition, EPA is responsible for limiting emissions of air pollutants that are hazardous to human health, but are not already regulated as criteria pollutants.

ORD provides the scientific data bases, methodologies, models, assessments, emission reduction technologies and corresponding quality assurance support to implement these legislative authorities. Five major issues have been identified within the scope of the air research program which cut across scientific disciplines and the pollutant-specific structure of the research program. In addition, EPA conducts a radiation monitoring and quality assurance program and a small program to review the health effects of non-ionizing radiation.

MAJOR RESEARCH ISSUES

Criteria Pollutants

What scientific support is necessary to develop and review primary and secondary NAAQS?

HEALTH EFFECTS: EPA lacks sufficient dose-response information to determine the lowest level of exposure to a particular pollutant at which adverse effects occur. This is especially true for subgroups of the population which may be particularly sensitive to pollutant insult. Without this evidence, the optimum level for an ambient air quality standard that adequately protects the public health cannot be determined.

For each of the criteria air pollutants, many of the sensitive population groups and the pollutant exposure ranges of interest have generally been identified. However, health effects testing of these pollutants must continue in both animal and human subjects to ascertain dose-response relationships. The health endpoints of concern are mainly respiratory, metabolic, and immune system effects of O_3, NO_2, SO_2 and particulate matter; the cardiovascular

and neurologic effects of CO; and the neurobehavioral effects of lead. In addition, research may be done on the health effects of very short exposure to high levels of particles and SO_2. This research would support re-evaluation of emergency level standards, particularly as they apply to sources which omit occasional bursts of pollutants for extremely short periods of time. Emphasis will also be placed on evaluating the effects of long-term, low level versus short-term, higher-peak exposures to oxidants, particularly NO_2, and the effects of both long-term and short-term exposures to the coarse fraction of airborne particles smaller than 10 microns in diameter. The information obtained from this research will be factored into the next round of criteria documents and used in the review of NAAQS.

To improve our ability to relate animal data to actual human consequences and to develop more reliable risk estimates of exposure to air pollutants, techniques will be developed to extrapolate from animal to human effects, from high to low doses and from acute to chronic effects. To do this, information in three critical areas is needed: dosimetry--the amount of pollutant which reaches specific target sites in the body after exposure to a given concentration of pollutant; species sensitivity--the potential variations in response of different animal species to the same dose of pollutant; and dose-response.

Human volunteers are being exposed to criteria pollutants for brief periods of time at concentrations similar to those encountered in daily life, in order to measure the resulting effects on heart and lung function, immune response, and other physiological and biological parameters. Similar studies are being conducted with animals. Animals are also being exposed chronically to these pollutants and the cumulative lifetime effect of these exposures will be determined. This dose-response data, combined with dosimetry and species-sensitivity information, will enable an inference of the effects that chronic exposure to a given pollutant may have on humans.

WELFARE EFFECTS: To assess the need for secondary air quality standards for criteria pollutants, research is needed on the impact of air pollution on vegetation and visibility degradation. Recent research on the effect of O_3 on crops indicates that physiological conditions such as water stress and O_3 exposure fluctuations may affect plant response to O_3. Therefore, research to reduce these uncertainties will be conducted.

To develop and implement air pollution abatement strategies for visibility protection, research will be conducted to determine the extent of visibility impairment. Specifically, the role of aerosols on visibility reduction will be assessed; visibility trends for the U.S. will be determined using available data bases; and measurement and monitoring techniques will be developed to more completely characterize the extent of visibility changes. A regional visibility research network will be established to provide data for analyzing source-receptor relationships, and models will be developed to assess visibility protection strategies. Research is also needed to assess the influence of particle size and composition on soiling, and to aid in the development of a risk assessment.

MONITORING: New and improved monitoring methods are needed to identify areas where public health and welfare are threatened and to establish air

quality trends. In addition, accurate, reliable monitoring methods are necessary to determine compliance with standards and to evaluate the need for enforcement actions. Within the area of criteria air pollution monitoring, immediate emphasis will be on refinement and validation of an automatic, cryogenic monitor for non-methane organic compounds (NMOC). Following laboratory validation, this monitor will be field tested.

Epidemiological research provides the most direct evidence of human health effects from environmental exposures to air pollutants. When feasible, epidemiology studies will be done to ascertain the health effects of indoor and outdoor exposures to the criteria air pollutants.

In addition, because the health effects of NO_2 are thought to be associated with high exposures of extremely short duration, a continuous NO_2 monitor is necessary. Over the next several years, research will be conducted to develop such a monitor, based on chemiluminescent principles. If the instrument proves successful, it can be further evaluated in pilot-scale field studies, then used in full-scale epidemiological studies on urban populations to assess the sources, exposures, and public health risks of NO_2.

SCIENTIFIC ASSESSMENT: Review and revision of criteria documents, based on new scientific information, is a continuing effort. The results of health and welfare research performed inside and outside the Agency will be used to revise the criteria document in time to support the review of the CO NAAQS. Revision of the NO_x criteria document will be initiated, and the addendum to the PM/SO_x document will be completed.

New Source Performance Standards and State Implementation Plans

What scientific support is needed to develop NSPS and SIPs?

CONTROL TECHNOLOGY: Although considerable progress has been made in controlling air pollution from both mobile and stationary sources, emissions of criteria pollutants are currently a major concern in a number of areas of the country. Thus, research will be conducted to characterize emission sources, and evaluate and improve the cost effectiveness of emission reduction technologies, thereby reducing the cost of complying with SIPs.

Because much is already known about most criteria pollutants, priorities for control technology have shifted to volatile organic compounds (VOCs), to assist in meeting ozone level attainment goals. VOCs, which react with NO_x and sunlight to produce ozone, are a major cause of the ozone non-attainment problem. Although emissions from major stationary sources are being reduced, small sources, such as dry cleaners, gas stations and paint users, are not being widely controlled. Although these sources individually emit small amounts of pollutants, collectively they may constitute a significant problem. Control technologies such as industrial flares, carbon adsorption, catalytic oxidation and thermal incineration will be assessed to determine their performance and cost in reducing VOC emissions from such sources. Emphasis will be placed on developing and evaluating methods to control VOCs without resorting to costly add-on control devices.

Improved control technology is also needed for sulfur and nitrogen oxides. For SO_x, further research will be done on conventional spray drying for utility and industrial boilers. Also, comparative assessments are needed for various absorbents to reduce the cost of spray drying flue gas desulfurization (FGD). The role of dry injection techniques in FGD systems will also be investigated. Research to control NO_x will focus on evaluating the applicability of combustion modification techniques to industries. Also, needed research on reburning and changes in precombuster burner designs will continue.

Research to control particles focuses on improving the performance, reliability and cost-effectiveness of the multi-stage electrostatic precipitator (ESP) and fabric filtration. The major purpose of this research is to improve collection of small particles which have become increasingly important in meeting particle standards. ESPs may assist in acid rain mitigation for use with dry add-on SO_2 removal processes and switching to low-sulfur coals with their more difficult-to-collect fly ashes. Another particle control measure which shows promise is electrostatically augmented fabric filtration (ESFF). Also, recent research indicates that proper conditioning of the particulate matter can reduce pressure drop significantly, resulting in fabric filters one-third the size of conventional units. Additional research to verify this finding is necessary and has begun.

ATMOSPHERIC PROCESSES: Pollutants emitted into the air often undergo chemical reactions that change the initial pollutants into different compounds. Models to predict this phenomenon are being developed at the urban and regional scale and for complex terrains, such as mountainous areas. These models, when fully developed, will provide information necessary to develop, evaluate and implement cost-effective air pollution control strategies for SIPs and PSD determinations.

Over the last few years, a variety of air quality models have been developed and evaluations of these models indicate that they need to be improved to increase the accuracy and reliability of modeling predictions. To improve urban scale models, smog-chamber studies will be conducted to simulate the atmospheric chemical processes associated with the formation of oxidants and inhalable particulate matter. Emphasis will be placed on the impact of lower hydrocarbon/NO_x ratios and the role of specific categories of volatile organic carbons (VOCs) such as aromatic hydrocarbons and aldehydes in producing oxidants. Other studies are needed to determine the occurrence, lifetimes and transformation processes to assess the environmental importance of potential hazardous air pollutants.

On the regional scale (up to 1000km), laboratory and field studies will be conducted to improve the ability of models to predict the atmospheric transport, transformation and deposition processes for air pollutants such as O_3 and particulate matter. Alternative mathematical techniques and new meteorological tracers will also be evaluated to determine their ability to improve modeling predictions.

MONITORING: Stationary source monitoring methods need improvement. Research will be conducted to increase the precision and accuracy of these monitoring systems. In addition, quality assurance support and audits will be provided to the Agency on a continuing basis.

Hazardous Air Pollutants

What scientific support is needed to develop regulations for hazardous air pollutants?

MONITORING: Unlike the situation for criteria air pollutants, few monitoring methods are available for measuring the concentration of potentially hazardous air pollutants, especially VOCs. New sampling and analytical systems and a set of validated source-sampling methods will be developed for monitoring important sources of hazardous air pollutants that currently cannot be monitored with adequate precision and accuracy. Research to develop methods of monitoring ambient hazardous air pollutant concentrations will be accelerated, as will work on passive monitors and new sorbents. This will extend the measurement capability to chemicals not collected by current methods and to new monitoring situations such as exposures near hazardous waste sites. The nationwide Toxic Air Monitoring System (TAMS) will be continued, to characterize urban atmospheres and determine national trends for non-criteria air pollutants in order to determine the magnitude and extent of the hazardous air pollution problem. The Total Exposure Assessment Methodology (TEAM) will be applied in several areas of the country to develop a national profile of exposure to hazardous pollutants. Early emphasis will be on VOCs. As monitoring capabilities expand, other pollutants may be investigated.

HEALTH EFFEECTS In general, the strategy for investigating the health effects of toxic air pollutants must be quite different from that employed in the study of criteria pollutants. First, because of the potential hazards of these pollutants, clinical studies of exposed human volunteers cannot be conducted; however, epidemiological studies may be feasible. Direct animal to man extrapolation is difficult, so it is necessary to develop animal models that use biological indicators of neurotoxic, genetic, reproductive, or developmental effects in humans. Research to develop such models will be undertaken during the next five years.

A major concern is the identification of pollutants which pose the greatest threats to human health, either because of the seriousness of their effects or because of the degree of exposure. Such research is underway and will be broadened in the future.

CONTROL TECHNOLOGY: The highest priority for research in this area is to assess technologies for their ability to reduce toxic emissions from various industrial and combustion sources. A near-term goal is to control emissions from wood-burning stoves, beginning with evaluations of the efficiency and longevity of wood stove catalysts.

As part of the long term strategy to control hazardous air pollutants (HAPs), industries which are deemed to be high priority sources of HAPs will be identified. Such industries include petroleum refining, organic chemical manufacturers, and iron and steel mills. Research will be performed to develop efficient and effective control strategies for such high-priority emitters.

ATMOSPHERIC PROCESSES: Consideration of the formation, atmospheric stability, and removal of HAPs is essential in assessing exposure and risk. Of particular

concern is the formation in the atmosphere of toxic pollutants from chemical reactions among individually innocuous compounds. On a schedule consistent with the Agency's regulatory calendar, laboratory and field studies will be performed to determine the reaction rates, products, and natural variabilities of HAPs under review. Chemistry will be studied in isolated laboratory systems, to obtain accurate data on kinetics and mechanics. They will also be investigated in photochemical smog chambers, which provide a better basis for extrapolation to the atmosphere. New studies will be undertaken to determine the extent to which HAPs are formed in the atmosphere from innocuous compounds.

SCIENTIFIC ASSESSMENT: Scientific data from the research described above will be used, along with research results from externally sponsored studies of HAPs, to develop Health Assessment Documents for priority pollutants. These documents are used by the Agency in determining the need to regulate hazardous compounds.

INTEGRATED AIR CANCER PROGRAM: There is a great deal of uncertainty regarding the relationship between air pollution and human cancer. Determining the extent to which air pollution is responsible for or related to human cancers could have a major impact on EPA's regulatory program. Thus, a long-term, interdisciplinary research program has been developed to address the major scientific questions regarding the relationship between air pollution and the development of human cancer.

The three basic goals of this program are to: (1) identify the principal airborne carcinogens; (2) determine which emission sources are major contributors of carcinogens to ambient air; and (3) improve the estimate of comparative human cancer risk from specific air pollutant emission sources. Field tests of relatively isolated single-source categories are essential for developing methods to evaluate the more typical multiple-source environments that the general population is exposed to. Therefore, a field test will be conducted in Boise, Idaho, an area with a simple airshed and a severe wood smoke problem during the winter months. The study will focus on quantifying carcinogens emitted from residential wood-fired combustion systems and motor vehicles. The results of this study will be immediately useful, particularly as surrogates for similar environments, while the study design can be adapted for use in areas with more complex geographic, meteorological, and sociological make-ups.

Mobile Sources

What scientific support is needed to develop mobile source regulations?

Modeling: As the driving fleet ages and changes occur in engine design, models to assess the impacts of mobile source emissions on ambient air quality need to be refined and studies must be conducted to evaluate the impact of new emissions. Greater emphasis will be placed on evaluating promising alternative fuels, particularly methanol. The two primary pollutants of importance from methanol-fueled vehicles are methanol and formaldehyde. Analytical procedures to measure methanol and formaldehyde will be developed

and emission characterizations performed. Research to determine the photochemistry of emissions from methanol-fueled vehicles will also be conducted. Emissions from future gasoline-fueled vehicles and diesel-fueled vehicles equipped with advanced control technologies will be characterized.

Global and Microenvironmental

What scientific data are needed to determine the impact of the quality of global and micro-environments on public health and the environment?

Stratospheric Modification: By preventing most harmful ultraviolet (UV-B) radiation from reaching the earth's surface, the stratospheric ozone layer serves as an important shield protecting human health and welfare. It has been theorized for several years that chlorofluorocarbons (CFCs) can cause depletion of stratospheric ozone if used in sufficient quantities. Several serious consequences are possible, including (1) increases in melanoma and other skin cancers, (2) suppression of the human immune system, (3) decreased productivity of commercially important crops and aquatic organisms, and (4) accelerated degradation of polymeric materials. In addition, it is possible that stratospheric ozone can contribute to the theorized "greenhouse effect". Recent research findings, particularly regarding atmospheric chemistry and physics, indicate that the process of stratospheric ozone depletion may be more complicated than was previously thought. There are also significant gaps in our knowledge of the health and welfare effects of increased UV-B radiation. Consideration of regulatory actions on these issue must be based on further research.

Toward that end, research is planned to: (1) evaluate potential future rates of growth in CFC emissions; (2) model changes in the ozone layer which may result from changes in atmospheric composition; (3) analyze predictive models in light of new atmospheric monitoring data; (4) determine potential health effects, particularly the contribution of increased UV-B radiation to the development of malignant melanoma; and (5) determine the effects of UV-B on crop productivity.

Indoor Air: In December 1983, sixteen Federal agencies formed the Interagency Committee on Indoor Air Quality (CIAQ) to coordinate information exchange of an indoor air research and development. This evolved in response to concerns expressed by several organizations, including Congress, about indoor air quality. The CIAQ has developed a comprehensive research strategy on indoor air, in which EPA plays a major role.

In this interagency approach to indoor air pollution research, EPA will concentrate largely on assessing human exposure to air pollutants through field studies using advanced monitoring techniques to measure total exposure to pollutants such as VOCs, inhalable particulates, and NO_2. Clinical studies are planned to assess the effects of these pollutants. Based on the results of these and related studies, predictive exposure models will be constructed and evaluated. The physiological and biochemical changes associated with simultaneous pollutant exposures indoors will be evaluated in these field studies, and the influence of particulate loadings on pollutant exposures will be investigated. Emissions from indoor combustion sources,

construction materials and consumer products will be characterized so that predictive models of indoor air concentrations of the emitted substances can be developed. The distinctive pattern of emissions can be used to help identify the sources of emissions in the field study. During 1986 and 1987, the Agency will continue research under the National Radon Mitigation Strategy, culminating in a guidebook for builders, homeowners, and businesses on protecting against high indoor radon levels.

Radiation Research

What technical support is necessary to ensure that the public is adequately protected from exposure to radioactive materials in the environment?

Monitoring: On a continuing basis, EPA supplies comprehensive radiological monitoring and surveillance services to the Department of Energy (DOE) to meet that Agency's nuclear test monitoring requirements, especially at the Nevada Test Site. Other locations at which such support is regularly provided include Mississippi, Colorado, and New Mexico. Advanced monitoring systems are employed, primarily off-site, to measure the amount of radiation escaping the site following test blasts. A report is generated yearly which details the locations monitored and test results. This work is expected to continue at the same level of effort during the next five years.

Quality Assurance: EPA conducts a radiochemical analytical quality assurance program which supports federal, regional, state, and local laboratories making radioactivity measurements to assess the impact of local nuclear facilities. The purpose of this program is to ensure that scientifically credible data, methodologies, and assessments are used when determining public exposure to radioactive materials. Each year, EPA reports on laboratory radionuclide studies conducted during the previous year. This is a continuing effort and is expected to remain at its current level of effort.

Non-Ionizing Radiation: As lead agency for Federal Radiation Guidelines (Atomic Energy Act, Executive Order 10831), EPA must address the public health implication of environmental exposure to non-ionizing radiation, such as that generated by high-voltage power lines, and microwave and frequency-modulated transmission. Toward that end, EPA has conducted non-ionizing radiation health effects research for several years. This program culminated, in 1985, in the publication of a document compiling information on the biological effects of non-ionizing radiation. This document was widely disseminated and is available to federal, regional, state, and local authorities and other persons interested in its contents.

At the present time, EPA is drawing its radiation health effects research to a close, having made significant progress in determining the level of public health risk posed by non-ionizing radiation. The Agency plans to maintain a core program, comprised of experts in the reproductive, thermal, physiological, and genotoxic effects of radiation. The function of this staff will be to review scientific findings as they are generated and advise the Agency on the impact, if any, that these data have on the Agency's position on non-ionizing radiation research. As necessary, the existing guidance document may be revised consistent with the implications of new research results.

SUMMARY OF LONG-TERM TRENDS

During the past 15 years, much progress has been made in cleaning up the nation's air. Increased use of lead-free gasoline has sharply decreased ambient lead levels and the recent move to speed up the lead phase down program promises to cut these levels even further. Urban areas are experiencing fewer severe pollution episodes. Catalytic converter use has greatly diminished carbon monoxide and hydrocarbon emissions from automobiles. Although some areas still exceed allowable levels of ozone, most locations across the country are generally in compliance with most NAAQS.

Given these trends, priorities are shifting in the air research program. New questions include: What are the hazards posed by unregulated toxic pollutants? What are the sources of these pollutants? What are the long-term health consequences of continued exposure to low levels of criteria pollutants? What physical and chemical interactions in the atmosphere can create or increase toxic pollutants? What are the actual pollutant exposures encountered by people throughout the day? To what extent do conditions or materials in the home contribute to those exposures? What can be done about visibility decrements or damage to materials resulting from air pollution?

Within the area of toxic air pollution research, EPA will focus on several objectives. Monitoring methods will be improved and attempts will be made to characterize urban atmospheres and determine national pollution trends. TEAM studies will be undertaken, with the goal of developing a profile of HAP exposures across the nation. Efforts will be made to identify the most toxic pollutants, by source, and to determine their health effects. Control strategies will be developed, first for high priority industries, such as chemical manufacturers and petroleum industries. The formation, transport, and fate of HAPs will also be investigated. The Integrated Air Cancer Program (IACP) will be expanded, drawing on the resources of several EPA laboratories to discover the extent to which toxic pollutants contribute to this country's rising cancer rates.

With the cooperation of other federal agencies interested in the hazards of indoor air pollution, EPA will be applying modern methods to monitor indoor exposures to radon, VOCs, NO_2, particulates, and other contaminants. Indoor emissions will be characterized and exposure models will be constructed to predict indoor exposures to specified pollutants. Ultimately this information will be of use in determining the total exposure -- indoor and outdoor -- that humans receive to these pollutants.

Within the criteria pollutant program, some of the concerns remaining include ozone non-attainment, health effects exposures to NO_2 and particulates. Ozone control research will focus on small stationary sources of VOCs, such as dry cleaners and gas stations, to develop applicable, low-cost methods of cutting VOC emissions. Health research on NO_2 will concentrate on clinical, epidemiological, and toxicological evaluations of NO_2 exposure, particularly in susceptible populations, such as children and persons with impaired respiratory systems.

RESOURCE OPTIONS

1986 Revised Current Estimate: $68.4M
1987 President's Budget: $63.3M

Projections

	FY 1988	FY 1989	FY 1990	FY 1991
No Growth	$63.3K	$63.3K	$63.3K	$63.3K
Moderate Growth	$65.2K	$67.2K	$69.2K	$71.2K
High Growth	$67.1K	$71.1K	$75.4K	$75.9K

No Growth: The program would proceed as described in this Agenda.

Moderate: Additional efforts would be devoted to augmented research in risk assessment, ozone non-attainment, and mitigation of risk. Specifically, emphasis would be placed on determination of risk. Reduction in the criteria air pollution program would be restored.

High: Research to characterize presence, extent, fate, effect, and source of air pollutants, both criteria and non-criteria, associated human and environmental exposure would be increased.

WATER

EPA's water research program provides the technical and scientific support necessary to implement the Agency's regulatory responsibilities under the Clean Water Act, the Safe Drinking Water Act, the Marine Protection, Research and Sanctuaries Act, and a number of Executive Orders and omnibus statutes. Most of the research on water issues is conducted by the ORD laboratories although a valuable contribution is made by universities and private research institutions supported in part by EPA grants and cooperative agreements. EPA's water research is important to the development of both drinking water and ambient water quality regulations. In addition, the program is heavily involved in the development and transfer of innovative and cost-effective treatment technologies to municipalities, industry and private landowners, and is accelerating its research into the environmental impacts of pollution upon aquatic biota and their ecosystems.

EPA's water research will continue to provide support in the following areas: developing new and revised drinking water Maximum Contaminant Levels and Health Advisories; developing Criteria Documents and the scientific underpinnings of ambient water quality regulatory policies; assisting the Regions and states in meeting the growing demand for toxicity based National Pollutant Discharge Elimination System (NPDES) permits; and providing technical support to the municipal waste-water construction program in pretreatment, sludge, infiltration/inflow and other areas.

The six research areas described in this report--Water Quality Based Approach; Marine, Estuarine and Great Lakes; Wastewater Treatment Technology; Drinking Water Technology; Drinking Water Health; Ground Water--represent the principal concerns in the water research area and correspond both to the organizational structure of the Water Research Committee and the Agency's water research budget. Although this is a comprehensive program, it does not include all ongoing research which contributes to EPA's water protection mission.

MAJOR RESEARCH ISSUES

Water Quality Based Approach (Permitting)

What information and methods are needed to support a water quality based approach to pollution control?

The Clean Water Act (CWA) recognizes two types of regulatory requirements needed to restore and maintain the quality of the Nation's waters: (1) Technology-based guidelines set uniform national requirements for discharges by industries and sewage treatment facilities; and (2) Water quality based standards define the uses to be made of water, such as drinking water supply or recreation, and subsequently establish site-specific criteria protective of that use. Despite significant reductions in point-source pollutant levels as a result of the implementation of technology-based

discharge limits, there are still water bodies which do not meet water quality standards. Moreover, there are increasingly important water quality problems caused by toxic substances, diffuse (nonpoint) sources, and reduced flow.

Use Attainability: This research will characterize water bodies for attainable uses based on their natural features and surrounding land forms. Research will continue on the development of comprehensive ecological criteria for meeting goals of the CWA and on the National Atlas and maps of aquatic ecoregions. Resources permitting application of remote sensing or aerial photographic interpretations for use attainability analysis (drainage basin mapping, land usage, historical usage and misusage) will be provided. Diffuse sources of contamination are currently regulated through "Best Management Practices."

Microbiological Contamination of Shellfish: A cooperative research effort has been undertaken with the U.S. National Oceanic and Atmospheric (NOAA) and the U.S. Food and Drug Administration (FDA) for determining if a quantitative relationship exists between microbial indicators of water quality and disease in shellfish (oysters and clams) consumers. Two field sites have been selected to study the occurrence of microbial water quality indicators and to harvest oysters and clams. Shellfish harvested from these sites (both are currently acceptable) will be fed to human volunteers to determine the incidence of gastrointestinal disease. The microbial water quality indicator that best correlates to the disease incidence in consumers will be proposed as the revised shellfish growing water quality indicator.

Waste Load Allocation: Environmental processes characterizations will increase available data bases, and waste load allocation models will be developed, improved, simplified and tested to implement the water quality based approach. The Center for Water Quality Modeling in Athens, Georgia will catalogue, maintain and provide models, user manuals and associated training and technical assistance to EPA Regions and states.

Monitoring and Quality Assurance: EPA will continue to identify, evaluate, standardize and validate analytical procedures for characterization/monitoring of water borne pollutants. Emphasis will be given to the establishment of protocols which screen water quality through biochemical and/or biological testing. In the area of chemical methods development, generic instrumentation approaches to monitoring (rather than a chemical-by-chemical approach) will be evaluated. Contamination of the water column, under-lying sediment or introduced sludge will be individually addressed in an attempt to maximize the economy of each class of measurement. Additionally, the proposed externalization of quality assurance costs (charging user fee for QA services) will continue to "free-up" resources to fund such high priority efforts.

Water Quality Criteria - Aquatic Life: Toxicity-testing methods for aquatic life will be developed, validated and provided to Regions and states for predicting instream water and biological impacts in fresh and brackish water and marine systems. Research will continue to support the integration of pollutant-specific controls with whole-effluent-toxicity testing procedures and Best Available Technology. The significance of toxicity and persistance

factors to biota will be determined and methods developed for integration into the permitting process. Field tests will compare site-specific criteria modification techniques with the whole-effluent-toxicity approach. Freshwater and marine water quality criteria and advisories for protection of aquatic life based on specific chemicals will be developed as needed and experimental "expert" systems for environmental assessment will be developed and tested.

Water Quality Criteria - Health Effects: Health effect bioassays developed in previous years to determine toxicity of municipal and industrial waste discharges will be field tested at several different locations. The results of these field evaluations will be combined and produced as a methods manual to support the National Pollutant Discharge Elimination System (NPDES) program.

In other areas, guidance for assessing the risk of human exposure to mixtures of toxic chemicals, the evaluation of site-specific health hazards and evaluations for CWA Section 301(g) permit modification requests will continue under the scientific assessment program. The cooperative ecological research with the People's Republic of China will address the impact of contaminants on freshwater organisms, emphasizing field verification of methodologies.

Marine, Estuaries and Great Lakes

What information and methods are needed to support environmentally sound ocean disposal, estuarine and Great Lakes programs?

Ocean Disposal: EPA is charged with regulating waste disposal activities in the marine environment. Among these activities are the dumping of wastes such as dredged material, sewage sludge and industrial wastes, the disposal of municipal and industrial wastewater through ocean outfalls, and the incineration-at-sea of industrial wastes. An improved understanding of the ecological consequences of these ocean disposal actions is needed to guide future public policy, satisfy international marine treaties and, where possible, protect and enhance coastal fisheries resources. Key questions concerning ocean dumping and incineration-at-sea involve procedures to be used in assessing the impacts of ocean disposal and procedures necessary to monitor dumpsites for long-term impacts and validate predictions made about potential impacts. The CWA requires secondary treatment for ocean-outfall discharges from publicly owned facilities, although waivers are allowed in selected cases. Therefore, EPA must have a scientific basis for determining when secondary treatment requirements may be modified and what effluent limitations should be imposed.

To support the ocean dumping and outfall regulatory programs, and to assess the impacts of incineration-at-sea, EPA's research will focus on the development and validation of protocols needed for prediction of impacts from these activities. This program will continue the development and testing of ocean disposal impact assessment procedures, coastal and deep-water monitoring methods, and procedures for characterizing the bioaccumulation potential and effects of ocean disposed contaminants.

Technology research related to ocean disposal will provide information used in correlating the types of treatment with subsequent environmental impacts in order to assess appropriate levels of treatment for ocean disposed wastes. The assessment of wastewater treatment mechanisms will focus on partitioning of toxic metals and organics on wastewater solids during treatment and the desorption or distribution encountered when sludge and wastewaters are discharged to the ocean.

Estuaries: Estuaries are valuable ecological systems, which are directly important to man for fisheries and recreation resources, and indirectly as nursery areas for ocean fisheries. Estuaries are subject to impacts by the production, transportation, consumption and release of toxic chemicals. Basic scientific uncertainties exist regarding these assessments which involve the quantification of loads, their transport and fate, and their cumulative effects on the resources. EPA's estuarine research program is guided by the Office of Water's Estuarine Protection Strategy, and will concentrate on the development and validation of hazard-assessment protocols for improved source-control decisions in the NPDES and Construction Grants Programs. Methods are also required for developing the rationale and technical justification for diffuse-source controls and for determining the most cost-effective combination of point and diffuse-source controls.

Great Lakes: Increased use of industrial chemicals and their presence in the Great Lakes have raised public concerns about toxic pollutants, particularly persistent synthetic organic compounds. Because of the complexity of many of these compounds, it is difficult to predict the potential adverse impact of these chemicals on organisms in the food chain, including humans. Analytical methods needed to detect environmental concentrations of organic compounds at trace levels are inadequate. Also, existing mathematical models, which have limited capabilities to relate pollutant exposure levels to the sources of the determination of biological availability and environmental effects of toxic organics, can be enhanced by the use of predictive models. For those determinations EPA will develop and apply accurate and sensitive methods for (1) those contaminants chemically suited for biological uptake and (2) toxic levels, fates and effects of contaminants that tend to build up within organism tissues. Further research will integrate fate and transport models with those addressing food-web uptake.

EPA will continue to study transport, fate and effects of toxic materials in selected areas of the Great Lakes ecosystem, with emphasis on contaminated sediments. This information will be used by the Great Lakes National Program Office, EPA Regions, contiguous states and the International Joint Commission under the U.S./Canada Water Quality Agreement.

Wastewater Treatment Technology

What information is needed to develop and assist the states in implementing sludge disposal regulations and to improve the reliability and cost-effectiveness of wastewater treatment facilities?

Sludge Management: The processing and disposal of sludge accounts for about half the total operating costs of a typical sewage treatment plant. Municipalities are facing increased economic and public problems with current land and ocean sludge disposal practices. Approaches to disposal are needed that will significantly reduce the volume of sludge, destroy pathogens, ensure that toxic metals are not a problem, reduce toxic organic compounds, and ensure that sludge disposal does not present a threat to ground water, the environmental and public health. To support EPA's regulations, research will focus on sludge-use criteria, procedures and requirements applicable to the regulatory process. EPA will refine methods to assess sludge-disposal options including research into ecosystem resiliency or stress resulting from disposal and methods to predict human health effects from exposures to sludge.

The Agency will initiate an effort on wetlands research to establish a scientifically-valid framework for categorizing wetlands and measuring the impact of change so that regulatory actions can be effectively tailored to specific problems.

Research on potential human health effects from sludge disposal involves collecting data on various chemical and bacteriological contaminants in sludge and developing hazard indices for effects associated with different exposure pathways. Studies have been initiated to evaluate health hazards from exposures to sludge where composted sludge is sold as fertilizer. Results from these and other studies will provide data for determining the effects to various sludge treatment processes on mitigating disease.

Health assessment profiles will support regulatory decision making on the effective treatment, conversion, use and disposal of municipal sludge. EPA will develop information on mitigating risk through sludge treatment, on disposal options, and will produce guidelines for conducting health risk assessments of sludge disposal. Research results will be used to calculate hazard indices for cancer and oral chronic toxicity related to hazards in the food web and inhalation and aquatic toxicity associated with the incineration and ocean disposal of sludge.

Research on sludge stabilization, pathogen reduction and dewatering offers a major opportunity to reduce substantially costs associated with sludge processing while causing minimal environmental impact. Pilot- and large-scale combination of activated sludge, anaerobic digestion and wet oxidation to determine the mass and volume reducing capabilities of the system will be evaluated, along with promising methods such as mechanical composting and conversion of sludge to fuel. Engineering research addressing sludge applications in agriculture, forests, landfills and land reclamation is needed to establish safe application rates and management techniques and to minimize surface and groundwater impacts. EPA will develop design and performance information for land applications of sludge and provide the assistance necessary to transfer this technology to municipalities.

Innovative/Alternative (I/A) Technology: EPA will provide technical and program support to states, municipalities, consultants and equipment manufacturers in the areas of 100% replacement and composite correction program, facility plan reviews, emerging technology assessments, technology evaluations, small wastewater flow technology and technology transfer. Also, assessments of promising wastewater treatment processes that have had limited full-scale application will be made.

Upgrading and Correcting Designs: The Agency will provide information to municipalities to upgrade existing plant capabilities and achieve compliance with minimal capital costs. Research in this area encompasses evaluation of high biomass systems, enhanced oxygen transfer, second generation nutrient control schemes, alternative disinfection processes, and a variety of innovative long-range approaches to biological treatment such as genetic engineering. In addition, operating plant data will be analyzed to identify operating and design deficiencies and develop low-cost procedures for operation and management.

Toxics Treatability and Toxicity Reduction: EPA will develop improved approaches for enhanced control of toxics in municipal wastewater treatment. The Agency will also develop toxicity reduction evaluation procedures for municipal and industrial wastewater treatment plants in support of water quality based permit limitations.

Water Quality Planning and Regulation Support: EPA will provide engineering data and managerial techniques necessary for states to apply a cost-effective systems engineering approach to implement waste-load allocations within their water quality control programs. This will provide more reasonable margins of safety in determining allowable stream loadings and reduce over design of advanced treatment plants.

Quality Assurance: EPA will continue the quality assurance and repository samples program. The performance of major NPDES dischargers' laboratories will be evaluated, and actions on NPDES alternate test candidate procedure applications will be recommended.

Drinking Water Technology

What new technologies are needed to continue to assure the safety of drinking water?

EPA's drinking water technology research program provides engineering data to support the development and revision of drinking water regulations as well as engineering information and technological support to states, municipalities, EPA Regions and utilities concerned with drinking water regulations and compliance. Major technological problems include the relationship between treatment strategies and deterioration of water quality within distribution systems, factors causing deterioration within distribution systems, and bringing small systems into cost-effective compliance. A related concern is the impact of distribution-system corrosion on drinking water quality and the need for low-cost techniques to solve this problem.

Disinfection By-Products: Research will continue on improving the knowledge on a number of unidentified by-products produced by chlorination as well as by-products of alternate disinfectants to chlorine. Evaluations of THM control using alternative disinfectants and treatment modifications will be continued.

Overall System Integrity: The persistence and regrowth of organisms in distribution systems are influenced by the physical and chemical characteristics of the water, system age, pipe materials and the availability of suitable sites for bacterial colonization. Investigations will also be carried out on other key factors that influence microbial regrowth, such as nutrients, temperature and sediment accumulations. Theoretical, laboratory and field studies will define factors associated with distribution-system repair and replacement criteria, including costs associated with optimal renovation strategies. Laboratory and field studies will evaluate the impact of changes in treatment and disinfection practices brought about by existing and new regulations.

Small-System Compliance: EPA is directing special attention to small drinking-water systems and their compliance with regulations. Research is evaluating the cost and engineering feasibility of specific treatment techniques to remove or control chemical, particulate and microbiological contaminants. Several evaluations will be at pilot- or full-scale. Laboratory studies are defining variables that govern the effectiveness and efficiencies of treatment processes prior to large-scale evaluations.

Monitoring and Quality Assurance: The Drinking Water Technology Research Program oversees the Agency-wide mandatory quality assurance program for drinking water. Ten regional laboratories are involved in the National Interim Primary Drinking Water Regulations laboratory certification program. Monitoring activities will also develop methods and total-measurement systems for precise chemical, microbiological and radiochemical analysis. This will provide accurate and cost-effective analytical procedures to monitor contaminants for use by the Agency, states, municipalities, and operators of public drinking water systems. Again, the externalization of quality assurance services will provide additional resources for funding high priority water research efforts.

Drinking Water Health

What are the health effects from exposure to chemical and microbiological contaminants found in drinking water?

EPA is required to develop national drinking water standards for contaminants that may cause an adverse health effect. Research to determine the effects and risks from exposure to drinking water contaminants is an essential step, and has been explicitly recognized by a provision of the Safe Drinking Water Act.

Health Effects Data and Risk Assessment: Toxicological research to develop dose/response data will support development of Maximum Contaminant Levels and Health Advisories for disinfectants and disinfectant by-products, synthetic organic chemicals, inorganic chemicals, radionuclides and

microbes. Risk assessments and criteria documents will be developed for drinking water contaminants. Epidemiological studies will determine the associations between dissolved radon and lung cancer, drinking water disinfection and cardiovascular disease, and drinking water quality and bladder, kidney, liver and colon cancer.

Methods Development: Research will be done to improve extrapolations from high to low doses and from laboratory animals to humans. The effects of different exposure pathways are being evaluated to improve the accuracy of risk assessments. Microbiological methods are being developed to identify infectious disease agents in water and determine the significance of the occurrence of these agents in water supplies. Methods to determine exposure and risks from chemical mixtures are also being developed.

Ground Water

What is needed to improve the scientific capability to monitor, predict, and clean up ground water contamination problems?

EPA and the States have a number of mandates for protecting ground water, and almost every regulatory and enforcement program in the Agency has some interest in ground water protection. In response to these needs, EPA's ground water research programs cover source control, monitoring methods, analytical methods and quality assurance, prediction and resultant assessment of risks, drinking water treatment and health effects, and cleanup methods for contaminated soils and ground water. This section focuses on: monitoring technology; prediction and assessment tools; underground injection control; aquifer cleanup; and technology transfer. These areas are not covered within the Hazardous Waste/Superfund or the Pesticides and Toxics chapters in this Research Outlook.

Monitoring Technology: EPA's research will improve cost effectiveness and accuracies of monitoring in three areas: methods, geophysical techniques and interpretive analysis. Sampling and well-construction methods will be evaluated to determine their effects on the accuracy of results. The development of performance standards that manufacturers can apply to new equipment will prove particularly important. Fiber-optics technology will be used for inexpensive and reliable ground water monitoring. Current methods will be adapted for use on underground storage tanks and nonhazardous landfills. Vadose zone (unsaturated) techniques will be evaluated for their applicability to various situations and soil-gas monitoring will be developed into an inexpensive and reliable method for plume delineation.

Geophysical methods adapted from the energy and minerals resource industry will be evaluated for their applicability to such ground water contamination problems as detecting leakage from underground injection wells, location of abandoned wells, and contaminant plume detection. Quality assurance methods will be developed and standardized to improve confidence in these techniques.

Interpretive analysis will be used to obtain more information from monitoring data, and to improve reliability. Efforts will continue to determine the completeness of coverage for methods to locate abandoned wells. "Variance analysis" will be applied to determine the frequency of sampling required in monitoring wells to gain the appropriate confidence under different circumstances. Finally, geographically based information systems will be used to make ground water monitoring data more useful to decision makers.

Underground Injection Control: This research will be extremely important over the next few years due to the regulatory requirements of the Hazardous and Solid Waste Amendments of 1984. EPA is required to reconsider the safety of underground injection as a hazardous waste disposal method and to ban such injection should there be migration out of the injection zone. EPA has a number of research activities underway to aid the Office of Drinking Water in making these determinations, including determining the fluid movement from wells, describing the interaction of injected fluids with the geological strata, and characterizing saline formations in the Texas Gulf Coast as receptors of hazardous wastes. Research will determine the mechanical integrity of injection wells, the location of abandoned wells and the practices associated with non-hazardous injection.

Predictive Methods: Predictive research provides the basis for assessing the risk of ground water contamination upon drinking water supplies and for understanding subsurface processes that eventually may lead to cleanup methodology. Sorption, biotransformation, transport, mixed solvent interactions, oxidation-reduction, hydrolysis, dechlorination, dispersion, fractured flow, and immiscible flow will be investigated for organic chemicals that could pose significant risk. Research will continue on virus survival and transport, and metals mobility. Contaminant-transport models will be adapted and modified to include the improved process descriptions. Field evaluations will determine the degree of confidence that can be expected from predictive models in various hydrogeologic environments.

Aquifer Restoration: Aquifer cleanup research will provide cost effective methods for cleanup of contaminated soils and ground water. Alternatives are needed to current approaches such as withdrawal and treatment or containment. Promising laboratory methods for enhancing subsurface biotransformation will be field tested, the safety of using genetically-engineered organisms for biodegradation will be determined, and the application of these methods to leaks from underground storage tanks will be evaluated.

Technology Transfer: Information transfer will continue to be an important part of ground water research. Specific training materials are under development in addition to technical assistance to the EPA regions and the states. Support will continue to the National Ground Water Information Center, a computerized bibliographic retrieval database, and the International Ground Water Modeling Center, a clearinghouse for ground water models and training.

SUMMARY OF LONG-TERM TRENDS

Most of the water research issues described in this chapter will continue into the next decade, with gradually changing degrees of activity and emphasis. Better analytical capabilities will continue to improve the capability to measure trace constituents in water, resulting in better identification of greater numbers of potentially deleterious chemical contaminants. Coupled with more toxicological and epidemiological information, water quality managers will face increasingly difficult decisions involving the environmental significance of complex mixtures of pollutants.

A significant near-term issue includes the development of toxicant information for complex mixtures. The growing inventory of chlorinated organic contaminants in complicated combinations requires significant changes in the research strategies and technological methods used to assess them. Whole-sample evaluations such as matrix bioassays, biological indicators and chemical surrogates will play a larger role in the future. To remain responsive, EPA's water research program must simultaneously develop and validate new methods for evaluating complex mixtures and their impacts while applying them in regulatory situations.

The environmental water quality issues, including estuary protection, ocean disposal and the water quality based approach, all reflect the emerging need to develop new tools to test and monitor ecological impacts, including effects on the community at system level. Over the next decade, major strides will be made in identifying safe, or "no-effect" levels of toxic organic contaminants in sediments and water, and in methods to establish biological availability and bioaccumulation in tissues.

Many communities and landowners rely upon ground water sources for drinking and irrigation. Questions regarding the quality of ground water have been increasing in recent years. Consequently, the dynamics of ground water and the residence times and fates of leached contaminants in aquifers will be a major water resource issue for the remainder of the century. The coming decade will see the refinement of the capability to simulate and predict the impacts of contaminants on underground sources.

In the wastewater treatment areas, no fundamental changes are foreseen. Improved engineering and the periodic emergence of innovative and alternative technologies will partially offset the rising cost associated with wastewater treatment. A major breakthrough in wastewater treatment, if there is to be one, may come from biological engineering, possibly by developing organisms which could be more effective in treating wastewater.

RESOURCE OPTIONS

1986 Current Estimate $51.9 Million
1987 President's Budget $46.9 Million

Projections

	1988	1989	1990	1991
No Growth	$46.9M	$46.9M	$46.9M	$46.9M
Moderate Growth	$48.3M	$49.7M	$51.2M	$52.7M
High Growth	$49.7M	$52.7M	$55.9M	$59.3M

No Growth: The program would proceed as described in this Research Outlook.

Moderate: Additional emphasis would be given to research on wetlands, pollutant fate and effects in ground water, sludge and estuaries. In addition, efforts would be directed towards developing techniques to quantify health risks from exposure to complex mixtures and to augment the drinking water repository-samples and quality assurance programs.

High: The research cited under the moderate growth option would be augmented and accelerated, and research on water quality criteria will be conducted.

HAZARDOUS WASTE AND SUPERFUND

The Resource Conservation and Recovery Act (RCRA) authorizes a regulatory program to identify wastes which pose a substantial hazard to human health or the environment, and develop management standards for wastes which protect human health and the environment. Research support for this program provides the scientific and engineering basis for characterizing wastes, determining the hazards they pose and formulating controls. In addition, Section 311 of the Clean Water Act authorizes research to support prevention and control of hazardous materials releases.

The Office of Emergency and Remedial Response (OERR) requires scientific and technical support from the Office of Research and Development to mitigate health and environmental problems at the priority sites listed under authority of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA). ORD's program provides a core of scientific and technical information to support the implementation requirements of CERCLA and the enforcement actions undertaken to obtain cleanup and recovery of costs. It concentrates on evaluating equipment and techniques for discovering, assessing, preventing, controlling, removing and ultimately disposing of hazardous substances released into the environment. Because of the nature of the Superfund-sponsored effort, activities consist of field testing and evaluating technologies developed in other research programs, such as hazardous waste.

MAJOR RESEARCH ISSUES

Alternative Technologies

What information and data are needed to support and permit the use of alternatives to land disposal?

The Agency is currently beginning to implement a program which will ban land disposal of certain classes of untreated hazardous wastes. Banning these wastes could require the availability of proven alternatives for treating or recycling waste materials. Although many of these technologies currently exist, there are many questions regarding their effectiveness on specific wastes and their capacity to address the anticipated volumes that will require treatment. This research will provide support for the Office of Solid Waste (OSW) in implementing the portions of the RCRA amendments which require banning certain hazard wastes from land disposal.

Research on alternative technologies assesses the environmental impacts of the major alternatives now under development, and in selected instances supports the evaluation of processes found by the Agency to offer substantial improvements over conventional hazardous waste disposal methods. Such evaluations will be conducted and used with existing data to form the basis for treatment standards.

Assessments of alternative technologies will be conducted at bench, pilot and field scales with emphasis on waste streams assigned high priority by OSW. Included will be aqueous waste streams from the chemical industry that are likely to be banned from landfills and wastes with a high potential

for volatile air emissions. Also, case studies of waste minimization, reduction, and recycle or reuse will be prepared.

Waste Characterization

What health and risk assessment information and procedures are needed to characterize wastes and assess the hazards they represent?

Assessing the risks associated with various methods of waste disposal is a critical aspect of the Agency's RCRA program, but is an area of major scientific uncertainty. Developing the scientific and technical information needed to establish the quantity and types of wastes that escape into the environment through different disposal methods and the effects they produce for both human health and the environment will remain a significant area for research activity for some time. Moreover, given that most existing information is based on the properties of individual chemicals, rather than the complex mixtures of chemicals typically found in wastes streams, the state-of-knowledge in this area will require several years to develop.

The information developed to support this research area will be used by OSW in permitting and enforcement decision making, regulatory policy making, and implementing the land-banning program. Products will provide more applicable, less expensive, and more accurate information and risk assessment methodologies.

A program to develop more accurate methods for predicting the quantity, composition and volatility of leachates from land disposal of wastes is underway. These and other methods for determining the escape of hazardous wastes into the environment, as well as predictive models in air, surface water and ground water, will have to be combined into multimedia tools for exposure assessment. Products of this research will be critical for the Agency's land-banning and ground water programs.

Chemical-specific Health and Environmental Effects Profiles will be prepared to support RCRA 3001 listing decisions. Support will also be provided to the Agency's effort to ban land disposal of certain wastes and will include evaluation of existing Acceptable Daily Intake (ADIs) and Unit Cancer Risks (UCRs) for hundreds of chemicals to ensure that the information they contain is accurate.

Short-term in vivo and in vitro bioassays will be developed into a screening protocol for determining which wastes are hazardous. Screens for determining effects on seven human health endpoints (e.g., carcinogenicity and mutagenicity) will be evaluated. When validated, these tests will constitute a major advancement in the Agency's ability to assess the toxicity of complex mixtures of wastes.

Environmental processes research will include development of multimedia assessment models for land disposal sites; quantitative structure activity predictions of waste toxicity; and ground water models for predicting waste concentrations.

Dioxin

What assessment and control information is needed to identify and address the problems associated with dioxins?

Research supporting this objective is intended to help the Agency assess and monitor the dioxin contamination problem and begin developing procedures for addressing it. Health research and risk assessment activities will be conducted, as will transport and fate research and a quality assurance support program. Technologies which have the potential to detoxify or decontaminate materials containing dioxins and dioxin-like compounds will also be evaluated.

Waste Identification

What analytic methods are needed for identifying the chemical constituents of wastes and thereby determining which wastes are hazardous?

Additional analytical methods for implementing Section 3001 of RCRA must be standardized and tested to determine their validity and reliability. New methods and procedures for detecting the presence of hazardous wastes under field conditions are also required to help implement Section 3013 of RCRA, which authorizes EPA to establish facility monitoring requirements.

New hardware and software developments offer considerable promise for reducing the costs and time, while improving the sensitivity, of laboratory analyses. Examples of the emerging technologies are superconductive fluids, quadrupole-mass-spectrometry, and thermospray injection. Considerable effort will be directed to evaluating and applying such technologies for hazardous waste analyses. One particular thrust will be in the development of technologies for rapid screening of large numbers of samples, particularly ground water samples. A second effort will be toward obtaining more comprehensive chemical profiles of volatile and semi-volatile organic chemicals in solids and other complex matrices. Concurrent with these activities will be a continuing effort to upgrade the computer programs supporting the analytical equipment, with special attention to computer interpretations of measurements.

This program will support activities in the following areas: development of bioassays into a screening protocol for detecting hazardous waste; development of subsurface monitoring and network design protocols for detecting potential ground water contaminants; validation of published SW-846 analytical methods and development of new, more cost-effective analytical methods. These will include inductivity coupled plasma and high performance liquid chromatography.

Land Disposal

What technical information is needed to support permitting of land disposal and land treatment facilities, as well as improvements in design requirements?

Land disposal will not be a "one-time" approval process. Permits will be reissued periodically and will incorporate improvements in the state-of-

knowledge as appropriate. To ensure these improvements, research will have to be continued.

Research in this area will provide guidance on design, permitting, operation, maintenance, closure and regulation of land treatment, storage and disposal facilities. It will also address controlling air emissions from facilities and include sampling and measurement procedures, evaluation of emission models and evaluation of control technologies. Land treatment research will determine the feasibility of land treating wastes and include laboratory, bench and pilot-scale studies on soil and waste processes, degradation and loading rates.

Incineration

What technical information and data are needed to support permitting of incinerators and improvements in design requirements? Results of this research will be used by EPA and other permitting officials to evaluate the acceptability of incinerating particular wastes and in monitoring operating units for compliance with performance requirements.

As the Agency begins banning certain wastes from land disposal, various disposal alternatives to land disposal will become increasingly popular, including incineration. However, in order to issue permits for incinerators, Regional Offices and the states will require technical information and assistance regarding their performance capabilities. Ensuring the safety of their operation will require that methods be developed to predict their performance, and that their reliability be increased through control of operational parameters which avoid formation of hazardous by-products.

Research will produce performance tests on incineration of wastes burned at the Combustion Research Facility. Real-time methods of determining incinerator compliance with permits will be investigated, as will improved sampling techniques for monitoring thermal destruction operations. Guidance manuals for states, regions and industry will be produced addressing best practices for burning wastes in industrial boilers, and assessing the impacts on emissions of incineration failures.

Releases

What procedures and information are needed to prevent, contain and clean up accidental discharges of hazardous materials? This research will support both the Clean Water Act's releases section and RCRA's underground storage tank (UST) provisions.

Accidental releases of oil and hazardous material to the land and water occur frequently and constitute a significant environmental hazard. Federal, state and local emergency response personnel require improved technologies for the prevention and control of hazardous material releases to make cost-effective, environmentally sound cleanup decisions.

Chemical-specific risk assessments will be developed to support the UST program. Monitoring support will provide spill imagery and analysis.

Development and evaluation of geophysical/geochemical sensors and volatile organic emission sensors for detecting leaks of hazardous materials such as gasoline, toluene and benzene will also be conducted.

Engineering research will produce manuals on procedures for on-site treatment of wastes and evaluations of containment, removal and dispersant technologies for controlling floating spills. Evaluations of leak detection and monitoring methods will also be produced, as will guidance manuals on non-destructive techniques for locating buried tanks and on underground storage tank release prevention techniques. A continuing effort throughout this period will be the evaluation of new technologies for the prevention and cleanup of releases. Innovative new systems will be sought, and if shown to be feasible, field-evaluated.

Environmental processes research for the UST program will develop a ground water transport and fate model for predicting concentrations of materials, including gasoline in ground water. A validated bioassessment protocol for determining the bioavailability and toxicity of releases will also be developed.

Quality Assurance

What measures are needed to assure the reliability and consistency of monitoring and analytical techniques and data used in support of the RCRA program?

The purpose of this program is to ensure that data of known quality are used throughout the Hazardous Waste program. Analytical standards and reference materials will be developed for and distributed to all participating laboratories. Quality control and performance evaluation samples are also being developed and distributed to appropriate laboratories. Technical support will be provided to all participating laboratories in the form of instrument calibration assistance and provision of reference materials.

SUMMARY OF LONG-TERM TRENDS

Research to characterize the potential exposure and effects posed by hazardous wastes is likely to be an area of significant growth. In order to effectively manage risk, answer the questions and concerns of the public and make the policy choices that will have to be made, more will have to be learned regarding the behavior and health effects of hazardous materials released into the environment.

Development and evaluation of alternatives to land disposal of wastes will remain an Agency priority. Research remains in its early stages and considerably more work is needed before alternatives will be able to satisfy the disposal requirements of large scale generators. Extensive testing and performance evaluations are needed to make these technologies available and years of effort will be required. Research will also be accelerated to provide support for the land-banning program and to support RCRA underground storage tank (UST) provisions.

Increasing emphasis will also be placed on research supporting the Agency's ground water program and on identifying the problems associated with municipal waste combustors. Additional ground water research will respond to program shortfalls identified by the Science Advisory Board and the Ground Water Task Force. It will focus on determining ground water affects pollutant transport and fate and developing the monitoring technology needed to identify problems. Research addressing municipal waste combustors will begin identifying the pollutants they produce, assessing the hazards they may pose, and the monitoring and control technologies needed to address the problems.

RESOURCE OPTIONS

1986 Current Estimate Hazardous Waste, $51.8 million; Superfund, $4.6 Million.
1987 President's Budget Hazardous Waste; $50.6 Million; No Superfund Request.

Projections

	1988	1989	1990	1991
No Growth	$50.6M	$50.6M	$50.6M	$50.6M
Moderate Growth	$52.1M	$53.7M	$55.3M	$57.0M
High Growth	$53.6M	$56.9M	$60.3M	$63.9M

No Growth: The program would proceed as described in this agenda.

Moderate: Additional resources would support waste characterization activities in support of the land-banning program and risk management decisions, ground water research and municipal waste combustion research.

High: Research described under moderate growth would be accelerated and augmented.

PESTICIDES AND TOXICS

Pesticides and toxic substances research provides support to meet the current and future needs of the Toxic Substances Control Act (TSCA), the Federal Insecticide, Fungicide,and Rodenticide Act (FIFRA) and, to a limited extent, the Federal Food, Drug and Cosmetic Act (FFDCA). Research efforts are geared toward providing scientifically valid yet cost-effective evaluations of the risks associated with pesticides uses and the manufacture and use of new and existing chemicals.

The research program in support of TSCA and FIFRA will continue to develop, evaluate, and validate health and environmental test methodologies and procedures to improve the predictability of human risk estimates, develop exposure monitoring systems, environmental fate and effects methods, and develop guidelines to perform environmental risk assessments. Additional research will develop and evaluate release and control methods for new and existing chemicals, structure activity relationships as predictors of chemical fate and biological effects, and procedures for ensuring the human and environmental safety of the products of biotechnology. The contamination of ground water from pesticides will be another area of interest in the ongoing research program.

MAJOR RESEARCH ISSUES

Test Method Development

What new procedures or tests are needed to ensure that industry's data on environmental or health effects are accurate, reproducible and consistent?

Under TSCA and FIFRA, manufacturers must test chemicals and pesticides for potential hazards to the public health and environment. Consequently, research is conducted to provide guidance for performing such tests. Regulatory decisions on a chemical depend on qualitative and quantitative scientific data from industry regarding potential adverse environmental and human health effects of exposure to the chemical. Since the sensitivity, reliability, cost and time constraints of these tests vary widely, carefully screened methods are being developed and approved by the Agency. When completed, such methods will be incorporated into testing guidelines for use by industry and others who must evaluate the safety of chemicals.

Scientific assessment efforts in the test method development area will focus on research activities to improve the Agency's ability to assess exposure to and the potential health effects associated with the use of pesticides or the manufacture, production, distribution, use or disposal of chemical substances or mixtures. This research is largely targeted on data inadequacies identified in the course of scientific assessment of chemicals during regulatory analyses. These research activities involve issues critical to the assessment of exposure and various adverse effects (carcinogenicity, developmental toxicity, reproductive effects, other chronic effects, and the estimation of heritable risk at low doses).

The monitoring program will focus on chemical and biological test methods needed to assess chemical hazards to humans and the environment. Real-time and rapid screening tests are needed for environmental monitoring to rapidly determine the existence of an environmental problem. In this area, research will be conducted with enhanced laser Raman spectroscopy to develop a real-time method for identifying chemical hazards. Bioassays using in vitro tissue culture responses and monoclonal antibody techniques will also be evaluated as potential screening tools for field evaluations. Finally, human exposure methods research will focus on advances in GC/MS analyses and the development of biochemical and immunochemical markers to detect exposure to particular pollutants.

Environmental effects research will evaluate existing methods and perform field studies to determine the sensitivity of available tests and identify species for potential future test methods development. In this area, major advances will be required to relate single-species and microcosm data to actual ecosystem effects and to adequately relate observed effects on one species to probable effects on other species (comparative toxicology).

Health test methods development will focus on toxic hazards in five areas: reproduction/teratology, neurotoxicity, immunotoxicity, mutagenic or carcinogenic effects, and genetically inheritable disorders.

Structure Activity Relationships (SAR)

What information is needed on substances and their similarity of chemical structure to determine what additional testing is needed to assure the safety of humans and the environment?

To enhance the efficiency of the regulatory process for toxic substances, it is convenient to group various chemicals which share common or similar chemical characteristics rather than to deal with each individual chemical. If it can be demonstrated that chemical relationships, such as similar molecular structures and similar modes of toxic activity, form a firm scientific basis for estimating probable environmental risks, then better guidelines and techniques can be applied and regulatory actions can be completed more quickly using less resources. This approach will provide both the regulator and the regulated a standard basis for determining if a substance might be toxic and detrimental to the living organisms or their environment.

SAR is vital for reviewing and screening PMN chemicals under Section 5 of TSCA. The findings and techniques established in this research will be used to select appropriate toxicity tests, to document test results, to develop fate and effects data bases where necessary and to provide the modeling means to predict toxicity.

Environmental effects research will include data base compilation and improvement in the precision and validation of SAR for predictng toxicity and such parameters as photolysis, biodegradation and likely metabolites in multimedia matrices.

Health research will focus on development of methods using a combination of descriptors based on molecular structure to predict genetic, carcinogenic, and other toxic activities using pattern recognition, statistical and thermo-

dynamic techniques. Additionally, chemical data bases in several areas of toxicological response will be constructed, and separately related to genetic and carcinogenic effects.

Special Human Data Needs

What effects do specific chemicals have on actual populations occupationally or environmentally exposed to the chemicals?

To improve the Agency's exposure estimating capabilities, these activities will examine population groups exposed to environmental contaminants which are suspect toxicants for particular organ systems to determine if biological indicators of dose and/or effects are related to environmental levels of exposure and if they are correlated with adverse effects measured by traditional methods.

Ecology: Transport/Fate/Field Validation

What methodologies (including mathematical models) are needed to assess the fate and effects of toxic chemicals and pesticides in the environment?

To adequately evaluate the likely perturbations a pesticide or toxic chemical may cause in the environment, it is necesary to understand probable exposure concentrations/durations, movements through ecosystems, degradation rates, reservoirs, effects and residues. The agency must have available techniques which may be applied to attain this information, must be capable of interpreting findings and must have a predictive capacity to anticipate problems. Activities in this area are designed to meet these needs, to improve the criteria and standards against which industry, the users or the Agency must comply. The intent is to provide new or improved state-of-the-art techniques are fill data gaps in order to have scientifically credible and legally defensible regulatory actions.

Research will be conducted to evaluate microcosms at freshwater, estuarine/marine and terrestrial seminatural and natural field sites. Multi-species laboratory bioassays will also be validated to allow data bases to be documented and published that will predict the effects of toxic chemicals on aquatic and terrestrial vertebrates and invertebrates. System level investigations will validate multi-species and community level toxicology methods. Field tests will be conducted to assess the influence of colloidal organic matter on the uptake of chlorinated toxic chemicals by benthic organisms. Finally, field evaluations will be carried out to verify select organisms responses to sediment bound toxics found in freshwater ecosystems.

Efforts in this area will also determine the specific species and testing methods to assess the effects of toxic chemicals on terrestrial, freshwater and estuarine/marine species to provide data which can be used as surrogate information for other organisms. Evaluations will focus on comparative toxicology correlations and on validating promising correlations. Wild species testing will be emphasized to compare with previously conducted laboratory tests especially with finfish which will be used as surrogates for mammals. Terrestrial toxicology research will also be conducted to validate tests which determine the toxicity of chemicals to different strains and sources of birds.

Pesticide oriented investigations will focus on representative estuarine, freshwater and terrestrial field sites and will consider pesticide dose, exposure, effects and functional alterations at the species/population level. Non-target organisms (e.g., fishes, invertebrates, crustaceans, birds) effects will be quantified in terms of mortality, reproduction rates and resiliency. This includes residue analysis and population censusing (pre- and post-treatment) information. Through extensive field sampling, data collection and analysis and simulated exposures, field findings will be compared to lab findings. Final evaluations will be published if lab results are comparable to field results and if hazard assessment criteria are adequate. Additionally, laboratory and field studies will commence to determine the relationships among the use of pesticides and other agricultural practices, pesticide characteristics and field conditions to mitigate ground water contamination problems.

Transport and fate processes and exposure information is highly critical to the Office of Pesticides and Toxic Substances (OPTS) operations. Various laboratory tasks will contribute exposure information on such parameters as sorption kinetics in sediments, pesticide transformation, biodegradation and movement. Methodologies applied will derive rate constants and determine the extent of the reactions observed resulting in descriptive mathematical expressions and exposure concentration estimates. Mechanisms and rates of degradation by natural microbial communities will be studied. Controlling environmental conditions and processes effecting degradation will be determined and quantitative relationships between the pesticide chemical characteristics and the environmental parameters will be factored in.

Field evaluation of methods and exposure models (with emphasis on leaching models) will be conducted via laboratory and field studies including analysis of residues in soils. This includes information generation on variability of soil water releases and ground water contamination and includes model calibration and improvements to predict exposure concentrations and toxicant movement. Appropriate workshops and symposia will be convened to transfer results to users. When developed and evaluated, these models will predict the environmental impact of pesticides and toxic substances.

Health: Markers, Dosimetry, and Extrapolation

How do we relate external dose to internal dose and to early indicators of disease states and how can we better extrapolate (from high dose to low and from laboratory animal to man) to support risk assessments?

For both the pesticides and toxic substances programs, health effects research will be focused on development of methodologies for extrapolation of animal data from high to low doses and between mammalian species to enhance human health risk assessment predictability. Additional studies in the toxic substances research program involve defining the relationship between biochemical indicators of exposure to neurotoxicants and behavioral dysfunction as well as studies in dosimetry and extrapolation related to genetically mediated health effects. Additional pesticides research includes evaluating the relationship(s) of age and dermal absorption using in vivo animal models as well as research on compound-induced reproductive alterations following

exposure during developmental periods. Data generated in the toxics and pesticides areas will be used to extrapolate toxicant risks to humans.

Exposure Monitoring

What improvements are needed for the monitoring methods, systems and analysis used to provide the data bases for estimating human exposure?

The major TSCA related monitoring efforts will be directed toward improvement in monitoring systems to estimate human exposure. Research will also be continued to develop approaches for multi-media/multi-pathway monitoring systems which generate data that will provide an estimate of total human exposure. Studies will also be conducted to incorporate environmental dose into personal exposure monitors and to provide a better understanding of the contribution of the different exposure routes on pollutant intake. The relationship of network monitoring to personal exposure monitoring will be evaluated in a Human Exposure Assessment Location Project.

Biotechnology/Microbial and Biochemical Pest Control Agents

What methods and technologies are needed to assure safety to public health and the environment from microbial agents and products of biotechnology?

Many of the techniques required to adequately control or regulate microbial organisms or "biochemical" products (e.g., pheromones) apply to both TSCA and FIFRA mandates. Beyond these basic techniques, however, there is a divergence -- microbial applications under TSCA are usually industrially oriented and relate to workplace exposure or accidental releases; the microbial applications under FIFRA are an intentional dispersion to control undesirable flora or fauna. Such microbial pest control agents (MPCA's) may be "natural" selected stock or may be genetically-altered.

Users of biotechnological products must follow recommended Agency guidelines in a testing regime designed to help prevent adverse environmental impacts. ORD helps establish these techniques, determines if environmental effects are exhibited by previously untested non-target organisms and conducts field-oriented validation studies as necessary to insure that testing criteria and guidelines are appropriate and functional. Engineering research will also be conducted to develop and/or improve methods to contain or destroy genetically engineered organisms.

Under FIFRA, research will develop or improve bioassay methodologies for determining the effects of biological control agents (BCA's) on non-target receptors or hosts. This includes providing testing protocols and effects information for unaltered and genetically altered microbial BCA's. Investigations will focus on routes of exposure, methods to detect and identify agents, toxicity, infectivity, persistence and effects. The information will be used for revising subpart M guidelines and for regulatory decisions in pre- and post-registration actions.

Pesticides health research in biotechnology involves development of data on the immunologic effects of microbial pesticides on mammalian cells. Methods are also being developed using monoclonal antibodies and biotinated DNA probes

to enable the identification of genetic material from biological pesticides in non-target sites such as mammalian cells. These methods will provide the basis for validation subpart M guidelines for testing microbial pesticides.

Under TSCA, efforts will be continued to develop scientific rationales and procedures for evaluating the environmental survivability, reproduction, distribution, effects and risk associated with the escape of genetically manipulated organisms. The results will be used to prepare protocols for use in evaluating TSCA products involving environmental application of microbes. This research will also support regulatory rule-making specifying which products are to be considered under TSCA.

In the toxic substances health research area, studies will be conducted to determine the genetic stability and function of a baculovirus expression vector in vertebrate cells. Additionally, a computerized data base will be developed which compiles the known characteristics of genetically engineered biological material. This research provides information on the health consequences of deliberate or inadvertent release of genetically altered viruses.

Engineering Release and Controls

What engineering and technological information is needed to identify the release of and exposure to toxic substances and to determine alternatives for control of these substances?

Under the premanufacture notification (PMN) process, manufacturers are required to submit information to EPA on the release and control of new chemicals and significant new uses of existing chemicals. EPA uses existing data to predict the risks of and from the release of new substances, and under the existing chemicals control program, evaluates technological alternatives to reduce the release of and exposure to chemicals that are already in use.

Models will be developed which predict release of and exposure to classes of new chemicals in order to assess chemical-unit operations and processes, and the physical and chemical properties of chemical substances. Additionally, models to predict potential exposure and release levels, and the best control measures to control release of and exposure to new chemicals will be developed. Treatability testing of potentially toxic chemicals will also be conducted.

Alternatives to mitigate the release of and exposure to specific existing and new toxic substances will be defined through the evaluation and adaptation of control measures related to the release of chemicals in the workplace and into the environment. Technologies, management practices, and personal protective equipment to limit the release into the environment and exposure to those toxic substances will be evaluated.

Under the Federal Insecticide, Fungicide, and Rodenticide Act, EPA is responsible for pesticide exposure studies, for reviewing and approving pesticide labels, for administration of the pesticide Farm Safety Program, and for supporting training and education programs for pesticide users through state extension services. The Agency is concerned that protective clothing currently recommended for use by pesticide users is not providing acceptable protection. This situation is aggravated by a lack of appropriate data. In order to improve the situation, EPA requires greatly improved documentation

regarding the effectiveness of protective clothing. This program will focus on generating breakthrough time and steady-state permeation rate data for concentrated formulations of high toxicity pesticides through a range of commonly available polymer gloves that may be suitable for use by mixers and loaders of pesticides. Evaluations of the job compatibility and degree of protection provided by clothing items other than gloves will also be conducted via laboratory and field testing.

Ecology: Ecotoxicity and Risk Assessment

What methods are needed to evaluate ecosystem risk as a result of exposure to existing and new chemicals?

In the past, the emphasis of ORD's scientific assessment program has been placed on the assessment of risk to human populations. However, there is also a need to assess the risk to non-human populations and the environment. The development of ecological risk assessment protocols and guidance for terrestrial and aquatic ecosystems (primarily endangered species and commercial fisheries) is necessary to quantify the probability that adverse effects may occur as a result of exposure to a toxic substance and to estimate the significance of such effects in the environment. Since environmental data developed by industry may vary greatly from chemical to chemical, procedures need to be developed which provide guidance and consistency for the various environmental exposure activities. This work will provide risk assessment protocols and guidelines for the assessment of effects to terrestrial and aquatic ecosystems.

Ecosystem risk research will provide a scientifically based system to assess ecological risks from exposure to environmental toxicants. This system will provide the capability to assess risks associated with different uses of chemicals resulting from various options for regulating pesticides and toxic chemicals to protect organisms in their natural environment. This research will provide for prognostic assessment, extrapolations to any patterns and levels of environmental release, inferences of types of responses to be expected in natural systems, and estimates of uncertainties in the assessments.

Finally, it will integrate chemical fate, exposure, and effects to provide the capability to conduct risk assessment for terrestrial and aquatic systems. Major program components will include development of a computerized framework linking all components to provide the capability to carry out appropriate analyses and obtain results in any desired form. It also will include data bases of scenarios such as river reaches, endangered species habitats, chemical properties, and properties of organisms including geographical range and habitat preferences. Such activities will utilize and develop traditional analysis techniques and models that calculate bioconcentration and effects for populations, communities and ecosystems and provide quantitative and qualitative probability statements of uncertainties involved in the assessments.

Support

What support is required for preparation and review of scientific assessments and for quality assurance?

For certain assessments the technical expertise of the ORD staff is required to conduct literature searches, interpret data or render technical and scientific judgments because of the lack of data. In cases where program office evaluations are complicated and/or controversial, independent peer review of assessments are required to ensure consistency. There is a continuing need for ORD participation in and review of major exposure and hazard assessments conducted by OPTS for supplying Agency policy makers with technical assistance from qualified scientists and for improving the scientific basis of Agency decisions in regulatory matters.

When requested, ORD will provide critical review of test rule documents for existing chemicals and screening of selected new chemicals under Section 5 premanufacture notifications. Such activities will support validation of toxicity tests, assist with exposure and risk assessments, and preparation and update of TSCA testing guidelines. This support will also encompass evaluation of complex problems associated with environmental fate, hazards and risks of toxic chemicals and bioengineered organisms as necessary for implementing TSCA.

Finally, in both the pesticides and toxics areas, support will continue for quality assurance and maintenance and dissemination of standard reference materials.

SUMMARY OF LONG-TERM TRENDS

Pesticides and toxic substances research efforts focus on both intentional and unintentional releases of chemical substances into the environment. Each of the issues covered in this chapter will continue into the next decade. Various degrees of emphasis are addressed below:

Test method development efforts will continue in support of both TSCA and FIFRA guidelines. As current methodologies are standardized, new techniques will be developed to fill gaps in existing methods. These new methods will focus mainly on endpoints other than carcinogenicity, and will provide more effective means to conduct quantitative risk assessments. To this end, efforts will increase for developing extrapolation techniques (from high to low doses and from animals to humans) for reducing the uncertainty of laboratory data used in predicting human risk. The development of biological markers will also assist in this area by providing more accurate measures of human exposure levels as well as serving as tools for epidemiological studies. Concurrently, the development of exposure monitoring systems will increase to provide new monitoring methods, systems and analyses.

Ecological hazard assessment research will continue to develop hazard assessment methods for determining the fate and effects of chemicals while effects and exposure methods will provide the means to evaluate risk. The integration of such methods and data will provide the means to develop protocols for environmental risk assessments. Such definitive techniques will be an ongoing, long-term process.

Research to provide information on the release and control of new and existing chemicals from manufacturing processes will allow the rapid and

accurate prediction of how much and where chemicals will be released into the environment, and with increasing accuracy, an estimation of their environmental effects. Such information is vital to the PMN review process and it is anticipated that the need for such data will continue to increase as the manufacture of new chemicals continues to grow.

EPA will provide methods to protect public health and the environment from the potential adverse impacts of microbial agents and the products of biotechnology. This research will help to determine containment facilities for bioengineered organisms and means of monitoring the survival and distribution of those intended for release.

The structure-activity research program will continue as the methods for predicting fate and effects of parents and degradation compounds become available, and the need for field validation efforts will increase to ensure the reliability of methods used to test chemicals.

RESOURCE OPTIONS

1986 Current Estimate 46.7M
1987 President's Budget 45.6M

Projections

	FY 1988	FY 1989	FY 1990	FY 1991
No Growth	$ 45.6M	$ 45.6M	$ 45.6M	$ 45.6M
Moderate Growth	$ 46.9M	$ 48.3M	$ 49.7M	$ 52.1M
High Growth	$ 48.3M	$ 51.2M	$ 54.3M	$ 57.6M

No Growth: The base program would proceed as described above. Established priorities would continue to guide the research. In general these priorities are: biotechnology research, SAR, risk assessment and field validation studies including transport and fate.

Moderate: The same level of effort would be maintained for TSCA research; increased resources would enhance and expand field validation studies.

High: With a high level of resources, the studies on ground water contamination would be increased. This is a problem of growing concern caused by both toxic substances and pesticides.

INTERDISCIPLINARY

The interdisciplinary research program develops risk assessment guidelines and ensures consistent application of these guidelines throughout the Agency. Activities in this area also support the dissemination of scientific and technical data from the Office of Research and Development (ORD). Finally, the interdisciplinary research program provides resources to conduct long-range exploratory research through the grants, centers and visiting scientists programs and provide central management, audits and compliance monitoring for the Agency-wide Quality Assurance program.

MAJOR RESEARCH ISSUES

Scientific Assessments

What activities and methods are needed to ensure scientific consistency and technical quality in Agency risk assessments?

The scientific assessment function has three major components: development of risk assessment guidelines, activities of the Risk Assessment Forum, and development of generic test methods which support the risk assessment process. The first guidelines were proposed in late 1984 and early 1985, and should be final in 1986. These include guidelines for: carcinogenicity risk assessment, mutagenicity risk assessment, health assessment of suspect developmental toxicants, health risk assessments of chemical mixtures and estimating exposures. In 1987 and 1988, the Agency expects to propose guidelines for assessing risk to the male and female reproductive systems and guidelines on the use of exposure measurements in risk assessment; final guidelines should be issued about a year later. The Agency is planning to develop guidelines for the assessment of systemic toxicants and for the assessment of ecological risk over the next several years. The Agency recognizes that guidelines are living documents, and therefore are subject to revisions and expansions, an effort which will take place in future years as appropriate.

The Risk Assessment Forum was established in 1984. It is a body of senior scientists within the Agency who meet regularly to resolve various scientific issues within the Agency. Its functions include: analyses of significant scientific and science policy issues, development of new risk assessment procedures, recommendations of revisions to the guidelines when appropriate, review of selected risk assessments nominated by top Agency management, and recommendations for risk assessment research. The Forum's first report was issued in late 1984. A Cancer Risk Assessment Research Needs Workshop will be held in 1986 under the auspices of the Forum. Implementation of the recommendations and priorities for research coming out of that workshop will begin in 1987.

Development of the generic test methods is also under the auspices of this research committee. These activities identify generic information gaps which will be filled in future risk assessments if the appropriate test methods are developed.

Technical Information and Liaison

What activities facilitate technology transfer to regions, states, and affected local governments?

ORD, as the primary research arm of the Environmental Protection Agency, provides scientific information needed by the regulatory offices of EPA to develop and enforce regulations. Appropriate and timely dissemination of research results supports the scientific basis for EPA regulations and increases confidence in the decision making process.

The Center for Environmental Research Information (CERI) provides centralized support for the production of information products in a cost-effective manner, insures consistent uniform dissemination of research results, and provides a technology transfer program to synthesize information and develop presentations to more effectively support specific high-priority program objectives at the lowest cost to the government.

CERI will continue to provide support to ORD laboratories by writing summaries of research projects conducted by or for ORD, editing documents and summaries, assuring the quality of material submitted for printing, typesetting and producing documents, assuring the quality of and preparing documents for submission to the National Technical Information Service, controlling the distribution of documents, and responding to requests for publications and documents.

The technology transfer program will assess the status of research and regulations, discuss with the Research Committees their priorities for the dissemination of material, develop innovative information transfer mechanisms, and ensure that information on improved technology and management practices is distributed to appropriate audiences to comply with EPA regulations. All information on products is developed using a team of participants from ORD, EPA program offices, and private industry.

Planned activities include:

- development of methods manuals for comparing different solid and hazardous waste treatment techniques and implementing those which are appropriate;
- dissemination of the results of research on the control of hazardous air pollutants;
- for small drinking water systems, description of technologies, costs and operating effectiveness of the methods available to meet drinking water regulations; and,
- dissemination of information on the effectiveness, cost, and design of new municipal waste treatment technology.

EXPLORATORY RESEARCH PROGRAM

How will the Agency conduct longer-range mission-oriented research which is not tied to specific regulatory timetables or program office requirements?

Recognizing the need for a more fundamental understanding of potential or emerging environmental problems, ORD established the Office of Exploratory Research (OER) in 1980. OER's basic function was to establish and manage a program of investigator-initiated, long-range research through grants to qualified investigators and to establish and administer a program of environmental research centers. In addition, OER was responsible for operating a system of peer review for competitively selecting and awarding research projects. To date, through its Research Grants Program, OER has supported over 400 research projects in various priority areas as identified by the Agency's planning mechanisms and ORD's Research Committee process and, through its Research Centers Program, supports research conducted at eight university-based research centers on various topics of priority concern.

RESEARCH GRANTS PROGRAM

A primary function of the Research Grants Program is to stimulate extramural scientists to work on EPA's technical problems and to provide a stronger creative base of mission-oriented research needed for the Agency's regulatory and enforcement efforts.

The Research Grants Program solicits investigator-initiated proposals by issuing annually a solicitation document which describes EPA's high priority long-term research needs. The solicitation is broadly distributed and is intended to stimulate scientists in the academic, research and industrial communities to respond with fully developed proposals for innovative research in areas of interest to EPA. Although all valid proposals are considered, the solicitation has typically emphasized research needs in five interdisciplinary program areas: environmental health; environmental biology; environmental engineering; chemistry and physics in air; and chemistry and physics in soils and water. In the future, the emphasis may change to include an emphasis on ORD's major research initiatives.

The grants selection process uses a dual review system of evaluating research proposals. Ad hoc panels, chaired by scientists or engineers from outside EPA, meet at least twice annually to discuss reviews of each proposal conducted by at least three experts in the relevant field. Applications that pass the scientific panel review are then reviewed by Agency personnel for their relevancy to the Agency's mission. The combined recommendations are rank-ordered and the grants are awarded based upon the availability of funds.

Grant support is typically awarded for two to three years and an EPA staff member is assigned as a project officer. Project monitoring is accomplished by the submission of technical progress reports and/or the publication of scientific papers in peer reviewed journals. Staff and formal site visits are conducted when appropriate.

The five interdisciplinary areas of the Research Grants Program are described below.

Environmental Health Research Program

The major objective of the Environmental Health Research Program is to obtain and provide a scientific basis upon which the Agency can make regulatory decisions concerning the protection of human health from environmental pollutants. The principle concern is to determine whether, and to what extent, exposure to various pollutants contributes to environmentally related health problems. Particular attention in the annual solicitation is on epidemiological studies, animal toxicology, bioassay development and mechanisms of action. Major areas of new emphasis will deal with understanding the mechanisms of inducement of disease and pathology, improving the validity of assays as predictors of potential human risks, and developing better model systems to determine the long-term effects of multi-media pollutant exposure.

Environmental Biology Research Program

The Environmental Biology Research Program supports a broad range of projects in the areas of ecosystem effects, aquatic ecosystem modeling, biotechnology monitoring, environmental assessment, marine studies and biodegradation in water and soil environments. The aim of the program is to provide a base of scientific knowledge which can be used to identify new and emerging problems and to develop appropriate remedies for their solution. One objective of this program is to provide information that, in combination with exposure data, allows the prediction of the environmental risk of pollution on individual organisms and on ecosystems. The risks include the reduction of productivity in agricultural areas, wetlands, and freshwater and coastal marine ecosystems as well as human exposure to toxic substances through accumulation in the food chain.

During the next five years, emphasis will focus on wetland problems and the development of modeling methods for predicting the ecosystem effects on wetlands. Another area of focus will be the development of methods for monitoring genetically modified organisms in the natural environment.

Environmental Chemistry and Physics/Water

The Environmental Chemistry and Physics of Water Program supports research leading to the basic scientific tools for establishing the levels at which pollutants occur or might occur in the environment under different conditions. The program includes projects in analytical chemistry, studies on chemical reactions and their rates and on the physics of the movement of pollutants in the water and soil. The resulting tools and information allow the estimation of exposure levels needed for risk assessment. The research also provides possible approaches to the treatment of waste sources. It includes small-scale laboratory studies and large-scale field projects relating to the transport and transformation of pollutants.

This program will emphasize problems related to ground water, sediments and measurement methods. For ground water the emphasis will be on developing

the techniques for estimating the parameters used in transport models and in validating the models. In the case of sediments, focus will be on the physics of movement and the capability of sediments to transport pollutants, particularly, heavy metals. Research on measurement methods will continue with some emphasis on methods applicable to sediments and associated substances such as humic materials.

Environmental Chemistry and Physics/Air

The Environmental Chemistry and Physics of Air Program is concerned with the study of the sources, transport, transformation and fate of air pollutants. The program reviews applications dealing with studies on time-space patterns of pollutant concentrations, detailed chemical and physical descriptions of pollutants, mathematical models connecting air pollutants with probable sources, and procedures for investigating the impact of pollutants on human health. The program draws upon the concepts and procedures of physics, chemistry and meteorology using models and measurement methods to develop quantitative description of these phenomena.

This program will emphasize models or other means of connecting air pollutants at a location with the contributing sources, the atmospheric chemistry of polyaromatic hydrocarbons (important toxic compounds) and reliable measurement techniques for the particulates of health significance.

Environmental Engineering Research Program

The Environmental Engineering Research Program supports the more basic or fundamental research needed to provide solutions to multi-media pollution control problems outside the scope of the Agency's response-directed research program. Therefore new, innovative pollution control and waste management techniques are sought to provide cost-effective solutions to complex problems involving air, water, and soils. Areas emphasized include water disinfection, wastewater treatment, water-related process biomonitoring methods, residuals control, and air pollution concerning volatile organic compounds, fine particles, SO_x, and NO_x. Hazardous wastes continue to receive particular attention, especially incineration processes and improved clean-up techniques.

ENVIRONMENTAL RESEARCH CENTERS PROGRAM

As part of EPA's strategy for approaching long-term research needs, ORD has created the Environmental Research Centers Program to support environmental research in science and engineering. The objective of the program is to support high-quality exploratory research in areas of importance to EPA. It is achieved by providing stable funding for extended periods of time to institutions with a demonstrated capability and interest in establishing and maintaining a long-term effort in a major area of research of concern to EPA. The program, which was established in 1980, consists of eight university-based environmental research centers (ERC's), working in four general areas: (1) industrial and municipal waste abatement and control, (2) pollutant transport and transformation, (3) ecological and biological effects of pollutants, and (4) environmental epidemiology. Each broad area of research is discussed below.

Industrial and Municipal Waste Abatement and Control

Three centers conduct research in this area. The Industrial Waste Elimination Research Center (IWERC) focuses its attention on reducing or eliminating the creation of pollutants. Two centers, the Advanced Environmental Control Technology Research Center (AECTRC) and the Hazardous Waste Research Center (HWRC), study the removal of wastes once they are formed. The AECTRC works primarily on the removal of contaminants from dilute waste streams, such as sewage discharges and stack effluents, while the HWRC studies methods to stabilize, detoxify or destroy waste products containing high concentrations of hazardous pollutants.

The principal areas of research at IWERC, listed in order of current priority, are: (1) metals speciation and separation, (2) sorption/desorption phenomena, (3) particle size and shape control, and (4) process catalysis and control. This priority list is not expected to change significantly, though more emphasis will be placed in the future on process and catalysis control, and on particle size and shape control.

AECTRC has investigated the degradation of low concentrations of organic contaminants in drinking water sources using biofilm systems. This work is expected to expand in the future, as is work on the supercritical extraction of pollutants. Current work on wet air regeneration of powdered activated carbon will be deemphasized. In the area of air pollution, AECTRC will increase efforts on studying the simultaneous collection of submicron aerosol particles, sulfur dioxide and oxides of nitrogen. With respect to the indoor radon problem, a systematic study will be made of the adsorption of radon on charcoal as a function of charcoal type, design parameters of the collection system, and interference from other gaseous species.

The HWRC will continue to emphasize the destruction, separation, and stabilization of hazardous waste constituents, particularly the development of optimal design parameters for complete or nearly complete incineration of combustible organic hazardous wastes. Future research will focus on: (1) a long-term research project on the operation and modeling of a full-scale industrial incinerator, (2) in-situ biodegradation of targeted environmental toxins in soil, (3) investigations of the feasibility of rotary kilns as low energy thermal desorbers for soil and solid waste contaminated with organics, and (4) the transport mechanisms involving pure organic phases in the unsaturated and saturated zones below spill and dump sites.

Pollutant Transport

Two centers study the movement and alteration of pollutants in the environment.

The National Center for Ground Water Research (NCGWR), devotes itself to understanding the movement and alteration of pollutants through the subsurface environment. Directly or indirectly, ground water is the major source of the nation's drinking water, but it may be contaminated with pollutants from a wide variety of sources. Efforts to mitigate this contamination are complicated by the extremely slow movement of pollutants underground.

In the next five years, the NCGWR will emphasize studies on subsurface biodegradation and on facilitated transport of trace organic compounds in saturated aquifers. Future studies will deal with microbial metabolism as a process involved in the fate of contaminants. The comparative ecology of aerobic microbes as influenced by subsurface parameters such as soil type and electron acceptors will be studied in order to predict and control microbial involvement in the fate of contaminants at hazardous waste disposal sites. Current work on subsurface anaerobic environments will be expanded to include isolation of chemical intermediates and end products. Another new project will be initiated, using state-of-the-art optical techniques, to determine whether sorption of contaminants is dominated by organic carbon or mineral surfaces.

The other center, the National Center for Intermedia Transport Research (NCITR), studies the important physical and chemical processes associated with the transport of particulate or gaseous environmental pollutants from one medium to another. Current and future studies at NCITR will emphasize the movement of hazardous wastes through air, land, or water.

Specific projects at the NCITR will concentrate on five topics: wet and dry deposition, soil and water processes, multimedia transport, ecosystem modeling and structural characterization, and source allocation. Plans for research include development of an improved correlation between dry deposition velocity and the roughness layer, determination of the ambient compositions and concentrations of organic pollutants in rain, fog and dew, studies on the chemisorption of halocarbons by clay, and the mitigation of organic pollutants in the unsaturated soil zone. In addition, NCITR will maintain current levels of research on studies to determine the significance of nitrogen-bearing trace compounds in air to nitrogen levels in desert ecosystems, the transfer rate of submicron aerosols to vegetation, and the effects of vegetation on the transfer of atmospheric pollutants.

Ecological and Biological Effects

Research on ecological and biological effects is conducted at two centers: the Ecosystems Research Center (ERC) and the Marine Sciences Research Center (MSRC). The mission of the ERC is to evaluate the state of knowledge on whole biological communities and ecosystems and to investigate its applicability to environmental regulation and management. Research conducted at ERC has been in the areas of ecotoxicity, biotechnology, air pollution effects on forests, plant-pest interactions, and impact assessment for the Hudson River system. The ERC plans to continue its research in all of these areas except research on the Hudson River system which will be phased down. ERC will also develop projects in two additional areas. The first of these, functional classification of ecosystems, has as its eventual goal to classify ecosystems into functional types, both in terms of the natural rates at which processes occur and in terms of their responses to anthropogenic disturbances. The other new area of research will be freshwater wetland ecosystems. The purpose of this project is to develop concepts and methods for simplifying assessment of the effects of human-induced changes in hydrology on northern freshwater wetlands.

The objective of research at the MSRC is to increase understanding of processes in coastal marine ecosystems that are of importance in evaluating the effects of pollutant discharges. The primary approach to research at MSRC is experimental, specifically, the use of mesocosms as models for predicting the responses of biological communities in coastal systems to pollutant loadings, and to determine the fates of pollutants. Such mesocosms fill a gap between laboratory experiments and field observations.

A major shift in research emphasis at MSRC is occurring. Previous studies emphasized the determination of the fates and biological effects of sewage sludge, fuel oil and specific hydrocarbons. These studies were "passive" in the sense that they described impacts of pollutants on coastal systems. In the future, more emphasis will be placed on studies whose objective is to recommend methods for control of unsightly, odorous coastal waters, rather than simply predict the occurrences of such events. As a start, MSRC has initiated a program to determine the efficacy of silica enhancement of ocean outfalls to control the explosive growths of phytoplankton (e.g. red tide) often associated with mephitic waters. Another major effort will be a field program to evaluate the state of Narragansett Bay with respect to a number of environmental features related to pollution or other anthropogenic effects. This effort is being carried out in cooperation with other studies of pollutant inputs, shellfish health, bacterial contamination, hydrodynamic modeling, etc., in association with the Narragansett Bay Project, also supported by EPA.

Environmental Epidemiology

The area of environmental epidemiology is addressed by one center, the Center for Environmental Epidemiology (CEE). Its primary objective is to improve the theoretical understanding of the human health risks associated with environmental pollution. The center has established four research priorities: (1) problem definition and feasibility assessments for epidemiology studies, (2) research to develop and improve epidemiological methods related to environmental health, for example, research on statistical and analytical methods, (3) research on exposure assessment relevant to epidemiological investigations, and (4) research support to EPA including review of data and reports, and identification of problems where epidemiology can support EPA's mission. These priorities will be maintained in future work.

Emphasis will be given to indoor air contamination, where research will focus on inhalation exposures to volatile constituents from water used for purposes other than drinking. A project relating to volatile constituents from shower water will be completed and a new study initiated to determine the source, strengths and dissemination of indoor volatile and gaseous constituents from water and other materials. Plans will be made to extend this project to measurements of organics in exhaled air of humans in homes where environmental exposures have been well characterized. This research will be a joint project between the University of Pittsburgh and Carnegie-Mellon University.

Efforts will be directed toward better characterization of environmental contamination. Work will be carried out on the development of a passive

sampler which has optimal properties for the routine monitoring of airborne vapors at very low concentrations such as are found in the general environment.

Some preliminary investigations will also be made in an area new to the center. This area is characterization of heterotrophic bacteria in air and water and the identification of pathogens. Work here will be exploratory and will be closely coordinated with work being conducted elsewhere in EPA. There is some evidence that these bacteria are important in human respiratory disease.

Quality Assurance

How does the Agency assure that its environmental data collection is of high quality?

A significant portion of EPA's budget is spent on collecting environmental data. Quality assurance (QA) activities play an integral role in the planning and implementation of environmental data collection efforts and in the evaluation of the resulting data. Quality assurance is the process of assessing whether the data provided by data collectors to line managers is of the quality needed and claimed. Quality assurance should not be confused with quality control (QC); QC includes those activities required during data collection to produce the data quality desired and to document the quality of the collected data (e.g., sample spikes and blanks).

The Quality Assurance Management Staff (QAMS) is charged with overseeing the quality assurance activities of the Agency. QAMS came into being in May 1979, when the Agency recognized the need for formalizing an Agency-wide quality assurance program for all environmental data collection activities. More recently, with the issuance of EPA Order 5360.1 in April 1984, the Agency's quality assurance program has been significantly strengthened and broadened. The Order mandates that QA be an integral part of all environmental data collection activities, from planning through implementation and review.

In recent years, the Agency's QA activities have focused on identifying the basic elements that are essential to effective quality assurance for environmental data. QAMS has put considerable effort into issuing guidance defining and analyzing these key elements. The long range outlook for the QA program is a transition from the guidance phase to implementation. During the next several years, QAMS will support all EPA environmental data collection programs in pursuit of the following priorities: 1) quality assurance program plans, 2) data quality objectives, 3) management systems audits and audits of data quality, and 4) documentation of routinely used measurement methods.

SUMMARY OF LONG-TERM TRENDS

The scientific assessment activity has three components: risk assessment guidelines, the Risk Assessment Forum, and development of methods for risk assessment. The end of FY 1986, the first round of risk assessment guidelines should be in place and work on longer term issues well underway. These include

development of guidelines for: health assessment of suspect reproductive toxicants, health risk assessment of systemic toxicants, and using data measurements for estimating exposures. The Agency has stated its commitment to continual review of all the guidelines and updating of them as new theories of toxicology or new risk assessment methods become accepted.

The Risk Assessment Forum meets regularly to resolve scientific disputes and recommend new science policies for Agency use. Though many of its analyses are short-term, its work includes longer-term analyses such as development of better methods for low-dose extrapolation in carcinogen risk assessment.

Technology transfer is a continuing responsibility. In response to requests from the EPA program offices and the needs expressed by the regions and the states, ORD disseminates the available technology and technical data to states and localities to enable them to meet their regulatory responisibilities. Technology transfer activities will include the design, production, quality control, and distribution of materials such as design manuals, user's guides, handbooks, and workshops.

The long-term goals of the research grants and centers program are to stimulate investigation of emerging environmental problems and identify steps which can predict their occurrence, address long-term exploratory research needs of importance to EPA's mission that require multi-media and multi-disciplinary approaches, extend the capabilities of EPA's laboratories, and establish links between EPA and the scientific and technical communities.

Among the areas which will be emphasized in the grants program during the next five years are modeling of wetlands ecosystem effects, the capability of sediments to transport heavy metals, and incineration processes for hazardous wastes. In the centers program, the trend will be to increase research on hazardous waste removal and control, modeling of marine ecosystems, and control of indoor radon.

The long-range outlook for the QA program is a transition from the guidance phase to implementation. During the next several years, QAMS will support all EPA environmental data collection programs in pursuit of the following priorities: 1) quality assurance program plans, 2) data quality objectives, 3) management systems audits and audits of data quality, and 4) documentation of routinely used measurement methods.

RESOURCE OPTIONS

1986 Current Estimate $24.6 Million
1987 President's Budget $19.4 Million

Projections

	1988	1989	1990	1991
No Growth	$19.4M	$19.4M	$19.4M	$19.4M
Moderate Growth	$20.0M	$20.6M	$21.2M	$21.8M
High Growth	$20.6M	$21.8M	$23.1M	$24.5M

No Growth: The program would proceed as described in this Research Outlook.

Moderate Growth: Additional development of new risk assessment methods would be sponsored. Also, solid and hazardous waste technology transfer would be expanded. Additional seminars and manuals would be developed to provide regional and state regulatory enforcement personnel with information on protection of drinking water supplies from ground water contamination and pollutant leaching from surface impoundments. In addition, the process for developing and implementing Audits of Data Quality would be accelerated.

High Growth: Risk assessment support would be provided to offices not normally part of the Research Committee process, for instance, the Office of Policy, Planning, and Evaluation. In addition, a major effort to expand and computerize the data base for routinely used measurement methods would make it more useful and accessible to all Agency users.

MULTIMEDIA ENERGY

The multimedia energy research and development program is designed to provide the scientific and technical information necessary to support the Agency's permit-issuing and standard-setting processes, and to allow for the development and utilization of energy sources in an environmentally acceptable manner. Research will be conducted to expand our knowledge of the phenomenon of acid deposition and provide information upon which mitigation decisions may be made; provide data on the performance, reliability, and cost of the limestone injection multistage burner (LIMB) control technology, and characterize and evaluate synthetic fuels discharges.

Acid deposition research is coordinated through the National Acid Precipitation Assessment Program (NAPAP), which is administered by the Interagency Task Force on Acid Precipitation. EPA is one of three joint chairs of the Interagency Task Force. The term "acid rain" is used to refer to the atmospheric deposition of acidic or acid-forming compounds in either their dry or wet form. These compounds exist in the atmosphere as gases or aerosol particles containing sulfur oxides (SO_x), nitrogen oxides (NO_x), hydrogen chloride, sulfuric acid, nitric acid and certain sulfate and nitrate compounds. While there is general scientific agreement that these compounds are responsible for varying degrees of acid deposition, many questions remain about the causes, effects, and methods of mitigating or controlling acid deposition. The objectives of acid deposition research are to develop the necessary data to fully understand the sources and characteristics of acid deposition; and to determine the extent of current damage or potential damage. This information is essential to the development of effective corrective strategies.

Another major research area is the promotion of innovative cost-effective pollution control technologies relating to energy production. A promising area is the development of the "limestone injection multistage burner" (LIMB) emission-reduction technology. The LIMB combines SO_x control with simultaneous NO_x control by using a mixture of pulverized coal and limestone in a low-NO_x burner. This technology may substantially lower the capital cost of SO_x control.

To be accepted as a possible acid rain emission control technology alternative, LIMB has to be demonstrated by the end of this decade. The EPA-sponsored cooperative test programs with industry and the State of Ohio on a 105 Megawatt (Mw) wall-fired boiler will be completed in 1989.

The third research area is the development and evaluation of data on synthetic fuel processes, including the characterization of discharges, and the assessment of emission-reduction technologies for mitigating these impacts. These synfuel studies reflect research associated with projects sponsored by the U.S. Synthetic Fuels Corporation (SFC). Since the SFC has been eliminated in FY 1986, EPA's funding of research in this area will be phased out. However, EPA will continue to participate in the Environmental Monitoring Review Committees for the four SFC project sponsors. That program will be administered by the Treasury Department and, by law, EPA will be a member of the Advisory Committee to the Secretary of the Treasury for the synfuels program.

MAJOR RESEARCH ISSUES

Emissions Inventories of Acid Precursors

How can emissions inventories be made more responsive to acid rain modeling and assessment needs?

Estimates of current emission rates (aggregated at the national level) are reasonably accurate for major categories of man-made acid deposition precursors. However, atmospheric transport models under development will require improvements in spatial and temporal resolution of emissions estimates to be consistent with the detailed atmospheric chemistry components of these models.

Carefully validated emissions inventories for individual states will be necessary for future implementation of any additional emissions control strategies. Depending upon the form that future emissions controls may take, a more refined definition of the relevant emissions from each affected state would be required for a specified baseline year.

Greater uncertainties exist in projecting future emissions, the effect of possible emissions-control requirements, and their probable costs. The mix of emissions sources in any specific region may also change with time. Efforts to project future emissions rates and to estimate the cost of alternative emissions-control strategies are dependent upon the development or improvement of models which replicate the behavior of each important "emitting sector" of the economy. Improved models will reduce controversy over the cost of any specified emissions control strategy. These cost estimates must be consistent with methods which have been fully reviewed by the engineering and economic communities. Future estimates of emissions will rely more on actual data and detailed emissions models.

Atmospheric Processes Affecting Acid Deposition

How can the transport, chemical transformation, deposition processes and the exposure of ecologically sensitive areas and man-made materials be determined?

The transport, chemical transformation, and deposition processes associated with acid deposition must be investigated on both the regional and local scales. These processes and the resultant source/receptor relationships require better definition so that reliable estimates of the impacts of given sources or control strategies can be made.

Our understanding of the atmospheric transport, physical and chemical transformation, and deposition processes of pollutants emitted into the atmosphere continues to improve. The program continues to emphasize model development, the collection of field data, and model evaluation to better differentiate the contribution of local versus distant sources of acid deposition. Results from this research will enable policy makers to predict changes in deposition levels resulting from reductions in nearby or distant emissions.

The Regional Acid Deposition Model (RADM) is an assembly of model components (modules or submodels) designed to simulate transport, dispersion, chemical transformation, precipitation scavenging and dry deposition. These modules will be updated and revised as the uncertainties in the processes become better understood and characterized. Field study data will be generated to improve our scientific confidence in the Regional Acid Deposition Model (RADM). RADM will be used in a number of important areas (e.g., to calibrate Lagrangian models, to develop control strategies, to perform source-receptor analysis, and to assess materials damage).

Dry-Acid Deposition Monitoring

What is the best method to obtain dry deposition monitoring data comparable to that from the existing National Trends Network (NTN) which concentrates on wet deposition?

The acid rain research program has been compiling several years of nationwide deposition data from wet precipitation. It is well known, however, that dry sources of acid deposition in the form of dust and humidity constitute a potentially significant component of total deposition. Very little data exist on this dry deposition due to the difficulty in developing and deploying accurate monitoring instruments. Also, dry deposition rates vary with surface cover and topography, as well as with environmental variables such as wind speed and humidity. As a result, the actual contribution of dry deposition in most areas is only estimated within an order of magnitude.

Prototype monitors do not measure dry deposition fluxes directly. Instead, they measure ambient air concentrations and use empirical factors to estimate the dry deposition rate. These monitors are being deployed in a network, in many cases co-located with wet deposition collectors. Samples are to be collected and analyzed in a central laboratory. The first several years will be dedicated to installing the network and making it fully operational. Once this is accomplished the research emphasis will shift to developing direct methods of measuring the dry deposition rate.

Aquatic Effects of Acid Deposition

What future changes in surface water chemistry will occur assuming current levels of acid deposition remain constant, and what is the extent and rate-of-change to aquatic resources stemming from acid deposition?

The most pronounced effects of acidification are in sensitive aquatic systems. Acidic deposition is believed to be a major contributing factor in episodic depressions of pH resulting, in some cases, in fish kills and other biological disturbances. Historical assessments have been uneven and of limited utility due to variations in sampling and analytical methodologies, potentially biased selection of samples, variable effects among different aquatic systems and a relatively inadequate data base. The scientific uncertainties surrounding the aquatic effects of acidic deposition fall into several major categories: the extent of sensitive or acidic surface waters in the U.S.; the detection of long-term trends in surface water chemistry; modeling changes in surface water chemistry; and the biological effects

associated with surface water chemistry; and the biological effects associated with surface water acidification. These uncertainties can be expressed in terms of extent, rate, and magnitude of change attributable to acidic deposition.

National Surface Water Survey: To reduce the uncertainties related to the aquatic effects of acidic deposition, the EPA, in cooperation with the NAPAP Aquatic Effects Task Group, has undertaken a National Surface Water Survey (NSWS). The NSWS is a field project with three distinct phases to document the chemical and biological status of lakes and streams in regions potentially sensitive to acidic deposition. The Survey also will select regionally representative surface waters based on chemical, physical, and biological parameters to quantify future changes in aquatic resources through a long-term monitoring program.

The first phase of the NSWS has quantified the chemistry of lakes and streams in areas believed to contain the majority of low-alkalinity waters. This phase of the survey was designed to determine what percentage of lakes and streams in the susceptible regions are acidic or have low alkalinity. Phase II is quantifying the biological components and the seasonal and spatial variability of a regionally representative subset of lakes and streams. These data should explain what percentage of lakes are devoid of fish, what chemical characteristics of surface waters are associated with the presence or absence of fish and what temporal variability can be expected in representative surface waters. The third phase will define selected lakes and streams as regionally representative sites for a long-term monitoring program to quantify future changes in the chemistry and biology of aquatic ecosystems. The primary objective of this phase is to determine what chemical or biological changes are occurring in regionally representative surface waters and at what rate.

Long-Term Trends: The detection of long-term trends in surface water chemistry is essential in understanding the response rates of natural systems to acidic inputs from the atmosphere and how fast natural systems might acidify due to natural causes. EPA's long-term monitoring sites are placed in areas in which there is little or no disturbance from human activities and which are remote from point sources of air pollution. However, their regional representativeness has not been established. The National Surface Water Survey will determine the criteria for regional representativeness and, in coordination with existing monitoring sites, will improve tracking of the responses of surface waters to changes in acidic inputs in various regions of the country.

Surface Water Chemistry Models: One of the most important goals of the aquatic effects program is the production of reliable models of the temporal changes in surface water chemistry due to acidic inputs. These models must be closely coordinated with the research in the terrestrial effects program which is responsible for most of the watershed-level and soil processes work. A major priority in the modeling of surface water chemistry will be the estimation of the extent of direct response and delayed response systems in the U.S. Response time variations are expected on the basis of soil, bedrock and hydrological differences among systems. Therefore, some watersheds will be in dynamic equilibrium with acidic inputs from the atmosphere and

will respond quickly, while others will exhibit significant sulfur retention or contain appreciable buffering capacities and will respond only after long delays. If direct response systems prevail in sensitive areas of the country, then no additional changes in surface water chemistry would be expected, given no change in present acidic loading rates. However, if delayed response systems predominate, then more waters may become acidic due to acidic deposition even if current loading rates do not change. Results from this research are expected to indicate the relative urgency with which additional controls on sulfur emissions might be required.

Biological Effects: A principal issue driving the debate over acid rain has been the biological effects of acidified surface waters. Preliminary research is expected to establish correlations between surface water chemistry and the status of fish populations. In order to do that, EPA will continue work that has already begun on the dose-response relationships between fish populations and concentrations of toxic metals (such as aluminum) that are thought to be elevated in acidic waters. EPA will continue work on the response of fish populations and other ecological endpoints in artificially acidified lakes as part of several large-scale on-going or planned studies. These studies will increase the certainty of the actual extent of declines of fish populations and other ecological effects associated with acidic deposition.

Watersheds and Soil Processes: A multiplicity of processes within watersheds affect the rate and magnitude of the acidification of surface waters. Watershed bedrock and surficial geology, system hydrology and biological processes are all important determinants of the response of surface waters to acidic inputs from the atmospheres. Surface water acidification is a watershed-level phenomenon, and an adequate scientific understanding of all the biogeochemical processes involved in watersheds is several years away. However, EPA does expect to expand its knowledge of those processes to more accurately predict the effects of changing acidic inputs. EPA's research strategy for the next five years is two-fold. First, it will accelerate the process-level research in the geochemical and physical characteristics of soils that are important in the response of surface waters. Second, EPA, in collaboration with other agencies participating in NAPAP, is establishing a network of carefully monitored watersheds in sensitive regions of the country. Data will be collected and analyzed on all relevant physical, chemical and biological parameters associated with surface water quality.

Terrestrial Effects of Acid Deposition

What is the effect of acidic deposition, alone or in combination with other pollutants, on forests?

Forest effects studies in acidic deposition have been focused in the Forest Response Program, jointly funded and managed by the EPA and Forest Service. This program was initiated in 1983 in response to public concern over the role of acidic deposition and air pollutants in forest decline.

The mission of the Program is three-fold: (1) to determine if acidic deposition, alone or in combination with other pollutants, are causing or

contributing to forest decline in the U.S., (2) if so, to determine the mechanism of effect, and (3) if so, to determine the dose-response relationship of forest response to loadings of acidic deposition, alone or in combination with other pollutants.

To meet the goals of the Forest Response Research Program, research has been organized to include historical data analysis, controlled lab and field experiments, site investigations and monitoring. Research will be undertaken by Research Cooperatives organized by forest type. In areas where phenomena have been reported field investigations and historical review activities will concentrate on examining forest condition in relation to atmospheric deposition and natural factors. These Cooperatives will also sponsor controlled lab and field studies to test hypotheses of damage relevant to forest type and deposition scenario. The Eastern Hardwoods Cooperative and the Western Forest Cooperative will initially undergo exploratory research to identify if further research is needed in these forest types.

The Mountain Cloud Chemistry Program is investigating the mechanisms of tree dieback and reduced growth rates at higher elevations in the East. These appear to increase in severity with increasing elevation. To address this research need, monitoring stations are to be established on the slopes and summits of selected mountains and will be co-located with forestry research stations. Samples from the network of forest research and monitoring stations will be analyzed and archived by a central laboratory. Development and standardization of monitoring instruments to perform reliably under the physically demanding conditions at these elevations will be required. A quality assurance and control program will be implemented to ensure long-term usefulness of these data and their intercomparability among sites.

Measurements of air and cloud droplet chemistry will be conducted as a function of time, geographic location and elevation. These observations will provide information on trends and will be used to address the effects observed upon mountain forest ecosystems. The observations will provide a means of estimating exposure of forest ecosystems to acid deposition by cloud deposition and other pollutants that may affect such ecosystems.

Materials Damage from Acid Deposition

What is the quantitative relationship between acid deposition and damage to structures, buildings, and other materials?

Qualitative relationships between acid deposition and resulting damage have been identified for a few materials under various conditions of exposure. The issue now is to quantify the rate of damage as a function of acid deposition, and to extend the development of damage functions to other materials. The assessment of the overall impact of acid deposition on materials also requires knowledge of the distribution of exposed building components and the economic behavior of consumers so that an economic loss may be associated with acid deposition materials.

Damage functions will be derived from physical chemistry theory, chamber studies and field exposure studies. As we improve our understanding of the basic mechanisms of these damage functions, efforts will shift to predictive

models of materials damage that will allow accelerated studies in controlled-climate chambers. Studies will also be extended to more complex systems of materials, such as reinforced concrete, brick and mortar, roofing systems, and painted surfaces.

In addition to the development of physical damage functions, it will be necessary to enhance the materials inventory and make estimates of consumer responses to acid deposition. This includes the way in which the end-of-the-service life of the material is determined, as well as the incremental costs of switching to more durable materials.

Limestone Injection Multistage Burner (LIMB)

What demonstrations of LIMB technology are needed to document its effectiveness in reducing emissions of sulfur and nitrogen oxides?

EPA has successfully developed and demonstrated advanced low-NO_x burner technologies applicable to large coal-fired steam generators (major emission sources for SO_x and NO_x). An associated potential benefit of this Low-NO_x burner development is the expectation of lower reductions for SO_x and NO_x, at a significantly reduced cost (3 to 5 times less than flue gas desulfurization) for retrofit applications. This LIMB (Limestone Injection Burner) approach involves SO_x-sorbent injection around the low-NO_x burners or at other points in the boiler. To bring the technology to commercialization will require a full-scale demonstration on a utility boiler of representative design. A demonstration of the technology is scheduled to be completed by 1990. This demonstration will be conducted on a 105 MW wall-fired boiler that will be modified to accomodate the LIMB technology. Another commercial-scale demonstration is planned for a tangentially-fired boiler in the near future.

To support these demonstrations, research will be conducted to determine what effects the process parameters have on sorbent activation and sulfur capture. Methods development continues to obtain highly reactive sorbents, to optimize reaction conditions to achieve maximum capture, and to minimize sorbent costs.

SUMMARY OF LONG-TERM TRENDS

As we enter the next decade, research to understand the phenomenon of acid deposition and to provide an information base for policy makers could take several directions. The on-going interagency (NAPAP) research program has a ten-year mandate from Congress which carries through 1990. However, both researchers and policy-makers realize that the phenomenon is a most complex and challenging scientific problem. They generally recognize that, although the accelerated research program will bring forth significant scientific findings by 1990, it is unlikely that all needed information will be generated by that time.

The long-term goals of the acid deposition program are to develop a number of products for policy makers including:

- o inventories and maps showing the magnitude and extent of receptors

that have been affected or could be affected by acid deposition;

- o estimates of the rate of change in the extent of effects
- o "target loadings" of acid deposition for different receptors in different regions of the country; and
- o quantification of the contribution of local versus long-range sources to acid deposition;
- o source-receptor models that can indicate which long-range sources or source regions contribute to acid deposition.

One of the major obstacles which has delayed the scientific understanding of the acid deposition phenomenon and the formulation of control or mitigation options for acid deposition is the lack of high quality data from long-term monitoring programs and from continuously-monitored intensive research sites. Several years ago, the acid rain program established a monitoring network for wet deposition (the National Trends Network). This network is just beginning to provide the multi-year data necessary for trends analysis. Major efforts are underway to initiate a dry deposition monitoring network, long-term monitoring of lakes and streams, mountaintop cloud and forest exposure monitoring, and watershed monitoring.

Scientific or policy developments could change the long-term direction of the research program. Some possible developments include: the scientific finding that part or all of the problem is minor; the scientific finding that part or all of the problem is getting rapidly worse or much more widespread; and/or congressional or executive action requiring emissions reduction. Such developments could bring about a considerable shift in emphasis in the research effort increasing the focus in one or more areas.

The energy research control technology issue in this chapter focuses on combustion of coal in an environmentally acceptable manner. A significant near term issue is the determination of how current control technologies can be adapted for acid deposition applications. Technologies currently being utilized to achieve NSPS compliance are costly and have a limited capability to be used in existing facilities on a retrofit basis. If additional acid precursor emission reduction from existing sources is legislated, improved lower-cost technological approaches will be required. The use of the Limestone Injection Multistage Burner (LIMB) technology is one of the approaches which is being investigated.

RESOURCE OPTIONS

1986 Current Estimate $59.1 Million
1987 President's Budget $59.6 Million

Projections

	1988	1989	1990	1991
No Growth	$59.6M	$59.6M	$59.6M	$59.6M
Moderate Growth	$61.4M	$63.2M	$65.1M	$67.1M
High Growth	$63.2M	$67.0M	$71.0M	$75.2M

No Growth: The program would proceed as described in this Agenda.

Moderate: Additional efforts would be made to evaluate the Regional Acid Deposition Model through field study data.

High: Additional efforts would be made to understand the linkages between terrestrial and aquatic ecosystems as they relate to acid deposition impacts. The program would accelerate acid deposition research to identify cause/effects mechanisms of forest changes, and expand the number of representative watersheds under study.