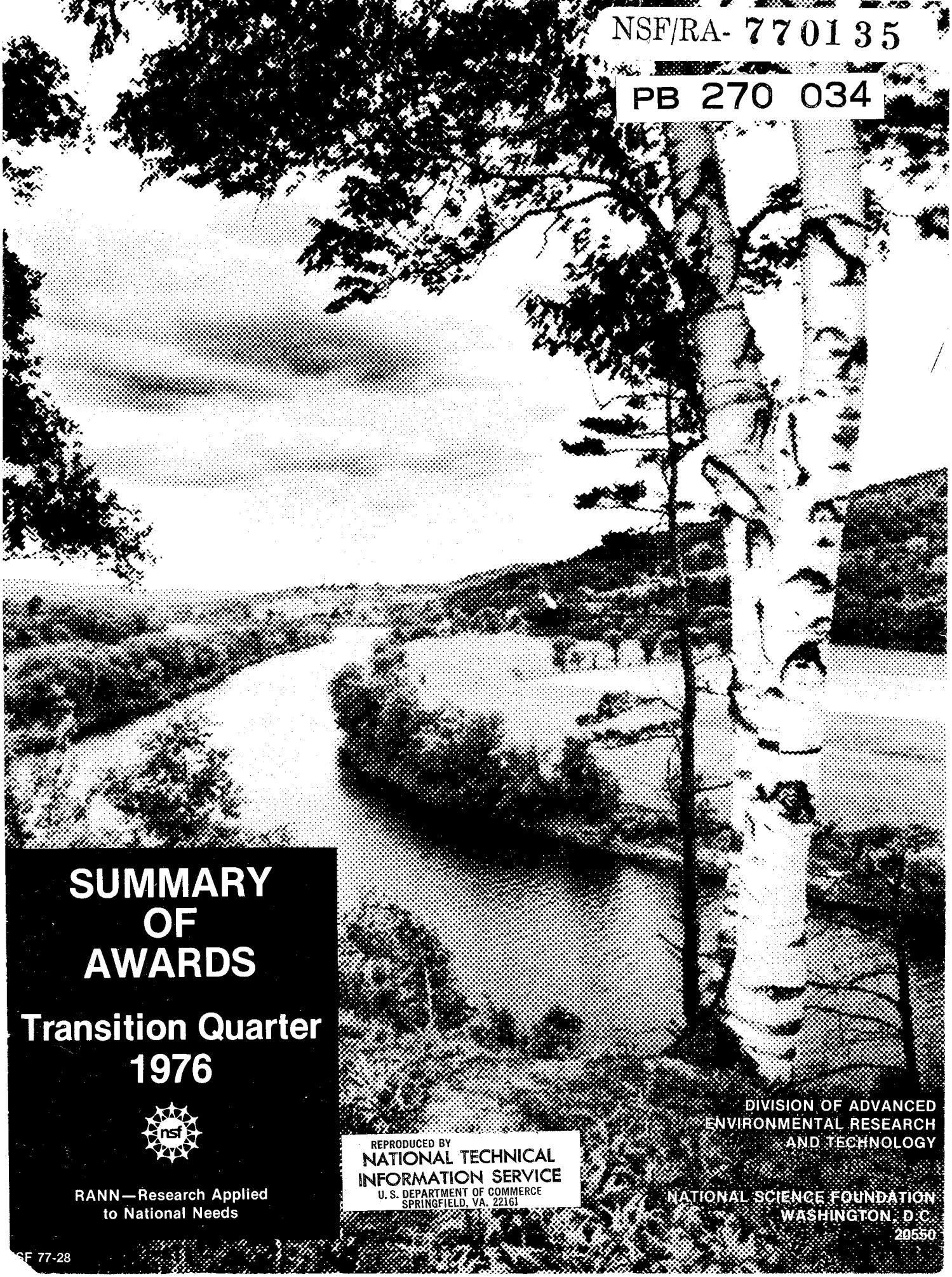

SUMMARY OF AWARDS

Transition Quarter 1976

RANN—Research Applied to National Needs

DIVISION OF ADVANCED ENVIRONMENTAL RESEARCH AND TECHNOLOGY

NATIONAL SCIENCE FOUNDATION
WASHINGTON, D.C. 20550

SF 77-28

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The Research Applied to National Needs (RANN) program was created in an effort to focus U.S. scientific and technical resources on selected problems of national importance. In order to achieve its objectives, RANN focuses its efforts in five major problem areas: Resources, Environment, Productivity, Intergovernmental Science and Development Incentives, and Exploratory Research and Technology assessment. This report presents brief summaries of projects funded by the Division of Advanced Environmental Research and Technology (AENV) during the three-month Transition Quarter (July 1 to September 30) between the end of Fiscal Year 1976 and beginning of Fiscal Year 1977. The report describes the nature of the division's five subelements: Chemical Threats to Man and Environment; Regional Environmental Management; Earthquake Engineering; Societal Response to Natural Hazards; and Weather Modification. An appendix which lists the grantees, titles of their research, and amounts awarded is also included in this report.

17. Key Words and Document Analysis. 17a. Descriptors

Grants
Resources
Environment
Productivity
Earthquakes
Hazards
Weather modification
Research

17b. Identifiers/Open-Ended Terms

Chemical threats to man and environment
Regional environmental management
Earthquake engineering
Societal response to natural hazards

17c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
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INTRODUCTION

In 1971, the Research Applied to National Needs (RANN) program was created in an effort to focus U.S. scientific and technical resources on selected problems of National importance for the purpose of contributing to their timely, practical solution. The RANN Program serves as a link between NSF's basic research programs and the development, demonstration, and operational programs of Federal mission agencies, State and local governments, and industry.

RANN Program objectives and research are based upon the specific needs of the Nation, and related challenges. Considerable emphasis is placed on the evaluation, dissemination, and utilization of the results of the research supported. Generally, the RANN Program seeks to: increase the effective use of science and technology in dealing with National problems involving public interest; shorten the lead time between basic scientific discoveries and relevant practical applications; and provide early warning of potential National problems, and initiate assessments and research useful in avoiding or solving such problems.

To better achieve its objectives, RANN focuses its efforts in five major problem areas: Resources, Environment, Productivity, Intergovernmental Science and Research and Development Incentives, and Exploratory Research and Technology Assessment.

The RANN Environment subactivity was established to enhance the Nation's capability to mitigate environmental hazards, whether natural or man-caused. The goal of the subactivity is predicated upon both the need to assure that the Nation's environmental objectives are being achieved at least cost, and a desire to more effectively reduce both human suffering and Federal and State expenditures required to cope with needs before, during, and after natural disasters.

This report presents brief summaries of projects funded by the Division of Advanced Environmental Research and Technology (AENV) during the three-month Transition Quarter (July 1 to September 30) between the end of Fiscal year 1976 and beginning of Fiscal year 1977. The report describes the nature of the Divisions's five subelements: Chemical Threats to Man and Environment;

Regional Environmental Management, Earthquake Engineering; Societal Response to Natural Harzards; and Weather Modification.

Research projects funded by RANN are reviewed by the scientific community and by representatives of user groups. Eligibility for support under the RANN Program hinges not only on scientific merit, but also on the projected impact of the results on government and the private sector in inducing constructive change in policies and practices. A key to the successful application of research results is the strong involvement of user groups during the planning and execution of the research. This involvement helps assure that the scientific activities supported by RANN are being driven by real-world problems.

Interested readers wishing further information on the individual Division-funded research projects or information pertaining to research in areas of science currently investigated by the Division are encouraged to contact the Principal Investigator directly, or the Division of Advanced Environmental Research and Technology.

CONTENTS

DIVISION OF ADVANCED ENVIRONMENTAL RESEARCH AND TECHNOLOGY

The goal of the RANN Division of Advanced Environmental Research and Technology is to enhance the Nation's capability to mitigate environmental hazards, whether natural or man-caused. This research activity seeks to provide a scientific and technological base for managing these risks by preventing or reducing the loss of life, property damage, and the disruption of vital ecological and community relationships from environmental hazards and conditions.

The advanced Environmental Research and Technology Division is organized into two program elements: (1) Managing the Natural Environment, and (2) Disasters and Natural Hazards. Research in the first area is concerned with providing the scientific base to allow improved public decisions about environmental problems. Research in the second area provides information to allow mitigation of the undesirable effects of such natural hazards as earthquakes and weather. The objectives are to:

- Identify and analyze the nature and extent of man-caused and natural environmental hazards.
- Identify and evaluate innovative social and technological methods to reduce environmental risks, and to mitigate the impact of disasters when they occur.
- Evaluate the opportunities for, and constraints to, the adoption of innovative mitigation procedures.
- Synthesize acceptable environmental risk management strategies.

In order to better deal with the research areas, the Division has divided the two major program elements into five subelements:

MANAGING THE NATURAL ENVIRONMENT
a) Chemical Threats to Man and Environment
b) Regional Environmental Management

DISASTERS AND NATURAL HAZARDS

a) Earthquake Engineering
b) Societal Response to Natural Hazards
c) Weather Modification

During fiscal year 1976, a total of $23,148,000 in awards was distributed by the Division to the following subelements:

Chemical Threats to Man and Environment	$5,323,000
Regional Environmental Management	$5,898,000
Earthquake Engineering	$6,527,000
Societal Response to Natural Hazards	$1,169,000
Weather Modification	$4,231,000

DEFINITIONS AND EXPLANATION OF FORMAT

SAMPLE STATISTICAL SUMMARY:

Feasibility Study of Filtering Techniques for Steel Factories;[1]* Michael K. O'Leary;[2] Department of Chemistry, Dorset University, Fitchburg, Massachusetts 01420;[3] $247,500 for 12 months beginning September, 1976.[4]

*1. **Title of the Specific Award:** 'Award' refers to financial support given in the form of a grant, contract, or other arrangement, depending on the nature of the research work to be completed and the terms of performance.

2. **Principal Investigator:** The chief scientist or administrator who is responsible for the research plan and fiscal expenditures as an NSF-sponsored awardee.

3. **Institutions Conducting the Research:** Any college, university, laboratory, industry, or other organization, whether operating on a profit or nonprofit basis, as well as State Governments and Federal organizations.

4. **Amount, Duration and Effective Date of Award.**

Supplemental Definitions

a. **New award:** refers to an award which has received no prior support from NSF, regardless of whether the principal investigator has received support on previous occasions.

b. **Renewal award:** refers to follow-on support of a project which is currently supported.

c. **Supplemental award:** refers to the addition of funds to an existing NSF supported project without increasing the duration of NSF support.

The following report presents brief descriptions of awards for scientific research given by the Division of Advanced Environmental Research and Technology during the period July 1, 1976 through September 30, 1976. Any and all references made in this document to actual award amounts are subject to adjustment by financial statements prepared by NSF at the close of Transition Quarter 1976.

Division-initiated funding actions excluded from this report are:

a) Purchase Orders
b) Funds for Personnel (Intergovernmental Personnel Act)
c) International Travel Awards

Where awards have received support from other organizations within or outside of NSF, only Division support has been indicated. In addition, when individual awards or supplements have been made using funds only from other agencies or divisions, these awards are not included in this report.

PERSONNEL OF THE DIVISION OF ADVANCED ENVIRONMENTAL RESEARCH AND TECHNOLOGY

Division Director ..... Charles C. Thiel, Jr.
Deputy Director ..... Marvin E. Stephenson
Senior Scientist ..... H. Kenneth Gayer
Special Assistant ..... Michael P. Gaus
Administrative Assistant ..... Dorothy F. E. Dooren

MANAGING THE NATURAL ENVIRONMENT

Chemical Threats to Man and Environment
Program Managers:

Richard A. Carrigan
Jarvis L. Moyers
Carter K. Schuth

Regional Environmental Management
Program Managers:

Edward H. Bryan
Gordon H. Jacobs
J. Eleonora Sabadell
Terry R. Sopher

DISASTERS AND NATURAL HAZARDS

Earthquake Engineering
Program Managers:

Michael P. Gaus
S. C. Liu
John B. Scalzi

Societal Response to Natural Hazards
Program Managers:

William A. Anderson
George W. Baker

Weather Modification
Program Managers:

Richard A. Dirks
Currie S. Downie

MANAGING THE NATURAL ENVIRONMENT

The Program element Managing the Natural Environment aims to provide a scientific basis for mitigating man-caused environmental threats to the natural environment in ways that are compatible with other social goals. Through its three subelements, the Program attempts to: identify, understand, and contribute to the reduction of contamination problems arising from mining and processing of metal ores, manufacturing and use of chemical products, and disposal of potentially toxic wastes; assess the environmental consequences of advanced and innovative technologies for processing energy and for storing and transporting energy and fuels; and continue research on land use, urban hydrology, and waste water disinfection.

The Program subelements in this area are:

- Chemical Threats to Man and Environment
- Regional Environmental Management

CHEMICAL THREATS TO MAN AND ENVIRONMENT

The Chemical Threats to Man and Environment subelement is focused on identifying, quantifying, and assessing the impact of the spread of hazardous chemical compounds on the environment and human populations. Many of the compounds are released deliberately or inadvertently in large quantities into the environment at one or more points in their production use cycles. The majority of these materials can be considered to have a potentially hazardous human and environmental impact. The benefits of manufactured chemicals, with a net sales of over $80 billion in 1974, and the potential benefits of new compounds, are so great that there exists strong justification for corresponding efforts to find better ways of assessing and reducing their hazardous side effects.

The objectives of this subelement are to:

- Identify and quantify contaminants resulting from manufacture, use, and disposal of organic and inorganic chemicals.
- Assess the potential for damage to ecosystem communities, populations, and ecological species along contaminant flow paths.
- Improve existing techniques in analytical chemistry specifically applicable to achieving the above objectives.

Research areas of specific interest within the Chemical Threats to Man and Environment program subelement are:

- Airborne Contaminants
- Nitrates
- Organic Chemicals of Commerce
- Program Development and Utilization

AIRBORNE CONTAMINANTS

The purpose of the Airborne Contaminants subelement is to identify, characterize, and quantify contaminants produced from atmospheric precursors of man-made and natural origin.

Field Measurements of Biogenic Sulfur Emissions; *Francis J. Berlandi* and *Dian R. Hitchcock;* Environmental Research & Technology, Inc., 696 Virginia Road, Concord, Massachusetts 01742; $111,700 for 12 months beginning September 1976.

Over the past decade stringent controls on sulfur dioxide emissions have resulted in sharp reductions in ambient levels of this contaminant in urban air, including New York City and Chicago. At the same time, particulate sulfate levels have not shown a corresponding decrease. Indeed, the presumably hazardous particulate sulfates have remained almost constant in East Coast urban areas while sulfur dioxide has decreased by 55 percent over a 6-year period. This unexpected result implies the existence of important sulfate sources other than those of cultural origin, and it raises the question that perhaps natural sources may be contributing significantly to airborne sulfates in certain areas.

Worldwide emissions of volatile sulfur compounds of biogenic origin are commonly believed to exceed the total amount of sulfur dioxide released to the atmosphere as a result of man's activities. Unlike the anthropogenic sources, which emit mostly sulfur dioxide, the biogenic sources are believed to contribute hydrogen sulfide, dimethyl sulfide, and minor amounts of other sulfur compounds. Like sulfur dioxide, the latter sulfur carriers seem likely to oxidize in the air to form sulfuric acid or some other particulate sulfate. These sulfate forms are believed to be hazardous to human health.

This project addresses the question of whether these biogenic emissions, which are believed to be dominant on a global scale, are also significant for the production of airborne sulfate particulates in regions impacted by anthropogenic sources of sulfur dioxide, like coal- or oil-burning power plants. The research is comparing the gaseous and particulate species collected on opposite sides of a large estuary where substantial biogenic emissions can be expected. The site is distant from concentrated anthropogenic sources and adjacent to an ocean, so that clean oceanic air can be sampled before and after crossing the estuary.

Workshop on Air Pollution and Administrative Control; *Ann F. Friedlaender;* Department of Economics, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139; $55,100 for 12 months beginning August, 1976.

There has been surprisingly little academic work directed at evaluating the administration and consequences of the recently enacted environmental laws. Both the Clean Air Act of 1970 and the Water Pollution Control Act of 1972, as implemented by the Environmental Protection Agency and various State implementation plans, have already had important effects on production decisions by private and public bodies.

The conference which this project undertakes is limited to problems of atmospheric pollution and is studying, in particular, the problems posed by both automobile emissions and stationary sources. It is

also considering whether the Clean Air Act could be amended to permit alternative pollution cost trade offs that might be preferable from society's point of view to the ones implied by the present Act.

The specific objectives of the workshop are: 1) to assess the implications of existing air pollution legislative and administrative decisions and the administrative problems associated with them and 2) to delineate guidelines for future decision making at the national level which concerns air quality improvement.

Upon completion of the conference, the commission papers, and conference proceedings will be published in a single volume available for general distribution.

The Chemical Lifetime of Sulfuric Acid Aerosols; *James J. Huntzicker;* Oregon Graduate Center, Beaverton, Oregon 97005; $77,100 for 24 months beginning September, 1976.

In recent years, studies by the United States Environmental Protection Agency have suggested that sulfuric acid aerosols, and perhaps other sulfates, are more damaging to human health than the common gas-phase predecessor, sulfur dioxide. Sulfuric acid aerosols are damaging to vegetation and material surfaces and are probably responsible for much of the acidic rainfall problem. Sulfuric acid aerosols are, in part, converted to less harmful sulfate salts as a result of neutralization by ammonia gas, which is also present in the atmosphere. However, present measurements of ambient levels of sulfuric acid, sulfates and ammonia suggest that there is much less neutralization than would be expected on the basis of chemical equilibrium. It would appear that the amount of acid neutralized is limited by the rate of the process rather than by its thermodynamics.

In this project, controlled amounts of ammonia and sulfuric acid aerosols are allowed to react for various times under a variety of conditions in a reaction chamber. Then the products and left-over reactants are withdrawn and analyzed in order to establish the rates of neutralization under various conditions and thus determine factors that might be controlled to hasten the neutralization of sulfuric acid aerosols in ambient air.

Users of the research include Federal, State and local pollution control agencies and major pollution sources, especially the electric power industry. Information from the project will be published in the open literature and presented at national meetings. Reports will be sent to interested users and an annual symposium for users will be held.

Nitrous Oxide Environmental Measurement Program; *Michael B. McElroy;* Department of Atmospheric Sciences, Harvard University, Cambridge, Massachusetts 02138; $126,200 for 20 months beginning October, 1976.

Nitrogen oxides reacting with other nitrogen oxides are the major natural mechanism for the destruction of ozone on the stratosphere. Nitrogen oxides reach the stratosphere mainly in the form of nitrous oxide ($N_2 0$), which is released from many biological processes at the earth's surface. Recently, there has been much concern that there may be enhanced destruction of ozone as a result of an added flux of nitrous oxide caused by the growing, extensive use of synthetic nitrogen fertilizers in agriculture. However, more accurate estimates of the natural production of nitrous oxide must be made before the significance of the fertilizer effect can be assessed.

Several groups are now making measurements of nitrous oxide production over open oceans or agricultural fields. In this project, the investigators are studying the nitrous oxide flux from near-shore areas of very high biological activity, such as estuaries and salt marshes, to complete the picture. Measurements of nitrous oxide are being made in water, sediment and air in these areas with a gas chromatograph modified for field use.

The results of this work will have broad implications for the stratospheric ozone problem, the use of fertilizers and the world food problem. In view of the importance of this issue, the results will at-

tract the attention of most users via presentation at national meetings and publication in rapid turnaround journals. However, to insure that the results reach the appropriate decisionmakers quickly, findings of the project will be transmitted directly to the various groups studying this and related stratospheric questions.

The award provides for a subcontract to Aerodyne Research, Inc. with Charles E. Kolb serving as investigator for that corporation.

Study of Chemistry of Atmospheric Particulates; *Tihomir Novakov;* Lawrence Berkeley Laboratory, Univeristy of California, Berkeley, California 94720; $70,763 for 12 months beginning October 1976.

In contrast with the usual studies of the total content of chemical elements of atmospheric particulates, this research seeks to define the molecular composition of the active surface layers of particles from ambient air and from pollutant sources. This will enable us to better understand their origins, their physiological and catalytic properties, and their agglomeration behavior. It thus relates to properties that may be more directly related to health effects, visibility reduction, and catalytic properties. It also seeks to clarify particle effects on the behavior of gaseous pollutants, particularly on the catalytic oxidation of sulfur dioxide to sulfate forms.

Particle analyses are made by photoelectron spectroscopy, X-ray fluorescence, wet chemical analysis, and infrared spectroscopy. Field collections of particulate materials are made and laboratory experiments are done to determine gas/particle reactions.

This is a renewal of a project that has shown the catalytic conversion of sulfur dioxide to sulfate on soot particles, along with findings of hitherto unsuspected nitrogen forms of possible significance for health effects and atmospheric chemistry.

The project is interacting closely with California regulatory and research agencies, such as the Air Resources Board and the California Department of Public Health.

Sources, Transformation and Speciation of Atmospheric Pollutants; *William H. Zoller;* Department of Chemistry, University of Maryland, College Park, Maryland 20740 $369,200 for 12 months beginning September, 1976.

A number of chemical elements are found to be markedly enriched in the particulates of urban polluted air. Some of these elements are known to be toxic, or are suspected of having adverse health effects when they occur in particles small enough to be retained in the lungs. Although much information has been gathered by investigators on the atmospheric loadings of trace elements in ambient urban and rural air, conclusions about the sources of these elements are presently based on inadequate data, or in some cases on untested assumptions.

A major objective of this project is to definitively characterize major isolated sources present in urban areas as to their emission of trace elements in a range of particle sizes, including the respirable size range. The sources include coal- and oil-fired power plants, automotive traffic, airports, municipal refuse incinerators, sewage sludge incinerators, steel plants, petroleum refineries, cement plants, and non-ferrous smelting operations. In addition to the trace elements, a group of individual polycylic aromatic hydrocarbons are included for analysis in both the particulate and gas phases. The latter substances are members of a class of known, or suspected, carcinogens.

A second objective is to determine how the emitted primary pollutants are modified or transformed when moving downwind from the source. This includes the loss of larger particles by fallout, the agglomeration of fine particles into aggregates, the condensation of gaseous species onto solid particles, and the chemical transformation of gaseous species.

A third objective is to determine the effect of a power plant burning high-sulfur fuels on the acidity of rainfall in the surrounding territory.

NITRATES

The objective of the Nitrate element is to provide the scientific and technological information which will assist in the resolution of the conflict between acceptable environmental levels of nitrate emanating from agricultural lands and maximum agricultural productivity.

Nitrate in Effluents from Irrigated Lands; *Parker F. Pratt;* Department of Soil Science and Agricultural Engineering, University of California, Riverside, California 92502; $529,300 for 12 months beginning June, 1977.

Because crops do not utilize all the nitrate supplied by fertilizers, some nitrate leaches into tile lines, or it drains into underground water bodies. The resulting contamination can cause the eutrophication of surface waters or it can lead to the accumulation of nitrate in surface or underground drinking water supplies to levels posing a public health hazard. In the irrigated farmlands of the Western States, nitrate levels in water draining below the root zone often substantially exceed the United States Public Health Service standard for drinking water. The needs of society for agricultural productivity and for environmental protection come into conflict because of the tendency of a productive agriculture to leak nitrate into water supplies.

This project is designed to help reconcile these conflicting needs by determining how soil conditions and farm management practices control the leaching of nitrate, and by relating these findings to knowledge of nitrogen requirements for optimum crop production.

On cropped field plots, fertilized with isotopically labeled nitrogen, the fate of nitrate of fertilizer origin is determined under different irrigation regimes and rates of nitrogen application by mass spectrometric measurements.

Observations of nitrate leakage from farmlands are correlated with soil type and management practice to identify those situations most significant for nitrate contamination of waters. Nitrate measurements are made on tile drain waters and on waters draining to aquifers.

The experiments are designed to assess the importance of gaseous losses of nitrogen for eliminating excess nitrate from soils, and to identify conditions that would favor this means of minimizing leakage of nitrate to drainage pathways.

The denitrification studies, together with the observations on the soil management variables and nitrate losses, will be used to prepare interpretations of standard soil mapping associations for characterizing cropping systems as to their tendency to release nitrate to drainage pathways.

This grant provides continued support to a previously funded program.

ORGANIC CHEMICALS OF COMMERCE

The objective of the Organic Chemicals of Commerce subelement is to develop methodologies for hazard prediction of organic chemicals. In addition, the subelement seeks to: 1) determine the transport, effects, and fates of critical organic compounds which pose threats to human populations and environments in high exposure areas; 2) investigate the health effects on humans of persistent low-level exposure to critical organic compounds in areas of high release; and 3) assess the economic, legal, and socio-political implications of hazardous levels of specific organic compounds in the environment.

Chemodynamic Studies on Bench Mark Industrial Chemicals; *Cary C. T. Chiou;* Environmental Health Sciences Center, Oregon State University, Corvallis, Oregon 97331; $55,200 for 12 months beginning September, 1976.

The extensive growth of the chemical industry, especially since World War II, has brought about the release of enormous quantities of synthetic chemicals into the environment. The productivity of these synthetic chemicals is in response to man's desire for a higher standard of living. Thus, we have a continuing increase in the production and use of drugs, food additives, pesticides and industrial chemicals. A number of these compounds have been found to cause severe health problems for man and other species.

In order to systematically identify presently used or new compounds that are likely to cause widespread environmental problems, a better knowledge of the environmental behavior and toxicological properties of several classes of synthetic organic compounds is urgently needed. In this project, several physical and chemical properties of a number of model compounds, representing several classes of industrial chemicals, are being measured in order to provide data needed to correlate the environmental behavior of compounds with their basic properties. This type of correlation should provide reliable predictive models of the environmental behavior of as yet untested compounds.

The information obtained in this project will be useful to regulatory agencies in registering, prescribing manner of use, and in monitoring and regulating synthetic organic chemicals. Equally, engineers and chemists will find it of value in the designing of plants, the designing of processes and the devising of effluent-control procedures. Beyond this, it will begin to build a body of knowledge regarding groups of industrial compounds that will be useful in analyzing first-order prediction about candidate members of this class.

A Profile Model for Chemicals in the Environment; *Alan Eschenroeder;* Environmental Research and Technology, Inc., 203 Chapala Street, Santa Barbara, California 93101; $75,700 for 12 months beginning September, 1976.

About two million chemical compounds are known, ranging from laboratory curiosities to the commercial perparations fabricated in billion pound quantities each year. Of particular concern are the hazardous metals, metallic compounds and synthetic organic compounds.

This project seeks to construct a computer-based

model for the prediction of the concentration levels of synthetic organic compounds in various portions of the physical and biological environment. The basic module for the simulation will be a compartment in which accumulation, transport, transformation and ultimate fate of a specified chemical is computed. The model assembles and integrates four such compartments, air, soil, water and biota, with appropriate hierarchies in each compartment to describe the overall temporal levels of the compound by incorporating a variety of dispersive use patterns.

The derivation in the relationship of rate and transfer coefficients to standard laboratory data is a subsidiary objective of this research. Testing the validation of this model on a substance for which there is an extensive data base is another goal. DDT has been selected as the surrogate compound.

The findings of the program will be fully documented in the final report. This report will be disseminated to governmental agencies, most notably the Environmental Protection Agency, and other groups concerned with the propagation of chemicals in the environment.

PROGRAM DEVELOPMENT AND UTILIZATION

The objectives of the Program Development and Utilization subelement are to assist the Chemical Threats to Man and Environment subelement in the: 1) development and assessment of Program initiatives and priorities; 2) promotion of cohesiveness in the overall Program effort by supporting interproject communication; and 3) implementation of effective utilization of Program outputs.

A Study of Trace Contaminant Research Utilization; *Joel Jacknow;* Environmental Quality Systems, Inc., 1160 Rockville Pike, Rockville, Maryland 20852; $14,800 for 12 months beginning June, 1976.

Environmental Quality Systems, Inc. is providing a systematic categorization of all the users of the Trace Contaminants program and the appropriate information transfer mechanisms by which the program output can be effectively conveyed to this audience. The effort includes: 1) a review of the present technical outputs of the Environmental Aspects of the Trace Contaminants program; 2) a systematic categorization of all the users of the Trace Contaminants program and the various information transfer mechanisms used to reach this audience; 3) the development of detailed lists of the users in each category detailed down to the cognizant organization unit; and 4) the preparation of a working document which incorporates the product of all these tasks into a format which will guide the research utilization activities of the individual projects in a coordinated program of information.

REGIONAL ENVIRONMENTAL MANAGEMENT

Research in Regional Environmental Management is designed to enhance man's ability to deal effectively with regional environmental problems. Focus is on environmental problems of selected regions and their component interrelated factors, including economics, growth, resource availability, social, institutional, and organizational, as well as physical factors. This user-oriented research is designed to produce information of value to the planning and management of regions or natural resources with maximum benefit and minimal environmental disruption. A continuing effort at coordination and information exchange between investigators and Federal agencies, State and local governments, and industry is maintained.

The objectives of the subelement are to:

- Evaluate attitudes of various societal groups toward the physical environment and demand for resource use; define factors influencing changes in attitudes and values concerning the environment; and assess the cost and benefits to various societal groups for alternative levels of environmental quality.
- Analyze economic and legal mechanisms as management options available to decisionmakers, the specific environmental effects of such options, and the potentially favorable or detrimental effects of other forms of public policy.
- Synthesize and evaluate management strategies utilizing appropriate environmental, economic, and social information.
- Identify the resource and ecosystem relations affected by development so as to be able to predict consequences of alternatives strategies to correct environmental problems.

In pursuance of these objectives, the Regional Environmental Management subelement is divided into five research areas:

- Environmental Risk Management
- Land Use
- Regional Environmental Systems Evaluation and Synthesis
- Residuals Management
- Urban Hydrology

ENVIRONMENTAL RISK MANAGEMENT

The Environmental Risk subelement constitutes a response to a National need to know and understand those natural events and human activities capable of harmful environmental consequences. To enhance our ability for management of environmental risks, the following needs are recognized.

- Clarify and develop appropriate environmental risk objectives, and identify the array of environmental hazards, and structure an understanding of their causes.
- Develop measures for estimating and comparing the consequences of activities or events while predicting risks and evaluating them according to social, economic, environmental, and other standards and objectives.
- Devise techniques and means for managing environmental risk and implementing risk control measures.
- Evaluate risk management strategies for effectiveness and equity.

Policy Modules for Environmental Management; *Ralph C. d'Arge;* Department of Economics, University of Wyoming, Laramie, Wyoming 82071; $149,000 for 15 months beginning September, 1976.

Environmental resources have special features making them distinct from other natural resources as well as other economic goods and services. These features include: common pool problems; stock and resource uncertainty; future demand uncertainty; uncertainty on technological substitutes; ownership patterns; discrepanies between private and social rates of discount; incentives for exploitation; and general discrepancies between marginal social and private costs. If these features are ignored, environmental resource decisions can be highly inefficient or inappropriate.

More than 200 existing economic models describing optimal price and use rates for natural resources have been generated for various purposes. Although addressing an extremely relevant policy issue, this literature has remained virtually untapped by policymakers because of its diffuseness and complexity. It is the purpose of this research to extend, generalize, simplify, and synthesize this existing set of environmental resource models. The results of this augmentive and taxonomic process will be utilized to develop a policy handbook accessible and understandable to decisionmakers which will provide guidelines and optimal rules for efficiently managing environmental resources through direct and indirect measures.

The work elements include a series of commissioned papers, a major conference, the development of policy modules, and regional seminars.

LAND USE

The objective of the Land Use subelements is to provide an improved scientific information base for maintaining environmental quality and managing regional environmental problems through land use decisionmaking. General research initiatives include efforts to: 1) determine land use impacts of selected governmental policies and programs and private activities; 2) determine physical, socio-economic, and environmental effects of various land uses; 3) determine problems, effects, and effectiveness of particular land use policies, decisionmaking processes, and management programs and techniques in achieving environmental and socio-economic goals; and 4) evaluate and demonstrate the capability of selected technologies for improving land use planning and management.

Testing a Forest Management Environmental Resource Analysis System; *Charles J. Chambers;* Department of Natural Resources, State of Washington, Olympia, Washington 98504; $21,000 for 12 months beginning September, 1976.

Timber harvest practices have significant but not easily estimated environmental effects, particularly on water quality. This supplemental grant supports an effort by the Department of Natural Resources of the State of Washington to test the transferability and effectiveness of computer based simulation models developed at the University of Washington. These models have been developed to provide a capability for assessing the environmental impacts of alternative timber harvest quantities and methods. The tests involve several forest types and harvest practices. The models are also assessing the economic and environmental effects of the Forest Practices Act in specific situations.

The Northwestern United States forests provide 50 percent of the country's lumber; therefore, successful application of effective models beyond the study area has the potential for significant impact on the timber industry and associated governmental and industrial decisionmakers.

Defining the Constitutional Issues of Growth Management; *David R. Godschalk;* Center for Urban and Regional Studies, University of North Carolina 108 Battle Lane, Chapel Hill, North Carolina 27514; $35,100 for 12 months beginning September, 1976.

In recent years, numerous urban and rural communities which faced very rapid growth rates began to formulate and adopt policies to control the rate, volume, character, and location of growth. The authority of localities to adopt such growth controls has been challenged by numerous law suits, especially in terms of their alleged infringement on Constitutional rights.

The objective of the original grant was to thoroughly analyze these growth management Constitutional issues. Major research questions included: 1) analysis of unique factors in different approaches; 2) identification of major growth approaches at the local level; 3) identification and analysis of Constitutional principles and challenges; 4) identification of major planning approaches utilized; 5) analysis of strengths and weaknesses of planning approaches; and 6) identification of future trends. A comparative case study approach was utilized.

The research has now been completed, and this supplemental grant is preparing and disseminating the project results in a format of high utility to planners, lawyers, public officials, and citizens at the local government level.

National Environmental Models of Agricultural Policy, Land Use, and Water Quality; *Earl O. Heady;* Iowa State University of Science and Technology, The Center for Agricultural and Rural Development, 578 East Hall, Ames, Iowa 50010; $235,000 for 12 months beginning August, 1976.

This project is a renewal of a previously awarded grant. The core of this effort has been to develop, apply, and make accessible a system of mathematical models that is capable of evaluating the effects of alternative policies and programs pertaining to regional land uses, environmental and water quality standards, agricultural technology, and trade policies on: 1) agricultural productivity, 2) food supplies and prices, 3) farm income and structure, 4) interregional redistributions of income and wealth, and 5) environmental quality.

This phase of effort centers on improving user accessibility and expanding the project's ability to deal with varied land resource categorization. This will complement the project's capacity to tailor models to meet specific problem demands. The system's usability will be facilitated by increasing the land resource categories to include all lands, updating key data bases, introducing more technically realistic crop production functions, and the development of programming tools that will greatly reduce the cost of using the system.

A Policy Study of a Region Under Stress: The Southwest; *Allen V. Kneese;* Department of Economics, University of New Mexico, Alburquerque, New Mexico 87106; $184,600 for 12 months beginning August, 1976.

The four states of Arizona, Colorado, New Mexico, and Utah, which jointly comprise the Southwest region of the nation and include major Indian lands and peoples, are increasingly important to the resolution of several national policy conflicts. The research objective of this proposal is the development of discussion and analysis of such prominent policy topics as environmental preservation, economic development, Indian issues, water allocation, urban problems, tax policy, and alternative institutional forms. The range and complexity of the policy issues in the Southwest and their interrelationships have become increasingly important to the wise management of the area from Federal, Regional, State, and local perspectives.

This policy study will draw upon both the prior analytical research and experience afforded by the comprehensive project "Southwest Region Under Stress" and the extensive research foundation developed over the past five years by the Lake Powell Research Project.

Collaborative Evaluation and Analysis of Cost Effectiveness of Applications of Controlled Environment Facilities; *Paul J. Kramer;* Department of Botany, Duke University, Durham, North Carolina 27706; $14,700 for 12 months beginning August, 1976.

One of the most important developments in research methodology in agriculture is the increased use of controlled environment equipment such as growth chambers and phytotrons. The use of such equipment has been productive in isolating and evaluating the effects of various environmental effects on plant growth. A series of experiments are being conducted to obtain information concerning the scientific and economic effectiveness of field plot research compared to research phytotrons.

The first experimental objective is to make careful measurements of the quantity and quality of growth made by plants of several species growing in field plots and phytotrons. The second objective is to make careful comparisons of the cost efficiency of research in phytotrons and in field plots.

Collaborative Research on Assessment of Man's Activities in the Lake Powell Region—Biological Limnology, Shoreline Ecology, and Heavy Metals; *Loren D. Potter;* Biology Department, University of New Mexico, Albuquerque, New Mexico 87106; $106,500 for 12 months beginning September, 1976.

This is a continuation of a previous award to conclude an interdisciplinary project concerned with the effects and ramifications of the development of Lake Powell and the arid region of the Southwest surrounding it. The general objective of this multifaceted project is to provide an improved scientific basis for mediating among competing interests in the development of natural resources in the Lake Powell region. The project involves nineteen subprojects and eleven different institutions.

This award is for three subprojects. They are concerned with biological limnology, shoreline ecology, and heavy metals. In each of these, completed field work provides the basis for final reporting of analytical results in technical publications, and for appropriate contributions to a comprehensive integrated report on the Lake Powell Ecosystem.

National Economic Models of Industrial Water Use and Waste Treatment; *Russell G. Thompson;* Department of Quantitative Management Science, University of Houston, Houston, Texas 77004; $6,900 for 3 months beginning August, 1976.

This award is a supplement to a previous grant for the purpose of purchasing 100 copies of Russell Thompson's book, *Environment, Energy and Capital in Fossil-Fueled Electric Power Generation,* and facilitating its publication. This is the second of three monographs that make the results of a three and one-half years study by Thompson at the University of Houston widely available in published form.

The purpose of this research has been to provide an economic basis for effluent controls and effluent related decisions in industry and government. The effects of alternative environmental controls on key water and power using industries have been the focus of sets of mathematical linear programming models for representative plants. The utility of this effort has been shown through a substantial series of user interactions. These include 1) the Texas Governor's Energy Advisory Council, 2) the Environmental Protection Agency, 3) the Texas Water Development Board, 4) the Houston-Galveston Area Council, and 5) the Federal Office of Management and Budget.

REGIONAL ENVIRONMENTAL SYSTEMS EVALUATION AND SYNTHESIS

The objective of the Regional Environmental Evaluation and Synthesis subelement is to conduct research into the overall utility of major environmental/economic modeling efforts, in general, and prior RANN-sponsored efforts, in particular.

Distribution of Spilled Oil in Relation to Beach Morphology; *Miles O. Hayes;* Coastal Research Division, Department of Geology, University of South Carolina, Columbia, South Carolina 29208; $9,800 for 5 months beginning September, 1976.

This program is a continuation of a previously funded program. The purpose of this study has been to develop a land-form classification of beaches in the Straits of Magellan, Chile and to measure the amounts of oil on the different classes of beaches, the oil coming from a massive tanker spill. Such knowledge would be useful in predicting the extent of oil-spill damage to be expected on a particular class of beach. Also, a study of beach processes would indicate changes wrought by wave action. The rationale for the research is the remarkable similarity of the Chilean beaches to those in New England and parts of Alaska, two areas likely to undergo considerably increased petroleum activity. The beaches have been classified, amounts of oil noted, wave action studied, and over 65 detailed beach profiles were measured along 100 kilometers of shoreline. Also, permanent survey stakes were set so that changes in beach form can be measured in the future.

Supplemental funds permitted an immediate assessment of another tanker spill accident in La Coruna, Spain. This second event provided the opportunity to observe short-term immediate changes on the impacted beaches not possible in the first instance. This second supplemental award gives the researchers the opportunity to revisit the impacted beaches in the Straits of Magellan six months after the original assessment to remeasure the beach profiles using the previous survey points as reference markers.

A Seminar to Facilitate Further Applications of the Livermore Regional Air Quality (LIRAQ) Model; *George D. Sauter;* Technology Applications Group, Lawrence Livermore Laboratory, Livermore, California 94550; $29,800 for 7 months beginning September, 1976.

The establishment of air quality standards has brought about the need for developing air quality models which may assist in selecting appropriate air pollution control strategies compatible with natural laws. This project has been concerned with the development and validation of a numerical model of the processes governing spatial and temporal distribution of air pollution in the San Francisco Bay Area which may be used to simulate air quality as influenced by various control strategies. The Lawrence Livermore Laboratory has recently developed such a model.

Although the model was developed specifically for use in the Bay Area, it is potentially applicable to a large number of other regional air quality problems. As a first step in making LIRAQ more readily available for additional applications, the University of California Lawrence Livermore Laboratory is holding a three day seminar, open to both potential users and commercial modeling groups. At the seminar, the model structure, data requirements, operating procedures, capabilities, and limitations of LIRAQ are being discussed and explained by members of the model development team.

RESIDUALS MANAGEMENT

The objective of the Residuals Management subelement is to synthesize residuals management strategies for minimizing environmental risk. Coupled with the need for solutions to problems of residuals management is recovery of potential resource values of waste constituents.

Utilization of Waste Heat in a System for Management of Animal Residuals to Recover and Recycle Nutrients; *Larry Boersma;* Department of Soil Sciences, Oregon State University, Corvallis, Oregon 97331; $41,500 for 12 months beginning August, 1976.

This award was made to fund completion of research directed toward the utilization of waste heat for the management of animal residuals to recover and recycle nutrients. The animal waste management system consists of a livestock confinement building from which the wastes are hydraulically transported to a solid-liquid separator. The sludge fraction is subjected to anaerobic digestion and the overflow is pumped into nutrient-recovery basins. Algae cultivated in these basins are being evaluated for their value as a constituent of animal feed. The algae growth-medium is returned to storage for reuse as the animal-waste, transport fluid. Algal-basins are heated with warmed water circulating through heat exchangers in the basins simulating the utilization of condensor-cooling water from the generation of electrical power. This project will conclude with a series of utilization seminars and workshops.

Wastewater Reuse for Regional Management of Water to Meet Urban Needs; *Arun K. Deb;* Roy F. Weston, Inc., Weston Way, West Chester, Pennsylvania 19380; $176,500 for 24 months beginning September, 1976.

Until recently, the general approach to solving the interrelated problems of municipal water supply and wastewater management was to consider them individually. It has been possible to obtain water of potable quality by treatment of surface and subsurface supplies. Natural waters benefit from prior and more recent actions to reduce or eliminate the discharge of pollutants from municipal and industrial sources. However, land development and more intensive pressures for increased utilization of farmland have increased the amount of pollutants entering waters from various non-point sources. It has become increasingly more difficult and expensive to bring water, as found in natural lakes, streams, ponds, and subsurface locations, to potable quality.

The objective of this research is to analyze alternatives to the single, municipal water supply system. The investigators plan to acquire data on existing water supply systems, formulate mathematical descriptions of unit processes and operations relating to treatment and transport of water and wastewater, and synthesize a method for analysis of these interrelated problems to obtain the least-cost solution.

Tertiary Treatment of Municipal Wastewater Using Cypress Wetlands; *Walter R. Fritz;* Boyle Engineering Company, 3025 East South Street, Orlando, Florida 32803; $43,700 for 12 months beginning September, 1976.

The objective of this study is to assess the feasibility of utilizing cypress wetlands for placement of effluents from secondary treatment processes to achieve tertiary treatment objectives, utilize

nutrients effectively, and conserve water. This engineering-feasibility study is being directly coordinated with the research at the University of Florida's Center for Wetlands, under the direction of Dr. Howard T. Odum. This program is investigating experimental cypress dome wetlands near Gainesville in Alachua County, Florida. The study includes considerations of engineering feasibility, cost-effectiveness, energy needs, effect on regional environmental quality, reliability of the concept and coordination with regulatory agencies. Expected results include the identification of specific locations in Florida and Southeastern states where wetlands in a similar configurational relationship with communities could be utilized to meet regional water quality and quantity management needs. Such communities would include utility companies, mobile home parks, and shopping centers, among others.

Utilization of Waste Heat from Power Plants in Aquaculture; *Carlos R. Guerra;* Public Service Electric and Gas Company, Research and Development Department, 80 Park Place, Newark, New Jersey 07101; $270, 868 for 12 months beginning September, 1976.

The objective of this award is to initiate a proof-of-concept experiment for the utilization of thermal discharges from power generating stations for the purpose of commercial culture of edible aquatic animals to determine the technical and commercial feasibility of the concept. The experiment assesses process reliability, reproducibility, and product acceptability.

An aquaculture facility at the Public Service Electric and Gas Company's Mercer Generating Station at Trenton, New Jersey, is being used for the sequential culture of freshwater shrimp from May through October and rainbow trout from November through April. Wastes from the processing of other foods are being investigated for their potential in reducing aquaculture-feed costs.

Subcontracts for portions of the research plan have been awarded to Trenton State College and Rutgers University. Nutritional factors being studied at Rutgers University include amino acid and calcium diet supplementation, food conversion efficiencies and physical factors influencing intestinal absorption of food, and potential pollutants such as coal, chlorine, and heavy metals. The Trenton State College subcontract is directed toward improvement in the management procedures. These include field application of nutritional data, intensive culture techniques and brood stock management. Long Island Oyster Farms, Inc. is assisting in the evaulation of commercial feasibility and the New Jersey Department of Agriculture's Division of Rural Resources is studying adaptation of agricultural facilities to the production of fingerling trout.

Feasibility of Utilization on Wetland Ecosystems for Nutrient Removal from Secondary Municipal Wastewater Treatment Plant Effluent; *Robert H. Kadlec;* Department of Chemical Engineering, University of Michigan, Ann Arbor, Michigan 48109; $43,500 for 4 months beginning August, 1976.

Treatment of wastewater has as its primary and secondary objectives the removal of suspended solids and carbonaceous material that would otherwise exert a demand upon oxygen resources of the receiving waters. In addition, nutrients remaining in the effluent from secondary treatment can stimulate the growth of algae and other aquatic vegetation which upon death and decay also exert a demand for oxygen. Alternatives for solving this problem include removal of the nutrients by chemical precipitation. However, another alternative is the use of highly productive wetlands into which secondary effluent can be directed and within which nutrient removal can be achieved simultaneously with an increase in the productivity of the wetland. Use of a wetland for this purpose can be considered a problem of designing a system of constraints on the supply rate and distribution of the effluent that permits the marsh to maintain itself and function in a manner such that

water output meets environmental quality standards while simultaneously maintaining the viability of the wetland ecosystem.

The objective of this project is the determination of the feasibility of using a peat marsh to achieve goals of advanced treatment for muncipal wastewater. A ten-acre site in the Houghton Lake Wildlife Research Area is being flood-irrigated with effluent from the Roscommon Township Wastewater Treatment Plant.

The design of a full-scale treatment facility and development of a management plan have led to the adoption of a concept for implementation by the township, State of Michigan and the United States Environmental Protection Agency. The plan is to utilize this wetland for expansion of the treatment plant to full-scale. Intensive evaluation of this proof-of-concept experiment is planned. The firm of Williams and Works is exploring the regional significance of the extension of this concept to other communities under a related grant.

Management of Physical Alterations to the Edges of the Chesapeake Bay and Their Effects on Environmental Quality; *William H. Queen;* Chesapeake Research Consortium, Inc., 100 Merrymen Hall, Johns Hopkins University, Baltimore, Maryland 21218; $93,000 for 5 months beginning July, 1976.

This award is for the completion of a research project which has been directed toward the assessment of the environmental significance of physical alterations to the shoreline of the Chesapeake Bay with a concentration on developing methods for predicting environmental effects from trends and rates of shoreline alteration. Recommendations, guidelines and criteria for management of the coastal development products of this research are based upon selective analysis of permit applications for alterations, case studies of a representative set of permit applications, and shoreline studies of selected Bay counties.

Results of previous work under this grant are being utilized to guide consideration of permit applications for alterations to the shoreline of the Chesapeake Bay by the regulatory agencies including the Baltimore and Norfolk Districts of the United States Army Corps of Engineers.

Although the research objectives have been expressed in terms of the physical alteration problems of the Chesapeake Bay, these same shore zone alteration problems are similar along much of the coastal shoreline of the United States. Therefore, any new procedures, techniques and methodologies for addressing these problems within the Bay region are likely to be useful to other regions in the United States that are being subjected to comparable pressures for development of shoreline property for commercial, residential, and recreational purposes.

Socioeconomic Correlates of Household Residuals—Phase 2: Management Strategies; *William L. Rathje;* Department of Anthropology, University of Arizona, Tucson, Arizona 85721; $26,900 for 12 months beginning September, 1976.

The supply, distribution, utilization, and waste of food are important national and international issues. At the local level, their presence as a constituent of mixed household refuse adds to the problem of non-renewable resource recovery from mixed discards and adds to the problem of their management to achieve adequate standards of local sanitation and regional environmental quality. Data collected since 1973 in Tucson, Arizona indicates that approximately nine percent of the food purchased by 600 sample households was discarded. If sample households were representative of all households in Tucson, an estimated 9,500 tons of food valued at $9-11 million were discarded to sanitary land fills in 1974. In the process of being stored, collected, and transported, these household discards can adversely affect the environmental quality if improperly managed.

The objective of this research is to correlate the

amounts and composition of household refuse with the social and economic characteristics of populations. The analytical and statistical concepts being developed are expected to be of use to municipal sanitation agencies in planning better management procedures for these households residual wastes.

The specific objective of this portion of the project is being conducted with the cooperation and assistance of the City of Tucson Sanitation Division, Department of Operations. It involves 1) the refinement of observations about the relationships between interview surveys and residuals analysis data; 2) the determination of the effects of economic stress upon nutrition; and 3) the correlation of demographic variables and composition of residuals with human and environmental risks associated with their management.

Symposium/Workshop on Environmental Impacts of Dredging; *W. Lee Schroeder;* Department of Engineering, Oregon State University, Corvallis Oregon 97331; $25,000 for 9 months beginning September, 1976.

This is a supplemental award for the purpose of funding a subcontract to the Research Triangle Institute of Durham, North Carolina which will organize a three-day workshop to critically review a draft of procedures for the assessment of the environmental impacts of dredging. The workshop will consider the impacts of dredging on biological systems with emphasis on relationships between and among benthic chemistry, sediment physics, marine traffic, and sediment turnover.

The conference is being coordinated with the United States Army Corps of Engineers Waterways Experiment Station's dredging research program and the United States Environmental Protection Agency. The final report is expected to be of interest to regulatory agencies, estuarine resource management agencies, and individuals or organizations in both the public and private sector who are or may be seeking permits to dredge. The project manager for the Research Triangle Institute is Martin F. Massoglia.

Immobilization of Hazardous Residuals by Encapsulation; *R. V. Subramanian;* Department of Material Sciences and Engineering, Washington State University, Pullman, Washington 99164; $56,600 for 12 months beginning September, 1976.

Liquid residuals that contain toxic or otherwise hazardous substances must be managed in such a way as to minimize the danger of contamination of the environment at management sites. The objective of this research is to devise and evaluate methods for solidification of liquids containing hazardous substances. This is a continuation of research started under a previous grant which resulted in the conclusion that encapsulation of hazardous aqueous wastes in a water-extensible polymer matrix is technically feasible. The encapsulation procedure results in a lightweight solid that can be safely transported and stored.

The object of this continuation period is to determine the long range leachability of the substances incorporated in the polyester matrix and its applicability to actual hazardous wastes. An evaluation of the immobilization process is being investigated for suspensions of particulates. Optimum conditions for the emulsification and curing steps are being standardized and strength properties of the solidified product will be determined. Leaching experiments are being conducted to assess the effects of different ion size and charge on leachability from the polymer matrix.

URBAN HYDROLOGY

The Urban Hydrology subelement is aimed at developing a framework to increase the information base of the processes of interaction between the land and water systems, in order that this material may be utilized to improve water resources planning and management. Objectives include: 1) assess the influence of a variety of land uses on quality and quantity in the aquatic system; 2) evaluate the integrated impacts of land, air, and water pollution; 3) measure and predict erosion and sedimentation in natural environments and areas disturbed by urbanization processes; 4) predict and measure costs and benefits of alternative policies and management schemes for water resources planning in urban areas; and 5) measure and predict societal attitudes and perception of alternative water resources management schemes.

Impact of Urbanization on Gullying; *Stanley A. Schumm;* Department of Earth Resources; Colorado State University, Fort Collins, Colorado 80523; $100,200 for 24 months beginning September, 1976.

Gullying is a major land management problem in the semiarid Western United States. Increased urbanization in this region is aggravating the problem. This study is designed to increase our understanding of the gully phenomenon and thereby enhance the ability of resource managers to take appropriate control measures.

To achieve these goals, a program of field work to inventory the scale of the problem in selected areas is being undertaken. It is dealing with the factors which control sediment yield and the rates of change of gully morphology. These studies are being compared with a laboratory study of the gullying process to define more accurately the physical principles involved. A mathematical model of gullying is being developed, using the data collected, to define the magnitudes of the components of the model. The program is using a Colorado State University scale-model watershed which is being tested and verified by means of prediction and subsequent confirmation of the gullying process in urbanizing watersheds within the study region. A handbook describing this methodology and its use by resource managers will result from this study and will be widely distributed.

Environmental Pollutants and the Urban Economy; *George S. Tolley;* Department of Economics, University of Chicago, Chicago, Illinois 60637; $38,300 for 12 months beginning August, 1976.

It is generally recognized that air and water quality is closely associated with certain categories of land use. Conversely, it is being recognized that air and water quality control policies may have a profound affect on land use and may indeed thwart the efforts to achieve original air and water quality objectives.

The objective of this project is to develop a framework in which benefits and costs of alternative environmental control policies can be evaluated. This project is particularly concerned with gaps in the knowledge of the effects of water pollution control policies.

Results are expected to be applied to specific policies relating to Federal water pollution control policies including the National Environmental Protection Act, the Federal Water Pollution Control Act, and those policies and regulations on a State and local level that were developed in response to Federal legislation.

Determination of Urbanized Headwater Flooding Damage Potential; *John H. Wiggins;* John H. Wiggins Company, 1650 South Pacific Coast Highway, Redondo Beach, California 90277; $32,000 for 5 months beginning September, 1976.

Flooding studies, up to this time, have chiefly centered on damage caused by major stream and river overflow. Localized flooding, less than 100 square miles, has not been treated on a national basis relative to its potential for damage or the mitigations that can be applied to reduce damage. Local flooding has not received the attention that many experts today contend it deserves. Although this type of flooding does not cause large "disasters," it is believed that the frequency of one to four or more structure events is high enough so that total losses from local flooding may approach 24 to 40 percent of the total losses from riverine floods.

This project is concerned with the development of analytical techniques to measure the relative importance of potential flooding in urbanized headwater locations. The analyses will be used to predict the hazards of urbanized headwater flooding associated with a variety of land use and other environmental policies. The resulting report will provide an analysis of losses due to shallow flooding, as well as the effects of various mitigations on loss modification, and will be aimed at managers concerned with land use and water resource decisions.

DISASTERS AND NATURAL HAZARDS

Destruction of property caused by natural hazards such as earthquakes costs billions of dollars and thousands of lives each year. In addition, extensive damage is attributed to certain weather hazards such as hail, drought, lightning, and highway fog. The Disasters and Natural Hazards Program element seeks to develop methods and techniques that can provide more cost-effective protection for man and his works from the life loss, injury, property damage, social dislocation, and economic and ecological disruption caused by natural hazards and disasters.

The three Program subelements are:

- Earthquake Engineering
- Societal Response to Natural Hazards
- Weather Modification

EARTHQUAKE ENGINEERING

Earthquakes are potentially the most devasting of natural disasters. The NSF Earthquake Engineering subelement supports a broad, basic, and applied research activity in all aspects of engineering, geotechnical geology, social, and behavioral sciences which are aimed at developing methods and procedures for the mitigation of earthquake disasters. The subelement's major thrust is to conduct research into the probable intensity of earthquakes that may occur, the response of new and existing buildings, and the behavior of the engineered man-made structures in order to investigate the losses due to earthquake events. In response to the need to assess the likelihood of such losses and to weigh these against the increased cost of planning and designing structures to avoid them, the Earthquake Engineering subelement is directed toward the following objectives:

- Develop economically feasible design and construction methods for building earthquake resistant structures of all types.
- Develop procedures for integrating information on seismic risk with ongoing land use planning processes.
- Develop an improved understanding of social and economic consequences of individual and community decisions on earthquake related decisions.
- Present program results in forms usable by the affected interest communities to control the vulnerability to earthquakes.

A New Approach to the Prediction of Earthquake Strong Motion; *Keiiti Aki;* Department of Earth and Planetary Sciences, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139; $146,700 for 18 months beginning July, 1976.

Scientific evidence has convincingly shown that no part of the United States is immune to the earthquake threat. For safety design of structures, the determination of the expected earthquake ground motion at the site is essential. For areas where historic earthquake data is available, the design ground motion can usually be constructed without much difficulty. For areas where little or no historic earthquake data exists the problem of predicting the site ground motion and establishing the design basis for earthquake-resistant structures remains unsolved.

In this project a semi-empirical approach is being developed to establish the appropriate scaling law, to determine the properties of the earth's crust, and finally to predict the strong ground motion of various seismic areas.

The theory, methods, models and results will be put together and published as technical reports. These reports will be widely distributed to practicing structural engineers, land use planners, building officials, as well as code bodies. The major significance of the reports will be the establishment of true regional seismic risk potential and realistic design seismic forces for structures.

Estimation of Strong Ground Motion from Small Seismic Events in Garm, U.S.S.R.; *Keiiti Aki;* Department of Earth and Planetary Sciences; Massachusetts Institute of Technology, Cambridge, Massachusetts 02139; $59,500 for 18 months beginning July, 1976.

In a cooperative field experiment project with Russian seismologists sponsored by the U.S. Geological Survey, a self-contained, mini-computer laboratory and four portable, digital seismic stations were operated for a period of six months in 1975 in the Garm district of the Republic of Tadzhikistan in the U.S.S.R. Garm is a very active earthquake region with a long history of geological and seismological research. As a result, it is a well instrumented area. This grant is to provide research support, including six months of data analysis and field work in Russia, in order to complete the cooperative program.

The purposes of this project are: 1) to study propagation phenomena and seismic source mechanism applying the techniques and experiences developed by U.S. seismologists; 2) to observe earthquakes of a tectonic region in Garm; and 3) to learn the related techniques and experiences of Russian seismologists.

It is hoped that the experiment will provide useful information about the high frequency content of seismic waves and its variation with azimuth near the source of an earthquake. It will also attempt to give the rationale for predicting strong motion records from records of small events. An important element of this research will be the exchange of ideas not only between seismologists and earthquake engineers, but also between American and Russian scientists.

The award provides for a subcontract to the University of California at San Diego.

Seismic Resistance of Precast Concrete Panel Buildings; *James M. Becker;* Department of Civil Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139; $276,900 for 24 month beginning September, 1976.

This project continues the preliminary work completed under an initial project which included a survey of the current practices in the seismic design of large scale precast concrete panel buildings, an examination of the problems of analytical modeling, and preliminary parametric studies using response spectrum model analysis.

The modeling approach developed in the previous study indicated the need for more realistic representations of the overall range of structural behavior of precast concrete panel buildings. Such representations to be developed in this project include the study of nonlinear, inelastic response of connection areas and panels, and consideration of the overall response of the three dimensional aspects of an entire structural system.

Interaction meetings between the research team and the essential interest-user groups has been planned. These groups have been divided into four categories: governmental agencies, design professionals, precast fabricators and contractors, and other research organizations.

Workshop on Earthquake Resistant Reinforced Concrete Building Design; *Vitelmo V. Bertero;* Department of Civil Engineering, University of California, Berkeley, California 94720; $130,000 for 16 months beginning August, 1976.

Research on various aspects of reinforced concrete design and construction has been performed by many researchers in the United States and abroad for many years. During the same period, the number of researchers has increased several times thus producing a significant amount of information on the behavior of reinforced concrete structures in seismic regions. To date, the research results are

spread throughout the literature and it is difficult for practitioners and individual researchers to assimilate the data properly and efficiently in the course of their everyday activities.

It is appropriate to assemble all the significant research results and current research activity into one volume, so as to assess its importance, to note the voids which exist, and to determine the priorities of future research and its application in the areas of design, planning and construction of such buildings in seismic regions. These are the objectives of the workshop.

The proceedings of the workshop will be published by the University Extension in cooperation with the Earthquake Engineering Research Center at Berkeley. Distribution of the reports will be to the participants and will be available to professionals, building code agencies, and officials of local, State, and Federal agencies.

Seismic Investigation and Design Criteria for Industrial Storage Racks; *John A. Blume;* John A. Blume & Associates, 130 Jessie Street, Sheraton Palace Hotel, San Francisco, California 94105; $184,300 for 24 months beginning September, 1976.

Storage racks are important to life safety in regard to the storage of emergency supplies, hospital drugs, medical inventories, blood bank storage capacities, and critical foodstuffs as a resource in post-earthquake recovery. Approximately 40 percent of all goods consumed in the United States are placed on storage racks at some time during their production-to-consumption cycle.

While some initial work has already been completed by the Rack Manufacturer's Institute, additional research is needed to verify and implement the initial findings. The objective of this research is to perform the necessary investigations to develop realistic criteria and procedures for the seismic design of industrial steel racks. Seismic motion criteria are being developed and detailed dynamic analyses are being performed using the data and results of earlier studies. The analytical results will be correlated and the experimental results of shaking table tests of full-scale racks, loaded and unloaded, so that future designs of industrial storage racks can incorporate realistic seismic resistance.

The comparative results and proposed code changes will be submitted to the model code organizations and distributed to the profession. The award provides for a subcontract to R.W. Clough of the University of California at Berkeley and H. Krawinkler of Stanford University, Stanford, California.

Seismic Resistance of Fossil-Fuel Power Plants; *John L. Bogdanoff;* School of Aeronautics and Astronautics, Purdue University, Lafayette, Indiana 47907; $75,000 for 3 months beginning July, 1976.

This project is a continuation of a previously funded program. The research concentrates on the determination of the dynamic behavior of large fossil-fuel steam power generating plants subjected to earthquake forces. The researchers are continuing to investigate the behavior of the principal structural components of this type of power plant: furnace-boiler, steam and feedwater piping system, coal and handling equipment and conveyor system, cooling towers, and stack.

The results of the research will be used to: 1) recommend improvements in the structural design for earthquake resistance of old and new plants; 2) recommend a policy on spare parts to be available in the event of a disaster; 3) recommend design guidelines and procedures; 4) develop simplified computer codes; and 5) recommend design provisions. Presently industry and professional engineers engaged in the design of fossile fuel power plants have no generally accepted design procedures for the seismic resistance of these plants. Hence, the research is timely and of importance.

Design Motion Simulation Close to Faults; *David M. Boore;* Department of Geophysics, Stanford University, Stanford, California 94305; $40,100 for 12 months beginning August, 1976.

An appropriate earthquake-resistant design of structures depends heavily upon the accuracy of the design ground motion at the site location. Existing methods for the determination of the design ground motions and spectra are mostly based on simplification of faulting actions and are limited in application to shorter distances because of insufficient close-to-fault ground motion records that are currently in existence. To overcome this difficulty, it is necessary to improve the useful existing methods to take into account the physical faulting mechanism and the statistical variation in the ground motion caused by various parameters.

The research is formulated to develop a valid and useful method to derive design motions close to the causative fault by combining basic seismological methodology, wave propagation techniques, source parameters knowledge, and statistics derived from the existing strong motion data. The project will: 1) develop a deterministic-statistical method for the specification of design motions; 2) carefully evaluate the available simulation techniques; and 3) continue the analysis of existing strong motion records to understand more fully strong ground motion within 10-20 kilometers of the fault.

The ultimate product will be a rational method of deriving design motions at sites close to faults. The developed method will be offered to practicing engineers, research committees, and code bodies to establish the design ground motions for various seismic areas.

Energy Absorption Characteristics of Structural Systems Subjected to Earthquake Excitation; *Ray W. Clough;* Department of Civil Engineering, University of California, Berkeley, California 94720; $103,000 for 6 months beginning August, 1976.

This is a continuation and expansion of work initiated under a previous grant. The program of activities includes the testing of structural components such as reinforced concrete beams and beam-columns, reinforced concrete beam and column subassemblies and reinforced concrete frames with spandrel walls. The moderate size earthquake simulator is being used to verify, extend, and modify an analytic understanding of the earthquake response of steel rigid and braced frames, reinforced concrete bare frames, reinforced concrete frames with shear or infilled walls, and masonry structures.

The results of these experimental activities will be correlated with theory and compared with the results of a separate field test program. Concurrent analytical research is being directed toward developing computational procedures which engineers can use to predict, with sufficient accuracy and economy for practical purposes, the inelastic response of real structures under strong earthquakes, the extent of damage likely to be inflicted, and the probability of complete collapse.

National Information Service for Earthquake Engineering; *Ray W. Clough;* Earthquake Engineering Research Center, University of California, Richmond, California 94804; $100,000 for 14 months beginning August, 1976.

The purpose of this project is to collect, organize, and disseminate all the research information currently available on earthquake engineering and related areas. This will provide an opportunity to collect and assess information from many different sources and at the same time be a single comprehensive source of information for researchers in the field. This will be geared to meet the needs of both academic researchers and design engineers.

The computer program distribution service currently in use has a total of 26 programs, each fully developed and suitable for use in professional engineering offices. Many new programs are being added to the library and are becoming available for distribution as they are developed. The Earthquake Engineering Research Library will consist of published and unpublished technical reports, site visits records, collected data from various seismic regions, and an abstracting service. An earthquake engineering abstract journal directed to the needs of researchers and engineers is published and distributed on a yearly basis.

Structural Loads Analysis and Specification; *C. Allin Cornell;* Department of Civil Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139; $375,600 for 24 months beginning September, 1976.

Structures, such as buildings and bridges, are subjected to a natural and man-made loading environment which is complex and hazardous. The present techniques for assessing the risks associated with various loads and load combinations have developed largely within special disciplines such as seismic and wind engineering. As a result, they lack the unity which could bring an improvement to load specifications and a comprehensive understanding of risk.

This study is to 1) develop unified sets of representations of the random characteristics of structural loads; 2) develop and study alternative codifiable treatments of loading and load combination specifications; and 3) carry out necessary research that these developments require. In addition to the continuing primary focus on developing a set of relatively simple unified models of loads, it is apparent now that there exist some unifying principles in the most advanced models of loads now available. An additional objective will be to clarify and report these more advanced unified concepts in models as well.

The new design provisions by the Applied Technology Council, which depend on these standards, will be affected directly. This project is a continuation of a previously funded grant.

Use of Concrete Demolition Wastes as Aggregates in New Construction; *Stamatia Frondistou-Yannas;* Department of Civil Engineering, Massachusetts Institute of Technology, Cambridge, Masschusetts 02139; $35,600 for 12 months beginning September 1976.

Concrete is the most widely used construction material, accounting for 75 percent by weight of all construction materials currently used. It follows that in urban areas sustaining destruction, concrete accounts for a major fraction of demolition wastes.

It has often been hypothesized that waste concrete is a technologically and economically promising replacement for concrete aggregate. A definitive test of this hypothesis would have major implications on decisions involving the clearance and rebuilding of destroyed areas. If the hypothesis is confirmed, the vast amounts of concrete waste in disaster areas could be accumulated on a convenient site in the destroyed area ready to be used as an immediate source of aggregate to rebuild the area. Recycling concrete in this manner may solve an occasionally difficult waste disposal problem. It may also solve the problem of local unavailability of natural aggregates from a quarry. This is a severe problem in some areas of the country.

This research project is a feasibility study to assess conclusively the technological and economic attractiveness of waste concrete as an aggregate. In terms of its economic attractiveness, the study will evaluate the cost-effectiveness of the recycling process. The technological aspect will ascertain the strength of recycled concrete in relation to its original strength.

This is a joint sponsorship program in conjunction with the Division of Advanced Energy and Resources Research and Technology of the National Science Foundation.

Evaluation of Liquefaction Potential of Saturated Granular Soils; *Jamshid Ghaboussi;* Department of Civil Engineering, University of Illinois, Urbana, Illinois 61801; $97,700 for 24 months beginning October, 1976.

In general, soils consist of a solid granular skeleton saturated by an air and water mixture. In the analysis of soil structures, some of the effects of the pore water or air/water mixture on the dynamic response of the soils are neglected. These effects may significantly influence the behavior and performance of certain types of earth structures, especially under dynamic and earthquake loading.

The objective of this research is to develop a methodology for the assessment of the liquefaction potential and the determination of pore pressure in saturated soil during earthquakes. This methodology is being used in a series of parametric and case studies leading to the development of recommended procedures for aseismic design.

In this project a two phase model will be adopted for the study of the quasi-static and dynamic behavior of soil structures. The solid and fluid portions will be treated as separate materials with appropriate individual material properties. Their interaction, including flow of the fluid with respect to solids, are being accounted for.

Seismic Resistance of Concrete Slab to Column Wall Connections; *Neil M. Hawkins;* Department of Civil Engineering, University of Washington, Seattle, Washington 98105; $248,800 for 24 months beginning September, 1976.

This grant is continuing the research of a previously supported award which was concerned with the strength of reinforced concrete slab-to-column and slab-to-wall connections subjected to strong dynamic loads.

Concrete flat-plate construction is an economical and aesthetically pleasing structural form that has become one of the most widely used concrete structural systems in the United States. Advantages of flat-plate concrete construction include minimized floor depths, reduced formwork costs, improved construction turn-around time per floor, minimum impediment to the placement of mechanical and electrical services, and maximum flexibility for architectural design. Unfortunately, the seismic resistance and the development of progressive collapse situations are not well understood and this has led to some dramatic failures of flat-plate concrete structures. It is the objective of this study to develop a better understanding of the behavior of concrete flat-plates subjected to reversed cycle dynamic loads and to transfer this information into design codes and new design procedures which will ensure the safety of flat-plate structures constructed in seismically prone regions.

The experimental phase of the project continues to be supported by a vigorous analytical program. This program has two parts. The first part of the analytical program concerns the development of mathematical models capable of predicting the experimentally observed results. The second part concerns the development of appropriate procedures, based on the experimental data, for predicting the theoretical seismic response of typical flat-plate structures. During 1975, a procedure was developed that predicted with great accuracy, the monotonic loading response measured in the interior column connection tests. In this continuation that procedure will be extended to reversed cyclic loading and dynamic response prodictions.

National Information Service for Earthquake Engineering - California Institute of Technology; *George W. Housner;* California Institute of Technology, Pasadena, California 91104; $207,700 for 36 months beginning September, 1976.

This grant provides continued support to the National Information Service for Earthquake Engineering (NISEE) at the California Institute of Technology.

NISEE has been a key factor in advancing the state-of-knowledge concerning earthquake engineering and in transferring this knowledge into practice. Increased concern regarding the safety and performance of buildings, dams, nuclear power plants, etc., has encouraged the engineering profession to adopt better techniques for the is and design of such facilities. Analysis of digital computer calculations is one such technique. The NISEE provides this data base for earthquake engineering in the United States and has been of particular value to engineers in the western part of the country. Virtually all calculations made by digital computers in the United States use ground motion data obtained from NISEE.

Each year NISEE receives thousands of requests for information from earthquake researchers and practicing professionals. Without the existence of NISEE, much of this information would be almost impossible to obtain. The Caltech Earthquake Engineering Research Library together with the Strong Motion Records Data Bank form one nucleus of this activity.

Support of the USCOLD Committee - Evaluation of the Incremental Seismic Risk Due to Reservoir Filling; *George W. Housner;* California Institute of Technology, Pasadena, California 91104; $7,400 for 12 months beginning September, 1976.

This project is the continuation of a grant previously awarded by the National Science Foundation. It is for the Commitee on Earthquake Effects on Dams, which is an integral part of the United States Committee on Large Dams (USCOLD).

The commitee has in progress the following projects; 1) collection of data on the effects of reservoir filling on occurrence of earthquakes near dams; 2) seismic instrumentation for dams; 3) collection of information on strong earthquake motions on or near dams; and 4) collection of information on all dams that have experienced strong ground shaking with or without damage.

The committee includes representatives of industry, academic institutions, and Government, all of which are concerned with the safety of dams from earthquakes and interested in the best procedures for planning and designing dams in seismic regions.

Study and Implementation of an Ionospheric Technique to Improve Tsunami Warning; *Kazutoshi Najita;* Department of Electrical Engineering, University of Hawaii, Honolulu, Hawaii 96822; $132,400 for 24 months beginning July, 1976.

The research for this project is directed toward three principal objectives: 1) operational tests of an ionospheric tsunami warning system and improvement of the electronic units previously developed; 2) integration of the system into the Pacific Tsunami Warning System on an experimental basis; and 3) improvement and simplification of the source-mechanism analysis method to determine numerical probability for tsunami generation as a basis for more accurate tsunami prediction data.

The devastative power of destructive tsunami waves generated by ocean-based earthquakes is well documented in the literature. The Alaska earthquake of 1964 generated tsunami waves which caused severe damage throughout the Gulf

of Alaska, along the West Coast of North America, and on the Hawaiian Islands. The Chilean earthquake of 1960 resulted in tsunami damage along the shores of South America, parts of North America, the Hawaiian Islands, New Zealand, the Philippine Islands, the Japanese Islands, and other areas in and around the perimeter of the Pacific Ocean.

Effects of Earthquake Motions on Reinforced Concrete Buildings; *Mete A. Sozen;* Department of Civil Engineering, University of Illinois, Urbana, Illinois 61805; $340,200 for 24 months beginning September, 1976.

This investigation is the second phase of a research program designed to identify and understand the mechanisms of energy dissipation in slender reinforced concrete structures subjected to strong ground motion, with a view to the development of simple but realistic design methods for earthquake resistance.

The first phase of the program involved tests and analyses of structural walls and frames acting independently. The second phase is a study to investigate the interaction between wall and frame systems in the nonlinear range of response.

The scope of the work includes: 1) tests of four small-scale ten-story structures incorporating walls and frames; 2) development of an analytical model to simulate the measured response histories; and 3) studies of the data jointly studied with the results from the previous tests.

Tests will be carried out using the University of Illinois Earthquake Simulator.

Tall Building Response Parameters Evaluated Under Different Levels of Excitation; *George T. Taoka;* Department of Civil Engineering, University of Hawaii, Honolulu, Hawaii 96822; $60,000 for 24 months beginning August, 1976.

The development of earthquake design procedures requires a proper understanding of the dynamic characteristics of a structural system under earthquake conditions. An identification of the dynamic characteristics of these systems can lead to a mathematical representation, or model, of the system. The structural response to ground motions can be computed with such a model.

The present project studies and compares the dynamic characteristics of seven tall buildings under forced and ambient conditions. The objective is to test the practical applicability of the following system identification methods: 1) filtered auto-correlation method; 2) maximum likelihood estimation; and 3) spectral moment method. This objective will be achieved by estimating the values of the dynamic response parameters of seven existing structures by the above methods, and by comparing the results with estimates obtained from forced vibration tests, by dynamic analysis, and from measurements gathered under typhoon and earthquake conditions.

Investigation of Strong Earthquake Ground Motion; *Mihailo D. Trifunac;* Department of Civil Engineering, University of Southern California, Los Angeles, California 90007; $78,700 for 24 months beginning October, 1976.

Contrary to general public opinion, the Eastern and Central United States are not free from the earthquake hazard. Although this area is not as seismically active as some states, such as Alaska and California, it has sufficient earthquake activity to be an important factor in the planning, locating, and designing of structures such as nuclear power plants, dams, aqueducts, and buildings.

The study intends to develop a more reliable method for the prediction of local strong earthquake ground motion taking into account all relevant geological and seismological parameters. The following research tasks are being conducted: 1) interpretation of strong-motion records based on different geological sites, different distances from the fault, and different earthquake magnitudes; 2) prediction of strong earthquake ground motion accelerograms for a given site; 3) analysis of the statistical properties of the response envelope spectrum and the effects of local geology; 4) analysis of the influence of various source parameters, such as stress drop, fault depth, and fault plane size, to the gound motion; and 5) analysis of the attenuation mechanisms of ground motions for different geographical and geological locations.

The results of the above tasks will be of practical value to the engineering profession in identifying the realistic regional earthquake risk and to structural designers in providing an accurate input description for local earthquake forces.

Seismic Vulnerability, Behavior and Design of Underground Piping Systems; *Leon R. L. Wang;* Department of Civil Engineering, Rensselaer Polytechnical Institute, Troy, New York 12181; $113,800 for 24 months beginning August, 1976.

Recent studies from earthquake experiences have found many important facts that are detrimental to many existing structures. Among the most vulnerable structures to seismic damage are the existing water and sewer distribution systems.

The continued function and maintenance of underground water/sewer distribution systems in seismic areas is vital to public health and safety in the event of an earthquake. Currently there are no rigorous earthquake provisions regulating the planning, analysis, design, and construction of these systems.

Traditional design of underground piping for water/sewer distributions systems to resist external loads is based on a static soil-structure interaction load/strength relationship. Existing city water/sewer main distribution systems, if conservatively designed under static loads, may or may not be able to resist a small or moderate earthquake.

This project intends to develop a systematic way of assessing the adequacy of existing water/sewer distribution systems, determining the vulnerability of the systems to earthquake damages and studying the cost-effectiveness of new designs to various magnitudes of earthquakes. A total of five analytical tasks on the dynamic analysis of beam-grid system, vulnerability papameteric, and cost-effectiveness studies of water/sewer systems will be conducted. These studies will lead to new design methodologies and recommendations for improving present design details for both new and existing systems.

An Evaluation of the Effects of Earthquake Input Motion Phasing on Structural Response Characteristics; *Stuart D. Werner;* Agbabian Associates, 250 North Nash Street, El Segundo, California 90245; $106,100 for 12 months beginning September, 1976.

Although not usually considered in most current design applications, the spatial variations of the seismic waves propagating across the length of the structure may, under certain conditions, have important effects on its response. To investigate these effects, this research program is developing techniques for analyzing phased input and spatially varying ground motions. Guidelines for assessing the importance of phasing effects on the earthquake-induced response of a given structure are also being defined.

The specific objectives are: 1) to develop techniques for determining the effects of earthquake motion phasing on the structural response; 2) to provide guidelines that indicate conditions for

which input motion phasing effects will be significant; and 3) to apply the techniques developed to the detailed analysis of selected soil-structure systems subjected to phased input motions. This project consists of a review of the current technology and an investigation on the response of simple structures located on or within an elastic half space. Such variables as soil properties, structure properties, and the excitation frequencies and angles of incidence of the seismic waves are being considered for a variety of soil-structure systems.

The results of this research will be of practical value to individuals and agencies associated with developing and maintaining earthquake resistant structures and lifelines vital to the support of a community. These would include transportation, communication, energy, water, and sewerage systems.

Prevention of Shear Strength Decay in Reinforced Concrete Members; *James K. Wight;* Department of Civil Engineering, The University of Michigan, Ann Arbor, Michigan 48109; $66,400 for 18 months beginning August, 1976.

Most reinforced concrete structures built in active seismic regions are designed with the philosophy that some inelastic deformations must be tolerated during a severe earthquake. To successfully satisfy this philosophy, a design criterion must be established that will allow certain members and connections within a reinforced concrete structure to undergo several cycles of inelastic deformation without suffering a significant loss in strength or energy dissipation capacity.

The current design procedures have only considered the preservation of flexural strength but have ignored the possible reduction in shear strength under the conditions of load reversals. This project is conducting experimental and analytical studies to investigate the use of intermediate longitudinal reinforcement and other special reinforcements to prevent a strength and stiffness decay in a reinforced concrete member under seismic excitation. In the experimental study, specimens of various member dimensions and reinforcement configurations are being tested. In the analytical program, the modeling of measured behavior and the effect of special shear reinforcement on building response are being investigated.

The results of the research will be used to formulate suggested revisions in the current design procedures for reinforced concrete structures.

SOCIETAL RESPONSE TO NATURAL HAZARDS

The broad objective of the subelement Societal Response to Natural Hazards is to evaluate recent and ongoing disaster-related programs of mission agencies at Federal, state, and local levels, and in private sectors. The research is designed to understand and evaluate the benefits and costs of different combinations of adjustments to natural hazards: prediction and warning, disaster preparedness, physical protection, land use management, insurance, and relief. Research is also aimed at finding the commonalities between adjustments for different hazards.

The three basic objectives of the subelement are to:

- Develop an understanding of the probable economic and social costs of the Nation's natural hazards.
- Survey and assess the several public and private disaster preparedness and response programs.
- Design, develop, and test alternative approaches to enable society to prepare for, respond to, and recover from disastrous events.

Legal Constraints on the Planning and Development of Disaster Home Warning Systems; *James L. Huffman;* Northwestern School of Law, Lewis and Clark College, Portland, Oregon 97219; $16,400 for 7 months beginning July, 1976.

Several government agencies, including the Defense Civil Preparedness Agency (DCPA), the National Oceanic and Atmospheric Administration (NOAA), and the National Weather Service, have been exploring the use of special radio systems to warn the general public of impending natural and man-made disasters. Rapid expansion of these radio systems is planned in the next three years. The systems raise several unresolved legal questions related to potential liability for system failures.

The objectives of this research project are 1) to identify those situations which present a substantial possibility that a legal suit might be successfully brought against warning system failures; and 2) to both identify and evaluate measures that might be employed to limit or eliminate liability for those suits.

The research methodology is studying applicable statutes and regulations, analyzing analogous case law, and exploring these issues with appropriate Federal Government and private officials. This method will meet the two objectives of describing potential rights and liabilities and suggesting legal strategies which promote responsibility and minimize the scope of liability.

Mitigation and Recovery Policies for Natural Hazards; *Howard C. Kunreuther;* Department of Decision Sciences, University of Pennsylvania, Philadelphia, Pennsylvania 19104; $197,600 for 12 months beginning September, 1976.

This project is developing and implementing a disaster model to compare the benefits and costs of alternative hazard mitigation and recovery policies with respect to earthquakes and floods. Three areas of work are outlined for study: 1) preparation of damage scenarios; 2) analysis and synthesis of data available within the sphere of disaster response and mitigation relative to vulnerability, levels of preparedness, and damage estimates based on respective community profiles, including financial characteristics; and 3) model development and validation for comparing various strategies.

This is one of the first studies to include economic and financial considerations among the mechanisms which can be utilized in disaster mitigation planning. Previous research work in vulnerability analysis studies has stressed building damage and related injuries and deaths but has not adequately included the questions of financial characteristics.

A final report of the research results will be published and circulated to relevant Federal, State and local agencies, as well as industry and financial institutions.

Social Implications of Volcano Hazards; *Marion E. Marts;* Department of Geography, University of Washington, Seattle, Washington 98195; $45,000 for 16 months beginning July, 1976.

For the United States, the volcano represents a low probability yet high risk natural hazard which poses special problems for public officials, disaster related agencies, planners and the public-at-risk. The volcano hazard is significant in three major areas of the United States: Hawaii, the Cascade Range of the Pacific Northwest, and Alaska.

This project provides for a social and behavioral study of the implications of two volcanic threats, Mount Baker in the Cascade Range in upper Washington and the Mauna Loa area of Hawaii. The award supports exploratory work aimed at collecting baseline information and testing concepts applicable to the social response to volcanic hazards, including how individuals, families and communities respond to warnings of potential volcanic eruptions, curtail use of certain areas near the volcanoes, reduce the water level in a reservoir, etc.

The project has two phases with phase one having two parts. The first part deals with the recent Mt. Baker mud flow threat and its modifying effects on the community. Part two of this phase deals with the potential for failure of the public service delivery systems if a mud flow from Mt. Ranier occurs and the potential for strengthening these systems in the Puyallup Valley of Mt. Ranier. This area has a significant risk population of approximately 50,000 people. Phase two focuses on Mauna Loa and provides a cross check on the findings from the Mt. Baker study.

The U.S. Geological Survey, Federal Disaster Assistance Administration, the Forest Service, the National Park Service, the State Department of Emergency Services in Washington, comparable services in Hawaii and interested scholars in the academic community are being involved in this study to help assimilate the various resources necessary for the success of the project.

WEATHER MODIFICATION

The purpose of the Weather Modification subelement is to establish the concept of weather modification as a tool to help fulfill societal needs. The research seeks to study those atmospheric mechanisms which can be or are being influenced by man to modify natural weather patterns and evaluate the impact of their modification on society.

The objectives of the subelement are to:

- Develop and test weather modification technologies which mitigate the undesirable effects of weather, such as damage caused by hail or drought.
- Identify problems and opportunities arising from the inadvertent modification of weather by human activities.

The Weather Modification Subelement consists of these research areas:

- Improved Weather Modification Technology
- Inadvertent Weather Modification
- Social, Legal, and Economic Impact of Weather Modification
- Weather Hazard Mitigation

IMPROVED WEATHER MODIFICATION TECHNOLOGY

The objective of the Improved Weather Modification Technology subelement is to utilize predictive models, advanced measurement systems, and statistical analyses to improve experimental design and evaluation.

An Accurate and Inexpensive Airborne Wind Measuring; *John Chisolm;* Sierra Nevada Corporation, Box 13751, University Station, Reno, Nevada 89507; $61,600 for 15 months beginning August 15, 1976.

The objectives of this research are to: 1) conclusively prove the accuracy of the positioning and wind field measuring systems; 2) demonstrate the usefulness of accurate time-referenced aircraft position for an operational meterological field program; 3) develop instrumentation and software that can provide a real-time display of wind field and position in an aircraft, and use such a system on a second meteorological field program; and 4) report on the results achieved in these two programs and disseminate such reports to the meteorological community and other potential users such as the FAA and the air transport industry for use in operational measurement of wind shear and wind field.

A prior award has resulted in the fabrication of a complete airborne position location and wind finding system. The system is made up of two subsystems: a position determining and recording subsystem, and an accurate heading and airspeed reference subsystem. The position location and

recording subsystem will be installed on an NHRE aircraft to demonstrate the usefulness of accurate time-referenced position data to an operational meterological field program.

A second complete position location and wind finding system will also be fabricated. This system will, however, compute and display position and wind field in real time in the aircraft and will be used on an operational air quality program by the Desert Research Institute, University of Nevada. The net result of the research effort will be the demonstration, in operational use, that all aircraft can in the future be provided with cost-effective equipment for the accurate determination of position and/or wind field, thus eliminating a major operational deficiency.

An Assessment of Synoptic Criteria for Ice Multiplication in Convective Clouds; *John Hallett;* Desert Research Institute, University of Nevada, Reno, Nevada 89507; $23,500 for 12 months beginning August 1, 1976

Lincoln: University of Nebraska Press, 1974.

The major dilemma of ice nucleation to produce precipitation in super-cooled cloud systems is that the concentrations of ice crystals in natural clouds often vary greatly, sometimes by several orders of magnitude, from the measured concentrations of active ice nuclei. Secondary ice crystal production by mechanical breakup may account for at least a part of this difference. Criteria on temperature and droplet size for secondary ice crystal production have been derived in laboratory studies by Dr. Hallett. The research will test the applicability of the laboratory derived criteria to convective clouds in Colorado and other specific precipitation regimes.

Specifically, the goals of this project are to: 1) establish whether conditions for ice crystal multiplication have occurred in the case studies; 2) predict conditions where natural ice multiplication processes would likely occur on the basis of such criteria as lifting condensation level and cloud condensation nuclei spectra; 3) delineate conditions where the evaluation of cloud seeding effects could be confused with natural multiplication processes; and 4) briefly extend the conclusions to other simple precipitation situations largely on the basis of standard National Weather Service data.

Results of this research will be of considerable importance to continental convective cloud modification projects such as NSF's National Hail Research Experiment (NHRE), and the Bureau of Reclamation's High Plains Experiment (HIPLEX).

Ice Nucleation Induced by Bacteria; *Leroy R. Maki;* University of Wyoming, Department of Microbiology, Laramie, Wyoming 82071; $59,000 for 21 months beginning August 15, 1976.

Although it has been postulated that inorganic soil particles provide major portions of ice nuclei found in the atmosphere, it has only been within the past four years that there was serious consideration that biogenic ice nuclei may play a significant role in natural precipitation processes. Biogenic ice nuclei may arise from two sources: the microbial decomposition products of vegetation, and the microbes themselves. Both of these sources have been shown to be active as ice nuclei but the bacteria may produce nuclei active at temperatures as warm as -1.3°C. Assessing the value of bacteria as potential freezing nuclei may offer the opportunity to seed relatively warm supercooled clouds and thus be of some value in weather modification, directly benefiting agriculture and other activities affected by the water resources of the nation.

The objectives of the program to develop bacterial-derived freezing nuclei are primarily three fold: 1) study the feasibility of producing bacteria-derived nuclei in quantity, for weather modification; 2) sample leaf litter, soil, lake and stream

waters, air, and natural precipitation for viable active microorganisms; and 3) characterize the freezing nuclei so as to advance the knowledge concerning the mechanisms responsible for the freezing of supercooled water under natural conditions.

If successful, the seeding of supercooled clouds by bacteria and fractions of bacterial cells may be of help in increasing precipitation or in the control of hail storms. An understanding of the importance of bacteria-derived freezing nuclei may aid in explaining observed weather patterns over vegetated, arid, and marine areas of the world.

INADVERTENT WEATHER MODIFICATION

The objective of the Inadvertent Weather Modification subelement is to delineate the mechanisms whereby, and the extent to which an agricultural region modifies its own climate, and an urban area modifies its surrounding weather, precipitation, and aerosol.

Lidar and Radiometric Data Analysis of Mixing Levels, Clouds, and Precipitation Processes; *Edward E. Uthe;* Stanford Research Institute, Department of Atmospheric Physics, Menlo Park, California 94025; $45,200 for 10 months beginning August 1,1976

Project METROMEX (Metropolitan Meterological Experiment) is a cooperative research effort of several participants, including the University of Illinois, University of Chicago, University of Wyoming, and Stanford Research Institute (SRI). This research represents the final year of a six year program in the St. Louis area to define urban-produced atmospheric anomalies in precipitation, clouds, and severe weather, analyzing their impacts, and developing methods for predicting similar anomalies in the vicinity of other urban-industrial sites.

The specific objectives of the Stanford Research Institute program are to analyze the lidar and radiometric data obtained in the previous years efforts, and synthesize the results obtained, integrating the results from the lidar and radiometric measurements into the overall METROMEX final report. This information will provide an analysis of the St. Louis urban-industrial atmosphere, including depth of the boundary layer; a comparison of the urban mixing depth as observed by lidar and an acoustic sounder; mobile lidar studies of urban rural differences in mixing depth, cloud development, and temperature; and multiwavelength sunphotometer studies of particulate optical depth and size distribution.

SOCIAL, LEGAL, AND ECONOMIC IMPACT OF WEATHER MODIFICATION

The thrust of the Social, Legal, and Economic Impact of Weather Modification subelement is to evaluate societal reaction to weather modification, to determine societal expectations, and to identify the needs for the scientific base necessary to bring about successful application of weather modification. Research in the subelement extends across the disciplines of political, social, legal, economic, ecological, and physical sciences in an effort to investigate the impact of weather modification technology on man.

The Utilization of Weather Modification Technology: A State Government Decision-Making Study; *W. Henry Lambright,* Syracuse Research Corporation, Merrill Lane, University Heights, Syracuse, New York 13210; $60,400 for 18 months beginning September 1, 1976

Despite Federal initiatives in advancing the technology of weather modification through research and development, little effort has been made by the Federal Government with regard to the regulation of weather modification activities. State governments, therefore, have taken the lead in developing regulatory policies which play the dominant role in affecting the present use of the technology. Because of the independency of action among the states, primarily in response to forces within their own borders, the resulting State policies range from permissive to highly restrictive and are often quite provincial in their view.

To explore the bases of State weather modification policy, this research focuses on the decision making processes in five states featuring a range of policy approaches: South Dakota, Colorado, Illinois, Pennsylvania, and California. The study will develop case histories and analyses of policy-making for each of the States. The case studies will be built upon an extensive literature search and in-depth interviews with key participants in the policy development. The cases cover the evolution of policy through three phases of action: 1) the pre-legislative phase of interest-group awareness, activity, and mobilization; 2) the legislative phase of statutory enactment; and 3) the administrative phase of policy implementation.

This study will help Federal and State officials to make more effective decisions regarding such emerging technologies as weather modification.

WEATHER HAZARD MITIGATION

The objective of the Weather Hazard Mitigation subelement is to reduce the undesirable aspects of selected weather hazards. The major effort is in the study of hail. The NSF sponsored National Hail Research Experiment (NHRE) is attempting to determine the potential for suppressing hail damage by cloud seeding, and the extent to which hail suppression might be accomplished economically on an operational basis.

The Kinematics of Thunderstorm Gust Fronts Relating to the Mitigation of Airport Flight Hazards; *August H. Auer,* University of Wyoming, Department of Atmospheric Science, Laramie, Wyoming 82071; $56,300 for 12 months beginning August 1976

The "wind shear" phenomenon, often occuring as a result of a frontal system or a thunderstorm "gust front," has contributed to several aircraft accidents and near-accidents. The wind shear, which may occur horizontally or vertically, can be of sufficient magnitude to cause low-flying aircraft problems on take off or final approach to a landing. A commercial airlines accident attributed to wind shear occurred at Kennedy International Airport on June 24, 1975, resulting in the death of 113 people.

The University of Wyoming is conducting an investigation of the meteorological phenomena associated with wind shear using the field site, facilities, and resources associated with the METROPOLITAN METEOROLOGICAL EXPERIMENT (PROJECT METROMEX) efforts in St. Louis during 1976. The research objectives are to: 1) observe and analyze the characteristics of downdraft and gust frontal structures associated with the larger type of cloud development; 2) relate the downdraft and/or wind shear characteristics to low-level aircraft operation, including takeoff and landing; 3) analyze the data and synthesize the results based on the findings from these investigations and all other data and findings available; 4) make recommendations for the best approaches to handle the types of problems involved; and 5) disseminate this information to the potential users: commercial airlines, private pilots, commercial crop dusters, utility and telephone companies, aircraft designers, and manufacturers.

National Hail Research Experiment; *Donald L. Veal;* National Center for Atmospheric Research, Boulder, Colorado 80303; $800,000 for 4 months beginning July 1, 1976

Initiated in 1971, the National Hail Research Experiment seeks to assess the potential for altering hail and rain fall by cloud seeding, and determine the extent to which beneficial modification can be accomplished effectively on an operational basis. The research involves: 1) the conduct of a broad based but highly focused research program for gaining understanding of the mechanisms of natural hail and rain development and the effects of seeding; 2) studies to improve the power of a statistical experiment in detecting seeding effects by the development of suitable covariates; and 3) social, economic, legal, and environmental studies on the potential impact of precipitation modification.

During this portion of the study, the following issues will receive high priority: 1) where, when, and in what quantities should seeding be carried

out in N.E. Colorado storms to prevent hailstones from growing to damaging size; 2) which observable meteorological parameters can be employed as classification variables or as covariates to increase the power of statistical tests; 3) what methods should be used to disperse artificial nucleants; 4) what is the optimum design for an instrumented surface network to reveal a hail suppression effect in the shortest possible time; and 5) what criteria can be developed to evaluate whether the redesigned seeding experiment should be undertaken.

In addition to the above mentioned research issues, the project, during the summer of 1976, will include observations of storms by a network of Doppler radars and several aircraft, including the amored T aircraft carrying greatly improved instruments. Following sufficient progress in the development of hailfall covariates and classification variables, and better information about seeding location, amount, and effectiveness, an improved seeding experiment will be designed.

APPENDIX

Principal Investigator/ Institution	*Title*	*Amount*	*Effective Date/ Duration*	*Page*
CHEMICAL THREATS TO MAN AND ENVIRONMENT				
Airborne Contaminants				
Berlandi, Francis J. Environmental Research & Technology	Field Measurements of Biogenic Sulfur Emissions	$111,700	9/76 12	9
Friedlaender, Ann F. Mass. Inst. of Tech.	Workshop on Air Pollution and Administrative Control	$55,100	8/76 12	9
Hitchcock, Dian R. Environmental Research & Technology	Field Measurements of Biogenic Sulfur Emissions	$111,700	9/76 12	9
Huntzicker, James J. Oregon Graduate Center	The Chemical Lifetime of Sulfuric Acid Aerosols	$77,100	9/76 24	10
McElroy, Michael B. Harvard University	Nitrous Oxide Environmental Measurement Program	$126,200	10/76 20	10
Novakov, Tihomir Univ. of Calif.-Berkeley	Study of Chemistry of Atmospheric Particulates	$70,763	10/76 12	11
Zoller, William H. Univ. of Md.-College Park	Sources, Transformation and Speciation of Atmospheric Pollutants	$369,200	9/76 12	11
Nitrates				
Pratt, Parker F. Univ. of Calif.-Riverside	Nitrate in Effluents from Irrigated Lands	$529,300	6/77 12	12
Organic Chemicals of Commerce				
Chiou, Cary C. T. Oregon State Univ.	Chemodynamic Studies on Bench Mark Industrial Chemicals	$55,200	9/76 12	13
Eschenroeder, Alan Environmental Research and Technology	A Profile Model for Chemicals in the Environment	$75,700	9/76 12	13
Program Development and Utilization				
Jacknow, Joel Environmental Quality Systems, Inc.	A Study of Trace Contaminant Research Utilization	$14,800	6/76 12	15

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	REGIONAL ENVIRONMENTAL MANAGEMENT			
	Environmental Risk Management			
d'Arge, Ralph C. Univ. of Wyoming	Policy Modules for Environmental Management	$149,000	9/76 15	19
	Land Use			
Chambers, Charles J. Washington State Dept. of Natural Resources	Testing a Forest Management Environmental Resource Analysis System	$21,000	9/76 12	20
Godschalk, David R. Univ. of North Carolina-Chapel Hill	Defining the Constitutional Issues of Growth Management	$35,100	9/76 12	20
Heady, Earl O. Iowa State Univ. of Science & Tech.	National Environmental Models of Agricultural Policy, Land Use, and Water Quality	$235,000	8/76 12	21
Kneese, Alen V. Univ. of New Mexico-Alburquerque	A Policy Study of A Region Under Stress: The Southwest	$184,600	8/76 12	21
Kramer, Paul J. Duke University	Collaborative Evaluation and Analysis of Cost Effectiveness of Applications of Controlled Environment Facilities	$14,700	8/76 12	21
Potter, Loren D. Univ. of New Mexico-Alburquerque	Collaborative Research on Assessment of Man's Activities in the Lake Powell Region—Biological Limnology, Shoreline Ecology, and Heavy Metals	$106,500	9/76 12	22
Thompson, Russell G. Univ. of Houston	National Economic Models of Industrial Water Use and Waste Treatment	$6,900	8/76 3	22
	Regional Environmental Systems Evaluation and Analysis			
Hayes, Miles O. Univ. of South Carolina-Columbia	Distribution of Spilled Oil in Relation to Beach Morphology	$9,800	9/76 5	23
Sauter, George D. Lawrence Livermore Laboratory	A Seminar to Facilitate Further Applications of the Livermore Regional Air Quality (LIRAQ) Model	$29,800	9/76 7	23

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	Residuals Management			
Boersma, Larry Oregon State University	Utilization of Waste Heat in a System for Management of Animal Residuals to Recover and Recycle Nutrients	$41,500	8/76 12	24
Deb, Arun K. Roy F. Weston, Inc.	Wastewater Reuse for Regional Management of Water to Meet Urban Needs	$176,500	9/76 24	24
Fritz, Walter R. Boyle Engineering Co.	Tertiary Treatment of Municipal Wastewater Using Cypress Wetlands	$43,700	9/76 12	24
Guerra, Carlos R. Public Service Electric and Gas Company	Utilization of Waste Heat from Power Plants in Aquaculture	$270,868	9/76 12	25
Kadlec, Robert H. Univ. of Mich.-Ann Arbor	Feasibility of Utilization on Wetland Ecosystems for Nutrient Removal from Secondary Municipal Wastewater Treatment Plant Effluent	$43,500	8/76 4	25
Queen, William H. Chesapeake Research Consortium, Inc.	Management of Physical Alterations to the Edges of the Chesapeake Bay and Their Effects on Environmental Quality	$93,000	7/76 5	26
Rathje, William L. Univ. of Arizona-Tucson	Socioeconomic Correlates of Household Residuals	$26,900	9/76 12	26
Schroeder, W. Lee Oregon State University	Symposium/Workshop on Environmental Impacts on Dredging	$25,000	9/76 9	27
Subramanian, R. V. Washington State Univ.	Immobilization of Hazardous Residuals by Encapsulation	$56,600	9/76 12	27
	Urban Hydrology			
Schumm, Stanley A. Colorado State Univ.	Impact of Urbanization on Gullying	$100,200	9/76 24	28
Tolley, George S. University of Chicago	Environmental Pollutants and the Urban Economy	$38,300	8/76 12	28
Wiggins, John H. John H. Wiggins Co.	Determination of Urbanized Headwater Flooding Damage Potential	$32,000	9/76 5	29
	EARTHQUAKE ENGINEERING			
Aki, Keiiti Mass. Inst. of Tech.	A New Approach to the Prediction of Earthquake Strong Motion	$146,700	7/76 18	32
Aki, Keiiti Mass. Inst. of Tech.	Estimation of Strong Ground Motion from Small Seismic Events in Garm, U.S.S.R.	$59,500	7/76 18	33
Becker, James M. Mass. Inst. of Tech.	Seismic Resistance of Precast Concrete Panel Buildings	$276,900	9/76 24	33

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Bertero, Vitelmo V. Univ. of Calif.-Berkeley	Workshop on Earthquake Resistant Reinforced Concrete Building Design	$130,000	8/76 16	33
Blume, John A. John A. Blume & Assoc.	Seismic Investigation and Design Criteria for Industrial Storage Racks	$184,300	9/76 24	34
Bogdanoff, John L. Purdue University	Seismic Resistance of Fossil Fuel Power Plants	$75,000	7/76 3	34
Boore, David, M. Stanford University	Design Motion Simulation Close to Faults	$40,100	8/76 12	35
Clough, Ray W. Univ. of Calif.-Berkeley	Energy Absorption Characteristics of Structural Systems Subjected to Earthquake Excitation	$103,000	8/76 6	35
Clough, Ray W. Univ. of Calif.-Richmond	National Information Service for Earthquake Engineering	$100,000	8/76 14	35
Cornell, C. Allin Mass. Inst. of Tech.	Structural Loads Analysis and Specification	$375,600	9/76 24	36
Frondistou-Yannas, Stamatia Mass. Inst. of Tech.	Use of Concrete Demolition Wastes as Aggregates in New Construction	$35,600	9/76 12	36
Ghaboussi, Jamshid Univ. of Ill.-Urbana	Evaluation of Liquefaction Potential of Saturated Granular Soils	$97,700	10/76 24	37
Hawkins, Neil M. Univ. of Washington	Seismic Resistance of Concrete Slab to Column Wall Connections	$248,800	9/76 24	37
Housner, George W. Calif. Inst. of Tech.	National Information Service for Earthquake Engineering	$207,700	9/76 36	38
Housner, George W. Calif. Inst. of Tech.	Support of the USCOLD Committee-Evaluation of the Incremental Seismic Risk Due to Reservoir Filling	$7,400	9/76 12	38
Najita, Kazutoshi Univ. of Hawaii-Honolulu	Study and Implementation of an Ionospheric Technique to Improve Tsunami Warning	$132,400	7/76 24	38
Sozen, Mete A. Univ. of Ill.-Urbana	Effects of Earthquake Motions on Reinforced Concrete Buildings	$340,200	9/76 24	39
Taoka, George T. Univ. of Hawaii-Honolulu	Tall Building Response Parameters Evaluated Under Different Levels of Excitation	$60,000	8/76 24	39
Trifunac, Mihailo D. Univ. of S. Calif.	Investigation of Strong Earthquake Ground Motion	$78,700	10/76 24	39
Wang, Leon R. L. Rensselaer Poly. Inst.	Seismic Vulnerability, Behavior and Design of Underground Piping Systems	$113,800	8/76 24	40
Werner, Stuart D. Agbabian Associates	An Evaluation of the Effects of Earthquake Imput Motion Phasing on Structural Response Characteristics	$106,100	9/76 12	40

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Wight, James K. Univ. of Mich.-Ann Arbor	Prevention of Shear Strength Decay in Reinforced Concrete Members	$66,400	8/76 18	41

SOCIETAL RESPONSE TO NATURAL HAZARDS

Huffman, James L. Lewis and Clark College	Legal Constraints on the Planning and Development of Disaster Home Warning Systems	$16,400	7/76 7	42
Kunreuther, Howard C. University of Pennsylvania	Mitigation and Recovery Policies for Natural Hazards	$197,600	9/76 12	43
Marts, Marion E. Univ. of Washington	Social Implications of Volcano Hazards	$45,000	7/76 16	43

WEATHER MODIFICATION

Improved Weather Modification Technology

Chisholm, John Sierra Nevada Corp.	An Accurate and Inexpensive Airborne Wind Measuring System	$61,600	8/76 15	44
Hallett, John Univ. of Nevada	An Assessment of Synoptic Criteria for Ice Multiplication in Convective Clouds	$23,500	8/76 12	45
Maki, Leroy R. Univ. of Wyoming	Ice Nucleation Induced by Bacteria	$64,300	8/76 21	45

Inadvertent Weather Modification

Uthe, Edward E. Stanford Research Inst.	Lidar and Radiometric Data Analysis of Mixing Levels, Clouds, and Precipitation Processes	45,200	8/76 10	47

Social, Legal, and Economic Impact of Weather Modification

Lambright, W. Henry Syracuse Research Corp.	The Utilization of Weather Modification Technology: A State Government Decision-Making Study	$60,400	9/76 18	48

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	Weather Hazard Mitigation			
Auer, August H. Univ. of Wyoming	The Kinematics of Thunderstorm Gust Fronts Relating to the Mitigation of Airport Flight Hazards	$56,300	8/76 12	49
Veal, Donald L. National Center for Atmospheric Research	National Hail Research Experiment	$800,000	7/76 4	49