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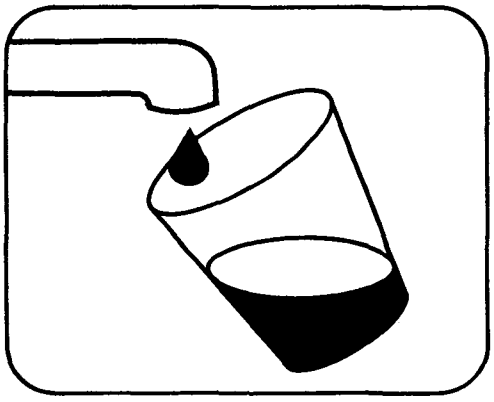

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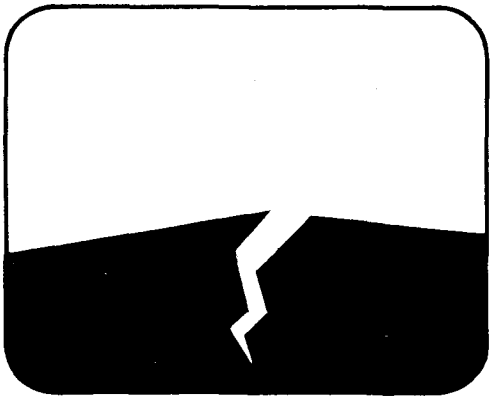

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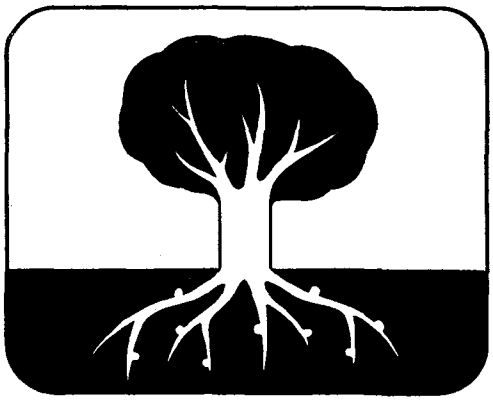

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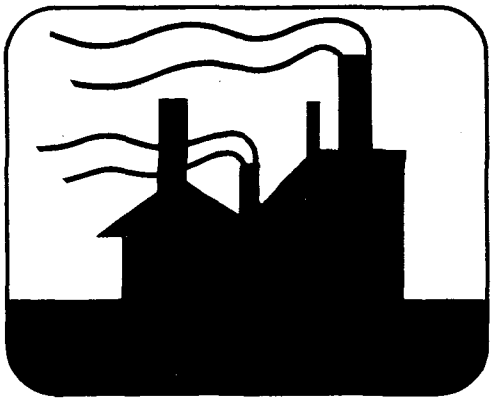

Chemical Threats to Man and Environment

Problem-Focused Research Applications

SUMMARY OF AWARDS FISCAL YEAR 1978

NATIONAL SCIENCE FOUNDATION
Directorate for Applied Science and Research Applications
Division of Problem-Focused Research Applications

CONTENTS

INTRODUCTION TO PROBLEM-FOCUSED RESEARCH APPLICATIONS (PFRA)

This publication summarizes awards made by the Division of Problem-Focused Research Applications (PFRA) in Fiscal Year 1978 (October 1, 1977 through September 30, 1978*).

The goal of the Problem-Focused Research Applications (PFRA) Division is to apply United States scientific and technological capabilities to selected problems of critical national importance in those instances where the absence of such application is clearly a barrier to problem clarification or resolution. Programs are structured around specific problems. The type and number of programs will change over time as new problems are selected and as ongoing programs are transferred or phased out. Each program supports a broad range of multidisciplinary basic and applied research and proof-of-concept experiments as appropriate to the problem being addressed. Major attention is given to research utilization and participation of potential users of the practical results of the research supported. Problem-focused research applications are critical if discoveries in basic research are to be applied in clearly demonstrable, beneficial ways in the public interest.

The common objectives of the programs within the Division are to concentrate research and proof-of-concept experiments on selected problem areas in order to:

- Facilitate the incorporation of science as a working tool for problem resolution in the public and private sectors;
- Provide support for problem-focused research that bridges from basic research discoveries to application; and,
- Enhance the capability and capacity of non-traditional research users to employ research results and methods.

PFRA programs are organized by the development of a series of problem-related hypotheses and objectives which determine the nature of a problem, identify critical leverage points to be examined, and establish an end-point for the research. Each of the Problem-Focused Research Applications programs has the following characteristics:

- It is an activity from which recognizable and generally measurable public benefits will accrue;
- It has wide geographical and social applicability;
- It requires the application of results from many scientific disciplines and professions;
- It intends to contribute to problem solution rather than to increase the depth or breadth of knowledge in any basic discipline; and,
- It provides results useful to the public and private sectors where disciplinary constraints, fragmentation, regulation or lack of market incentives inhibit research initiatives by others.

In FY 78 the Division had four major program elements: Alternative Biological Sources of Materials; Chemical Threats to Man and the Environment; Community Water Management; and Earthquake Hazards Mitigation. Alternative Biological Sources of Materials deals with selected aspects of the problem of meeting the Nation's future needs for materials. Chemical Threats to Man and the Environment seeks to identify, quantify and assess the impact of man-made contaminants and naturally-occurring toxicants on human health and the quality of the environment. Community Water Management addresses the Nation's capability to effectively and efficiently manage the use and reuse of water in the built environment. The objectives of the Earthquake Hazards Mitigation program are to develop methods and techniques that can provide effective protection for man, his works, and institutions from life loss, personal injury, property damage, social dislocation, and economic and ecological disruption associated with potential or realized earthquake hazards.

The Summary is organized by the four major programs of the Division. Proposals were selected for award on the basis of peer review by the scientific and user communities to ensure the scientific merit of the research and its relevance to program objectives and user needs. A description of the research problem and its significance is provided for each award.

The Appendix contains an alphabetical listing of awards by Principal Investigator.

Requests for additional information about specific projects should be directed to the Principal Investigator at the address shown.

*The Division of Problem-Focused Research Applications was established in February, 1978 as part of a reorganization that created the Directorate for Applied Science and Research Applications. The Division absorbed most of the research programs that had been administered by the Division of Advanced Environmental Research and Technology in the former Directorate for Research Applications.

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CHEMICAL THREATS TO MAN AND THE ENVIRONMENT

Program Managers ..... Richard A. Carrigan
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COMMUNITY WATER MANAGEMENT

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Program Managers ..... William A. Anderson
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Translator ..... Georgeann Vleck

*As of September 30, 1978

DEFINITIONS

This publication contains brief summaries of the projects funded by PFRA in Fiscal Year 1978. Projects selected for funding were subjected to peer review by the scientific community and by representative user groups to ensure their scientific merit and their relevance to program objectives. The Summary of Awards is organized by program. For each award, the problem area is described and an attempt to indicate how the research may help to solve the problem is made. An alphabetical listing of awards by Principal Investigator is included in Appendix A.

- 'Award' refers to financial support given in the form of a grant, contract, or other arrangement, depending upon the nature of the research work to be completed and the terms of performance.
- 'Effective Date' refers to the calendar date on which NSF funding of a research project becomes active.
- 'New' refers to an award which has received no prior support from NSF, regardless of whether the Principal Investigator has received support on previous occasions.
- 'Renewal' refers to follow-on support of a project which is currently supported.
- 'Supplement' refers to the addition of funds to an existing NSF-supported project without increasing the duration of NSF support.
- 'Principal Investigator' refers to the chief scientist or administrator who is responsible for coordinating the research plan and fiscal expenditures as an NSF-sponsored awardee.
- 'Institution' refers to any college, university, public or private laboratory, industry, or other organization, whether operating for profit or on a nonprofit basis, as well as State and local governments and Federal organizations.

Division-initiated funding actions excluded from this report are:

- Purchase Orders
- Funds for Personnel (Intergovernmental Personnel Act)
- International Travel Awards

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ALTERNATIVE BIOLOGICAL SOURCES OF MATERIALS

In order to meet its current and future materials resource requirement, the United States has begun to identify and develop domestic sources of (or substitutes for) raw materials which presently must be imported. The Fiscal Year 1978 objectives of the *Alternative Biological Sources of Materials* program were to determine which domestic biological sources were promising alternatives to imported raw materials, to develop biologically based processes to enhance the usefulness of domestic biomass sources, and to determine the socioeconomic, technical, and environmental impacts of the proposed biological alternative systems on the country. Three major areas were investigated in Fiscal Year 1978.

The first area, the biological conversion of lignocellulosic materials to useful chemicals and materials, appears to have an attractive potential for replacing some of our requirement for petroleum while at the same time decreasing waste and pollution in our environment. Lignin, cellulose, and hemicellulose from agricultural and forest crops and residues may be transformable by chemical and biotechnological methods into useful chemicals.

Biological nitrogen fixation was the second area of emphasis in Fiscal Year 1978. Biologically synthesized fertilizer nitrogen could reduce our dependence on fertilizers industrially derived from natural gas. Research supported addressed the possibilities of enabling nonleguminous plants to enter into symbiotic relationships with nitrogen-fixing bacteria, of increasing the amount of fixed nitrogen generated by free-living nitrogen-fixing soil bacteria, and of using nitrogen fixed by microorganisms for application to crop lands.

The third area emphasized in Fiscal Year 1978 was the possibility of using the plant guayule (a desert shrub native to Texas and the Southwest) as a potential source of natural rubber. Some rubber products, such as airplane and heavy duty truck tires, still require a certain amount of natural rubber in their manufacture. Guayule, if an acceptable domestic source, would not only relieve our dependence on foreign sources of natural rubber but would also enable us to use semi-arid, marginal lands for the production of a critical material.

Pretreatment Methods for the Degradation of Lignin; *Billy R. Allen,* Battelle Memorial Institute, 505 King Avenue, Columbus, OH 43201; $85,730 for 9 months beginning September 1, 1978.

Lignin and cellulose are the two most abundant naturally occurring organic materials on earth. Cellulose is used for a large number of industrial purposes, but lignin, a polymeric condensation product of phenylpropane moieties, represents an underexploited resource. In order to make lignin more attractive as an industrial material and potential feedstock for chemicals, lignocellulosic materials

need to be treated in appropriate fashion to separate and modify the associated lignin.

This project will conduct a comprehensive review of the literature dealing with the pretreatment of lignocellulosic materials and potential conversion processes for obtaining valuable products from lignin; interview industrial, university, and government researchers to obtain additional information for evaluating the pre-treatment methods; select the most promising pretreatment methods possible for further investigation; and disseminate the information through the preparation of a position paper and through a conference at Battelle's Columbus Laboratories.

While much information can be obtained from the literature, much more current and realistic data can be obtained by discussing candidate pretreatment processes with industrial and academic researchers. When collaborated with the information obtained in the literature review, this information should form a solid basis for deciding which pretreatment techniques have long-term potential and which do not. Since one benefit that may be achieved through pretreatment is the modification of the structure or chemical functionality of lignin to produce valuable products from this material, any evaluation of this project will consider the effects of pretreatment on the physical and chemical properties of lignin. The evaluation of pretreatment technology for lignocellulosic substrates will be based on an analysis of the benefits (i.e., the potential increased economic return from both the cellulosic and lignin fractions) achieveable with each pretreatment versus the additional cost of pretreatment. The two processing schemes which are currently viewed as being the most promising for cellulose utilization are pretreatment followed by weak acid hydrolysis of cellulose and pretreatment followed by enzymatic hydrolysis.

Semisolid Fermentation of Grass Straw; *A. W. Anderson,* Oregon State University, Department of Microbiology, Corvallis, OR 97331; $13,145 for 12 months beginning May 8, 1978.

The objective of this research is to develop an animal feed by semisolid fermentation of ryegrass straw that is currently burnt at the site of harvest. A combination of laboratory, *in vitro* screening, *in vivo* metabolism, and animal feeding studies have been conducted. Pretreatment with sulfuric acid followed by fermentation with a yeast provided a product with increased digestibility and protein value, but it was unpalatable to animals. This project will evaluate other pretreatment methods, e.g., phosphoric acid and attribition grinding, and test the product in animal trials.

Chemicals from Wood by Organic Solvent Treatment; *Gary C. April,* University of Alabama, Department of Chemistry & Metallurgical Engineering, University, AL 35486; $129,800 for 24 months beginning June 15, 1978.

Forests account for two-thirds of all dry organic matter produced on land. The conversion of wood into chemicals for the production of most of our synthetic plastics, fibers and rubbers is potentially feasible. However, further scientific and technical improvements are needed if chemicals are to be obtained in an economically viable fashion.

The overall objective of this research project is to separate the individual components of wood (cellulose, hemicellulose, and lignin) by organic solvent systems. Specific objectives are to:

- investigate the extraction efficiency of organic alcohol and hydrotropic (organic acids) systems for selectively removing lignin from southern pine wood;
- determine the composition and properties of the extracted lignin, cellulose and hemicellulose phases with emphasis on solvent recovery and recycling;
- determine the technical and economical feasibility of continuous organic alcohol and hydrotropic extraction of pine wood; and
- collect data that would permit the design and construction of a scale-up facility for work in subsequent studies. This facility would be used to test the feasibility of the proposed process at the pilot plant level.

Phase I of the project involves the screening of several organic solvent systems to construct a priority list of solvents and operating conditions which show promise of delignifying wood at reasonable conversions and yields with a minimum loss of the solvent.

Delignification kinetics will be measured to relate the effectiveness of one system to another. A detailed design using the one or two systems showing the greatest promise in the screening studies will complete this part of the study.

Phase II of the research will deal with the evaluation of one or more systems demostrated to be technically and economically promising. A preliminary feasibility study will be made resulting in the preparation of flow sheets, cost of operation, energy requirements and pollutional impacts.

Fusion, Regeneration and Development of Algal Protoplasts; *Martha D. Berliner,* Simmons College, Department of Biology, Boston, MA 02115; $53,995 for 12 months beginning April 1, 1978.

This project will utilize the fusion and regeneration of protoplasts (i.e., cells stripped of their rigid cell walls) of single cell algae as a means to develop new algal cultures with improved properties such as ease of harvesting and protein quality. It is hoped that the methodology as so developed will facilitate the manipulation and regeneration of higher plants in order to breed new crop plant varieties. Specific objectives are:

- to obtain high yields of protoplasts of various species of green algae;
- to assess the quantity and quality of algal cell protein;
- to fuse protoplasts from different species and regenerate the hybrids into new algal cultures; and
- to elucidate the mechanism of protoplast induction and regeneration.

If successful, the results will facilitate the translation of modern cellular genetics into a practical system of plant breeding.

The results of this research will be of interest mainly to other investigators working in the area of plant cell and protoplast regeneration. They will be disseminated via presentations at scientific meetings, the American Society of Plant Physiologists, and publications in professional journals.

Feasibility of Producing Natural Rubber from the Guayule Plant; *Daniel M. Bragg,* Texas A&M University, Industrial Economics Research Division, College Station, TX 77843; $130,874 for 15 months beginning September 15, 1978.

A National Academy of Sciences panel report has urged the development of guayule, *Parthenium argentatum,* as an alternative domestic source of natural rubber in the United States. The panel further recommends the initiation of a feasibility study, technology assessment, and environmental impact analysis of guayule. The objective of this proposal is to conduct such a feasibility study by pursuing several specific tasks:

The market for guayule rubber will be evaluated with regard to

- the total world demand for elastomers in 1985 and 1990,
- the total world supply of synthetic and natural rubbers in 1985 and 1990,
- the prices for synthetic and natural rubbers in 1985 and 1990, and the market potential for guayule rubber in 1985 and 1990, and
- the market potential for guayule rubber in 1985 and 1990.

Analyses of the economics of guayule rubber production will be conducted, with emphasis on

- the cost of alternative systems for producing guayule,
- the cost of transporting guayule from the field to the processing mill,
- the cost of processing guayule to give natural rubber and other by-products
- the competitiveness of rubber relative to other conventional agricultural crops, and
- the policy alternatives that may be required to make guayule economically viable.

A workshop will be held to discuss and evaluate the results of this study. Participants will include researchers, representatives of federal agencies, rubber product manufacturers and potential guayule growers.

Enhancing Plant Productivity with Nitrogen-Fixing Bacteria; *Winston J. Brill,* University of Wisconsin, Madison, Department of Bacteriology, Madison, WI 53706; $216,600 for 12 months beginning April 13, 1978.

Plant protein is derived ultimately from chemically synthesized nitrogen that is applied to crops as fertilizer or that is fixed from molecular nitrogen gas by certain bacteria which are either free-living or exist in a symbiotic relationship with a plant. Most nitrogen on this planet is fixed by biological systems, and the broad goal of this research project is to enhance this natural process. Specifically, the major objectives of this project are to determine whether coating legume seeds with the binding proteins from *Rhizobia* (the specific bacteria responsible for nitrogen fixation) can improve the nitrogen-fixing ability of the symbiotic plant; increase the ultimate value of soybean and alfalfa by constructing and testing superior strains of appropriate *Rhizobia;* and assess the feasibility of fertilizing cereal plants with ammonium-excreting mutant strains.

Prior research has focused on the construction of free-living *Azotobacter* strains capable of excreting excess ammonia. This present activity is built partly on that work but is focused on symbiotic plants of agronomic importance — soybean and alfalfa. Dr. Brill's research involves the construction and testing of *Rhizobium* mutants and the use of the binding proteins to hopefully increase nodulation, nitrogen-fixation and crop productivity, and to assess the feasibility of fertilizing cereal plants with ammonia-excreting bacteria. At the moment, the use of binding proteins to enhance crop productivity seems to represent a unique approach and one which it is hoped will yield useful results.

Conversion of Lignocellulose by Actinomycetes Microorganisms; *Donald L. Crawford,* University of Idaho, Department of Bacteriology, Moscow, ID 83843; $99,076 for 24 months beginning September 15, 1978.

Lignin and cellulose are the two most abundant naturally occurring organic materials on earth and potentially represent important industrial raw materials. Further, as a result of man's increased utilization of these resources, they are becoming a major waste disposal problem. An approach to more effective utilization and conversion of lignocellosic materials is through biological systems using either intact microbes or possibly isolated enzymes.

Previous research has shown that lignin is degraded by actinomycetes microbes, and a number of active strains have been isolated. The objective of this research project is to characterize the more promising lignin-degrading microbes and to optimize the necessary parameters. In addition, the regulatory relationship of lignin degradation to cellulose hydrolysis is to be examined.

The principal users of this research will be pulp and paper companies, chemical companies, and mission agencies, including USDA (FS) and DOE.

Conference on Chemicals and Materials from Renewable Resources; *Alexander Cruickshank,* University of Rhode Island, Gordon Research Conferences, Department of Chemistry, Kingston, RI 02881; $3,560 for 3 months beginning June 15, 1978.

The Gordon Conferences are established and recognized meetings devoted to timely and important scientific topics. The purpose of this award is to provide support for the Gordon Conference on "Chemicals and Materials from Renewable Resources" held in Wolfeboro, New Hampshire from July 3-7, 1978.

The purpose of this conference is to stimulate research in universities, research foundations, and industrial laboratories. In particular, this conference intends to bring together scientists for multidisciplinary discussions on the production of biomass and its conversion to chemicals and materials.

An Integrated Approach to the Conversion of Lignocellulose from Wood into Useful Chemicals; *Irving S. Goldstein,* North Carolina State University at Raleigh, Department of Wood and Paper Science, Raleigh, NC 27607; $159,205 for 12 months beginning June 12, 1978.

Synthetic organic materials derived from petroleum play an indispensable role in our economy in the form of adhesives, electrical insulation, fibers, plastics, and rubbers. The increasing cost of petroleum as well as its ultimate depletion make the substitution of a renewable resource as a raw material a desirable objective.

Wood is the most important component of biomass, with forests comprising two-thirds of all dry matter produced on land. The conversion of wood into chemicals for the production of most of our synthetic plastics, fibers, and rubbers is technically feasible. Intermediates include ethyl alcohol (which can be further processed to ethylene and butadiene), phenols and furfural. However, further technical effort is needed to improve the economics of the chemical conversion of wood. The overall objective of this project is to study the conversion of the wood components (hemicelluloses, cellulose and lignin) from low-quality southern hardwoods to useful chemicals in a systematic, integrated manner.

Project objectives include examination of the hydrolysis of the hemicellulose of a southern hardwood (sweetgum) with hydrochloric acid to determine rates of hydrolysis and yields of sugars for optimum conversion. This project will also examine the hydrolysis of sweetgum with strong hydrochloric acid after removal of hemicelluloses by prehydrolysis. The optimum conditions for hydrolysis including pretreatments such as irradiation (if warranted) will be determined. The conversion of lignin residue from HCT hydrolysis of sweetgum into low molecular weight phenolic and other aromatic compounds by catalytic hydrogenation, followed if necessary by hydrodealkylation and dehydration, will also be studied. Data from these tasks will be used to design a cost-effective and energy efficient integrated wood chemicals plant.

Insecticidal Activity of *Beauveria Bassiana;* *Edward A. Grula,* Oklahoma State University, Department of Microbiology, Stillwater, OK 74074; $41,855 for 12 months beginning August 7, 1978.

Beauveria bassiana, a fungal pathogen isolated from silkworm larva, has been studied extensively as a biological agent for the control of insect pests. It is reported to have been produced and applied on crops in the Soviet Union for many years. Field tests in the U.S.A. have given rather erratic and inconclusive results, however. This is not surprising, since little work has been done to develop strains with a high level of virulence, to identify the nature of the presumed toxins excreted, and to determine the conditions under which maximum insecticidal activity is expressed. This research will correct this situation so that highly active mutants can be developed, isolated and used effectively in the field.

This research will seek to fully develop the insecticidal potential of *Beauveria bassiana* and to facilitate its use as an agent for the control of insect pests. To accomplish this objective four specific tasks will be pursued. Research will identify which products excreted by the growing fungus are most responsible for its insecticidal activity. These products include protease, chitinase, lipase, wax degrading enzymes, and an antibiotic, beauvericin. The environmental conditions required for maximum expression of activity of the excreted products will be defined. The mechanism of fungal infectivity and resistance in the larvae will be delineated. A superactive mutant suitable for use as a control agent will be isolated. This project is a part of the US-USSR Science and Technology Cooperative Program.

Synthesis and Applications of Nucleic Acids to Biological Nitrogen Fixation; *John Hachmann,* Collaborative Research, Inc., 1365 Main Street, Waltham, MA 02154; $229,967 for 18 months beginning September 26, 1978.

Protein derived from plants or animals is an essential food for humans, and the bound nitrogen therein is obtained predominantly through the biological action of both symbiotic and free-living microorganisms that have the ability to transform nitrogen gas first into ammonia and then into amino acids. The microbes involved in nitrogen fixation are under genetic control and may be regulated to enhance their

net productivity through genetic engineering techniques, some of which are ultimately dependent on the availability of defined sequences of nucleic acid fragments.

The objective of this research is to improve the chemical synthesis of oligodeoxy-nucleotides for the eventual purpose of using these compounds as tools for the transfer of genetic information in biological nitrogen fixation. Specifically, the objectives are to improve the methodology for chemically synthesizing defined sequences of nucleic acid fragments and to initiate studies toward applying this information to enhance biological nitrogen fixation. With regard to chemical synthesis, the goal is to improve the triester method for synthesizing nucleic acid fragments (oliogdeoxy-nucleotides), a promising new method which is reliable and less costly than that currently practiced. In particular, the aim is to improve the synthesis of protected mononucleotides, the basic component of nucleic acids consisting of a base, sugar residue, and phosphate ester; to improve the yields of the chain elongation reaction; and to develop a solid phase method of synthesis. With regard to gene transfer techniques, the aim is to synthesize suitable oligodeoxy-ribonucleotide primers for copying genes and to investigate the physical properties of the sequences by thermal denaturation. In addition, as more information becomes available about DNA sequences directly involved in nitrogen fixation (something which is occurring very rapidly), the appropriate fragments will be synthesized and their physico-chemical properties will be examined.

The principal users of the research results will be other investigators in the field of nitrogen fixation especially the molecular geneticists. However, besides nitrogen fixation, the techniques to be developed will also find application in related fields such as photosynthesis, non-conventional foods, and other resource-related segments.

Enzymatic Transformations of Lignin; *Philip L. Hall,* Virginia Polytechnic Institute, Department of Chemistry, Blacksburg, VA 24061; $142,900 for 24 months beginning November 14, 1977.

While Lignin is the second most abundant organic material produced by plants and constitutes a vast renewable resource, its structural complexity and chemical intractability have prevented its effective utilization. Biodegradation of wood, including lignin, is accomplished in nature by various microbes. Enzymatic transformations of lignin into useful materials would appear to be a viable alternative to conventional chemical processing of this renewable resource.

The overall goal of this project is the development of enzymatic or semi-enzymatic processes for the conversion of lignin into commercially valuable materials. Specifically, the objectives of this three-year project are to determine the actual chemical changes observed in lignin during the key early steps in lignin biodegradation by microorganisms in laboratory cultures; optomize the production of lignolytic enzymes by microorganisms through systematic variations of fermentation parameters and lignin substrates; isolate, purify and characterize the more important lignlytic enzymes; refine computer-aided techniques for lignin analysis and characterization, especially with regard to the development of routine methods for monitoring microbiological and enzymatic lignin modifications; and, systhesize labeled lignin precursors and prepare labeled lignins and synthetic lignin-like polymers.

Breeding Improvement of Rubber Yield in Guayule; *George P. Hanson,* California Arboretum Foundation, 301 N. Baldwin Avenue, Arcadia, CA 91006; $90,930 for 12 months beginning March 12, 1978.

Guayule (Parthenium argentatum), a shrub native to the desert regions of Central Mexico and Southwestern United States, contains a rubber which when purified is virtually indistinguishable from the natural rubber of *Hevea brasiliensis.* During World War II the U.S. cultivated and processed guayule as a source of natural rubber, but the effort was phased out when Hevea rubber from Southeast Asia again became readily available and use of petroleum based synthetic rubber increased.

Today natural rubber remains an essential commodity; because of its special properties, heavy duty tires continue to require a large proportion of natural rubber. Each year the U.S. imports one-fifth of the world's supply. Now that petroleum is increasingly in

short supply and Southeast Asian rubber is potentially subject to trade restrictions, interest is again directed toward guayule as a domestic source of natural rubber. An extensive study of guayule completed by the National Academy of Sciences has shown it to be in the national interest to re-establish guayule as a domestic alternative to Hevea rubber.

This award will initiate a plant breeding program to develop improved varieties of guayule to a point where it can be an economically viable crop. The objective is to demonstrate a sufficient increase in yield potential in 3 years so that the project can be transferred to private sector users.

Seeds will be collected from high yeild native wild strains of guayule in Texas and Mexico and from other research groups. Various strains of guayule will be crossed, and the resultant seeds grown and hybridization work supported. Plants will be analyzed for rubber content by mechanical or chemical extraction. Disease resistance will be an additional criterion in the selection process. The importance of soil type, fertilizer application, and watering regime will be evaluated and a standardized system adopted. Greenhouse, nursery, and field facilities will be established to grow and maintain breeding and test stock in support of the above tasks. Seeds of promising strains will be increased and made available to interested groups. At the end of the first year renewal criteria will determine if continuation of the grant for a second year is justified.

Enhancement of Biological Nitrogen Fixation by Genetic Manipulation of *Rhizobium;* *Donald R. Helinski,* University of California, San Diego, Department of Biology, La Jolla, CA 92093; $111,062 for 12 months beginning June 1, 1978.

The development of recombinant DNA and gene cloning techniques has opened up new avenues of research in the field of biological nitrogen fixation. The techniques provide new tools for answering some of the fundamental questions about how nitrogen fixation genes operate in bacteria. They also provide the means for altering bacteria and plants in such a way as to increase rates of fixation of atmospheric nitrogen as a substitute for fertilizer nitrogen.

The objective of this research is to enhance the nitrogen-fixing ability of the bacterium *(Rhizobium meliloti)* that forms a symbiotic relationship with the alfalfa plant *(Medicago sativa L.).* This is to be done by manipulating the genes of the bacterium, using recombinant DNA and gene cloning techniques. The modified bacterial strains will be screened for effectiveness in providing nitrogen to alfalfa seedlings. The eventual application of this research would be in the substitution of atmospheric nitrogen fixed in the symbiotic system for chemical fertilizer nitrogen.

Genes from the entire *R. meliloti* chromosome will be cloned on a suitable plasmid in *Escherichia coli,* and the hybrid plasmids will be established in *R. meliloti* strains. To screen for increased symbiotic effectiveness, alfalfa seeds will be inoculated with the modified bacteria, and the dry weights and nitrogen contents of seedlings raised under controlled conditions will be measured at suitable intervals.

Biological Solar Energy Conversion: Approaches to Overcome Yield, Stability, and Product Limitations; *Bessel Kok,* Martin Marietta Laboratory, Biosciences, 1450 So. Rolling Road, Baltimore, MD 21201; $74,312 for 12 months beginning April 15, 1978.

The overall objective of this project is to assess the feasibility of using photosynthesis for producing energy-intensive substances from renewable resources. An assessment will be made of the causes of loss of photo-synthetic activity after isolation of chloroplasts from leaf cells, and of the differences in electron transport activities among chloroplasts isolated from different leaf tissues. In particular, the role of manganese ions is protecting chloroplasts from the attack of fatty acids, and the roles of the two photosystems in mesophyll and bundle sheath cells will be studied.

When this project was first funded (in 1975), the intention was to use isolated chloroplasts in a biological solar energy conversion system, in which the electric potential generated by the two photosynthetic photochemical systems would be used *in vitro* to produce hydrogen from water. The practicality of such a scheme seems increasingly in doubt. The research will be rounded off to the point where the results can at least be used to assess the limitations to photosynthesis in living systems. This would be of interest to other scientists who use isolated chloroplasts in their research studies.

A Multifaceted Approach to Enhancing Biological Nitrogen Fixation; *Marvin Lamborg,* Charles F. Kettering Research Foundation, 150 East South College Street, Yellow Springs, OH 45387; $199,956 for 12 months beginning July 1, 1978.

The goal of this project is to increase the capacity for nitrogen fixation of several living organisms, and of the enzyme that is involved in the process, through physiological and chemical research. Four tasks will be performed.

Azolla is a water fern, the leaves of which contain a nitrogen-fixing alga, *Anabena azollae.* It has the potential to supply large amounts of nitrogen to a rice crop, and is used for this purpose in Asia. The objective of this part of the program is to determine the responses of the basic physiological processes involved in CO_2 and N_2 uptake to environmental factors such as temperature, pH, light, nutrients, and chemical contaminants (herbicides, insecticides) for four species of *Azolla.*

Rhizobium is the nitrogen-fixing bacterium that supplies nitrogen to legumes by nodulation of the roots. Binding compounds called lectins are thought to play a critical role in the infection and nodule-forming processes. The proposed assay will take advantage of this for identifying and counting rhizobial cells in samples of soil or commercial inocula for use on soybean seeds. It should be faster and cheaper than existing assays.

Studies of the physiology and genetics of *Rhizobia* are much simplified if the bacteria can be grown in the free-living state in laboratory flasks rather than in nodules on the roots of plants. Unfortunately, only the slower-growing species of *Rhizobium* will fix nitrogen in these conditions. The goal of this part of the project is to discover the reason for this. The roles of oxygen tension and extracellular polysaccharide will be studied specifically.

Nitrogenase is the enzyme that catalyzes the fixation of nitrogen in living organisms with the expenditure of much less energy than is used by current chemical processes. There are many practical problems involved in the use of nitrogenase outside living cells. The objective of this part of the project is to assess the possibilities of using the molybdenum cofactor of the enzyme as a key entity in a novel nitrogen fixation process.

Workshop on Selecting and Breeding Legumes for Enhanced Nitrogen Fixation; *Thomas A. Larue,* Boyce Thompson Institute of Plant Research, Department of Biochemistry, Ithaca Tower Road, NY 14853; $13,340 for 6 months beginning September 1, 1978.

In the immediate future, increased use of legumes is likely to be the method of choice for reducing the nation's dependence on nitrogenous fertilizer made from fossil fuels. During the last few years there has been an upsurge of research on nitrogen fixation by the symbiotic legume/bacterium system, and impressive gains have been made in our knowledge of the biochemistry, physiology and genetics of the system. However, little of this new information is in a form that can be used by plant breeders. Academic scientists frequently do not know how plant breeders work, and hence are unable to communicate their findings in a usable form.

In plant breeding it is necessary to screen many different combinations of plant genotypes and bacterial strains. The methods of measuring nitrogen fixation that are used in basic research are usually too expensive and inconvenient to operate on such a large scale. Bench models of simple, inexpensive, and portable instruments have recently been developed but are not in widespread use.

This workshop was held October 23-24, 1978 at the Boyce Thompson Institute, Ithaca, New York. The purpose was to review recent developments in measuring symbiotic nitrogen fixation and related plant processes, to present research reports on plant selection and the genetic contribution of the plant, and to consider the requirements of legume breeders and agronomists for simple assays related to nitrogen fixation. Participants will include scientists studying symbiotic fixation, agronomists, and breeders concerned with forage and seed legumes, industrial scientists studying plant growth regulators, and representatives of firms manufacturing scientific equipment.

A summary report on the workshop will be published. It will be distributed to workshop participants, granting agencies and other interested organizations and individuals. The availability of the report will be publicized in appropriate professional agronomy journals and newsletters.

Bioconversion of Saline Water; *Gilbert V. Levin,* Biospherics, Inc., 4928 Wyaconda Rd., Rockville, MD 20852; $25,000 for 6 months beginning October 1, 1977.

Conversion of saline water by distillation, reverse osmosis or electrodialysis has proved to be uneconomical. A main reason for this is the cost of providing the energy for the system. It is proposed that a new and simpler system be developed based on the ion exchange properties of algae. The algae would be induced to take up the salt from the saline water, making use of solar energy. They would then be transferred to a holding basin, in which they would be induced to give up the salt. The algae would be recycled, and surplus algae could be used as a source of protein. The research is designed to resolve the key question of whether or not algae can indeed be induced to take up and release sodium chloride in a controlled fashion.

Enhancing Biological Production of Ammonia from Atmospheric Nitrogen and Soil Nitrate; *James M. Lyons,* University of California — Davis, College of Agriculture and Environmental Sciences, Davis, CA 95616; $818,237 for 12 months beginning June 27, 1978.

This award provides incremental funding for the second year of a 5-year continuing grant. The major objectives of this multidisciplinary project are to enhance nitrogen fixation in bacteria by genetic manipulation, to increase the efficiency of symbiotic nitrogen fixation in legumes, to evaluate the potential for supplying nitrogen to rice crops through the *Azolla/Anabaena* symbiotic system, and to increase the efficiency of conversion of nitrate to ammonia in soil bacteria and in crop plants.

Highlights of the first year's research included the construction of new strains of a clover *Rhizobium* that forms nodules on soybean roots; the development of a rapid assay for hydrogen uptake that can be used to screen *Rhizobium* strains for energy efficiency; the identification of a genetic trait associated with delayed leaf senescence and prolonged nitrogen fixation in soybeans; the development of field management techniques that allow *Azolla* to supply up to 50% of the nitrogen requirements of a rice crop; and the construction of a new strain of the soil bacterium *Klebsiella* that can continuously convert nitrate to ammonia.

In the next year, mutants of blue-green algae will be evaluated under field conditions. A comparison of nitrogenase mutants and nitrate assimilation mutants will greatly contribute to our understanding of nitrogen nitrate assimilation carried out by both bacteria and legumes.

Production of Hydrogen by Marine Blue-Green Algae; *Akira Mitsui,* University of Miami, Department of Marine and Atmospheric Science, Coral Gables, FL 33124; $153,724 for 12 months beginning June 22, 1978.

The objectives of this research project are to characterize promising species of marine blue-green algae in terms of relevant biochemical properties and to optimize the biological phenomenon of enhanced hydrogen production by appropriate environmental (physiological) means. Previous support to the principal investigator, Dr. Mitsui, focused on the collection and isolation of superior hydrogen-producing photosynthetic organisms from marine environments. Promising microbes were discovered and one particular blue-green algae, Miami BG 7, is a very active hydrogen producer.

Experiments will concentrate on Miami BG 7, because it presently appears to be the most promising candidate for future application. At least three different types of H_2 producing strains will be compared to the H_2 producing mechanism of Miami BG 7. This type of comparative study should provide valuable insight into the causal factors behind high H2 photoproduction rates.

The most important unanswered questions are: a) What are the electron and hydrogen donors for the process; b) Is the mechanism of H_2 photoproduction by BG 7 similar to that described in other microbes or is it a result of another and new biochemical pathway; c) Is the H_2 production reaction catalyzed by hydrogenase and/or nitrogenase; and d) What is the nature of the relationship between energy state and H_2 photoproduction? The effect of various inhibitors of H_2 production and related photosynthetic functions

will be tested. Another important issue in this study is the nature of the enzyme catalyst for H_2 production. Two prime candidates are the enzymes hydrogenase and nitrogenase. The next step in determining the feasibility of a commercial biological hydrogen production system is to test whether the results obtained can be duplicated on a larger scale.

One of the more immediate users of this research will be the Fuels from Biomass Program at the Department of Energy.

Isolation of Lignocellulose-Transforming Microorganisms; *Dale M. Norris,* University of Wisconsin, Madison, Department of Entomology, Madison, WI 53706; $97,777 for 12 months beginning February 15, 1978.

Cellulose and lignin are the two most abundant naturally-occuring organic materials and potentially represent important sources of industrial materials if efficient processes for converting them can be developed. Such a possibility exists with biological systems based on lignocellulose-transforming microorganisms. The broad objectives of this project are to isolate lignocellulose-transforming microorganisms (bacteria, yeast and fungi) that live in a symbiotic association with wood-attacking beetles, and to characterize the transformations of lignin with the free-living microbes. Particular attention is to be given to the degradation of ground hardwood lignins to phenolic substances which stimulate the feed intake of dairy animals.

Specific project objectives include the selection of appropriate hardwood lignocellulosic substrates for good growth and conversion by the microbes; the isolation and identification of the microbial complex of the wood-attacking beetles that degrade hardwood lignin; the development of a minimum liquid medium in which a chosen complex of microbes efficiently degrades native hardwood lignin into substances that include appetite stimulants for dairy animals; the development of techniques for quantifying the microbial degradation of native hardwood lignin in a liquid medium; and the further development of quantitative insect bioassays for determining which degradation products from the microbial breakdown of hardwood lignin stimulate the appetites of dairy animals.

The Conversion of Agricultural By-Products to Sugars; *Peter J. Reilly,* Iowa State University of Science and Technology, Department of Chemical Engineering/Nuclear Engineering, Ames, IA 50010; $119,735 for 12 months beginning April 11, 1978.

An enormous amount of plant material, mainly cellulose, hemicellulose, and lignin, is produced and discarded every year. Much of this residue would be utilized as food stuff or as industrial raw materials if methods could be found to economically break it down into molecular entities that are either readily digestible by and nutritious for humans or animals, or could be made by chemical or biological means into useful chemical products. The subject matter of this project is the enzymatic breakdown of xylan — the predominant hemicellulose in grasses, cereal grains, and hardwoods — into xylose and smaller amounts of other sugars. In turn, xylose can be metabolized by many microorganisms to produce single-cell protein or other useful products, or it can be hydrogenated to xylitol — a potent sweetener.

Xylan, a polymer of xylose which comprises up to 30% of the total dry weight of cereal grains, can be hydrolyzed by both acids and by the xylanase family of enzymes. The acid hydrolysis process can cause extensive degradation of the products, allowing the possibility that enzymic hydrolysis when fully optimized will be the preferred method. The saccharification of the xylose-containing oligosaccharides produced by the xylanases is accomplished largely by relatively specific glycosidases, especially B-xylosidase.

The objectives of this three year investigation are to isolate and purify the xylanase enzymes involved in xylan hydrolysis, characterize the individual enzymes in terms of the operational characteristics of stability, specificity, and kinetic properties, and assess the feasibility of using an ultrafiltration enzyme for converting corn cob and corn hull xylan to useful sugars. This project is highly complementary to other projects dealing with the conversion of lignocellulosics.

Capturing the Sun Through Bioconversion — Conference II; *Peter Schauffler,* Bio-energy Council, Suite 204, 1337 Connecticut Avenue, N.W., Washington, D.C. 20036; $170,000 for 24 months beginning September 1, 1978.

Bioconversion represents the use of biological systems for the production of organic matter (biomass) and the subsequent conversion of this photosynthetically derived material into more useful and desirable forms (food, fuels, chemicals). The objectives of this international conference in bioconversion were to assist in the general understanding of the potential of bioconversion and to identify the technical and socio-economic issues needed to achieve implementation. Subject matter discussed included biomass sources (wastes and special energy crops), conversion processes (biological and thermochemical) and potential products (fuels, feeds, fertilizers and feedstocks). The conference format provided for summary status reports and projections in plenary sessions followed by intensive specialized workshops.

The Enhancement of Biological Nitrogen Fixation; *Karel R. Schubert,* Michigan State University, Department of Biochemistry, East Lansing, MI 48824; $35,000 for 24 months beginning August 15, 1978.

The primary objective of this research is to define factors affecting the processes of dinitrogen reduction and ammonia assimilation in symbiotic nitrogen-fixing organisms. The legume-*Rhizobium* system will be the major target for these studies with efforts concentrated on the soybean *(Giycine max) — Rhizobium japonicum* symbiosis.

The research focuses on two primary objectives. The first is to define the relationships between nitrogenase-catalyzed hydrogen evolution, the reutilization of hydrogen through the action of hydrogenase, and the energy requirements and efficiency of the nitrogen-fixing process. The second objective is to elucidate the pathways of nitrogen and carbon metabolism involved in the process of ammonia assimilation in nodulated plants and to investigate the interactions between these pathways as they relate to the magnitude of nitrogen fixation and yield. The proposed research addresses basic questions concerning the fundamental processes involved in nitrogen fixation and ammonia assimilation in symbiotic systems. The knowledge gained from these investigations will be applied to the task of enhancing biological nitrogen fixation.

Pyrolytic Conversion of Lignocellulosic Materials; *Fred Shafizadeh,* University of Montana, Wood Chemistry Laboratory, Missoula, MT 59801; $177,000 for 24 months beginning July 15, 1978.

The impending shortage of chemicals and other materials and the limited supply of petroleum necessitate new efforts for efficient utilization of renewable lignocellulosic materials. Pyrolysis, the controlled thermal treatment of materials, provides an efficient process for converting lignocellulose into a wide range of useful products including sugars, chemicals, solvents, charcoal and fuels. This project will examine promising routes for converting lignocellulosic materials to useful chemicals through pryolytic means.

Specific objectives are to

- investigate the thermal depolymerization of cellulose in wood and agricultural materials into levoglucosan (an anhydride of glucose);
- examine, in an integrated fashion, the pyrolytic processes for producing furfural, acetic acid, methanol and carbon as byproducts from the hemicellulose and xylan components of the raw materials;
- establish the application and utility of the novel pyrolytic products, especially levoglucosan and levoglucosenone; and
- investigate the use of thermal treatments to increase the susceptibility of cellulose to enzyme hydrolysis.

This is the only ASRA-supported project that deals with the conversion of lignocellulosic materials into chemicals through pyrolytic means. This approach represents a unique opportunity to provide useful reactive intermediates which may have utility as feedstocks for a host of polymers.

Regeneration, Selection and Evaluation of Plants from Protoplasts of Potato; *James F. Shepard,* Kansas State University, Department of Plant Pathology, Manhattan, KS 66506; $99,600 for 12 months beginning February 15, 1978.

Breeding of new plant varieties via hybridization has enabled man to improve almost every plant he has ever cultivated. However, the procedure is exceedingly time-consuming and tedious, often requiring four to five years before the emergence of a new plant variety with desirable characteristics.

A potential breakthrough in the methodology of plant breeding is indicated by recent discoveries that isolated protoplasts of certain plants are capable of regenerating into whole, complete plants. Since protoplasts can be manipulated in various ways to incorporate new genetic material, they provide a simple and elegant vehicle for the creation of new varieties of agronomically important crops.

This concept can now be tested on a major food crop. Dr. Shepard has succeeded in regenerating whole plants from protoplasts prepared from leaf tissue cells of the potato plant. The potato is a particularly felicitous choice for this investigation since useful potato cultivars are highly heterozygous and will easily lose a desirable character when they are crossed with each other. Thus, it is extremely difficult to introduce new genes, e.g., for disease resistance, into a useful cultivar by standard backcrossing methods. This constraint is circumvented when mutants of single cells or protoplasts are selected and propagated into plants.

The overall objective of this proposal is to demonstrate the feasibility of using single cells and protoplasts to develop new varieties of potato with desirable characteristics. Specific objectives of the research tasks to be pursued are

to enhance the efficiency of regeneration of whole plants from protoplasts;

to create periclinal chimeras from two varieties of cell cultures;

to develop disease resistant varieties by selecting protoplasts tolerant to fungal toxin; and

to construct new varieties by manipulation or fusion of protoplasts.

The plants so developed will be evaluated for agronomic value in the field.

Renewable Resources-Enzyme Technology Digest; *Harry Sobel,* NEUS, Inc., P.O. Box 1979, Santa Monica, CA 90406; $93,600 for 36 months beginning April 15, 1978.

Enzyme technology and renewable resources are two interconnected emerging areas of wide application. Enzyme technology refers to the controlled use of enzymes, biological catalysts which provide us ultimately with renewable resources for food, fertilizer, building materials, fuels, chemicals and many other useful materials. These two areas are of interest to both the public and private sectors and to federal agencies including the National Science Foundation.

The objective of this grant is to provide for support to create an information exchange, the *Renewable Resources — Enzyme Technology Digest.* The primary objective of this digest is to disseminate pertinent information concerning work in progress at the interface of these two areas. The digest will be produced four times per year and will be available to the general public on a paid subscription basis.

Feasibility of Introducing Food Crops Better Adapted to Environmental Stress; *Arthur A. Theisen,* Soil & Land Use Technology, Inc., 11021 Wood Elves Way, Columbia, MD 21044; $24,919 for 9 months beginning October 1, 1977.

Present-day U.S. Agriculture is based on a few selected crops. There is a well-documented need to introduce new crops that would provide more flexibility in the system. The goals should be better use of all available land, less intensive use of energy, less pollution of water resources by fertilizer and pesticide and reduced soil erosion. Crops that are more tolerant to environmental stress can be grown better on marginal land, and would use less of our valuable natural resources.

In this project, information that is already available

will be searched for species that appear to be well adopted to growing conditions in temperate regions of the United States, and that are also tolerant to stress. Up to 15 species will be selected for field testing and further analyses at a later date. The analysis will be based on an existing computer inventory and on personal contacts. The feasibility of introducing these species into the agricultural production-to-consumption systems of the United States will be evaluated.

Incorporation of a Nitrogen-Fixing Organelle into Plant Cells; *Leo P. Vernon,* Brigham Young University, Department of Chemistry, Provo, UT 84602; $125,062 for 12 months beginning May 31, 1978.

All living things require compounds of nitrogen. Nitrogen compounds suitable for plants can be supplied by chemical manufacture or by natural nitrogen fixation. Some plants can fix atmospheric nitrogen through symbiotic relationships with bacteria, but most species of crop plant can not. Large amounts of expensive nitrogen fertilizer made with scarce natural gas are now used to grow crops such as corn. The long-range aim of this research is to enlarge the class of useful plants which fix their own nitrogen. In this project a novel approach will be used to take a first step toward the incorporation of nitrogen fixation capability in crop plants.

Blue-green algae which have formed symbiotic relationships with cells of other organisms will be isolated from the host cells, modified to enhance their rate of nitrogen fixation, and incorporated into higher plant cells which are photosynthetic but which do not fix nitrogen. The rationale for this scheme is that algal cells which have already formed symbiotic relationships should be prime candidates for the transfer. If the plan succeeds, the result will be an entirely new system for fixing nitrogen in higher plants.

Development of Superior Cultivars of Jojoba; *Demetrios M. Yermanos,* University of California — Riverside, Department of Plant Sciences, Riverside, CA 92521; $113,585 for 12 months beginning July 1, 1978.

Jojoba, *Simmondsia chinensis,* is a shrub native to the arid lands of the southwestern U.S. and northern Mexico. The oil from jojoba seed is an excellent substitute for sperm whale oil, and is potentially useful in various pharmaceutical, cosmetic and industrial applications. The Bureau of Indian Affairs has supported a program to develop jojoba as an agricultural crop for Indian reservation lands in Arizona and California. However, so far no support has been available to conduct a systematic selection and breeding program to develop superior cultivars suitable for cultivation on large plantations.

This award will provide support for such a program, in which six tasks will be pursued:

- select, breed and propagate agronomically superior cultivars of jojoba;
- determine the genetic variability in jojoba in terms of seed composition;
- develop cold-resistant and salt tolerant varieties;
- determine the effect of cultural practice on seed and oil yield;
- develop strains containing both male and female characteristics in the same plant;
- and establish methods to clone superior plants by tissue culture.

Chemical Stimulation of Rubber Synthesis in Guayule; *Henry Yokoyama and George P. Hanson, California Arboretum Foundation, 301 N. Baldwin Avenue, Arcadia, CA 91006; $55,896 for 12 months beginning May 1, 1978.*

A March 1977 NAS/NRC panel report has urged the development of guayule, *Parthenium argentatum,* as an alternative and domestic source of natural rubber in the U.S. The panel further recommended the immediate initiation of a program to improve rubber yeild in guayule through breeding and selection. It now appears that plant breeding may not be the only approach to yield improvement. A chemical bioregulator 2-(3, 4-dichlorophenoxy)-triethylamine, was recently found to enhance rubber accumulation 2

to 6 times when sprayed on the young guayule plants. (*Science* 197-1076, 1977). This project will assess the feasibility of using stimulation with chemical bioregulators as a means to maximize rubber yield and rubber quality in guayule.

Available guayule strains and hybrids generated in the existing breeding programs supported by NSF will be evaluated for yield enhancement under bioregulator stimulation. Stimulation has been shown to be strain dependent and greater in strains with larger amounts of parenchymatous tissue. If this observation is validated it may be possible to select the most desirable plants by anatomical examination. Anatomical studies will also ascertain where within the plant tissue bioregulator induced rubber is accumulated. By incorporating bioregulator response into plant breeding programs, selected cultivars could produce as much rubber in a 1-2 year old plant as the best existing variety can produce in 3-4 years. Treatment parameters will be optimized to determine how to maximize yeild under commercially feasible conditions. To ensure that the yield increase obtained by chemical stimulation does not affect the physicochemical properties of the rubber, samples of rubber from treated and control shrubs will be evaluated. Resin samples from treated and untreated shrubs will be analyzed and compared using gas liquid chromatography.

Since the bioregulator used in this project is not available commercially, adequate amounts will have to be synthesized. Other bioregulators will also be synthesized and tested, with the view of developing effective compounds which do not contain chlorine. Approximately eight compounds will be evaluated, and some idea on the structure-activity relationship generated.

CHEMICAL THREATS TO MAN AND THE ENVIRONMENT

Every year thousands of chemicals are released into the environment in our industrialized society. The scientific community, industry, and Federal, State and local governments need a scientific basis for determining which of the chemicals among these thousands are the most hazardous to human health and the ecosystem. Such knowledge forms the basis for regulations to control toxic substances and for strategies to manage contaminants before they are released into the environment. The ultimate goal of the Chemical Threats to Man and the Environment program is to provide techniques and methodologies for the development of necessary knowledge on the properties and behavior of chemicals in the environment.

The Chemical Threats to Man and the Environment program in Fiscal Year 1978 supported research to increase our scientific knowledge of man-made and naturally occurring toxicants and to make this knowledge available to appropriate users. Emphasis was placed on developing methodologies for the prediction of toxicological effects of chemicals before their wide use. Emphasis was also placed on determining the pathways chemicals take after their release into the environment and on discovering the transformations and recombinations that occur within and among chemicals in air, water and soil.

A Water Pollution Monitoring Laser System; *Silverio P. Almeida,* Virginia Polytechnic Institute, Department of Physics, Blacksburg, VA 24061; $93,711 for 12 months beginning November 1, 1977.

An important indicator of the quality of a water body is its population of a variety of diatom (algae) species. The various diatom species can be identified and counted manually in water samples observed with a microscope. However, this technique is subjective, expensive for large numbers of samples, and too slow for detection of rapidly changing conditions. The objective of this work is that of developing and testing a system for automatic assay of various diatom species in water samples. Potential diatoms in water samples are compared under laser light in a microscope with previously obtained patterns of diatoms of various types and the match between the sample and pattern is checked via computer under various orientations. The computer then stores the counts of various diatom species. The basic hardware and computer programs have already been developed. During the present year the system is being tested with many types of samples, and refinements of the system are being made.

The laser optical system proposed is designed to automatically scan and select in a given sample the types and numbers of various diatoms. Coherent spatial filtering techniques are employed in the system. The collected data are digitized and read into a computer which has semi-automatic control over the monitor system. The rate of counting and identifying diatoms with such a system would be far greater than can presently be done by humans. Thus, this instrument, when perfected, will permit a person to do in a few hours what now takes 1-2 weeks.

Workshop on Scientific Aspects of Polybrominated Biphenyls to be Held in East Lansing, Michigan during October 1977; *Steven D. Aust,* Michigan State University, Department of Biochemistry, East Lansing, MI 48824; $9,100 for 12 months beginning October 15, 1977.

This award provides funding for a workshop which will provide a forum for the presentation and discussion of research results on the environmental contaminants polybrominated biphenyls (PBB's). Due to a packaging mixup, the PBB's were used in formulating cattle feed. Consequently, many cases of human and animal poisoning have been reported. These have resulted in human and animal illness and the necessary destruction of chickens and dairy cattle. There has been significant suffering and economic loss. Since this incident, the environmental presence of the PBB's has been detected elsewhere. This is of great concern because of the very toxic, persistent, and bioaccumulative nature of the PBB's.

This workshop seeks to bring together the scientists involved and interested members of the public for the purpose of discussing the results to date, their possible significance, and need for further research. Sessions include analytical chemistry, pathology, metabolism, toxicology, epidemiology and environmental fates and dynamics.

Natural and Fertilizer-Induced Emissions of Nitrous Oxide from Soils; *John M. Bremner,* Iowa State University of Science & Technology, Department of Agronomy, Ames, IA 50010; $129,083 for 12 months beginning February 15, 1978.

Recent research by atmospheric scientists has indicated that fertilizer-derived nitrous oxide (N_2O) may pose a serious threat to the stratospheric ozone layer protecting the earth from biologically harmful ultraviolet radiation from the sun. This has created international concern that increased use of nitrogen fertilizers to aid food production may promote destruction of the ozone layer by denitrification of nitrate.

The primary purpose of the research proposed is to acquire sufficient knowledge concerning natural and fertilizer-induced emissions of nitrous oxide from soils to be able to assess the impact of nitrogen fertilization on the contribution of soils to atmospheric nitrous oxide. Emissions of nitrous oxide from unfertilized and fertilized soils will be measured in field and laboratory studies, and factors affecting release of nitrous oxide from soils through denitrification and nitrification of fertilizer nitrogen will be investigated. The soils selected for study will include diverse types, and measurements of nitrous oxide emissions will be performed under a wide variety of field conditions. Nitrous oxide will be determined by a gas chromatographic procedure that involves use of an ultrasonic detector and permits use of the xenon in air as an internal standard. The work will include a critical evaluation of methods available for nitrous oxide analysis of air and for field measurements of nitrous oxide emissions from soils. The mechanism of nitrous oxide production during nitrification of ammonium and ammonium-yielding fertilizers in soils will be studied, and an attempt will be made to determine if nitrous oxide is an obligatory intermediate in reduction of nitrous to nitrogen by soil microorganisms.

The Development of a Method for the Detection of Sources of Organic Pollutants Using Carbon-Isotope Ratios; *Albert A. Caretto,* Carnegie Mellon University, Department of Chemistry, Pittsburgh, PA 15213; $115,000 for 18 months beginning October 1, 1978.

The banks of the Monongahela River in Western Pennsylvania are lined with all types of industrial establishments such as steel mills, coking plants, petrochemical users, and fossil fuel-fired power plants. Several incidents involving organic contaminants in river waters which affect the potability of the drinking water supply in this highly populated area have occurred. In many cases, the analytical capabilities that are presently available have been unable to pinpoint the source of the contamination.

This proposal is a prescription for the development of a relatively new methodology to aid in the identification of the source of such pollutants. The methodology involves the measurements of stable isotope ratios in elements, such as carbon and sulfur, which are incorporated in the pollutant.

While there are many possible organic pollutants of

interest, in the present proposal the investigators expect to choose only one class of compounds in order to develop an analytical procedure and demonstrate its utility. The selected compounds to be studied are the phenolics.

This research will use the principle that carbon-isotope ratios vary considerably and that different sources will exhibit different ratios for the same organic compound. As a demonstration, one particular compound or class of compounds will be studied and methods will be devised for the required analyses. Preliminary results indicate that for phenols there is a significant source-dependent variation of isotope ratios. Techniques to concentrate samples without isotope fractionation and to measure isotope ratios with very small samples will be developed. Samples from the rivers of western Pennsylvania will be analyzed to study the value of the technique.

It is hoped that if this project proves to be a success it will lead to an expansion of effort with the support of other interested agencies such as the Environmental Protection Agency and State and local authorities. Such further effort would eventually include application of the methodology developed here to all other organic pollutants of interest and ultimately to the solution of practical problems. With full development and extended levels of experience and expertise, the degree of protection of the public from "incidents" will be enhanced. This will come about when Federal and local environmental enforcement agencies have access to highly advanced techniques of source identification.

Field Measurements of Biogenic Sulfur Emissions; *David Chang,* Environmental Research and Technology, Inc., 696 Virginia Road, Concord, MA 01742; $117,883 for 12 months beginning May 1, 1978.

This project will test the hypothesis that volatile sulfur compounds produced biogenically in surface waters and muds are released to the atmosphere where they transform to particulate sulfates in amounts comparable with those attributable to anthropogenic sources. The objective relates to the basis on which the Environmental Protection Agency contemplates imposing particulate sulfate standards. The reason for concern about sulfate particulates is that preliminary studies have indicated that annual geometric mean particulate sulfate concentrations of 6 to 12 micrograms per cubic meter appear to be the threshold level for the increased incidence of a number of respiratory diseases such as influenza, asthma, emphysema, bronchitis, and pneumonia. These levels are reached or exceeded in a number of population centers in the U.S..

The present control strategy is to achieve any proposed standard through further reductions in the anthropogenic emissions of sulfur dioxide from the combustion of fuels. If this project's hypothesis is correct, such reductions would not achieve the lowered sulfate levels in all cities. Preliminary studies suggest that much of the sulfate does not originate in anthropogenic emissions of sulfur dioxide, but is derived from biological emissions, and that in many localities these emissions are promoted by extensive local water pollution. The effect may be most pronounced in urbanized coastal areas where the high sulfate content of sea water also provides raw material for biological sulfur reduction in estuaries. If biogenic sulfur emissions are setting a high base-line level of sulfate particulates, the installation of costly stack-gas scrubbing technology could result in only a small fraction of the expected benefit. If the hypothesis is correct for certain areas, public policy could be made more effective by considering alternate control measures, like water pollution control, or remote power plant siting in areas where the biogenically determined sulfate baseline is unavoidably high.

The research will be done by comparing the gaseous and particulate species collected on opposite sides of a large estuary where substantial biogenic emissions can be expected. The site will be distant from concentrated anthropogenic sources and adjacent to an ocean, so that clean oceanic air can be sampled before and after crossing the estuary. The total amounts and isotopic compositions of particulate sulfate and sulfur dioxide will be measured. By these and ancillary measurements of sodium and chloride, it is hoped to distinguish between airborne sulfur compounds from sea salt, from the decomposition of organic matter, and from the biological reduction of sulfate in sediments.

Soils As A Source or Sink of Atmospheric Nitrous Oxide; *John M. Duxbury,* Cornell University, Department of Agronomy, Ithaca, NY 14850; $110,112 for 12 months beginning August 15, 1978.

Scientists have postulated that man's activities are increasing the flux of nitrous oxide (N_2O) from the earth's surface into the atmosphere. This may ultimately weaken the earth's protective ozone shield and allow increased penetration of harmful ultraviolet radiation. It has been argued that a major portion of the increased N_2O is a consequence of the use of nitrogen in modern farming systems, i.e., that increased fixation of nitrogen leads to greater amounts of denitrification and hence N_2O.

It is widely accepted that a portion of the fertilizer nitrogen applied to soils is denitrified and this is considered to be an increase over the undisturbed environment. The quantity of fertilizer nitrogen denitrified probably averages 10-15% of that applied, but can vary from almost none to almost all depending on environmental conditions and crop management practices.

This project is designed to test this hypothesis. This will be done by measuring nitrous oxide fluxes across the soil-atmosphere interface and the fluxes of nitrous oxide and nitrate nitrogen in drainage water at selected agricultural and nonagricultural sites, and by determining the conditions under which soils act as a source or a sink of atmospheric nitrous oxide. The sites to be studied include mineral soils in central New York State and organic soils in western New York State and southern Florida. Both fallow and cropped land with various fertilization treatments will be studied. Field work will be supplemented by laboratory studies to characterize phenomena observed.

N-Nitroso Compounds in the Environment; *David H. Fine,* Thermo-Electron Corporation, 85 First Avenue, Waltham, MA 02154; $226,317 for 12 months beginning January 23, 1978.

According to EPA, "As a family of carcinogens, the nitrosoamines have no equals." Nearly every nitrosoamine subjected to animal studies has been found to be carcinogenic. Many secondary and tertiary amine compounds are known to react with nitrites to form nitrosoamines. Because of the possible formation of nitrosoamines in meat or in the body, the FDA recently placed new restrictions on the use of nitrite compounds as preservatives in bacon.

Many agricultural herbicide, insecticide, and fungicide formulations in use today contain compounds that are secondary or tertiary amines or compounds which can be readily hydrolyzed to form secondary amines. Since it is known that many secondary and tertiary amines are easily nitrosated in the presence of nitrite ions to form the highly carcinogenic N-nitroso derivatives, it is presumed that these reactions occur between pesticides and nitrites in soil. However, until recently there has been no analytical technique with the required sensitivity to detect these compounds at their expected low levels in the environment.

Over 2000 compounds that are possible precursors of N-nitroso compounds are in use as pesticides in the U.S. today. Given the presence of nitrite ions in soil as well as the acidity of soil, there is a significant probability that a major fraction of the U.S. population is being exposed to hazardous levels of N-nitroso compounds.

In this study, research will focus on N-nitrosoamine derivatives in soil, water and agricultural crops from areas treated with known amounts and types of pesticides. Samples will be subjected to gas-phase chromatography (gpc) and high-pressure liquid chromatography (hplc). Materials separated by gpc and hplc will then be passed into the Thermal Energy Analyzer (TEA), developed by Thermo-Electron Corporation, which is a very specific analyzer for N-nitroso compounds. In addition to the above, measurements of the yields of N-nitroso compounds from several important classes of pesticides will be made under simulated soil and ground-water conditions.

The intent of this research is to develop a rapid screening method to determine which pesticides undergo nitrosation so rapidly that one should assign a high priority to study of them in the field.

Effects of Pollutants on Gills of Freshwater Fishes; *Paul O. Fromm,* Michigan State University, Department of Physiology, East Lansing, MI 48824; $26,311 for 12 months beginning May 17, 1978.

Gills represent that tissue or organ of fishes which is maximally exposed to waterborne pollutants. Continuous ventilatory activity insures that the concentration of any toxicant present in the aquatic environment is maintained at the respiratory surface. It is reasonable to believe that a study of the action of pollutants on fish gills will provide valuable information relative to the impact of man's activities on the aquatic environment.

The primary objective of this project is to develop an isolated perfused gill preparation as a model to study the effect of selected pollutants on fish.

This objective will be achieved by:

- quantitating the flux of water across isolated perfused gills and studying the chemical and physical factors which influence this flux;
- exposing isolated gills to selected waterborne pollutants and evaluate the effect they may have; and,
- characterizing the biotransformation of pollutants during transit from the ventilatory fluid into the blood vascular system.

The research consists of three main projects: (1) Experimental investigation of the permeability properties of the isolated gill and the effect of pollutants on same; (2) a study of the salt transport capabilities in gills exposed to pollutants; and (3) biotransformation of pollutants by gills. Each project will involve an extensive literature survey, design, testing and establishment of experiment procedures to be used, and data collection and analysis.

User groups includes state and Federal agencies such as DOE and EPA that are concerned with water quality criteria and specifications for construction of industrial and municipal water treatment facilities; water pollution biologists such as many members of NABS; and members of the biological community concerned with information dealing with the biology of fishes, membrane permeability, ion transport, and stress physiology of aquatic animals.

Mycotoxins as a Potential Human Health Hazard; *Anil C. Ghosh,* Sisa Incorporated, 767B Concord Avenue, Cambridge, MA 02138; $25,000 for 6 months beginning October 1, 1977.

A large number of molds can grow on various foods, feeds and grains and are capable of producing secondary metabolites. Many of these metabolites as well as the isolates of the fungi are known to cause human and animal diseases. However, with but few exceptions such as for the aflotoxins, there are no practical and rapid methods available for the detection of these mycotoxins in foodstuffs and feedstuffs.

It was the goal of this study to develop methodology for the detection and estimation of toxins elaborated by molds frequently encountered as contaminants in soybeans, rice, wheat, chocolate syrup, cheese, flour, and animal feedstocks. Mycotoxins identified will also be tested for mutagenicity.

Enzyme Monitored Receptor Assay System for Industrial Organic Chemicals; *Patrick E. Guire,* Kallestad Labs, Inc., 1000 Lake Hazeltine Drive, Chaska, MN 55318; $47,016 for 12 months beginning September 15, 1978.

This research will develop an immobilized enzyme-immunoassay system for detection and measurement of industrial chemical contaminants of our current environment. The project will also demonstrate the system's sensitivity, specificity, and general usefulness in detecting environmental contaminants, metabolites thereof and indicator chemicals (e.g., antibodies) produced in response to prior exposure. Such an assay system will be designed to provide an economically feasible and technically sound data-gathering methodology for epidemiologic studies of current levels of contamination and prior exposure to contaminants. Successful completion of this feasibiliy demonstration project may lead to development of similar, highly sensitive assays for many environmental contaminants. These will include both semi-quantitative field test kits (e.g., color test strips) and quantitative assays for environmental chemicals and potentially, for antibodies or other receptors induced by prior exposures.

Dinitrotoluene and antigenically-related industrial

environmental contaminants will be studied first. The proposed assay method involves the preparation and use of a cofactor derivative containing a covalently linked hapten group. Binding of antibody to the hapten-cofactor/enzyme complex will result in reversible inactivation of the enzyme. The cofactor-hapten complex will be coupled to the immobilized enzyme through a long spacer arm, allowing multiple uses of the solid phase immunoassay product. The presence of hapten in the test solution will be detected through its displacement of some of the antibody, resulting in reactivation of the enzyme.

It is hoped that the results of this research project will lead to the development of other similar assay systems for use by regulatory agencies such as the Environmental Protection Agency and the National Institute of Occupational Safety and Health, as well as by industrial companies, in measurements necessary for the control of industrial chemical environmental pollution.

Twelfth Annual Conference on Trace Substances in Environmental Health to be held in Columbia, Missouri: June 6-8, 1978; *Delbert D. Hemphill,* University of Missouri, Columbia, Department of Horticulture, Columbia, MO 65201; $18,350 for 12 months beginning June 1, 1978.

The Twelfth Annual Conference on Trace Substances in Environmental Health is a continuation of series of scientific meetings held under the auspices of the University-wide Environmental Health Program of the University of Missouri system.

The purpose of these Conferences is to explore the effects on man and eco-systems of trace amounts of organic chemical substances. The Conferences examine the occurrences of these substances in environmental media, biota, and foods, and the processes by which they are transported through environmental pathways or produce their effects on living forms and ecosystems. This particular Conference will bring together the various disciplines concerned with effects of trace substances in the environment; facilitate exchange of the latest scientific information in interdisciplinary areas related to information on trace substances and their effect on the health of man and his ecosystem; define the indirect effects of trace substances upon man through changes in his ecosystem; explore methodology for the evaluation and for the control of the effects of these trace substances, particularly in the field of analytical chemistry and field measurement; and produce a proceedings so that investigators who were unable to attend the meeting may have the advantage of the material presented.

These conferences form part of an overall interdisciplinary approach necessary to understand the complexity of environmental and ecological problems and methods for their control.

Quantitative Structure Activity Relationships in Toxic Substances; *A. J. Hopfinger,* Case Western Reserve University, Department of Macromolecular Science, Cleveland, OH 44106; $144,903 for 24 months beginning March 1, 1978.

A large number of chemicals are discharged into the environment as a result of their production, use, or disposal. Many of these chemicals are toxic in one way or another, and identification of chemicals with their manifestations of toxicity is one of our major concerns today. Testing of all chemicals for all effects is neither practical nor desirable. Methods to identify chemicals with probable toxicities are necessary to provide effective use of our limited resources testing. Quantitative property/effect relationships (including structure/activity correlations) are, in principle, a set of tools that could identify the most potentially damaging substances.

With the thousands of new compounds synthesized each year, hundreds of which end up being made in commercial quantities, there is a rapidly increasing body of potential toxicants. A means of identifying and classifying these toxic substances, preferably in advance of bulk production, is very much needed. If molecular propensity to toxicity can be predicted, there is hope of calculating the properties of a chemical before it is manufactured or released.

This project seeks to develop such a method using quantitative structure/activity relationships based on physico-chemical properties calculated from molecular mechanics. A number of physical properties of various chemicals will be calculated for stable conformations of the compounds using Conforma-

tional Analysis of Molecules in Solution by Empirical and Quantum Techniques (COMSEQ) software. These will include various energies (binding, steric, solvation, etc.), geometric terms (bond lengths, bond angles, etc.) and activity descriptors such as charge distribution, dipole moments, molecular volume, and partition coefficients. These will be correlated with experimental data on biological effects of the compounds to determine what, if any, relationships exist. The correlation will be tested by using them to predict effects of additional compounds and checking the predictions against experimental results.

Cytogenetic Effects of Mutagens and Mitotic Poisons on Mammalian Cells; *T. C. Hsu,* University of Texas—Anderson Hospital and Tumor Institute, Department of Biology, Houston, TX 78712; $79,307 for 12 months beginning January 24, 1978.

There is an urgent need for quick, inexpensive and reliable tests for screening chemicals for adverse health effects. Conventional tests in laboratory animals are accepted as applicable to the human experience but there are not adequate resources, trained personnel, or time to exhaustively test the thirty thousand or more commercial chemicals in use in the United States annually. New, rapid techniques are needed for screening chemicals for their potential to cause mutations so that those with the highest potential can be extensively tested and their risk assessed in order that intelligent regulatory decisions can be made concerning the use of such chemicals. Several test systems using bacteria are in wide use but the simplicity of the bacterial mechanisms are obscuring possible effects to humans.

It is therefore the purpose of this project to use mammalian cells as test systems. During the next twelve months, a protocol will be developed for the rapid screening of chemicals for their ability to cause chromosome breaks or otherwise interfere with mitosis in mammalian cells both in cell culture and *in vitro.* In addition, attempts will be made to refine a technique for visualizing premature condensed chromosomes so that background abnormality rates can be estimated. An investigation will also be initiated to assess the feasibility of using male, Mammalian meiosis as a test system for environmental mutagens. And finally, investigation will be made using selected chemicals which cause "dominant lethals" in the Chinese hamster to ascertain the mechanism of this process.

Chemiluminescent Analysis of Hydrogen Peroxide in the Ambient Atmosphere; *Gregory L. Kok,* Harvey Mudd College, Department of Chemistry, Claremont, CA 91711; $3,612 for 6 months beginning June 22, 1978.

After several decades of research and control measures, photochemical smog remains a severe economic, health and aesthetic problem in the Los Angeles basin and, to a lesser extent, throughout the U.S.. Control measures are slowly proving effective in reducing air pollution, but are costly and restrictive. It has become necessary to verify the validity of our models of smog production, since even small modifications in the detail of the mechanisms on which we calculate our regulations may have enormous financial and technological impact. Many excellent models for photochemical smog production have been developed, but the reliability of these models is dependent on accurate values of kinetic rate constants as well as accurate data on ambient levels of various species for the verification of the models.

Analyses for NO, NO_2, O_3, SO_2 and some hydrocarbons are now made routinely in the ambient atmosphere. Reactions of these species in the atmosphere are moderately well known and give a good starting point for most models of photochemical smog. To further extend photochemical smog models, analyses are needed for species such as hydrogen peroxide (H_2O_2), nitrous acid (HNO), and nitric acid (HNO_3).

These species are formed via photooxidation reactions, and concentration information will provide new data on smog-formation processes. In addition, measurements on these species will, by implication, give concentration information on other short-lived species. Hydrogen peroxide is formed from the combination of HO_2 radicals; thus, measurements of H_2O_2 will give relative information on the concentration of HO_2 radicals, a species which would appear to be almost impossible to determine directly.

The current analytical method for H_2O_2 in the atmosphere employs the reaction of H_2O_2 with titanium

(IV) and 8-quininol to form a colored complex. The complex is extracted into chloroform and assayed spectrophotometrically. This method is slow and involves long sampling times to obtain the desired sensitivity. This project will develop an automated, chemiluminescent analyzer for the determination of H_2O_2 in the ambient atmosphere. This unit should have a very high sensitivity as well as relative freedom from interferences. It will be necessary to develop a generator of accurately known, sub-ppm concentrations of H_2O_2 in the gas phase for calibration of the instrument. Following development and initial tests of the analyzer, it will be used for field measurements of H_2O_2 in the Los Angeles Basin to determine its concentrations as a function of temperature, ozone concentration, solar intensity, and other parameters related to smog formation.

Technical Assistance to the TSCA Interagency Testing Committee; *John C. Kolojeski,* Clement Associates, Inc., 1010 Wisconsin Ave., N.W. Suite 660, Washington, D.C. 20013; $144,287 for 6 months beginning December 1, 1977.

With the passage of the Toxic Substances Control Act (PL 94-469), on January 1, 1977, the problem of premarket testing for the determination of the hazardous nature of new chemical substances and mixtures as well as existing materials in current, widespread use became a regulatory issue. The provisions of the Act established an eight member interagency Advisory Committee to the Administrator of the U.S. Environmental Protection Agency. The Committee is to advise the Administrator on those chemical substances and mixtures which ought to require further testing relevant to a determination of the associated risk of injury to human health or the environment.

This award provides technical assistance to the Interagency Advisory Committee by providing appropriate information on exposure and health and environmental effects for a large number of manufactured chemical substances and mixtures; consulting with the Committee during its review of the data provided; providing support to the Committee in the selection of those chemical substances and mixtures having the greatest potential for damage to human health and the environment and for which further testing appears to be appropriate; and providing support to the formulation of the Committee's recommendations to the Administrator of the U.S. Environmental Protection Agency in accordance with the specifications of the Act.

Research on an Immunochemical Assay for Asbestos in the Environment; *H. R. Lukens,* IRT Corporation, P.O. Box 80817, San Diego, CA 92138; $24,280 for 6 months beginning October 1, 1977.

Asbestos is a public hazard by virtue of its carcinogenicity and widespread use. Unfortunately, no simple, inexpensive, sensitive and specific method for the detection of asbestos exists. This research is directed toward producing an immunoglobulin with specific binding sites for asbestos which can be labeled with a fluorescent tracer and used to measure asbestos in environmental and biological samples quickly, at low cost, and with a high degree of sensitivity and specificity.

Production of such an immunoglobulin in rabbits is being attempted via the injection of an immunogen comprised of an ovalbumin-asbestos conjugate. The successful production of the desired antibody will be tested in experiments that compare the degree of affinity for asbestos of the gamma globulin fraction from immunized rabbits with that of the same fraction from control animals.

Characterization of Aquatic Organics and Complexes; *Walter J. Maier,* University of Minnesota, Department of Civil and Mineral Engineering, Minneapolis, MN 55455; $160,530 for 12 months beginning May 9, 1978.

Many organic compounds are capable of forming complexes with transition metals and other elements. The complexes may have different properties from the uncomplexed metal with respect to movement

through soil and water and across membranes. Some of the metals subject to complexation are considered toxic (e.g., mercury, cadmium); others (e.g., iron, manganese, chromium, copper) can be toxic if present in excess.

The intensive utilization of land and water resources coupled with the proliferation of new chemicals has resulted in an accumulation of organic and inorganic constituents in natural waters. A significant fraction of these components have been shown to be detrimental to the public health and the aquatic ecosystem. Federal regulations have mandated control or elimination of inputs of many of these contaminants. However, accurate information on the distribution, concentration, interactions, residence time and ultimate fate of natural and anthropogenic organic materials is not available.

This research will carry out a comprehensive study of acquatic organics that will provide a more rational basis for the formulation of policy and setting of standards for the control of trace contaminants. To do this, the research will characterize aquatic organics in the Upper Mississippi River as related to identity, chemical-physical properties, source-related behavior, transport, and metal-interactions. Water samples are being obtained from the river and major inflows consisting of precipitation, subsurface seepage, surface runoff and municipal-industrial effluents. Initially, aquatic organics are separated by molecular size and elemental composition, and subsequently fractionated into hydrophobic and hydrophilic classes from which acidic, neutral, and basic components are separated and concentrated. Techniques such as high pressure liquid chromatography, gas chromatography-mass spectrometry, and chemical ionization mass spectrometry and are being used to intensively characterize and identify organic components in these fractionated samples.

Information on the behavior of trace organic, metal, and micronutrient substances in the water environment obtained from this research should be of interest to all regulatory agencies with responsibilities for public health, environmental protection, and fish and wildlife resources.

Approaches for the Acquisition of Mass Spectral Data for Inclusion in the NIH/EPA Mass Spectral Data Base; *David P. Martinsen,* Fein-Marquart Associates, Inc., 7215 York Road, Baltimore, MD 21212; $24,874 for 6 months beginning October 1, 1977.

Large quantities of mass spectral data are currently being measured and filed away without being available to the chemical community. There exists a fully operational, Federally operated, computerized system which can profitably employ these data and make them available to the general public. This project is developing procedures to seek out unreported data, acquire them, and incorporate them into the computerized system. The problems of coordinating the interests of the various U.S. Government agencies and the United Kingdom will also be considered.

Nitrous Oxide Environmental Measurement Program; *Michael B. McElroy,* Harvard University, Department of Atmospheric Sciences, Cambridge, MA 02138; $140,428 for 12 months beginning July 19, 1978.

Nitrous oxide causes destruction of stratospheric ozone by acting as a source of reactive oxygen atoms. There is considerable concern that activities of man may be increasing the amount of nitrous oxide in the stratosphere, which could eventually result in decreasing the ozone "shield". This project was intended to help define the relative contributions of natural background and human-enhanced sources of nitrous oxide by looking at production of nitrous oxide in riverine and estuarine waters under various natural conditions and human impacts.

Measurements of rivers and freshwater ponds show that the contribution of freshwater systems to atmospheric nitrous oxide varies greatly. The Potomac, for example, shows variations with weather, season, and location. Measurements of dissolved oxygen, nitrous oxide, ammonium, nitrate, and nitrite will be made and used to study the biogeochemistry of nitrogen in the Potomac River near Washington, D.C. year-round.

This project will help develop an accurate, reliable gas chromotographic method for field measurement of nitrous oxide, will help to determine production of nitrous oxide by biological activity in near-shore areas, and will relate biologically-produced nitrous oxide to that produced from fertilizers.

Isotopic Labeling Techniques to Study the Photooxidation of Hydrocarbons in Air; *G. D. Mendenhall,* Battelle Memorial Institute, 505 King Avenue, Columbus, OH 43201; $80,000 for 12 months beginning September 1, 1978.

A central goal of atmospheric chemistry is to develop a comprehensive description of the roles of primary air pollutants in their interactions with themselves and with the natural environment by which they determine their final product, typically polluted urban air. Polluted air is characterized by known and unknown effects on health, by destructive effects on man-made materials and structures and, most conspicuously, by visibility-degrading hazes and smog. To a major extent, these effects results from the properties of secondary pollutants formed in the atmosphere after the primary pollutants are emitted by their sources.

The variable and changing composition of motor fuels can influence the character of the secondary gaseous and particulate pollutants of the air. Different classes of hydrocarbons in gasoline can be assumed to yield photochemical oxidation products differing in their effects on the health of humans and other living forms, and in their haze-forming properties. This research is designed to elucidate the reaction pathways connecting certain hydrocarbon types with their oxidation products. It will apply isotopically labeled compounds and gas chromatography-mass spectroscopy for both product identification and quantitation. The amounts of several oxidation products from a hydrocarbon labeled with stable isotopes of carbon or hydrogen will be determined by reverse isotope dilution with unlabeled products. Identification of products will be further assisted by incubation of unlabeled oxidation products with water labeled with stable isotopes of oxygen or hydrogen, followed by mass spectroscopy after different exchange reaction times. The steps involved in the oxidation of hydrocarbons under simulated atmospheric conditions will be determined sequentially, i.e., some of the first-formed products will be examined separately to determine secondary products, and so on. The results of the study will be a detailed understanding of the fate of organic substances in the atmosphere, and the development of new methods to study such changes.

The primary objective of the research, is to apply labeling by stable isotopic substitutions of parent organic molecules to the identification of reaction pathways and products. A second objective is to better characterize the functional classes of hydrocarbons in terms of the health effects of their oxidation products. A third objective is to identify those classes of hydrocarbons that are most effective for haze formation.

Reactive Tapes for Automatic Environmental Analyses; *Larry D. Nichols,* Moleculon Research Corp., 139 Main Street, Cambridge, MA 02142; $24,805 for 6 months beginning October 1, 1977.

Solution chemistry combines with instrumental optical techniques to provide a powerful analytic tool for environmental applications. This technique, when automated on the basis of conventional solution-handling methods, leads to complex and expensive systems such as those currently available. Such systems are very valuable for analyses conducted in central laboratories, but more service-free and less expensive systems are needed for extensive decentralized and remote environmental monitoring.

Impregnated tapes potentially represent a way of handling solutions in a form more compatible with automatic operations. Present tape systems do not use the full potential of accurate photometric equipment because inert, highly transparent tapes have not been available with high liquid content, good strength, and large diffusion constants.

This project will optimize trial analytic schemes for use with an improved tape, test sample-concentrating methods based on tape, prepare tape samples, and demonstrate analytic performance.

The Role of Primary Particulates in Urban Air Pollution; *Tihomir Novakov,* Lawrence Berkley Laboratory, Energy/Environment Division, University of California, Berkeley, CA 74709; $185,700 for 14 months beginning August 18, 1978.

The atmosphere is degraded by suspended particulates consisting of solid particles and microscopic liquid droplets. Some of these particles, like wind-blown dust, fly-ash, and soot, are primary par-

ticulates directly emitted into the atmosphere by pollutant sources. Others, secondary particulates, are formed right in the atmosphere by chemical reactions of precursors emitted in gaseous form by sources. Still others are primary pollutants that have been chemically modified after entering the atmosphere.

Airborne particulate sulfate of unspecified chemical form has been associated with the incidence of respiratory ailments such as emphysema and asthma. Earlier work has supplied evidence that significant quantities of airborne sulfate are carried on the surfaces of primary carbon particles (soot), where the sulfate is formed by the carbon-catalyzed oxidation of gaseous sulfur dioxide.

The objective of this project is to assess the contribution of primary carbon (soot) emissions to the degradation of visibility through urban atmospheres. The visibility-degrading effect of primary carbon is compared with that of the secondary carbonaceous particulates formed by the oxidation of hydrocarbons in the atmosphere. A second objective is to define the roles of primary carbon in mediating the chemistry of the gaseous sulfur and nitrogen compounds in polluted air. The speed of the carbon-catalyzed oxidation of sulfur dioxide will be determined to help assess the significance of sulfate production on carbon particle surfaces and to gauge the importance of this process for the generation of hazardous airborne particulate sulfate. A parallel study is devoted to describing the surface-chemical forms of nitrogen compounds produced on carbon surfaces by reaction with atmospheric ammonia and nitrogen oxides. Polycyclic aromatic hydrocarbons associated with soot particles will be investigated to determine their reactivity to nitrogen dioxide under practical conditions occurring in polluted air. This approach is designed to explore possibilities of the formation of unsuspected carcinogens in urban air.

New methodology is being studied for measuring the atmospheric burden of primary carbon by applying the optical attenuation of a laser beam by a filter carrying less than a mono-layer of collected airborne particles. Raman spectroscopy is applied to the measurement of graphitic soot. Techniques for probing the chemistry of surface reactions on carbon include ESCA (electron spectroscopy for chemical analysis), infrared spectroscopy, wet chemical analysis, and x-ray fluorescence.

Development of Antisera to Benzo [A] Pyrene and its Metabolites; *Kent Painter,* Western Chemical Research Corp., 2300 N. Highway 287, Fort Collins, CO 80521; $81,872 for 6 months beginning October 1, 1977.

During the last ten years radioimmunoassay techniques have employed radioactive tracers and highly specific antisera to achieve unparalleled sensitivity in the quantitative analysis of many biological materials. This proposal will develop analytical methods which will permit the monitoring of the environment and workers exposed to carcinogenic polynuclear aromatic hydrocarbons at trace levels far below current methodology. The specificity of the method allows the analysis of substances in complex biological fluids (serum, urine, waste water, plant and animal tissue extracts) without the necessity of time consuming and expensive chromatographic separations and is totally automated.

The preparation of high affinity antisera would find many additional applications, such as inhibiting carcinogenesis *in vivo* by immunological methods, as well as in prophylaxis and treatment of known exposure cases. If the antiserum were attached to a solid support, liquids such as waste water could be passed over the support to remove the antigen (e.g., benzo [a] pyrene) and the antiserum could be regenerated and reused. Among other applications of benzo [a] pyrene antiserum is the employment of solid-phase immobilized antibody techniques to the removal of benzo [a] pyrenes from wastewater. Antisera will be prepared and assays developed using standard immunological techniques. Several derivatives will be prepared and evaluated to determine antigenicity of the molecule, and to provide a supply of antisera which will be useable for the various hydroxylated metabolites produced in different ecosystems and species.

Atmospheric Transformations and Mutagenic Activity of Primary and Secondary Air Pollutants; *James N. Pitts,* University of California—Riverside, Department of Chemistry, Riverside, CA 92521; $253,240 for 12 months beginning February 1, 1978.

Polluted urban air is the product of a diverse mixture of man-made contaminants that react chemically

with one another and with naturally occurring atmospheric constituents to form a new class of secondary contaminants. These include visibility-degrading aerosols, gaseous bioirritants, and various substances having unspecified effects on human health. Smog-forming chemical processes have definite time-courses that determine air quality at locations remote from the source where a given parcel of air acquired its primary pollutants. The diversity of chemical species emitted by multifarious sources and the complexity of the chemical and photochemical processes involved complicate the work of pollution control authorities who cannot defend regulatory decisions without credible scientific evidence connecting demonstrable effects with identified sources.

Following earlier research to develop a kinetic computer model of smog photochemistry, this project undertakes to clarify the roles of certain highly active minor chemical species in smog formation (nitrous acid, pernitric acid, the hydroperoxyl radical). It seeks to elucidate the formation and roles of particulates in photochemical air pollution, and to determine the chemical transformations of amines and nitrosamines in simulated polluted air. These objectives include the isolation of mutagenic fractions from ambient air, and the identification of their chemical nature and origins. Finally, the research will investigate the chemical nature and possible mutagenic properties of airborne pollutants from agricultural burning. Experimental techniques include simulated photochemical smog formation, infrared spectroscopy, chemical analysis, gas and liquid chromatography, mass spectroscopy, and bacterial assays for mutagenesis.

Development of Screening Methods for Developmental Abnormalities; *Robert L. Seecof,* City of Hope Medical Center, 1500 East Duarte Street, Duarte, CA 91010; $177,020 for 12 months beginning July 1, 1978.

This proposal deals with problems of man-caused environmental hazards, specifically with chemical threats to ecosystems and human populations in the form of teratogens and mutagens. Populations of humans and other animals are continuously exposed to potentially teratogenic compounds in the form of drugs, industrial by-products and wastes. These agents cause birth defects directly by interfering with embryonic or fetal development and indirectly by mutating genes. This proposal deals chiefly with chemical agents that directly injure exposed embryos or fetuses. Such teratogens are estimated to cause about 4% of all human birth defects and the actual percentage may be higher. Birth defects within non-human populations may be contributing to ecosystem imbalances, and this could be detrimental to human welfare in the long.

Procedures will be developed for detecting teratogens by adding them to cultures of *Drosophila* cells and determining which responses to cell differentiation and tissue formation are the best indicators of teratogenicity. An array of known teratogens and nonteratogens will be tested *in vitro* in order to determine if cells discriminate between these classes and also to catalogue the effects of these compounds on the cells. Procedures will be developed for testing metabolic products by feeding compounds to rodents and then assaying their serum *in vitro* for effects on developing embryos. Procedures will be developed for testing compounds for teratogenic effects in intact *Drosophila,* and for their known teratogenic effects in mammals. It is anticipated that the procedure developed will serve as a screen to detect teratogens that are dangerous to humans and ecosystems, and the data collected will contribute to our understanding of the role of teratogenesis in ecosystems and our understanding of basic biochemical and developmental aspects of teratogenesis.

The Detection of Pyrrolizidine Alkaloids and their Metabolites; *Henry J. Segall,* University of California—Davis, Department of Physiological Sciences, Davis, CA 95616; $117,470 for 12 months beginning June 1, 1978.

The pyrrolizidine alkaloids are hepatotoxins which are found in a wide variety of plants. Ingestion by livestock of plants containing pyrrolizidine alkaloids can cause acute and chronic liver and lung damage and may lead to death. The chronic effects of prolonged ingestion by humans of small amounts of these alkaloids in contaminated grain products or teas is unknown. The rising public interest in and use of "natural" foods may result in consumers unsuspectingly exposing themselves and their families to these toxins. Herbal teas sold in health food stores and pharmacies have been found to contain pyrrolizidine

alkaloids. Pyrrolizidine alkaloids are not the active toxins but are metabolized to various pyrroles by mammalian and human livers. One disturbing fact is the ability of pyrrolizidine toxicity to be transferred through milk. It is not known if lactating cows who consume pyrrolizidine-containing plants pass the parent compounds and/or metabolities through to their milk.

This study of pyrrolizidine alkaloids and their metabolites begins a new thrust in the Chemical Threats program, which now supports research on the behavior and effects of naturally-occurring environmental contaminants in addition to anthropogenic contaminants. The specific research to be sponsored under this grant will add much needed new environmental assay methodology for the detection of an insidious class of toxicants.

Analytical methodologies are being developed to identify these alkaloids and their metabolites in plants and in the milk of cows which consume the plants. Analytical tools being employed include high pressure liquid chromatography and gas chromatography/-mass spectroscopy. Plants to be examined include *Senecio vulgaris, Senecio jacobaea, Seneca longilobus* and *Amsinckia intermedia.*

Chemical and Physical Characterization of Submicron Aerosols; *John H. Seinfeld,* California Institute of Technology, Department of Chemical Engineering, Pasadena, CA 91125; $118,608 for 12 months beginning July 11, 1978.

Aerosols in the urban atmosphere contribute significantly to visibility degradation and health effects, yet despite years of investigation their origins and evolution remain poorly understood. It is essential that we gain a better understanding of the formation, growth, coagulation, transport and deposition of atmospheric particles as they pertain to air pollution problems.

This research is to develop a fundamental understanding of the formation and growth of submicron aerosol particles of importance in air pollution through theoretical and experimental studies aimed at elucidating the processes affecting the distribution of chemical species with respect to particle size. The project will determine the processes which govern the emissions of submicron particles from combustion sources; develop a comprehensive mathematical model capable of simulating the dynamics of the size and composition distribution of air pollution aerosols; and develop a low-pressure impactor capable of fractionating particles below 0.5 micrometer diameter for use in conjunction with combustion studies and measurement of trace metal concentrations in ambient air and in the vicinity of power plant plumes.

Development of Procedures for the Analysis of Organic Compounds in the Atmosphere; *Robert E. Sievers,* University of Colorado, Department of Chemistry, Boulder, CO 80309; $135,500 for 24 months beginning February 1, 1978.

This project will develop improved sampling and analysis techniques suitable for characterizing the trace organic composition of the atmosphere. This research effort will include investigation of the suitability of a number of sorbent materials for efficient collection of organic vapors, which will then be described, identified and quantitated by modern gas chromatography and mass spectrometry techniques. The techniques developed in this program will be applied in Colorado.

Experience indicates that a combination of two porous sorbents results in effective trapping of both low and higher molecular weight gaseous hydrocarbons and oxygenates. A combination of Tenax GC (poly-2.6-diphenyl-p-phenylene oxide, a porous polymer for higher molecular weight substances) and Carbosieve B (a carbon molecular sieve, effective for low molecular weight compounds) will be investigated. Organic constituents in the sample will be sorbed with air flow through the two sorbents in one direction, and a concentrated sample will then be backflushed during the desorption step. Optimum sorption tube dimensions, flow rates and sampling times will be determined. An appropriate air pumping system for sampling ambient air will be devised and constructed. Several other porous polymers may be investigated for use in sorption sampling tubes should problems develop with the system described above.

Gas chromatography with flame ionization, electron capture, mass spectrometer and possibly microwave emission detectors will be used in this project. Gas chromatography will separate the mixtures into single compounds or small groups of compounds. Relevant structural information and functionality determination will be made by mass spectrometry.

This work will be of significance to obtaining a better understanding of the ozone problem associated with urban pollution. Our current knowledge about the complex atmospheric chemistry of hydrocarbons nitrogen oxides and ozone suggests that a more detailed understanding of ozone precursors and distribution sources is required to fully understand the ozone problem.

Prediction of Volatilization Rates of Chemicals in Water; *James H. Smith,* SRI International, Physical Chemistry, 333 Ravenswood Ave., Menlo Park, CA 94025; $79,589 for 12 months beginning August 1, 1978.

Transport of chemicals from water bodies to the atmosphere by volatilization (evaporation) can be an important environmental pathway for certain chemicals. Compounds of low molecular weight and high vapor pressure, such as vinyl chloride, have been shown to volatilize rapidly. However, some high molecular weight, low solubility compounds such as DDT also volatilize at an appreciable rate. This process may be important for compounds introduced into both fresh water and marine environments by inadvertent spills (e.g., chemicals, fuels) or industrial effluents.

The phenomenon of evaporation of organic chemicals is important in two areas of environmental concern. The water entering wastewater treatment units such as API separators, cooling towers, settling ponds, and biotreatment plants within industrial facilities often contains toxic organic chemicals. The effluents from these facilities are usually dumped into a receiving water body such as a river, lake, or the ocean. The chemicals may thus be transported to other locations. Significant amounts of the chemicals may also be transferred from the treatment unit or the water body to the atmosphere.

The rates of processes such as volatilization must be known before recent legislation requiring control of emission of toxic chemicals into the environment can be fully implemented. In view of the large number of chemicals that must be evaluated, inexpensive methods of predicting volatilization rates of toxic chemicals from water to air are needed. This research program will add significantly to our ability to predict the volatilization rates of organic chemicals from both fresh and marine waters.

This research will show that the procedures based on predicting and/or measuring the ratio of the evaporation rate of the chemical to the oxygen reaeration coefficient, K_v^s/K_v^o and using this ratio to estimate volatilization rates under a variety of environmental conditions are generally applicable to a wide range of compounds and environmental situations. Values of this ratio will be measured for toxic compounds that are of immediate environmental concern and for which volatilization is likely to be the major environmental pathway, These include benzene, chloroform, carbon tetrachloride, and bromodichloromethane. Other compounds may be selected after consultation with NSF and EPA staff.

The results of this research program should be of immediate and considerable value to both private and public organizations that must assess the fate of substances in the environment. It is expected that applications of these results to specific compounds or environmental situations will be developed for the Office of Pesticide Programs (EPA), Office of Toxic Substances (EPA), and the Environmental Research Division (DOE).

Chemical Structure, Reactivity and Carcinogenicity of Halohydrocarbons; *Benjamin L. Van Duuren,* New York University, Department of Environmental Medicine, New York, NY 10012; $300,000 for 24 months beginning May 8, 1978.

Historically, chemicals that are cancer-causing in humans have been identified as carcinogens only after their discovery during epidemiologic studies based on occupational exposure. With the advances made during the past 30 years in chemical carcinogenesis research, particularly in studies on structure-activity

relationships and metabolic pathways, it is now possible to expect that the carcinogenicity of certain chemicals may be predicted generally, if not specifically. This project is an integrated study of a major class of commercially important organic chemicals, halogenated hydrocarbons, and will seek possible linkages between the chemical properties of halogenated hydrogen compounds and their adverse biological behavior.

Nine halohydrocarbons have been selected for the study of chemical structure-carcinogenicity relationships. They are: vinylidene chloride, perchloroethylene, allyl chloride, 1, 3-dichloropropene, chloroprene, hexachlorobutadiene, ethylene dichloride, ethylene dibromide, and tetrabromoethane.

The ultimate aim of this work is to determine the stereochemistry, *in vivo* and *in vitro* metabolism and carcinogenic activity. Such studies will lead to the determination of the nature of the activated carcinogenic intermediates of these carcinogenic halohydrocarbons which need to be metabolically activated. It will also yield new information concerning those compounds which are direct-acting carcinogens.

This project's user community consists of the scientific advisors and scientists of major state and federal organizations concerned with the impacts of chemicals on the biological environment. Determination of structure-activity relationships of organic chemicals in this small but highly competitive field will, if the promise which it appears to hold matures, become quite conventional in future prescreening processes for new chemicals.

Pollutant Flow Through the Marine Food Web; *David Young,* Southern California Coastal Water Resources, Biology, 1500 East Imperial Highway, El Segundo, CA 90245; $69,980 for 12 months beginning February 15, 1978.

At present, conclusions reached by scientists studying pollution in the sea frequently depend on the untested assumption that toxic pollutants move upward through the marine food web, becoming more concentrated with each increase in trophic level. This concept is now being challenged by a number of scientists who suggest that the marine food web is unstructured and that energy and pollutants also flow downward. The implications of these differing patterns of translocation bear heavily on regulatory decisions affecting offshore municipal disposal practices, oil production and transshipment operations and other similar uses of the nearshore marine environment.

This project is pursuing field investigations off the coast of Southern California to determine whether or not structured food webs exist in a major wastewater disposal zone and to what extent concentrations of pollutants in several different classes follow any structure that is identified. Species of biological life representing several growth and reproductive stages located at control sites and in the disposal zone are being collected, characterized and analyzed for lipid content, cesium, potassium, toxic trace metals, detectable chlorinated hydrocarbons and certain petroleum derivatives. These and other data are to serve as the basis for the examination of the food chain amplification concept.

COMMUNITY WATER MANAGEMENT

The Community Water Management program addressed our need for fundamental knowledge and its application regarding the management of water at the community level. The program's Fiscal Year 1978 goal was to explore innovations in water and wastewater management to maintain acceptable levels of health, safety and environmental quality at reasonable cost. The aggregate demand for water, most of which is used for agriculture and industry, has reached a point where community needs for more dependable water supplies of acceptable quality have become increasingly more apparent. Reuse, whether direct or indirect, is now the rule rather than the exception. Community Water Management supported the scientific investigation of means to meet community needs for management of water and wastewater, including innovative and alternative technological concepts and social, institutional and economic barriers to their acceptance and use. Research results were targeted toward use by engineers who provide consulting and design services to communities, and to the local, State and Federal agencies which act in regulatory capacities with regard to the management of water and environmental quality.

The Thames/Potomac Seminars: A Comparative Study of River Basin Management; *Anne M. Blackburn,* Interstate Commission on the Potomac River Basin, Public Education, 814 East West Tower, 4350 East West Highway, Bethesda, MD 20014; $17,800 for 8 months beginning April 1, 1978.

In the Metropolitan Washington area, where water supply and water quality problems are severe, 16 governmental jurisdictions are concerned with using or managing Potomac River water. While a powerful basin-wide water resources management authority could lessen fragmentation and reduce conflicts, its establishment is unlikely, but its functions, including communication, coordination and cooperation between the existing agencies, programs and levels of government to provide reliable and safe community water supplies, effective methods for processing of wastewater, and subsequent disposal to meet regional water quality standards, are necessary.

The Thames River Basin in England is a river basin with many of the same characteristics as the Potomac, but one for which a high degree of integrated management has been successfully achieved. Since 1974, the Thames Water Authority has had full responsibility for water supply, water withdrawals, industrial discharge permits, collection and treatment of sewage, recreation, land drainage, flood control, fisheries management and navigation. The Thames management system was formed by linking existing facilities and administrative programs into a highly integrated super-structure within which the original sub-elements retained many of their functions. A study of how the various sub-elements were made to fit and work together in the Thames Basin could provide guidance to water management authorities in the United States, using the Potomac as an example. These seminars will help to provide this information.

Hydrometeorologic Studies of Urban Water Resource Problems; *Stanley A. Changnon,* University of Illinois, Urbana, Atmospheric Sciences Section, Urbana, IL 61801; $131,200 for 12 months beginning September 1, 1978.

The specific objective of this project is to develop and demonstrate to the engineering user community a real-time rain prediction-monitoring system utilizing modern weather radar plus limited rain data for use in the operation of the Chicago water resources system. The ultimate goal of the project is to design rain gauge and radar systems having widespread general application to urban areas; establish those precipitation measurements required in urban areas for optimizing design of urban hydrologic systems (storm and sanitary); establish those methods and techniques that will make the Chicago-centered findings transferrable to other cities facing similar problems of storm water and sewage disposal control; and provide precipitation data and information needed to define more accurately the time-space distribution characteristics of heavy storms in the Chicago region.

The proposed effort will essentially complete all of the first phase of a 3-year research plan. This involves development and testing of a real time, prediction-monitoring system for controlling urban sewer flows in heavy rainstorms through use of a combination of radar and rain gauge data. Phase II will involve development of methods to achieve major improvements in the design of hydrologic structures and water quality facilities. The major task in the third year will be the testing of the real-time, predictive-monitoring system developed from data and information accumulated in field and analysis programs. Results will be widely disseminated through reports and technical papers presented at meetings and in scientific journals.

It is intended to combine the Chicago findings with those obtained in earlier studies on rural and urban networks to provide design hydrologists with better meteorological input for the thunderstorm-dominated climate of the Midwest.

Mechanism of Plant Virus Inactivation in Soil Injected with Municipal Wastewater and Treatment Plant Sludges; *P. C. Cheo,* California Arboretum Foundation, 301 North Baldwin Avenue, Arcadia, CA 91006; $37,766 for 12 months beginning June 6, 1978.

Intensive application of sludge to land has recently emerged as an attractive alternative despite serious questions of its effects on soil including the fate of viruses that may survive treatment and present risk to human and plant life. Assessment of environmental risk and its management is an important consideration in determination of the acceptability of soil application of sludges.

The objective of this research is to investigate the mechanism(s) of anti-viral activity in soil and assess its significance and applicability to current trends toward utilization of land for management of municipal wastewater treatment plant sludges. Preliminary laboratory experiments with the tobacco mosaic virus have indicated that bacteria normally found in soil may be responsible for inactivation of plant viruses.

Specific objective of this project are to investigate anti-viral activity in soil and assess its significance with reference to current emphasis on utilization of land for management of municipal wastewater treatment sludges. Objectives will include isolation of anti-viral factor(s) from soils; reproduction of virus inactivation in the laboratory and determination of the range of physical and chemical conditions for optimal activity; assessment of the potential for application of results under field conditions to reduce time during which viruses retain viability and infectivity; and investigation of mechanisms of the virus degradation process and its potential role in the inactivation of other plant and animal viruses.

Studies will be undertaken to determine the mechanism of antiviral activity. Projections are likely to become possible regarding the potential utility of results obtained with the well-studied tobacco mosaic virus to other viruses of economic significance to farmers and viruses which are health significance to humans.

Conversion of Municipal Wastewater Treatment Plant Residual Sludges into Earthworm Castings for Use as Topsoil; *Jack E. Collier,* Collier's Earthworm Compost Systems, Inc., 2022 Cabrillo Court, Santa Clara, CA 95051; $15,620 for 12 months beginning September 11, 1978.

Earthworms, millipedes, slugs and sowbugs are soil invertebrates that feed on rotted wood and leaves rich in fungi, bacteria and protozoans. In doing so these animals, in conjunction with soil microorganisms (fungi, bacteria, protozoa), help to produce humus and thus improve the physical properties and structure of soils in which they are active. A better understanding of these natural processes and how they are affected by municipal wastewater treatment plant sludges is necessary to establish application rates for sludge that are in accord with the absorptive capacity of the soil ecosystem.

This research is to determine the feasibility of utilizing earthworms to accelerate the stabilization of municipal wastewater treatment plant sludges. The marketability of the earthworm castings and earthworms will be assessed to determine the degree to which economic returns may offset the costs of this stabilization process. This will include determination of optimum density of earthworms in cluture-beds, quality of earthworms and castings with regard to heavy metals, and ability of the castings to function as a plant growth medium.

Knowledge gained in this experiment may be used by municipal sewage treatment plants, worm growers and potential users of castings such as farmers, orchardists, nurseries, landscapers, sod farms, golf courses, tree farms, and foresters. Potential users of surplus worms include farmers, bait shops, aquaria, tropical fish growers, zoos, universities, wastewater treatment plants and the pet food industry.

Symposium on Water Reuse; *William J. Cooper,* Department of the Army, U.S. Army Bioengineering Research and Development Lab, Washington, DC 20315; $10,000 for 12 months beginning September 1, 1978.

This is an award to provide the NSF portion of funds for an interagency agreement with the U.S. Army Bioengineering and Development Laboratory to provide partial support for the National Symposium on Water Reuse to be held in 1979. The work is being conducted by the American Water Works Association Research Foundation. Other agencies contributing support for the conduct of this symposium include the Office of Water Research and Technology, U.S. Department of the Interior and the U.S. Environmental Protection Agency.

Efficacy and Impact of Intensive Plant Harvesting for Lake Management; *Grant Cottam,* University of Wisconsin, Madison, Department of Botany, Madison, WI 53706; $164,124 for 14 months beginning March 1, 1978.

Excessive growth of higher aquatic plants in lakes and reservoirs is a cause of increasing concern among users of freshwater systems. The water body may become completely choked with plants, impeding both water flow and recreational or commercial uses.

Much of the increase in aquatic plant growth is anthropogenic and is directly related to increased concentrations of nutrients in the surface waters. Programs to reduce phosphorus availability are considered essential. Inorganic phosphorus can be tied up temporarily in rooted aquatic plants and will be temporarily unavailable to algae, and if harvested at that time, can be removed from the system. If the weeds are left in the lake, the phosphorus is released once again as the vegetation decomposes.

A number of strategies have been suggested to deal with this problem, including the use of herbicides, biological control, habitat manipulation, mechanical harvesting, and nutrient control by interception near or at the source. Of all these approaches the two latter are the more promising, since removing the plant tissue from the surface water prevents the recycling of phosphorus through the aquatic system.

The proposed program will be undertaken at Lake Wingra, Wisconsin, a shallow, eutrophic lake located in the city of Madison. An active program of research on the harvesting of aquatic plants has been carried

out over the last four years. Emphasis in the project was on the development of new harvesting, processing and utilization techniques to increase the productivity of the harvester.

In order to find uses for the harvested vegetation its chemical and physical properties were studied. A considerable amount has been learned about the nutritional contents of local aquatic plants, and some preliminary work has been done to determine the potential and the problems of utilizing aquatic vegetation as feed for conventional livestock.

Concurrently, Lake Wingra has been the site of basic research relating to nutrient cycling. Certain submergent and emergent vegetation are being studied as well as macrophyte-nutrient interaction, role of littoral vegetation on nutrients and carbon transport, and potential effects of harvesting on the nutrient budget of the lake.

Wastewater Reuse for Regional Management of Water to Meet Urban Needs; *Arun K. Deb,* Roy F. Weston, Inc., Weston Way, West Chester, PA 19380; $9,067 for 6 months beginning February 14, 1978.

The objective of this research is to develop an efficient systems model and solution methodology for assisting municipalities, consulting engineers and planners in analyzing multiple-supply approaches to water management to determine whether this approach is beneficial to them in long-term planning related to water management.

Raw water from both surface and sub-surface sources has benefited from actions to reduce or eliminate the discharge of pollutants from municipal and industrial wastewater treatment plants. At the same time, progressive development of land for housing and more intensive pressures for increased utilization of farmland have increased the amount of pollutants entering waters from diffuse, non-point sources. It has become increasingly more difficult and expensive to bring water found in natural lakes, streams, ponds and subsurface locations to "potable" quality. We have reached a point where we should question the need to supply water of potable quality to meet community needs, only a small fraction of which require water of potable quality.

Data from representative communities will be collected to determine a pattern of domestic and industrial water usage in terms of quality and quantity in communities of three population size groups (20,000, 100,000, and 500,000). Water and wastewater flows over a fixed period of time will be projected for both domestic and industrial users. A method of optimum analysis of water transportation systems will be developed, incorporating capital costs and operating and maintenance costs to maximize economy. The models of single and multiple supply systems (with or without reuse) for individual communities of various sizes will then be used to develop an area-wide water quality management model which will be analyzed to evaluate both the merits and shortcomings of a multiple-supply management system. A general computer program will be developed and tested to simulate all the systems which will be analyzed for various technical and economical conditions. Major threats to public health from multiple water supply management systems compared to conventional systems will be identified, analyzed and compared. The problems for implementation of the multiple-supply management system in an existing city or a new city will also be identified and possible solutions evaluated. The study results will be evaluated from technical, economic, and public-health points of view and evaluated to determine cost effectiveness and practicability.

The research is directed toward a result that will help city and regional personnel, their consulting engineers and planners to identify the physical, technical and economic conditions under which a multiple supply approach is of significant advantage in long-term water use and resource planning.

Process Integration for Optimum Management of Municipal Wastewater Treatment Sludges; *Richard I. Dick,* Cornell University, Department of Environmental Engineering, Ithaca, NY 14850; $77,181 for 12 months beginning January 15, 1978.

Approximately 40-50% of the total costs of wastewater treatment are attributable to the management of treatment plant sludges. Current practice in sludge management does not typically integrate sludge treatment and subsequent management with the wastewater treatment processes. Other shortcomings

of current practice include inability to predict sludge composition by knowledge of inputs and lack of capability to predict the change in physical properties of sludges that result from treatment process modifications. The problem of sludge management can only become larger in the future as requirements for higher degrees of treatment result in production of larger quantities of sludges and as current practices for their disposition become more constrained.

The objective of this research is to determine the influence of both design and operating variables in the practice of wastewater and sludge processing on thickening and dewatering characteristics of sludges. Emphasis will be on the inclusion of disinfection in the evaluation of alternative sludge management concepts and utilization of a previously developed integration procedure to assess the practical implications of changes in processing.

Previous research has found that our ability to integrate unit operations and processes in sludge management is limited by the lack of availability of quantitative expressions for the influence of various wastewater and sludge treatment processes on the physical properties of sludge. These properties in turn influence the performance of subsequent thickening and dewatering processes. This research therefore proposes to experimentally determine the influence of the mean cell residence time in the activated sludge process, the retention time in aerobic and anaerobic biological digestion processes, the suspended solids removal efficiency in primary wastewater treatment, and the dosage of inorganic and organic conditioning chemicals on the physical properties of sludge. Effects to be experimentally evaluated will include settleability, dewaterability and elutriation.

An important element of the research plan is to evaluate widely held but apparently unfounded beliefs regarding the effects of anaerobic digestion on dewaterability. Studies of the influence of retention time in biological stabilization processes on sludge settleability and dewaterability will be conducted in continuous flow laboratory reactors housed in constant temperature rooms using various combinations of municipal primary and waste activated sludge.

During the first year of the research, experiments on the influence of mean cell residence time in the activated sludge process on physical properties of sludge will be completed, and experiments on the influence of retention time in biological stabilization processes will be started. Studies of the influence of irradiation on the physical properties of sludge will be initiated during the first year of the project and completed during the second year.

This research is expected to be of interest to municipalities and regional authorities, industry, equipment manufacturers, consulting engineers, government agencies, and researchers.

Synthesis of a Municipal Wastewater Sludge Management System; *Charles Finance,* Media-Four Productions, 6519 Fountain Avenue, Hollywood, CA 90028; $2,375 for 3 months beginning April 1, 1978.

This award provided support for the production of a film on residual sludge management. The film describes current sludge processing and management concepts that are the subject of research at the Massachusetts Institute of Technology, University of New Hampshire, Colorado State University and the State University of New York-Syracuse. The film will be utilized in the synthesis and communication of a management concept for sludges that is based upon disinfection with high energy electrons, and pipeline transport to a management site where it will be injected into the upper six inches of topsoil. Monitoring procedures for the process and site are presented in the context of the need to provide information that can be used to assess the environmental impact of this sludge management concept.

Advanced Treatment of Community Wastewater by Flow-Through Cypress Strand Wetlands; *Walter R. Fritz,* Boyle Engineering Corporation, 3025 E. South Street, Orlando, FL 32803; $163,759 for 24 months beginning September 1, 1978.

Until approximately 20 years ago, wastewater treatment which essentially removed much of the suspended and dissolved organic matter was accepted as adequate. Treated wastewaters so released into streams contained primary nutrients including nitrogen and phosphorus. Treatment concepts were subsequently developed to biologically oxidize organic matter and solubilize the nutrients. More recently, capital-

intensive chemical and biological processes have been advocated for removal of these nutrients and land application concepts have been re-introduced to meet needs for conservation of both the water and nutrient content of community wastewaters.

In 1972, NSF began to support research at the Universities of Florida and Michigan aimed at determining whether wetlands, known for their productivity, could be utilized to provide the tertiary, advanced or "polishing" stage of treatment without interfering with their environmental and ecological role. The results of basic studies led to their application to actual wetlands. In Michigan, the type of wetland selected was a peat bog and in Florida, a cypress-dome.

Results of the applied research conducted at the University of Florida directed toward use of cypress wetlands to accomplish tertiary treatment objectives has clearly shown that cypress domes can accomplish these objectives. In a related project investigators have determined that while cypress domes are effective, their ability to be utilized is limited by their physical size and availability. Cypress wetland strands, which are overland, flow-through swamps, appear to be a more practical solution for larger communities. Whereas only 3% of the treatment plants surveyed in Florida could use domes, 28% could use a dome and/or flow-through system (strand).

This project will assess the practical feasibility of using cypress strands to meet advanced (tertiary) treatment standards for community wastewater. Using an existing flow-through system at Jasper, Florida, specific objectives are to

- determine allowable loading rates (in terms of wetland area, length of flow and contact time) for cypress strand tertiary treatment systems;
- characterize the processes which accomplish the treatment and the factors which would effect allowable loading rates;
- determine the hydrological patterns within and surrounding the swamp to determine the effects of dilution during storm conditions;
- examine the environmental effects and changes in vegetation productivity caused by the application of secondary effluent; and
- integrate these findings with those from the dome-studies into a format which can be utilized by communities, their consulting firms and regulatory agencies in designing and evaluating designs of wetland wastewater treatment concepts.

Feasibility of Obtaining Public Cooperation for Source-Separation in Management of Solid Wastes; *Haynes C. Goddard,* University of Arizona, Department of Anthropology, Tucson, AZ 85721; $25,000 for 12 months beginning May 1, 1978.

Analysis of household refuse offers several advantages as a quantitative measure of household-level food utilization. A large number of interrelated resource behaviors can be studied simultaneously. The analysis of household refuse is an unobstrusive measure for a study of food waste, a topic that has been shown to be highly reactive to distortion in study by conventional methods. The study of household refuse imposes no inconvenience on the subject of the research. Data can be collected at relatively little cost compared to other methods.

Findings of this study to date have shown that certain relationships exist between economic status and patterns of use and waste, and also have shown that a discrepancy exists between what people indicate they have used or wasted in interviews and what is actually recovered from their household residuals.

This current research will test and refine observations about the relationship between interview and survey data and residuals analysis data; study the effects of economic stress upon nutrition; establish correlations between demographic variables and the material composition of household residuals; and construct modes of consumer behavior and provide accurate food "waste" data for potential use in waste management and recycling programs.

In addition, the current project will determine the effectiveness of concurrent media campaigns designed to encourage source separation of newspaper and resource recovery-source reduction of beverage containers. Prior data and procedures developed in previous NSF-funded research will be analyzed to provide baseline and trend information. A preliminary study of hazardous materials in household residuals using the entire data bank will be performed to provide insights into residuals composition that will help assess risks associated with its management.

Water Management in New England: A Method for Integrating Short-Run Operational and Long-Range Investment Strategies; *Harris Gold,* Water Purification Associates, 238 Main Street, Cambridge, MA 02142; $130,782 for 12 months beginning September 1, 1978.

Although New England is a relatively water-rich area, the independence of suppliers and the lack of large-scale water supply infrastructure make the region susceptible to water shortages. Effective water management in this regard requires a decision-making approach which recognizes the existence of droughts as caused by meteorological or demand conditions and considers both short-term and long-term improvements. This study will develop methods for analyzing short-term policies and their effectiveness in conjunction with intermediate and long-term approaches. It will do this by using New England as a case study, so that a realistic set of economic, industrial process, and institutional factors can be considered in a relatively urbanized and water-rich area.

The focus of this research is to develop and evaluate an integrated method for optimizing operational and long-range investment strategies. A stochastic dynamic programming method for analyzing potential water shortages will be formulated and tested. This will be linked to a capacity expansion formulation that optimizes investment decisions. The integrated method will then be tested in a New England Case Study by comparison to current strategies. No current method combines long- and short-term perspectives with demand and supply management strategies.

The integrated method will be tested in New England at the city, sub-region and river basin levels and compared to current strategies. This research will be accomplished by carrying out tasks centering on a delineation of technological and institutional mechanisms for matching supply with demand; the formulation and testing of an optimization method for choosing the levels of demand reduction and supply increase in light of uncertain future supplies; and tests of the use of developed methods on specific cases and comparisons with policies that would result from standard water resource planning methods.

The project is expected to provide a set of working water management tools that combine short- and long-range outlooks and demand and supply modification strategies which are needed and do not now exist.

Direct transfer of developed water management tools is expected through the specific case study efforts, workshop seminars, and a manual of practice.

Utilization of Waste Heat from Power Plants in Aquaculture; *Carlos R. Guerra,* Public Service Electric and Gas Co., Division of Research and Development, 80 Park Place, Newark, NJ 07101; $115,000 for 24 months beginning January 16, 1978.

Because of the large volume of thermal discharges in the U.S., power plant cooling water could become important for the production of aquatic animal species by providing a year-round supply of water of optimal temperature. Aquaculture operations based on river water species would not be restricted to coastal areas. Aquaculture plant siting near large consumer centers would provide marketing advantages and business and employment opportunities.

In 1974, PSE&G undertook research to investigate the technical and economic feasibility of utilizing waste heat in aquaculture. The technical feasibility of a two-species system (shrimp and trout) has been sufficiently established as possible to consider expansion of the research to provide a measure of its commercial feasibility. This proposal seeks to establish the conditions under which the concept under evaluation would be commercially viable. Commercial viability of the system will depend upon achievement of high survival and growth rates of both species and larger tanks and ponds to increase the system's productivity. Results have shown that all stages of the shrimp life cycle can be successfully cultured in condenser cooling water. High survival and good growth rates have been observed with shrimp grown in heated ponds. Trout adaptation to discharge water has been successfully demonstrated also.

This award will initiate a proof-of-concept scale evaluation of the use of heated discharged from the cooling of condensers at power generating stations to culture edible aquatic animals. An aquaculture facility utilizing Delaware River water heated in the condensers of 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. An objective of this research is to confirm the technical feasibility of the concept at a sufficiently large scale to determine its commercial feasibility. Research will focus on process reliability, reproducibility and product acceptability. Subcontracts for portions of the research plan have been awarded to Trenton State College and Rutgers University. Nutritional factors being studied include amino acid and calcium diet supplementation, food conversion efficiencies, and physical factors influencing the absorption of potential pollutants such as coal, chlorine and heavy metals. The Trenton State College effort is concentrated on improvement in management procedures including field application of nutritional data, intensification of culture techniques and brood stock management. Another subcontractor, Long Island Oyster Farms, Inc., will help assess the system's commercial feasibility. The New Jersey Department of Agriculture's Division of Rural Resources is studying adaptation of agricultural facilities to production of fingerling trout.

Stabilization of Community Wastewater Sludges by Soil Invertebrates; *Roy C. Hartenstein,* SUNY College of Environmental Sciences & Forestry, Department of Zoology, Syracuse, NY 13210; $150,739 for 12 months beginning June 1, 1978.

Soil invertebrates (specifically earthworms), in conjunction with soil microorganisms (fungi, bacteria, protozoa), help in producing humus and thus improve the physical properties and structure of soil in which they are active. A better understanding of these natural processes and how they are affected by municipal wastewater treatment plant sludges is necessary to establish application rates for sludge that are in accord with the absorptive capacity of the soil ecosystem. A better understanding of these natural processes may lead to better utilization of soil invertebrates for sludge stabilization and thus result in more efficient land management of sludges.

Prior research by Dr. Hartenstein has established that anaerobic digestion, a process used commonly in treatment of community wastewater treatment plant sludges, has a toxic effect on earthworms, whereas aerobically digested sludge does not. Research has shown that passage through earthworms greatly accelerates the rate of subsequent stabilization of sludges. While *Salmonellae* were shown to be drastically reduced in numbers by passage through earthworms, there was no similar effect upon the eggs of parasitic worms. No accumulation of heavy metals was observed in earthworms fed on sludges containing typical amounts of copper, cadmium, nickel, lead and zinc.

These findings led to the proposal of an intensive study of the possibility of utilizing earthworms to accelerate stabilization of sludges. In this project the toxicity effects that have been linked to the digestion process are being studied to determine the potentially limiting effect they present to the use of agricultural land for management of sludge. The nutritional requirements and metabolism of earthworm species are being studied as they may be affected by temperature, moisture and oxidation-reduction potential. The quality of earthworm castings is being determined by measurement of their dehydration properties. The response of earthworms to sludge as a soil conditioner is being determined by studies of their gain in weight, time required to achieve sexual maturity, fecundity, viability of offspring, and longevity. The efficiency of transforming sludges into castings is being determined by gravimetric measurements of the conversion-rate and apparent assimilation of organic matter in relationship to the biomass of the earthworms.

Results of this study may be applied either to development of intensive conversion systems or cultivation of earthworms or to a better management of land used for intensive management of sludges by direct injection and stabilization in place.

Application of Sequencing Batch Reactors for Treatment of Municipal and Industrial Wastewater; *Robert L. Irvine,* University of Notre Dame, Department of Civil Engineering, Notre Dame, IN 46556; $8,396 for 12 months beginning August 25, 1978.

Public Law 92-500 requires that the discharge of pollutants into the Nation's waters be eliminated by 1985. "Fill and Draw" wastewater treatment concepts promise high standards of performance at lower cost

and greater reliability than continuous-flow systems. Reintroduction of the fill and draw mode of operation is seen as a major step toward meeting the intent of P.L. 92-500 by improving the performance and reliability of wastewater treatment plant operations.

This research will investigate the potential use of sequencing batch (fill and draw) reactors in biological wastewater treatment processes to avoid or eliminate the unreliability and inconsistency that is characteristic of continuous-flow concepts subject to normal variations in wastewater quality. Expected benefits include equalization of strength, quiescent sedimentation, modular construction and ability to retain total control over final discharge until the quality of effluent has been determined. Laboratory-scale studies using synthetic wastes and combining equalization, organic carbon removal, and quiescent sedimentation in the same fill and draw system are being utilized to verify design procedures which will be tested at the University of Notre Dame pilot plant. Cost comparisons with continuous-flow concepts will be made.

Wetland Utilization for Management of Community Wastewater; *Robert H. Kadlec,* University of Michigan, Department of Chemical Engineering, Ann Arbor, MI 48109; $141,744 for 12 months beginning February 15, 1978.

Nutrients remaining in the effluent of municipal wastewater after secondary treatment can stimulate the growth of algae and other aquatic vegetation, which upon death and decay exert a demand for oxygen. Nutrient removal becomes, therefore, an objective of tertiary wastewater treatment. One alternative to chemical precipitation or complex engineered biological processes is the use of natural 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 ecosystem.

Prior NSF-supported research provided the basic ecosystem models that were utilized to guide small-scale pilot studies. The success of these pilot studies led to a decision by the Houghton Lake Sewer Authority to ask the State of Michigan for approval for a full-scale, proof-of-concept implementation. Based on this research background, the State approved. Construction was completed during the spring of 1978.

This project has been a joint effort of the University of Michigan, the State of Michigan, the Houghton Lake Sewer Authority, Williams and Works, Inc., and the U.S. Environmental Protection Agency, which recently reaffirmed its interest in having communities examine "land-based" alternatives for management of their wastewaters.

This project will assess at full scale the feasibility of using a wetland for meeting the objectives of advanced treatment for domestic wastewater. Evaluation of performance will be directed toward the effects of this method for managing effluents on the hydrology of wetlands, their soils, and the quality of emerging water. Observations will include effects of this practice on wetland vegetation, land and aquatic animals, insects, algae, bacteria and viruses.

The research plan consists of

- detailed analysis of phosphorus and nitrogen uptake;
- determination of the effects of wastewater effluent application on virus, bacteria, algae, vegetation, and soils;
- determination of the effects on selected parameters of water quality;
- determination of the effects of this use of a wetland on public useage which is primarily limited to hunting and trapping of muskrat, deer and beaver;
- analysis of acquired data establish the reliability of predictive models and their extrapolation limits; and
- reduction of all experiences into scientific and technical reports and papers including an operations manual for guidance of designers, operators and planning agencies.

Evaluation of Coliform Bacteria and Bacteriophage Relationships in Assessment of Water Quality; *Judith F. Kitchens,* Atlantic Research Corp., 5390 Cherokee Avenue, Alexandria, VA 22301; $69,616 for 12 months beginning October 1, 1978.

Due to the difficulty and cost of analysis for pathogenic bacteria in water, procedures that provide an index to the presence of pathogens are substituted. Standard procedures for determination of coliform organisms in water require a minimum of one day for presumptive evidence, and several more days for confirmation of results. While useful for routine quality-control and for the conduct of sanitary surveys, the standard procedures do not provide as rapid a readout of results as would be needed to permit water to be tested and corrective measures taken while the water which is being tested is under control of a treatment plant.

The goal of this research is to produce a test procedure that provides an accurate and reliable index of bacterial pollution of water more rapidly and inexpensively than methods currently is use. The objective of this research is to adapt a procedure known as the "reverse Phage Titer (Reaction Text)" (RPTRR) to the low levels of bacterial pollution normally associated with community water supplies. Specific objectives include

- investigation of the potential use of multiple host bacteria for bacteriophage to improve their correlation with coliforms;
- improvement in methodology used for counting bacteriophage plaques; and
- determination of the effects that disinfection of waters being evaluated has on the reliability of the test procedure.

Although the numbers of bacteriophages present were shown by RPTRR to be quantitatively related to the numbers of total and fecal coliform organisms present in water, the degree of correlation was influenced by chlorination. An improvement in the sensitivity of this procedure is considered necessary for its adoption as a routine, standard method.

Enhancement of sensitivity of the RPTRR is being studied by increasing the sample size, use of bacteriophage concentration techniques such as filter absorption and selective membranes, by adsorption/infection of bacteriophage on host cells, and by use of multiple bacterial hosts. Factors influencing bacteriophage replication and formation of plaques are being studied to provide a basis for improvements in counting procedures, and the effects of stress caused by chlorination of water are being evaluated as they may affect the accuracy and reliability of the RPTRR Test procedure.

An Investigation into the Chemistry of the UV—Ozone Water Purification Process; *Eriks Leitis,* Westgate Research Corp., 1931 Pontius Avenue, Los Angeles, CA 90025; $107,099 for 12 months beginning August 14, 1978.

This is a continuation of NSF research on the combined mechanisms of action of ozone and ultraviolet (UV) light to decompose organic materials in water. The UV-ozone process has proved to be effective in decontaminating certain classes of organic wastes, but the empirical approach by which the process has been developed has not led to an understanding of the chemical and photo-chemical mechanisms involved. The objective of this work is to continue to determine what these mechanisms are for representative organic molecules and what factors control their action. The ultimate purpose of this research is to gain an understanding of the mechanistic details sufficient to enable the rational design of applications of the process to a variety of chemicals in waste streams and in drinking water.

Hypotheses formulated from experiments on model organic chemicals in water solution involving ozonation with and without UV light and treatment with reagents that generate hydroxyl radicals will be tested by application to related and more complex compounds. Readjustment of the prediction of reaction mechanisms will then be made and tested with specific pollutants. Various process parameters will be varied, e.g., UV and ozone dosage and acidity/alkalinity (pH). Reaction product analysis will be made by resin preconcentration or solvent extraction followed by gas- or liquid-chromatography and mass spectroscopy.

The groups most directly interested in the outcome of the proposed research will be those concerned with waste management activites of the chemical process industry, the manufacturers of commercial chemicals, the governmental regulatory bodies having specific

oversight on the release of chemical wastes during manufacture, and special interest groups in the Departments of Defense and Interior.

Public Health and Nuisance Aspects of Community Wastewater Sludge Management; *Steven J. Marcus,* Energy Resources Co., Inc.; Residuals Management, 185 Alewife Brook Parkway, Cambridge, MA 02138; $126,407 for 8 months beginning August 1, 1978.

The utilization of soil for management of sludges has been limited by lack of suitable technological means for their application to land without unfavorable local environmental impact. Longer-range, potentially-limiting factors include the possibility of contamination of the land with pathogenic organisms that are contained within the sludges and which remain viable over extended periods of time. Methods for managing sludges to minimize risk and reduce nuisance include composting, various types of heat treatment, and disinfection by use of radiation. NSF-supported research is directed toward integrating disinfection, transport, and soil-injection into a system for management of community sludges with minimal environmental risk while simultaneously capturing the value of nutrients they contain.

All land-application alternatives share the common attribute of uncertainty relative to the degree to which disinfection will be necessary to meet acceptable levels of risk. Regulations designed to protect public health and minimize nuisance are likely to be more conservative and costly than necessary. This project will investigate the potential public health problems associated with the production, distribution, and use of composted community wastewater sludges, and will assess the legal, institutional, and technical means that exist to meet acceptable standards of risk. This research is expected to result in the identification of areas where available information is insufficient for resolution of major questions, and in specification of additional research necessary to generate the required information.

The general objective of this research is to assess the existing scientific and technical bases for management of community wastewater treatment plant sludges to meet acceptable standards relating to protection of public health and avoidance of nusiance. Specific objectives are to assess the potential public health problems associated with the production and use of compost derived from community wastewater sludges; to develop recommendations for legal, institutional, public health and engineering measures necessary in processing, distribution and use of sludges to reduce risk to public health to an acceptable level; to identify areas where available information is insufficient and to specify additional research required to generate the necessary information for acceptable management of community wastewater sludges; and to prepare a source document addressing the legal and public health aspects of composting for use by administrators and planners engaged in making sludge management decisions.

This study is specifically directed toward the composting of sludges because this process is one which may expose individuals engaged in the production, distribution and use of processed sludges to risks from pathogenic bacteria, viruses, molds, protozoa and parasitic worms. Draft reports will be prepared on the following topics and will be critically reviewed in a project workshop: survival characteristics of pathogenic organisms subjected to composting procedures, health risks posed by application of viable sludge pathogens to land, and the legal and institutional constraints that arise from and are associated with the production, distribution and use of composted sludges.

Disinfection of Enteric Viruses in Sludge by Use of Energized Electrons; *Theodore G. Metcalf,* University of New Hampshire, Durham, Department of Microbiology, Durham, NH 03824; $16,948 for 6 months beginning June 1, 1978.

This study has investigated the feasibility of the use of high energy electrons for control of human enteric viruses contained in community wastewater treatment plant sludges. Specific objectives include characterization of the relationship between electron doses delivered and rates of inactivation of enteric viruses in sludges and the factors influencing virus inactivation; application of virus inactivation parameters established from bench-scale experiments under static conditions to an evaluation of factors en-

countered in a continuous-flow radiation system and the conditions necessary for achieving optimal virus inactivation effectiveness in that system; and, determining whether the virus inactivating effectiveness of energized electron treatment of waste treatment residuals can be increased through the addition of ferric iron and aluminum ions to the residuals prior to treatment.

Studies to date provided basic bench-scale data on the radiation doses needed for inactivation of enteric viruses and factors influencing inactivation. Background data compiled included seasonal variations in the types and numbers of enteric viruses found in raw sewage, sludge and effluents. The distribution of virus between sludge and effluent was plotted and virus recovery methods were developed. A direct proportionality between sludge layer thickness and radiation doses required for inactivation of virus has been shown. No significant differences in virus disinfection effectiveness could be shown between purified, monodisperse virus suspensions, and suspensions in which the degree of virus aggregation varied from slight to marked. The best recoveries of virus from raw sludge were made by direct elution. Recovery of virus from formed precipitates was poor and was discarded. The ability of sonication to improve recovery efficiency is currently under study.

This award will provide technical support and virus study expertise for the balance of the MIT co-project (see John Trump) support period. Assessment of the virus disinfection effectiveness of the on-line radiation unit installed at Deer Island will be the single, most important research objective. Studies carried out will be in support of Deer Island activities and most likely would involve problems related to equipment design and/or operational procedures. Such studies will make use of bench-scale experiments to resolve questions or problems.

Utilization of Cypress Wetlands for Management of Municipal Wastewater Treatment Plant Effluents; *Howard T. Odum,* University of Florida, Department of Environmental Engineering Science, Gainesville, FL 32611; $20,800 for 24 months beginning August 30, 1978.

It may be feasible to use the many cypress wetlands in the Southeast U.S. to manage a region's water resources, recycling and conserving nutrients and water from regional wastewaters, stimulating plant growth to provide regional greenbelts for esthetic enhancement and protecting wildlife. Such use of wetlands may result in large savings in costs for providing advanced treatment for municipal wastewaters.

In cooperation with the Rockefeller Foundation, this project continued studies of the response of cypress wetlands to their use for conservation of the nutrient and water content of effluents from municipal wastewater treatment plants. Results over a period of three years indicate that cypress dome-wetlands conserve water by returning treated wastewater to subsurface formations after removing its content of nutrients, heavy metals and bacteria and viruses. Final observations will determine the growth response of trees and understory vegetation to the application of wastewater.

Workshop on Water Quality and Health Significance of Bacterial Indicators of Pollution; *Wesley O. Pipes,* Drexel University, Department of Biological Sciences, Philadelphia, PA 19104; $9,800 for 6 months beginning February 7, 1978.

Because of the relative difficulty and cost of making determinations of the presence and number of pathogenic organisms in water, analysis for indicator organisms is substituted in routine assessment of water quality. The objective of this project is to conduct a workshop that will critically review the current state of knowledge regarding the significance of bacterial indicators of pollution and contamination used in the assessment of water quality.

The workshop will include preparation of draft reports on recovery and identification of indicator organisms, statistical analysis and interpretation of numerical data, water quality significance of indicator organisms, and public health significance of their presence and count. Attendees will represent local, regional, state and Federal agencies with responsibilities for establishing criteria for wastewater treatment plant effluents, siting of treatment facilities, recreational and other contact uses for receiving waters, and management of wastewater treatment

plant sludges. The final report will be directed toward the identification of research needs and their prioritization to improve assessment of risk to public health that is associated with the presence of indicator organisms in water.

Target users for results are the regulatory agencies which have responsibility for decisions about effluent criteria, criteria for recreational use of receiving waters, disposal of wastewater treatment facilities and applied research on water quality and health effects.

Potential Health Risks Associated with Injection of Residual Domestic Wastewater Sludges into Soils; *Bernard P. Sagik,* University of Texas at San Antonio, Department of Sciences/Mathematics, San Antonio, TX 78285; $87,477 for 12 months beginning June 12, 1978.

The intensive application of municipal wastewater treatment plant sludges to soil is considered to be an attractive alternative despite questions of long-term adverse effects. While providing the advantages of economy, technical superiority, and more acceptable esthetic and environmental impact, sludges concentrate viruses removed from wastewater. This is of significance to the ultimate acceptability of soil-application. Acceptability will be influenced by an assessment of the risk to health associated with this management practice in comparison with alternatives.

This research will assess the potential risks to human health that are associated with the practice of applying sludges from municipal wastewater treatment plants to soil. Specific objectives include the development of criteria for selection of appropriate application sites and recommendations for monitoring of the sites. This will require the evaluation of soil properties with respect to virus survival and movement as influenced by total precipitation and its intensity, frequency and duration.

Virological criteria for the selection of appropriate land application sites to minimize risk are being developed, as are recommended procedures for monitoring of the sludge management sites. Soil properties that are being studied include pH, cation exchange capacity, types of cations present, soil texture, and soil structure. The release characteristics of viruses from soils to which sludges have been applied are being studied as they may be affected by total precipitation. A conference on assessment of potential risks relating to the use of land for management of municipal wastewater treatment plant sludges was conducted in December, 1977. A workshop was planned for the second year of this research to review a draft of recommended criteria for selection and monitoring of sludge injection sites.

Utilization of Wetlands for Management of Pond Stabilized Domestic Wastewater; *Jeffrey C. Sutherland,* Williams and Works, Inc., 611 Cascade West Parkway, S.E., Grand Rapids, MI 49506; $85,103 for 19 months beginning May 1, 1978.

Since 1969, Vermontville, Michigan, a community of 900 people, has been served by a wastewater treatment system consisting of two 4-acre stabilization ponds discharging into four seepage fields. Two or more of the fields are in use at any given time. The ponds store effluent from September to June and discharge to the seepage fields from June to September.

The flooded condition and nutrients in the wastewater have encouraged luxuriant wetland vegetation, especially cattails and duckweed, to become established. Such plants are a nuisance, since they can obstruct the flow of water, and also upon decay exert a demand upon available oxygen. The profuse growth of such plants indicates that nutrients, phosphorus and nitrogen in particular, are not being adequately recovered. This project will carefully assess the wetlands' performance characteristics and potential in meeting needs for cost-effective methods to remove plant nutrients from wastewater.

Field-investigation of this system will be conducted over a period of 12 months. The study will include documenting flow and water quality, and identifying and quantifying plant species growing in the ponds and fields. Research will concentrate on surface and groundwater quality, water budget, vegetation of the seepage fields, treatment costs and an energy analysis of the system.

Present costs of operating the pond-surface irrigation-wetlands treatment system include keeping the area neat (mowing around the ponds), recording

flows, sampling and analyzing the final influent, electrical costs of pumping, equipment repair and administrative time and travel. The cost of continuing the program with and without plant harvesting will be calculated for communities in the size range of Vermontville.

On-Shore Impacts of Off-Shore Oil and Gas: Methodology, Development and Tests; *Ben Tencer,* Roy F. Weston, Inc., Weston Way, West Chester, PA 19380; $21,914 for 3 months beginning April 17, 1978.

Impending oil and gas developments on the U.S. Outer Continental Shelf (OCS) raise prospects that vital energy supplies will be expanded. Such activities are likely to produce a variety of benefits and costs to the U.S. Affected onshore communities and regions are already evidencing certain needs. In order to enhance benefits and limit social, environmental, and monetary costs, cognizant federal and state agencies must be able to accurately anticipate direct and indirect effects of OCS development.

This is a supplemental award to further research the impacts of offshore oil and gas exploration. This research will assemble, assess, and link appropriate economic and environmental assessment methodologies; test this methodological package on the Baltimore Canyon Region; and prepare documentation on impact methodologies for use by Federal and state planning officials.

High Energy Electron Irradiation of Municipal Wastewater Liquid Residuals; *John G. Trump,* Massachusetts Institute of Technology, Department of Electrical Engineering and Computer Science, Cambridge, MA 02139; $27,159 for 12 months beginning July 11, 1978.

Management of residual sludges from wastewater treatment processes accounts for approximately one-half of the capital and operating costs of wastewater treatment systems. Residual sludges contain suspended organic and inorganic solids including pathogenic bacteria, viruses and higher life forms of significant potential pathogenicity. Disinfection and possibly sterilization of the liquid residuals is technically possible by incineration or chlorination. Incineration tends to transfer pollutants to air, is expensive, and is nonconservative for beneficial recycle of organic matter and nutrients to soil. Chlorination of wastewater effluents has recently been identified as a possible practice that leads to formation of chlorinated hydrocarbons of potential carcinogenic significance.

Ionizing energy has the potential for providing a technically feasible approach to disinfection with reduced energy requirements and at lower cost than alternatives. The process utilizes electrons accelerated in a vacuum to high energy by a high voltage. They emerge as a focussed beam which is repeatedly swept across a thin wide band of moving sludge of rapidly flowing wastewater. The principal disadvantage of electrons is their limited penetration capability, which necessitates presentation of the sludge to the electron beam in a relatively thin layer.

This phase of this ongoing project will determine the technical and economic feasibility of in-line (continuous) high energy electron irradiation of municipal wastewater treatment plant influent, effluent and residual sludges. Emphasis during the proposed continuation will be directed toward undigested sludges. Experimental effort will be directed toward engineering feasibility including comparative costs, energy requirements and environmental effects. Specific objectives include determining the operational characteristics of Boston's Deer Island facility in sufficient detail as to specify and evaluate its technical performance and costs of operation and maintenance; evaluating the Deer Island facility's effectiveness with regard to bacteria inactivation, parasite inactivation, and virus inactivation, and for presenting sludges to the beam in requisite "thin" layers.

The project will also investigate the destruction of toxic compounds such as polychlorinated biphenyls, nitrosamines, pesticides, and herbicides in water and sludges by electron dosages in the pathogen-disinfecting range; improvements in the dewatering characteristics of electron-irradiated sludge; mutagenic activity, and modifications to increase the flexibility, cost and energy economy and reliability of the electron sludge treatment process.

Research on Controlled Soil Microbial Detoxification of Herbicide Residues; *George D. Ward,* George D. Ward & Associates, 821 N.W. Flanders, Portland, OR 97209; $208,445 for 24 months beginning October 1, 1977.

Sludges vary in their content of toxic substances depending on their source. The relative relationship of toxic and hazardous substances to inert content reaches a peak when sludges are those resulting from the manufacture of herbicides and pesticides. The management of sludges by their application to land is based upon the assumption that soil ecosystems have the capability of detoxification of the sludge components exhibiting this property, or alternatively, that land used for that purpose will function as a "permanent" site or "burial ground" for the applied substances. The investigators observed bacteriological degredation of phenoxy herbicide residues and concluded that it might be possible to construct fully contained, optimum condition soil treatment cells directly at the source of the individual waste materials with release only upon confirmation of degradation and determination that release can be accomplished safely.

Preliminary research was conducted on the feasibility of achieving bacteriological detoxification of herbicide and pesticide manufacturing residues through the action of naturally occurring soil microorganisms under controlled soil conditions. Sludges from community wastewater treatment plants were used as a nutrient source and stimulant for growth and basic support of the soil microorganisms capable of using herbicide and pesticide residues as a food source for carbon. For the conditions examined, it was found that naturally occurring soil microorganisms do have the capability of bacteriological degradation of in a microbial process that appears to be potentially continuous as well as safe.

This award will support continued research to determine the feasibility of detoxification of phenoxy herbicide manufacturing residues by action of soil microorganisms under fully contained, as well as mechanically controlled, optimum soil conditions. The research is expected to lead to design details suitable for the construction of full scale, contained-soil treatment cells suitable for use by the agricultural chemical industry as a practical means for managing large quantities of hazardous chemical manufacturing byproducts. Similar contained-soil treatment cells may be utilized by pesticide and herbicide users and commercial applicators for the safe field disposal of unwanted, dilute pesticide and herbicide solutions resulting from washing of equipment, excess mixtures or outdated formulations.

Prediction and Control of Heavy Metals and Toxic Organic Materials in Sludges; *Leon W. Weinberger,* Environmental Quality Systems, 1160 Rockville Pike, Rockville, MD 20852; $199,364 for 12 months beginning September 1, 1978.

Wastewater sludges contain suspended soilds and dissolved substances that are precipitated and/or adsorbed to settleable solids during treatment. Sludges may be incinerated, buried and/or placed in water or on agricultural land, but no matter what the subsequent management practice the content of potentially toxic inorganic and organic substances continues to present a potential environmental threat. For example, spreading sludge on agricultural lands fertilizes the soil; however, the heavy metals that may be present in the sludge can adversely affect crops grown on the land. Control strategies are likely to include some mix of source-management and processing to achieve the removal and dispersal (dillution) of toxic substances to acceptable levels of concentration.

In this project, it is assumed that the composition of sludges with regard to their heavy metal and toxic organic content can be predicted from knowledge of existing laws and regulations, those likely to be implemented, knowledge of present treatment technology, and likely developments in the future.

The results of these projections will provide the basis for the formulation, development and evaluation of strategies for the control of potentially toxic and hazardous substances in sludges. Existing data are being collected and reviewed to provide a baseline of present composition of sludges from communities differing in size and mix of domestic, commercial and industrial components. Current and anticipated future regulations are being analyzed to predict their impact on sludge composition. The effects of alternative treatment and control strategies are being assessed for their potential role in changing the amounts of inorganic compounds of heavy metals and organic

substances of similar significance which become fixed and concentrated in wastewater treatment plant sludges. A capability to predict the compositions of sludges is a necessary step toward development of control, processing and management strategies to meet acceptable levels of these pollutants and contaminants in the receiving media.

Mobility and Survival Characteristics of Viruses in Cypress Dome Wetlands; *Flora M. Wellings,* Florida Department of Health and Rehabilitation, Health/Rehab Services, Epidemiology Research Center, 4000 W. Buffalo Avenue, Tampa, Florida 33614; $48,072 for 12 months beginning April 15, 1978.

This research will evaluate the virological safety of cypress dome wetlands used in providing advanced treatment to municipal wastewater. Dr. Wellings has been conducting virological research with the support of the Rockefeller Foundation for the past three years in cooperation with the University of Florida. The Rockefeller project was concluded in the fall of 1977 after phasing the study down to a minimal base level. The continuation of the UF project through November of 1979 provides an opportunity for the intensive study of the mobility and fate of viruses.

The study area includes approximately 320 acres of planted pines and cypress swamps located in Alachua County, Florida. Wastewater is discharged into a holding pond and from there into the experimental cypress dome. The purpose of passage through the pond is to permit solids to settle out to avoid clogging of the dome with sludge.

The quantity of virus present in the wastewater has been shown to vary considerably throughout the year, which is true in all treatment plants. The situation has been more acute at this study site because of the limited number of people contributing to the biological waste pool. Background data indicate that more extensive monitoring must be carried out during the "enterovirus season", i.e., May through October, as early studies have suggested, that heavy rainfall may result in desorbing of adsorbed virus, thus permitting virus movement into deeper strata.

Daily samples will be obtained from the plant, lagoon, dome pond and three monitoring wells. Viruses will be extracted from large volume samples and incubated, and the viruses identified. The virological safety of cypress dome wetlands can thus be assessed.

A joint workshop for this and related wetlands projects was conducted in the fall of 1978.

EARTHQUAKE HAZARDS MITIGATION

At least 70 million Americans in 39 states reside in areas described by seismologists as regions of major or moderate seismic risk. Communities which experience earthquakes are affected not only through direct property damage, loss of life and personal injury, but also through the losses incurred in the operation of disaster relief and rehabilitation programs, loss of income due to business disruption, reduced property values, and disaster-caused psychological problems.

At the request of the President, a report entitled *Earthquake Prediction and Hazard Mitigation Options for United States Geological Survey (USGS) and National Science Foundation (NSF) Programs* was prepared in 1976. A coordinated NSF/USGS earthquake research program was developed based on Option B of this report. The social, economic, and political actions required to attain the earthquake prediction and hazards mitigation goals of the joint program are based on technological capabilities that require development through research.

The objectives of PFRA's Fiscal Year 1978 Earthquake Hazards Mitigation program were to develop methods and techniques that can provide effective protection for man, his works and institutions from life loss, personal injury, property damage, social dislocation, and economic and ecological disruption associated with potential or realized earthquake hazards. PFRA's Earthquake Hazards Mitigation program for Fiscal Year 1978 was composed of three subelements: *Siting, Design* and *Policy.*

SITING

Earthquake damage can be caused by fault slip, by heavy ground shaking transmitted to a structure by its surrounding soil and rock media, or by the failure of the rocks or soil underlying a building or structure. When soils are strongly shaken, they can amplify the bedrock motion and modify the characteristics of motion imparted to supported structures. Soils can fail through a variety of mechanisms such as settlement, loss of bearing capacity, embankment or slope instability, and soil liquifaction. In addition, an earthquake may trigger hazardous secondary geophysical events such as tsunamis (tidal waves), rock and land slides, or flash flooding due to ruptured dams.

The *Siting* program of Earthquake Hazards Mitigation provided support in Fiscal Year 1978 for research on earthquake energy generation, the transmission and propagation of shock waves through various geologic and soil conditions and the impact of earthquake ground motion on structures. Siting also stressed the development of criteria and guidelines for qualitatively and quantitatively estimating local and regional seismic risk, the development of a comprehensive program to improve geotechnical engineering practices, and efforts to ensure that information on seismic and other natural hazards was integrated into land-use, urban and coastal zone planning procedures.

Prediction of Conditional Expected Tsunami Inundation on Hawaiian Shorelines; *William M. Adams,* University of Hawaii, Manoa, Department of Geology and Geophysics, Honolulu, HI 96822; $30,943 for 12 months beginning August 1, 1978.

The objective of this research is to reduce the variance of predictions of tsunami innundation of coastal areas by developing a physical model which allows for inclusion of local effects. Hawaii will be used as a test case for the development of the model. Computations based on the developed model will be compared with historical data to determine the validity of the new approach.

This research will apply a hybrid finite-element numerical model for harbor oscillation and wave scattering to the prediction of tsunami innundation on Hawaiian Shorelines. This method has previously been applied to the problem of establishing tsunami wave elevation near the shoreline versus frequency-of-occurrence curves for the Hawaiian Islands. The work essentially requires running an existing FORTRAN program on the IBM 370 of the University of Hawaii; making the application of the finite-element model to a few idealistic situations having analytical answers; and finally, actual application to the practical situation in Hawaii. Because of the slow speed of the 370 compared to the CDC 7600, the work will be initially directed to a sparse net; later, after the program is satisfactorily running, "production" runs will be made. The methodology developed will be applicable to areas such as Alaska, Oregon, or California.

A New Approach to the Prediction of Earthquake Strong Motion; *Keiiti Aki,* Massachusetts Institute of Technology, Department of Earth & Planetary Science, Cambridge, MA 02139; $47,610 for 8 months beginning May 15, 1978.

The fundamental requirement for reliable earthquake-resistant structural design is the establishment of a reliable site ground motions. In a previous NSF-sponsored research project, Dr. Aki achieved a breakthrough in the development of a "Barrier Model" for earthquake strong motion prediction. Further testing of the Barrier Model must be made using all available data.

The Barrier Model is characterized by five source parameters: fault length, width, maximum slip, rupture velocity, and barrier interval. The first three parameters may be constrained from plate tectonics, and the fourth parameter is roughly constant. The most important parameter controlling the earthquake strong motion is the last parameter, "barrier interval." Once the five parameters are known, strong motion can be calculated completely.

Preliminary results suggest that the barrier interval may be accurately determined if the maximum slip is given. This means it may be possible to predict strong motion accurately by knowing only size of the fault plane and the maximum slip. The prediction of strong motion would increase immensely the safety confidence of structural design practices in both high risk and low risk seismic regions. Another consequence of the Barrier Model is the possibility of predicting the occurrence of aftershocks by studying the spectrum of the main-shock. This possibility is of great importance for the mitigation of earthquake hazard.

This project will further test the Barrier Model by employing three different data sets: surface measurements of slip across fault breaks along the total fault length; scaling laws of seismic spectrum for small earthquakes; and near- and far-field seismograms from a large earthquake.

An Experimental Investigation of the Earthquake Response of Sediment-Filled Valleys in Garm, USSR; *Keiiti Aki,* Massachusetts Institute of Technology, Department of Earth & Planetary Science, Cambridge, MA 02139; $196,018 for 24 months beginning February 16, 1978.

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 of the USSR. This grant provided research support including six-months of data analysis and field work in Russia in order to complete the cooperative program. The purpose of this project was to apply the tech-

niques and experience developed by U.S. seismologists for studying propagation phenomena, seismic source mechanisms and observations of earthquakes of a tectonic region in Garm, and to learn the related techniques and experience of Russian seismologists. The project included theoretical and experimental work on estimating strong ground motion on the basis of seismograms of small events.

Better measurement of the spectrum of radiation from earthquakes will allow better estimates of the effectiveness of fault propagation in focusing high-frequency energy in certain azimuths. This study will improve the understanding of the variation of energy in the frequency band of interest in earthquake engineering with distance and azimuths, and the determination of the relationship between effective accelerating stress that controls strong motion and stress drop. Such findings will allow better estimation of the probability of very high accelerations and velocities, and will yield valuable data concerning attentuation, site amplification, and wave coherence.

Earthquake Response and Aseismic Design of Underground Piping Systems; *Teoman Ariman,* University of Notre Dame, Department of Aerospace & Mechanical Engineering, Notre Dame, IN 46556; $135,213 for 24 months beginning February 15, 1978.

Lifelines represent about one-half of the total value of structures which are vulnerable to earthquakes. Underground lifelines fulfill a vital role in conducting and distributing energy, communications, transportation, and water. The disruption of the services by these facilities due to an earthquake could cause catastrophic problems. The damaging effect of earthquakes to lifeline systems could be greatly amplified by impeding firefighting, preventing essential communications, transportations, etc. In spite of the potential vulnerability of these essential services, until very recently no building code provisions existed to regulate the design and construction of these structures. Even today, there are only minimal provisions in major national codes. The lack of these regulations is entirely due to an absence of scientific and engineering directed specifically to these topics.

The objective of the proposed research is to investigate the earthquake response and earthquake-resistant design of underground piping systems utilized in energy transport; specifically, buried natural gas pipelines. An analytical study program will be conducted to analyze the seismic behavior and failure mechanisms of such systems and to develop improved design methods and guidelines for seismic conditions.

Case studies will be made to survey the various causes of service interruption and consequences in connection with earthquakes. Analyses will consider the type, size and location of pipes and pipe breaks, mechanics and patterns of deformation and damage, frequency and distribution of damages, and so forth. An extensive literature survey, both domestic and foreign, will be made to study the seismic damage due to traveling seismic waves, relative ground movements, and their relation with the properties of soil media.

Reliability Analysis of Slopes During Earthquakes; *Dimitrios Athanasiou-Grivas,* Rensselaer Polytechnic Institute, Department of Civil Engineering, Troy, NY 12181; $125,400 for 24 months beginning January 15, 1978.

Slopes, whether naturally formed or man-built (in the form of earthdams, cuts, embankments, etc.) are among the most frequently encountered geotechnical structures. Although much experience has been already accumulated about their design and performance, geotechnical engineers still face considerable uncertainties when they analyse a slope's stability. These uncertainties reflect the slope's loading conditions, the variability of the material parameters, the seasonal changes of the ground water table, the particular method used in the analysis, etc. The possibility of an earthquake further complicates the engineer's task.

Because of the possibility of excessive life and economic losses, soil slopes are among the most important engineered structures, especially in earthquake prone areas. This research will recognize some of the significant uncertainties and introduce probabilistic tools for their description. A main objective is to assess the reliability of soil slopes for various magnitudes and occurrence rates of earthquakes. The

measure to be used will be their probability of failure. The statistical distribution of the maximum acceleration caused by an earthquake will be described as a function of the mean earthquake occurrence rate, the focal distance between earthquake source and site of quake, and a number of empirical regional parameters. Probability density functions for certain geometric and strength parameters will be also introduced. The probability of failure will be assessed by means of the Monte Carlo simulation method.

Underground Lifelines in a Seismic Environment, Phase II; *Melvin L. Baron,* Weidlinger Associates, Department of Civil Engineering, 110 E. 59th Street, New York, NY 10022; $361,139 for 12 months beginning May 1, 1978.

Lifelines supply and distribute essential services and functions to communities (energy, communications, transportation, water). The continued maintenance of these systems in seismic areas is vital to the health and safety of the communities they serve; they also represent nearly one-half of the total investment in structures.

At the present time, there are no more than rudimentary provisions in a few building codes regulating the planning, design and construction of underground lifelines. The major reason for this is the almost complete absence of scientific and technical knowledge regarding the detailed behavior of these structures in seismic environments. The purpose of this project is to improve such knowledge and to apply it through risk and optimalization studies to planning, design and construction of lifeline structures.

During the first phase of this grant, research included

- a survey of utilities concerning current practices related to earthquakes and the perception of risk;
- preparation of Damage Matrices in which ultimate loads on configurations of jointed pipe, both cast iron and concrete, are defined for both static and dynamic excitations;
- development of the "Interference Response Spectrum" concept and application of the interference spectrum to define the effect of the noncoherent portions of earthquake motions on pipeline response;
- development of risk analysis methodology for underground lifeline networks, and the applications of this methodology to the Tokyo metropolitan area water transmission system;
- studies on the physical interpretation of Japanese earthquake data, including statistical correlation between pipeline damage and earthquake-induced ground strain;
- investigation of free field strain estimation procedures which depend on subsurface geology and the extent of the lifeline;
- analytical and numberical studies of pipe-soil interaction, to develop model solutions from which simplified interaction models can be derived; and
- partial translation of a Japanese design guide for petroleum pipelines.

Based on the Phase I work, a set of research problems were chosen which will provide useful information for the establishment of design guidelines. The problem areas which will be conducted in Phase II are Incoherent Seismic Motions, Pipeline Damage and Failure, Pipe-Soil Interaction, Experimental Test Data, Risk Analysis and Cost-Benefit Studies, and Design guidelines.

Optimal Design of Earthquake Strong-Motion Networks; *Jack R. Benjamin,* Engineering Decision Analysis Co., Inc., 480 California Street, Suite 301, Palo Alto, CA 94306; $50,416 for 12 months beginning August 1, 1978.

The objective of this project is to develop a decision-making methodology for locating strong-motion instrumentation which considers the needs and capabilities of potential users. Users include the Seismic Engineering Branch (SEB) of the United States Geological Survey (USGS), universities, and other agencies who have instrumentation programs. The methodology will include consideration of network configuration, number and type of instruments, network pattern with respect to tectonic, geologic, seismologic, and structural engineering requirements as well as various cost factors and derived benefits. It will be largely based on statistical decision concepts and linear programming techniques. The methodology will be useful as a guide for National Science Foundation management in evaluating future proposals in instrument location.

The existing strong-motion systems will first be examined to reconstitute the decision process that resulted in these systems, and to evaluate their performance to date in terms of value received to the sponsoring group and by more general audiences.

The basic model will be evaluated and trial areas in the United States will be selected to test the utility of the methodology. Recommendations for the necessary coordination between USGS national network programs, state and local agencies, and university projects will be made.

Primary users of the results of this project will be the USGS, other Federal government agencies, the State of California, and university researchers.

Seismological Analysis of Strong Motion Records; *Bruce A. Bolt,* University of California—Berkeley, Seismographic Station, Department of Geology and Geophysics, Berkeley, CA 94720; $47,723 for 24 months beginning May 1, 1978.

Ground motion records are the essential data base necessary for the investigation of the characteristics and the associated physical process of earthquakes. Many basic seismological questions concerning the strong motion records currently available remain unanswered. These questions are critically related to design to mitigate damage and life loss due to earthquakes.

This project aims at increasing our understanding of strong motion records from the viewpoint of seismological wave theory, wave propagation, and source mechanics by studying wave analysis of recent strong motion records; common physical features in terms of source mechanisms; interpretation of strong motion wave patterns in time domain as a function of frequency; fault rupture modeling using finite-element programs; analysis of focusing and scattering of strong motions by crustal complexities using finite-element programs; field program of recording strong motions in central California; and interpretation of strong motion records in terms of general seismological theory. The overall objective of this project is the prediction of earthquake intensities given certain fundamental information on the nature of an earthquake's source and surface conditions.

A Strong Motion Seismograph Array in Northern Baja California; *James N. Brune,* University of California—San Diego, Department of Geophysics, La Jolla, CA 92093; $36,800 for 12 months beginning November 21, 1977.

During the first year of this project, ten conventional SMA-1 strong motion accelerographs were installed and seven instruments were scheduled to be installed to complete a proposed Baja-Sonora array. This award is to provide additional funds for eight digital accelerograph systems in lieu of the seven conventional analog systems originally proposed. The decision to go for digital systems is based on evidence that the digital system requires much less effort to obtain digital records and generally has higher resolution, fidelity and dynamic range as compared with the conventional systems. The future trend is such that conventional systems will gradually be phased out by digital systems, which will probably dominate strong-motion networks because of their outstanding features. In the long run the digital system has the benefits of cost-effectiveness and efficiency.

As part of a cooperative program with the National University of Mexico (UNAM), the installation and maintenance of timed strong motion array in Northwest Mexico near the Cerro Prieto, Imperial, Agua Blanca and San Miguel Faults is undertaken in this project. This area is one of very high seismicity and there is an excellent probability of recording a large earthquake on an array of strong motion instruments within few years. This will provide important information on earthquake source mechanisms, stresses, and maximum accelerations and velocities.

Numerical and Experimental Study of Earthquake Strong Motion; *James N. Brune,* University of California—San Diego, Department of Geophysics & Planetary Physics, La Jolla, CA 92093; $159,672 for 24 months beginning March 15, 1978.

This research is aimed at defining the basic character of earthquake ground motion within the zone where damage to civil structures is likely to occur. Physical and numerical modeling techniques will be used. The complex physical processes involved in earthquakes are dynamic and vary spatially in a manner that is not easily characterized. Engineers and seismologists have developed some understanding of individual processes that occur during an earthquake, but nobody has succeeded in combining the various processes to simulate earthquake ground motion in the computer. This is a difficult task. Preliminary results indicate that the problem appears solvable.

The major objective of this project is to carry out studies on the characterization of earthquake ground motion in terms of fault proximity, fault type, and intervening earth structure by numerical computations and laboratory experiments. The results from spontaneous shear ruptures in foam rubber have provided new information on rupture mechanics and the focusing of wave energy in the direction of rupture. The efficiency of a three-dimentional finite element method for modeling crack-induced waves has been demonstrated by accurately reproducing analytical results for a growing circular crack and by simulating surface motions in laboratory experiments. New results obtained using computer methods concerning surface contours of maximum particle velocity during an earthquake, response spectra as a function of distance and direction from a strike-slip earthquake, and seismic amplification curves for a three-dimensional sedimentary deposit will be used in this research. The project is intended to further calibrate the computer methods for modeling actual earthquakes, to simulate ground motion under a variety of conditions, and to produce rules for characterizing ground motion which are suited to the needs of design engineers.

Committee on Scholarly Communication with the People's Republic of China: Earthquake Hazards Mitigation; *Mary B. Bullock,* National Academy of Sciences, 2101 Constitution Avenue, N.W., Washington, DC 20418; $41,300 for 12 months beginning July 1, 1978.

The Committee on Scholarly Communication with the People's Republic of China is the American organization responsible for scientific and technological exchanges with the People's Republic of China. CSCPRC has been particularly active in promoting and conducting exchanges in the area of earthquake studies.

CSCPRC will send a delegation to China in August 1978 to visit technical institutes and organizations involved with earthquake hazards mitigation. The objectives of the delegation are to explore the work being done in the People's Republic of China in the field of earthquake engineering and hazards reduction; to investigate the records and research on the destructive Tangshan earthquake of 1976; and to renew and expand the contacts made between Chinese and American earthquake engineers and seismologists, and consequently the organizations which they represent, which were made during the visits of the American Seismological Delegation in 1976. The trip will last for three to four weeks depending on the assessment of the time needed by the delegation. The topics of concern to this delegation will include the design and installation of strong motion accelerographs; recordings and analysis of destructive ground shaking and building vibrations; research on the response of structures and soils to strong ground shaking; research on the design of structures to withstand strong earthquake motions; and how earthquake hazards are assessed and mitigated, including how the interaction between scientific and engineering capability is put into practice.

Earthquake Waves in Soil Deposits; *Ahmet S. Cakmak,* Princeton University, Department of Civil Engineering, Princeton, NJ 08540; $72,900 for 12 months beginning January 25, 1978.

Local soil conditions can significantly influence earthquake ground motions and therefore the intensity of the earthquakes. Traditionally the soil medium is treated as a one-dimensional shear beam or series of

discrete mass-spring-dashpot systems, or as a two-dimensional layered system. However, the geological configuration and the material properties of local soil deposits are very rarely determined with sufficient accuracy to justify a deterministic analysis.

This project is to conduct an analytical study on the investigation of seismic wave propagation in a random soil medium. The objective is to develop a stochastic representation and modeling of soil deposits taking into account the uncertainties of local geology and seismic ground motions. Progapation characteristics of waves and the effects of stratification will be studied aiming at the prediction of acceleration, velocity, displacement, and energy spectra of strong motion earthquakes. The results will be used to provide reliable and accurate assessments of the effects of soil-structure interaction.

Seismic Response of Three-Dimensional Dam-Reservoir Systems; *Allen T. Chwang,* California Institute of Technology, Department of Engineering Science, Pasadena, CA 91125; $110,774 for 18 months beginning March 15, 1978.

The potential failure of an arch dam or a gravity dam during a destructive earthquake could cause enormous property damage and loss of human lives to a densely populated community downstream. On the other hand, unnecessarily conservative over-design of dams may be very wasteful of national resources and taxpayers' dollars, especially when the inadequate design is due to a lack of sound knowledge and ability to determine the dynamical properties of the dam-reservoir system. Dams in regions of active seismicity should therefore be optimally designed to resist earthquakes.

Studies in the past were generally limited to simple dam-reservoir systems and treated the water-dam interaction and other important interaction effects in a rather crude manner. Knowledge to date is not yet sufficient to provide a sound basis for the safety design of dams. The objective of this proposal is to determine by analytical and numerical methods the earthquake behavior of a realistic, dynamically coupled dam-reservoir system. Three-dimensional arch and/or gravity dam models with arbitrary reservoir geometry will be considered. The effect of hydrodynamic interaction, the flexibility effect, the effect of phase variation and spatial attenuation of seismic waves, and the effect of the side confinement of the dam will be thoroughly investigated.

A complete mathematical formulation for the transient response of a three-dimensional dam-reservoir system during earthquakes will be established based on the following considerations:

- the irrotational motions of compressible water in a reservoir;
- the effects of surface water waves;
- the flexibility of the dam structure;
- the geometry of the dam;
- the phase variation and attenuation of seismic waves; and
- the geometric shapes of the reservoir.

Modeling of Foundations for Embedded Structures; *Gautama Dasgupta,* Columbia University, Department of Civil Engineering and Engineering Mechanics, New York, NY 10027; $59,563 for 24 months beginning February 1, 1978.

This research is designed to fulfill the need of providing the foundation engineering community with rational, economical, and accurate techniques of soil-structure interaction analysis. An exact representation of a foundation which takes into consideration all constitutive and kinematic nonlinearities poses a complicated problem in the field of computational mechanics. A simplified system which idealizes the soil region to be a linear viscoelastic medium has been concluded from experimental evidences to be a satisfactory approximation. For a linear soil-structure system the frequency domain solution has gained popularity due to the availability of efficient Fourier transformation algorithms and computer programs. The substructure method, which allows one to concentrate the numerical effort on a particular component of a composite assembly, has been found to be very effective in carrying out the response analysis of the soil-structure interactive system. This formulation utilizes the impedance matrices (which are the fre-

quency dependent, force-displacement relationships for complex harmonic oscillations) for the two subsystems, viz. the structure and the soil zone. In order to represent the arbitrariness in geometry and member properties of the structure, well-accepted finite element codes have to be used. Thus, the remaining principal research activity for the analysis of linear soil-structure systems is an accurate evaluation of the foundation impedance matrix.

The objective of this project is to develop substructure deletion and subdomain solution techniques for modeling the foundation of embedded structures. Such techniques will provide a more accurate account of radiation damping phenomena and can treat irregularities in geometry with relative ease. The research will lead to efficient and economical computer codes and design table and charts for general use. Aspects of the mechanics of a non-classical boundary value problem will be analyzed to illustrate the applications. Efficient algorithms and computer codes for the construction of foundation impedance matrices will be developed for the use of practicing engineers and research scientists. Numerical tables and design graphs will be presented for ready analysis of standard structure-foundation interaction problems.

Collaborative Research: Processing and Analysis of Oroville Earthquake Aftershock Ground Motion Records; *Thomas C. Hanks,* U.S. Geological Survey, 12201 Sunrise Valley Drive, Reston, VA 22092; $114,033 for 12 months beginning July 19, 1978.

In this and in a companion proposal, the U.S. Geological Survey and the California Institute of Technology will jointly conduct a two-year investigation of the remarkable set of strong-motion accelerograms and continuously recording seismograms taken in the course of the aftershock sequence of the Oroville, California, earthquake, a data set without precedent in the history of seismology. 313 positively identified strong-motion accelerograms were obtained for 86 different aftershocks. These data will considerably extend the magnitude range for which strong-motion accelerograms were previously available. It is intended to exploit this remarkable data set in detail, both with conventional studies of peak ground motion characteristics, seismic source parameters, and lateral variations of the upper crust in the epicentral region, and with a special effort to model complete ground motion time histories with more powerful waveform synthesis techniques.

The most general seismological approach to the accurate and reliable estimation of strong ground motion is to calculate entire ground motion time histories arising from physically prescribed models of earthquake faulting in layered models of the earth's crust. Very few earthquakes have been modeled at the level of accuracy and uniqueness in the frequency band required for engineering analysis. This situation is due in part to the lack of appropriate data.

The Oroville aftershock accelerograms provide an unprecedented opportunity to assess current seismological methodology. It is intended to demonstrate with this research the efficacy of seismological methodology in the accurate estimation of strong ground motion over much of the frequency band of engineering interest by direct comparisons of observations with calculated ground motion. The processed data from this project will be made immediately available to the earthquake research community. The strong-motion model developed in the study will also be made available as quickly as possible so that it may be tested and possibly incorporated in engineering and land use studies.

Collaborative Research: Processing and Analysis of Oroville Earthquake Aftershock Ground Motion Records Part II; *Donald V. Helmberger,* California Institute of Technology, Department of Geology & Planetary Sciences, Pasadena, CA 91125; $40,395 for 12 months beginning July 19, 1978.

This project is a joint program between the Seismological Engineering Branch of the U.S. Geological Survey (SEB/USGS) and the California Institute of Technology (CIT). The objective of the research is to utilize a remarkable set of strong-motion accelerograms and continuously recorded seismograms taken in the aftershock sequence of the Orville, California earthquake of 1975 to develop an improved model to predict local ground motion time histories which could occur due to an earthquake. The SEB/USGS will process 100 aftershock accelerograms; analyze data in terms of ground motion

parameters, body wave spectra, and seismic source parameters; and will perform studies on synthesis of ground motion time histories. The CIT will process long-period data in terms of velocity and displacement time histories for 40 seismograms; analyze data for the elasto-dynamic response of half space to faulting motions; and generate systhetic motion histories. The ground motion modeling study will be carried out jointly by USGS and CIT. Close coordination between USGS and CIT will be maintained to maximize the research productivity. The developed model should predict ground motion over the frequency band of engineering interest and a wide range of magnitudes. The results will be published in a four volume series format and made available to the earthquake research community.

Earthquake Ground Motion Modeling for the Central United States; *Robert B. Herrmann,* St. Louis University, Department of Earth & Atmospheric Sciences, St. Louis, MO 63103; $93,200 for 12 months beginning May 31, 1978.

The object of the proposed research is to provide improved earthquake ground motion predictions for events located in the central United States. The need of proper input for the earthquake-resistant design of structures built in the central and eastern United States is very real and immediate. Various Federal agencies require seismic input into their structural design. There are some inadequacies with the seismic input presently available due to the lack of an adequate strong-motion data base east of the Rocky-Mountains. As a consequence, input data from other source regions, which are known to be unrepresentative of actual conditions in the central and eastern United States, are used for lack of anything better. Thus, some structures may be under-designed and others over-designed. The present design techniques use either the maximum possible earthquake or a statistical estimate of the risk of exceeding a particular acceleration, velocity, or intensity level at the site.

A search will be made of the central United States data base of seismograms of local earthquakes dating back to 1910 in order to determine the special characteristics of earthquake sources in the region. Using western United States strong motion data together with the knowledge acquired about the spectral characteristics of central United States earthquakes, a subset of the western United States strong motion data set will be selected as being representative of a reasonable central United States earthquake, once the differences in seismic wave transmission are corrected for. Improved empirical scaling relations will be developed.

The computational framework for deterministic base rock ground motion time histories will be developed as a function of the characteristics of the transmission medium, the earthquake focal depth, focal mechanism and source time function. This model will be applicable to regions other than the central United States, once the transmission medium and seismic source are specified. Saint Louis University will operate a regional seismic array for the USGS in the New Madrid Seismic Zone, and under this project a digital strong-motion acquisition system will be purchased, calibrated and field installated. Data arising from this array will be used for the determination of source properties and improvement of ground-motio prediction models.

Seismic Response of Structures and Strong-Motion Instrumentation; *George W. Housner,* California Institute of Technology, Department of Engineering and Applied Science, Pasadena, CA 91125; $448,360 for 12 months beginning February 15, 1978.

The annual investment in construction in the highly seismic regions of the United States is in excess of $20 billion; hence, in 20 years an investment of some $400 billion will be exposed to the potential hazard of destructive ground shaking. Improved methods of earthquake resistant design could save billions of dollars and many lives during the coming decades.

This project will investigate the earthquake response of full-scale structures, seismic response of tanks on deformable foundations, the earthquake response of strongly nonlinear structures, will conduct finite element analysis of earthquake response, will develop a pilot digital accelerograph network, will analyse strong-motion records for magnitude determination, and will operate and upgrade the Caltech strong-motion accelerograph networks.

The results of the research will have practical applications and will be put into practice through the Principal Investigators serving as consultants to engineering projects and serving on advisory committees; through lectures and seminars, and through reports and publications which will be made available to regulatory bodies.

Workshop on Tsunami Research to be held in Los Angeles, California, October, 1978; *Li-San Hwang,* Tetra Tech Inc., 630 N. Rosemead Boulevard, Pasadena, CA 91107; $53,412 for 12 months beginning April 15, 1978.

Tsunami studies have attained prominence due to the widespread and devastating consequences of tsunamis. The various phases of tsunami generation, propagation and coastal effects have been the subject of intensive investigations in the past. Recent papers appeared to be duplicative of earlier studies. Many experts felt the time had come to convene a gathering for the interchange of ideas and results and a clear definition of the state of tsunami knowledge so that further progress in tsunami research might be attained. Findings would direct the effort of researchers towards those areas of tsunami studies which have received scant attention but are of the utmost practical consequence.

With the two-fold objective of identifying new avenues of research and outlining current and past research efforts, a tsunami workshop has been developed. Topics of discussion will include tsunamigenic earthquake ground motions, the near-field problems associated with tsunamis as well as other more traditional topics concerning tsunami behavior: e.g., run-up, trans-oceanic propagation, resonances and wave forces on structures.

Copies of the workshop proceedings will be widely distributed to researchers, public officials and practicing engineering firms. These groups will be encouraged to provide additional feedback on the coupling of tsunami research to user needs.

Research on a Portable Vibrating Structure for Soils Investigations; *Paul Ibanez,* Applied Nucleonics Co., Inc., P.O. Box 24313, Village Station, Los Angeles, CA 90024; $24,282 for 6 months beginning October 1, 1977.

One of the largest sources of uncertainty in evaluating the seismic response of important structures such as nuclear power plants is the error in soil parameters used in the soil/structure interaction model. No adequate method for high strain *in situ* measurement of soil properties is currently available. This award is to develop such a method consisting of a portable structure excited by eccentric mass vibrators. The measured response of the structure would be coupled with theoretical models of the soil and a Bayesian parameter identification scheme to back-evaluate critical soil parameters. Improved confidence in soil parameters should reduce expensive conservatism in nuclear power plants.

Analysis of Strong-Motion Data Network Programs; *Wilfred D. Iwan,* California Institute of Technology, Department of Engineering, Pasadena, CA 91125; $35,854 for 36 months beginning June 1, 1978.

The National Science Foundation is currently supporting a number of programs related to strong-motion earthquake instrumentation and data management. The objectives of these programs are to record strong ground motions and the response of representative types of structures during potentially damaging earthquakes, and to disseminate this data and information about sites and structures for use in earthquake research, in engineering design practice, and by regulatory agencies. These programs are a key element within the overall NSF-sponsored earthquake engineering research program activity.

A Strong-Motion Data Network Study Panel will be established to study the major programs dealing with strong-motion earthquake instrumentation and data management. The specific objectives of this panel are to make recommendations on the operation of the major data network programs to the organizations involved and the funding agencies, to provide coordination for the major government and university-based data network programs, and to assist in the transfer of

data to the user community. The panel will be comprised of individuals representing various user groups. Members of the panel will meet twice a year and will make site visits to ensure a cohesive understanding of the operation of various elements of the strong-motion network. Necessary coordination and administration for the activity of the study panel will be provided by the Universities Council for Earthquake Engineering Research (UCEER) through the office of its Executive Secretary.

International Workshop on Strong Motion Earthquake Instrument Arrays; *Wilfred D. Iwan,* California Institute of Technology, Department of Engineering & Applied Science, Pasadena, CA 91125; $66,871 for 12 months beginning November 15, 1977.

This project organized and convened an International Workshop on Strong Motion Earthquake Instrument Arrays held in the Spring of 1978. The objective of the workshop was to provide the basis for a plan for the future development of dense three-dimensional strong motion earthquake instrument arrays. The workshop was organized by a Steering Committee appointed by the International Association for Earthquake Engineering. International experts representing a variety of specific earthquake engineering-related disciplines were invited to participate. The workshop consisted of a series of working subgroup sessions supplemented by general sessions. Specific areas addressed by the workshop included: number and size of arrays, potential favorable locations, instrumentation performance specifications, expected short-term and long-term rates of data collection, data reduction, storage and dissemination, potential costs of installation and operation, modes of international cooperation, and the coupling of free-field structural response measurements.

The workshop consisted of general sessions and smaller working subgroup sessions. The goal of each subgroup was to develop recommendations which could help to maximize the payoff probability and cost effectiveness of any array programs. The commendations of each subgroup were presented to all participants at one or more general sessions. The outcome of the workshop will be a set of recommendations which should constitute one or more research plans or strategies for the development of strong motion instrument arrays.

Strong Motion Seminar — Workshop, California Institute of Technology, January, 1978; *Paul C. Jennings,* California Institute of Technology, Department of Civil Engineering and Applied Mechanics; Pasadena, CA 91125; $14,350 for 12 months beginning January 15, 1978.

This award provides for the organization and convening of a Seminar-Workshop on strong motions produced by earthquakes to help foster the scientific and engineering development of this fast-growing field. The objective of the workshop is to provide a technical exchange between the engineering and the seismological communities followed by a session of future research directions that seem the most fruitful. About 25 experts from the engineering and seismological disciplines who are particularly interested in strong motions will be invited to participate. The main areas to be discussed are:

- characterization and parameterization of strong ground motions,
- simulation and modeling of strong motions: deterministic and statistical, and
- source mechanisms and estimation of strong motion for great earthquakes.

A major product of the Seminar-Workshop will be a report summarizing invited papers and recommendations which may serve as a guideline for future development of this important field.

Statistical Investigation of Engineering Seismology; *Leon Knopoff,* University of California—Los Angeles, Institute of Geophysics and Planetary Physics, Los Angeles, CA 90024; $46,960 for 8 months beginning April 1, 1978.

Most seismic risk studies have been done on the basis of local or regional seismicity. Very few studies have taken the fault rupture mechanism into consideration. In order to improve the accuracy or

reliability of short-term earthquake risk assessment, an event projection (simulation) model based on both the physics of the source and on historical data is needed. A linear fault model has been developed by Dr. Knopoff and has been used to produce synthetic earthquakes catalogs whose entries are statistically similar to natural earthquakes. But the information content of the subcatalogs is insufficient when assessed on the basis of the statistical models developed. The objective of this project is to continue and to extend the research on statistical engineering seismology to introduce more physics into the stochastic models, at least at a level which is higher than at present. This project will also investigate the statistical relations in deterministic models of the interaction among earthquake events, in the hope that a comparison of these statistics with those of real catalogs will improve the models of the earthquake source and of earthquake faults.

The ultimate goal of this research is to develop an improved model and numerical methods based on physics and statistics to estimate the regional earthquake risk and to quantify the risk in meaningful engineering terms for engineering applications. To achieve the project objectives, an extensive two-year analytical and computer simulation program is required. Currently operational seismicity simulation programs at UCLA will be used and analytical and computer experiment efforts will be directed toward production and analysis of synthetic earthquake catalogs. The basic development of computational algorithms and underlying theory will also be continued and extended. The results will then be integrated with existing statistical and physical data to determine the source parameters and seismicity constants of the region, and to assess the earthquake risk of the region for engineering applications.

Response of Submerged Structures to Seismic Excitation; *Denny R. Ko,* Dynamics Technology, Inc., 3838 Carson Street, Suite 110, Torrance, CA 90503; $87,325 for 12 months beginning July 15, 1978.

During the past few years, offshore oil exploration and production have increased tremendously. Many of the new fields are far from shore, and the adjacent land area is often uninhabited. The conventional method of using a pipeline and an onshore terminal is becoming impractical. Large savings may be realized by storing oil at the producing areas and shipping by tankers to the point of usage.

The primary forcing function storage tanks must be designed to resist is that due to waves and seismic-induced hydrodynamic forces. Because of the high costs incurred in the construction of these large installations and the environmental hazards attending failure of such structures, the importance of accurate evaluation of the hydrodynamic forces cannot be overemphasized. In order to predict the response of an underwater tank to waves and earthquake, the development of a reliable computation method for the construction of storage tanks in seismic areas is a pressing need. This proposed study is specifically aimed at the earthquake-induced response of a completely submerged tank filled with oil and water.

Under earthquake excitations, internal waves are generated at the interface of oil and water inside the tank, as are fluid motions in the surrounding water. If the tank is perfectly rigid, the motions of the fluids inside and outside the tank may be studied separately. The tanks, however, are flexible; therefore the equations of motion of the interior fluids are coupled with those of the exterior water and tank structure. The effects of tank lateral deformations on tank response, the importance of which has been amply demonstrated both analytically and experimentally by studies of ground tanks to earthquake excitations, will be the emphasis of the proposed study.

This research will formulate a general finite element solution procedure and develop a computer program for the response calculation of submerged underwater tanks (rigid and flexible) to seismic actions. Specifically, the tanks will be of general but symmetric geometries and they will be completely filled with oil and water and sealed (although it is realized that, in reality, the fluids inside the tanks do communicate with surrounding water). Moreover, provisions will be made for the presence of the interior compartments and to accommodate arbitrary bottom topography.

Research fundings should be of interest to industries, oil companies and consulting engineering firms involved in the design and construction of storage tanks.

Distant and Local Tsunamis in Coastal Region; *Jiin-Jen Lee,* University of Southern California, Department of Civil Engineering, Los Angeles, CA 90007; $135,865 for 24 months beginning November 15, 1977.

One of the most destructive forces occurring in nature is the tidal wave or tsunami, which is generated through tectonic displacements associated with submarine earthquakes and volcanic eruptions. The behavior of a tsunami wave in a coastal region is complicated and difficult to understand because of the reflection, refraction, diffraction and dissipation of waves due to local site topography.

This research will study, both numerically and experimentally, tsunami behavior in coastal regions due to distant or local tsunamis. Specific objectives are to develop a dissipative model equation for the propagation of nonlinear, dispersive wave train into region of variable depth, develop dissipative model equations for the propatation of nonlinear, dispersive wave train into three dimensional coastal regions, study the behavior of waves generated by bed or boundary displacements caused by earthquakes in the coastal region, and calculate and measure transient tsunami wave forces on the structural element with emphasis placed on the dynamic forces produced by tsunami bores.

The results of this research will be of utmost importance to coastal engineers and coastal zone planners who bear the responsibility for efficient design of coastal structures or coastal communities.

Earthquake Stability of Reinforced Earth Structures; *Kenneth L. Lee,* University of California—Los Angeles, Department of Engineering, Los Angeles, CA 90024; $19,000 for 12 months beginning January 27, 1978.

This supplemental award to an ongoing project will provide funds to purchase a digital data acquisition system that is essential for shaking table tests of reinforced earth structures at the University of California, Los Angeles (UCLA).

The primary objective of this research is to provide seismic design guidance to engineers and designers for reinforced earth structures such as retaining walls, dykes and dams. This research is intended to perform model tests with small walls up to 15 inches high on the horizontal sinusoidal motion shaking table at UCLA; large scale model tests with walls up to 5 feet high on the large shaking table at Berkeley to verify and extend the small scale model tests; forced vibration tests to obtain the model frequencies of existing walls at different excitation levels; soil-tie friction studies; and analytical and semi-empirical studies to refine the stress distribution analysis. The problem of wall deformations which develop during sustained strong shaking will also be studied.

This research will lead to a logical final conclusion which will enable engineers to proceed confidently with seismic designs for particular projects involving the reinforced earth techniques.

Structural Response Under Random Wind Loading; *Y. K. Lin,* University of Illinois, Urbana, Department of Aeronautics and Aeronautical Engineering, Urbana, IL 61801; $54,671 for 12 months beginning June 21, 1978.

One dynamic natural hazard to man-made structures is strong gusty wind. Large deflections and structural instability can be caused by gusty wind under certain unfavorable loading conditions. The problem of structural response to wind loading is complex and belongs to the general category of fluid-solid interaction. Because the structural motion changes the wind forcing field, the problem is clearly nonlinear. Further complication arises from the fact that the velocity field usually has a random part (turbulence), and that the structural motion may become unstable if the wind is sufficiently strong. Since the wind excitations are random processes, the stability of the structural motion should be interpreted in a probabilistic sense, usually in terms of moment stabilities or sample stability.

Although the use of the theory of stochastic processes in dynamic system analyses can be traced quite far back, the concepts of stochastic stability have not been applied to wind-loaded structures to date.

This project will conduct analytical studies to

establish the mathematical theory for structural response to random gusty wind in the along-wind and across-wind direction, apply stochastic stability concepts to solve the wind-induced structural instability problem, investigate the vortex pattern of wind and its effect, and demonstrate the application of the research results in the analysis and design of actual building and bridge structures. The research will provide a basis for improved design practice for structures under wind conditions.

Soil Structure Interaction with Arbitrary Seismic Environment; *John Lysmer,* University of California—Berkeley, Department of Civil Engineering, Berkeley, CA 94720; $43,700 for 24 months beginning November 21, 1977.

The site response problem and the soil-structure interaction problem are fundamental to proper design of earthquake-resistant structures. In the past few years considerable research activity in these areas has taken place. However, most current approaches to the site response problem assume that the seismic environment in the neighborhood of the structure consists of vertically propagating S- or P-waves. While there is evidence to suggest that this is a reasonable assumption for design purposes, it is also one of the most controversial aspects of current discussions of the validity of the seismic analyses. Many researchers and practitioners have argued that earthquake motions in the ground consist of much more complicated motions involving surfaces waves and inclined body waves and that these wave patterns must be considered in the analysis. However, at this date, no generally applicable method has been developed which include such wave forms in the subsequent soil-structure interaction. The soil-structure interaction problem has proven to be very complicated and expensive to investigate because of the large extent and unusually complicated geometry of various types of structures and their foundations. Many different methods of analysis have been proposed. However, with the exception of a few cases involving simple geometries and SH-waves, all published methods for soil-structure interaction analyses are limited to the case of a seismic environment which consists of propagating S- or P-waves. There is a very real need to investigate other types of motion.

The objective of this proposal is to develop a theory and a finite element computer code, Complex Response Earthquake Analysis Method (CREAM), which can evaluate the seismic response of structures to an arbitrary seismic environment which may consist of surface waves, inclined S-waves, inclined P-waves, or a combination of these. The program CREAM will be developed with special attention to its later application by the practicing profession.

The theory and documentation for CREAM will be published as a report of the Earthquake Engineering Research Center at the University of California at Berkeley to the National Science Foundation and the program will be made generally available through the National Information Service — Earthquake Engineering/Computer Applications at the same location.

Operation of the National Program in Strong-Motion Instrumentation; *R. B. Matthiesen,* U.S. Geological Survey, 12201 Sunrise Valley Drive, Reston, VA 22092; $956,524 for 12 months beginning February 17, 1978.

This award will provide continued support for the NSF Seismic Engineering program of strong motion instrumentation and data management. The objectives of the program are to record strong ground motions and the response of representative types of structures during potentially damaging earthquakes, and to disseminate this data and information about the sites and structures to external users in earthquake engineering research and design practice. The program is divided into three projects: network design, network operations, and data management. The network design project is completing a basic plan for a nationwide strong-motion instrumentation network; the network operations project has brought about a more efficient operation of the existing network; the data management project is working toward improved information retrieval and data processing methods while disseminating the available data and information about the program. Results are presented in Seismic Engineering Program Reports that summarize the preliminary data and information obtained each quarter, in Strong-Motion Data Reports that present more detailed data processing and analysis, and through technical reports and papers presented or published in appropriate meetings and publications.

Structure-Fluid Interaction Due to Earthquakes; *Chiang C. Mei,* Massachusetts Institute of Technology, Department of Civil Engineering, Cambridge, MA 02139; $87,000 for 24 months beginning November 15, 1977.

Structure-fluid interaction has been of interest in earthquake engineering for quite some time. Induced by oscillatory ground movement, dynamic fluid pressure may interact with structural vibration to cause near-resonant vibration and failure of the structure. Improved knowledge of this phenomenon is necessary for safe and economic design and maintenance of concrete dams with water filled reservoirs on one side and of offshore structures surrounded by water.

The general category of fluid-structure interaction also includes the interaction between structures and storm-generated gravity waves, where the fluid mechanics is quite different from those concerning earthquakes.

This project is to conduct theoretical and numerical investigations of structure-fluid interaction problems. Proper formulation of the general class of such problems will be established and effective treatment of the fluid dynamic aspects with infinite surrounding fluid will be carried out. Emphasis will be placed on gaining detailed physical understandings and on extending an efficient hybrid finite element numerical method for analyzing the formulated problem. Two-dimensional and three-dimensional problems will be studied. Special attention will be directed to demonstrate the application of the research results in the analysis and design of dam-reservoir systems and in offshore storage tanks subjected to the combined excitations of earthquakes and waves.

Technical reports including computer programs will be distributed to industries, oil companies, U.S. and foreign government agencies of public works such as Waterways Experimental Station and the California State Dam Safety Commission, research institutes and universities.

Seismic Effects in Liquid Storage Tanks; *William A. Nash,* University of Massachusetts, Amherst, Department of Civil Engineering, Amherst, MA 01003; $85,014 for 24 months beginning February 15, 1978.

This study will be oriented toward developing rational design criteria for slab-supported liquid-filled containers subject to seismic excitation. The dynamic response of a partially filled cylindrical tank excited by transverse and/or vertical motion will be investigated. This includes the buckling patterns in the upper portion of the container above the liquid and the portion below the free surface. The up-lift effect of lower extremity of the tank at the juncture with the base slab will be investigated. The effect of sloshing liquid impinging upon the tank top and the effects of tank prestressing will be studied. Experiments will also be conducted to supplement the analytical studies. The results will be presented in the form of easily used computer programs to permit comprehensive design to withstand earthquakes.

US/ROC Cooperative Research in Earthquake Engineering; *Joseph Penzien,* University of California—Berkeley, Earthquake Engineering Research Center, Berkeley, CA 94720; $44,094 for 12 months beginning August 1, 1978.

In 1975, Professor Joseph Penzien of U.C. Berkeley and Professor Le-Wu Lu of Lehigh University initiated correspondence with Professor S. T. Mau of the National Taiwan University, to inquire into Taiwan's interest in establishing a program of cooperative research in the field of earthquake engineering. Prompted by the strong interest shown, meetings were held and detailed plans for the establishment of a modest cooperative program in three subject areas resulted.

The cooperative program is divided into two parts. Part I is a program between the University of California, Berkeley (UCB) and the National Taiwan University (NTU). Part II is a program between Lehigh University and the National Taiwan University. The objective of this cooperative program is to study fundamentally important subjects in both siting and design areas and to obtain useful technical information which will benefit both countries.

The UCB-NTU program is separated into two subject areas: "Attenuation, Intensity, and Characteristics of Strong Ground Motions," and "Seismic

Response of Embedded Structures''. In the first study area available data from both countries will be used to study attenuation laws, maximum acceleration, and other ground motion characteristics in order to find common features, correlations and descrepancies. In the second study area a hybrid mathematical model consisting of finite element representation for near field of foundation and continuous representation for far field will be developed to study the soil-structure interaction of both rigid and flexible structures during earthquakes.

During the project period, UCB and Lehigh will maintain close liaison to exchange information and to discuss and to consult each other on various technical problems concerning both projects.

An Experimental Study of Tsunamis: Their Generation, Propagation and Coastal Effects; *Fredric Raichlen,* California Institute of Technology, Department of Engineering and Applied Science, Pasadena, CA 91125; $279,558 for 36 months beginning February 1, 1978.

The devastative power of tsunami waves generated by ocean-based earthquakes is well documented. 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 in the Hawaiian Islands. The Chilean earthquake of 1960 resulted in tsunami damage to South America, parts of North America, Hawaii, New Zealand, the Phillippines, Japan, and other areas in and around the perimeter of the Pacific Ocean.

This research is directed toward a better understanding of several different aspects of the tsunami problem, including the generation, projection and local coastal effects of tsunamis. To satisfactorily and accurately construct plans for protection for the effects of tsunamis, it is necessary to better understand various aspects of the local coastal effects on tsunami generation, propagation and the local coastal effects. The major tasks to be undertaken are: wave propagation over shelves, harbor response to linear and nonlinear transient waves, run-up on the shore and on-shore structures, and three-dimensional generation, spreading and transformation of waves through deep ocean onto the continental shelf.

Project results will be made available to the scientific community and to users such as designers and planners of coastal or offshore structures. The study will lead to a better understanding of tsunami propagation and coastal effects and will assist in various aspects of prediction of run-up and innundation.

Dynamic Soil Structure Interaction; *Jose M. Roesset,* Massachusetts Institute of Technology, Department of Civil Engineering, Cambridge, MA 02139; $172,473 for 24 months beginning March 1, 1978.

Soil-structure interaction can have significant effect on the earthquake response of a structure and therefore should be taken into account in the design and analysis of structures subjected to earthquake conditions. The problem is very complex because of difficulties in accurately modeling the complicated soil-foundation structure system and accounting for all parameters. Many important aspects of the soil-structure interaction problem, such as nonlinear effects (both geometrical and material), frequency dependence effects, non-vertical incident wave effects, material property uncertainty effects, etc., remain without satisfactory solutions.

This project is directed to improve the present knowledge in various important aspects of soil structure interaction with particular application to the seismic design of structures. Research tasks included the dynamic stiffness of rectangular foundations, the dynamic behavior of pile foundations, the effects of angle of incidence of shear and compression waves and effects of surface waves, the efficiency of nonlinear soil models, and the effect of uncertainties in soil properties. The results will overcome some of the shortcomings in our current knowledge on the subject and will improve current earthquake-resistant design practices for major structures and facilities.

The Dynamic Response of Anisotropic Clay Soils with Application to Soil Structure Analysis; *Adel S. Saada,* Case Western Reserve University, Department of Civil Engineering, Cleveland, OH 44106; $69,876 for 12 months beginning January 25, 1978.

In recent years a number of studies have been made to determine the response of soils to various dynamic loadings. Rotating machinery, radar towers, vehicular traffic, earthquakes, and conventional explosions involve relatively small vibrations. In the design of foundations and underground structures for steady state and transient dynamic loads, representative values for critical soil properties are generally difficult to obtain. Among those soil properties are the moduli and the damping factors of the various layers. For the same layer these properties can vary widely because of their dependence on such parameters as the states of strain and stress of the soil, its fabric, the amplitudes and frequencies of the dynamic loads, the number of cycles, and so forth.

The objective of this research is to study the dynamic response of anisotropic clays (naturally deposited as well as compacted) to cyclic loadings with the principal stresses at various inclinations to the axis of symmetry. Shear moduli and damping ratios will be determined experimentally for the various degrees of anisotropy and their associated void ratios and moisture contents. The improved soil properties to be obtained during the experimental work will be used to improve the predicted dynamic response of the deterministic soil model and to develop a probabilistic description of output response using expected variabilities of the soil properties to be estimated from both field and laboratory data.

The research proposed is aimed at two kinds of clays: naturally deposited clays, which are usually saturated and which acquire the property of cross anisotropy during the process of deposition and subsequent one-dimensional consolidation; and compacted clays, which in the field remain unsaturated for long periods of time and whose structure will depend on the moisture content during compaction.

Experiments involving low-frequency cyclic loadings will be conducted using a special pneumatic analog computer. High frequency experiments and the determination of the dynamic moduli and damping ratios of the clays will be conducted using a specially designed "Long-Tor Drnevich resonant column" device which allows the specimens to vibrate in the torsional and longitudinal modes independently or simultaneously inside a triaxial cell. The directional behavior of both kinds of clays under cyclic loading, their moduli, and their damping ratios will be studied for a spectrum of water contents, degrees of anisotropy, amplitudes, and frequencies of loading.

The influence of material properties found will be studied using finite element techniques applied to embankments, earth dams, and other structures subjected to earthquakes and various dynamic loadings. Probabilistic techniques will be applied to model the variance of soil-structure response due to these loadings. The variance of soil properties will be estimated from laboratory tests and from assumed distributions of soil variability in the field.

Earthquake Engineering of Large Underground Structures; *Roger E. Scholl,* John A. Blume & Associates, 130 Jessie Street, San Francisco, CA 94105; $78,600 for 18 months beginning April 1, 1978.

The objective of this research is to define the state-of-the-art of earthquake engineering of underground structures. This will be accomplished by studying the interaction of seismic waves with underground cavities, making an assessment of contemporary underground seismic engineering design technology, and identifying "gaps" in the knowledge base.

In the past, facilities that have been constructed underground have included water supply and distribution systems, sanitary sewers, box conduits, underground passageways, tunnels, mass transport systems (including stations), subaqueous tunnels, and many others. More recently, much larger structures have been and are being built underground, including liquid and gas storage reservoirs, pumping stations, underground power facilities, sewage treatment and water treatment plants, and military and national defense installations. Because of new environmental and population density factors, the underground construction of major industrial installations, such as nuclear power plants and radioactive waste repositories, is becoming more feasible and environmentally desirable.

However, the response of underground structures to seismic motions is not known. Because of the anticipated increased use of underground construction

technology, it is necessary that the risk of probable disaster from earthquakes (or man-induced seismic motions) and their attendant effects (i.e., ground failure, vibratory motion) on such structures be clearly identified.

The studies to be conducted include seismic wave propation analyses, a summary of observed effects of earthquakes on underground structures, and a summary and commentary on contemporary seismic-resistive analysis, design, and construction procedures. The research will result in the publication of a report summarizing worldwide experience concerning underground earthquake engineering, describing the important features of earthquake wave propagation, commenting on current design and construction practices, and recommending future experimental and analytical research.

Influence of Site Characteristics on the Damage During the October 1974 Lima Earthquake; *H. B. Seed,* University of California—Berkeley, Department of Civil Engineering, Berkeley, CA 94720; $36,242 for 12 months beginning January 1, 1978.

The effect of local soil conditions on the damage pattern has been studied for a number of earthquakes throughout the world. Characteristics of the soils overlying rock or rock-like material have had a strong influence on the observed damage to structures. The October 3, 1974 Lima, Peru earthquake, which caused a total of 70 deaths and over $200 million property damage, presents a unique opportunity to study the effect of local site conditions on earthquake damage. The general subsurface soil conditions are well known and damage data due to past earthquakes is abundant.

This project will consist of six major studies: (1) a damage survey and preparation of damage distribution map of the greater Lima area, (2) a survey of subsurface conditions of Lima area, (3) boring and further geophysical tests of selected sites, (4) laboratory tests of subsurface materials, (5) development of subsurface profiles, and (6) analysis of data, soil response and cross comparison with results from previous earthquakes.

Generally speaking, the project will analyze the nature, characteristics, and distribution of the damage observed during the October 1974 earthquake; study the general distribution and properties of the subsurface soils in Lima; and, from these two separate studies, determine whether the observed damage distribution is related to the subsurface soil conditions. The results of the studies will help clarify the effects of site conditions on earthquake damage, not only in the Lima area but in general, and will help to check the validity of present methods of allowing for these effects in newly developed building codes.

A Generalized Study on Seismic Risk Analysis; *Haresh C. Shah,* Stanford University, Department of Civil Engineering, Stanford, CA 94305; $300,000 for 36 months beginning January 1, 1978.

Research in the general area of seismic risk has been recognized by the earthquake engineering community as of the utmost importance. Seismic risk and its associated uncertainties must be considered if rational building regulations or codes are to specify the community's seismic safety requirements for buildings and other constructions, emergency preparedness plans, and the constructed environment.

Principles of probabilistic forecasting and decision-making are commonly used by researchers. In recent years a considerable amount has been done in the area of the probabilistic estimation of seismic load parameters. However, many shortcomings still exist in current seismic risk analysis procedures. Among these are unsatisfactory treatment of ground motion duration, amplitude, and frequency content. Further, current risk maps are insufficient because they are usually based on historical data within a very short time period. Specific geologic and seismologic conditions are not taken into consideration, and the loading parameter used in the maps is unclearly defined.

This project will conduct a comprehensive risk analysis program to overcome the above shortcomings. The objective is to develop for engineering design and decision purposes a unified theory and comprehensive analysis methodology for seismic risk evaluation.

This will be done by developing a better approach for estimating the ground motion input duration and defining the response duration, more stable parameters to represent the input amplitude and fre-

quency content, better statistical models that take into account specific geologic and seismologic conditions, and a consistent probabilistic approach for the above analyses. Also needed are a clear understanding of the needs of structural designers and the objectives of building codes and their relationship with the probabilistic information on the seismic environment.

Second International Conference on Earthquake Microzonation for Safer Construction-Research and Application, November, 1978 — San Francisco; *Mehmet A. Sherif,* Applied Engineering Resources, Inc., 114 E. De La Guerra Street, Santa Barbara, CA 93102; $85,830 for 18 months beginning February 15, 1978.

Microzonation by definition involves the determination of relevant site characteristics and their translation to a form that will enable engineers to design safer structures in seismically active regions.

This project supported the second "International Conference on Microzonation — Research and Application", held in San Francisco in November, 1978. The purpose of the conference was to bring together a group of persons from a diverse background of disciplines such as geophysics, geology, seismology, engineering, architecture, urban planning, city, county, state and government administration, insurance, planners of major engineering works, investors and developers, economists, and sociologists, to summarize the state-of-the-art" of knowledge concerning earthquake microzonation techniques around the world. The Conference also promoted discussion of the various theories and concepts developed since the first Microzonation Conference in 1972, contributed papers on current basic research in this area, identified future research needs, and published a comprehensive proceedings. The proceedings will serve to promote utilization of research findings and will serve as a future reference document for those who are faced with the responsibility for incorporating relevant site characteristics in the planning and location of communities and the design of safe structures in seismically active regions.

Induced Seismicity at Nurek Reservoir, Tadjikistan, USSR; *D. W. Simpson,* Columbia University, Palisades, NY 10964; $207,125 for 21 months beginning January 31, 1978.

The seismicity of a region can be severely modified by the impounding of large reservoirs. Earthquakes with magnitudes near 6 have occurred near five large reservoirs, resulting in millions of dollars of property damage, structural damage to dams, the loss of more than 200 lives and injuries to thousands of persons. Throughout the world, over 100 large dams are now under construction or in the planning stage, at least some of which are likely to cause induced activity.

The potential for a major disaster due to water impounding of a reservoir is obvious from past experience, yet the nature and physics of this type of seismic activity is not adequately understood. The objective of this joint US-USSR joint project is to study the induced seismicity at Nurek Reservoir, Tadjikistan, USSR where extensive seismograph stations have been in operation since 1955. Detailed data are available on pre-impounding conditions near the reservoir. The changes in the rate of seismic activity related to the filling of the reservoir and other aspects of the seismic regime will be investigated. A model which can be used to predict the times of greatest potential for increased seismicity will be tested and used to generate practical information for the safety, construction, and operation of the reservoir.

An existing network of ten Soviet seismograph stations within 50 km of the Nurek Reservoir is being augmented with a ten station network of American radio-telemetered seismographs located within 10 km of the reservoir. A model has been developed to explain many of the observed features of the temporal and spatial characteristics of the induced seismicity at Nurek. This model, based on the interaction between stresses created by the reservoir load and increased pore pressure, shows that the times of greatest potential for increased seismicity are following rapid increases and during rapid decreases in water load. Tests of this model and further refinements to it will be made as the reservoir continues to fill.

Strong Motion Accelerograph Network in the Los Angeles Basin; *Ta-Liang Teng,* University of Southern California, Department of Geological Sciences, Los Angeles, CA 90007; $383,712 for 24 months beginning March 15, 1978.

Los Angeles more than any other metropolitan area in the United States represents a situation which combines a high seismic hazard with a large population. There is an immediate need for a specialized array of strong motion accelerographs in the Los Angeles basin. A carefully designed array would fill a serious gap in the data from any future strong earth-quake, and would benefit both engineers and seismologists in a long term program of hazard reduction. Data from this array would be used for a careful study of the distribution of strong shaking, attenuation patterns, and the effect of geological structure and local conditions of the Los Angeles basin.

This project will establish a dense accelerograph array in the Los Angeles basin and study the structure of the basin and its effects on strong shaking. This research will help to show how seismic hazard depends on location and to what extent detailed seismic zoning is feasible, and will improve knowledge of local earthquake mechanisms and shear wave velocity structures.

One hundred accelerographs will be installed in the Los Angeles basin and vicinity. Based on the seismicity of the region, the array proposed would be expected to record about four earthquakes inside the array per year. These events would be useful to study S-wave velocities, and the array would certainly contribute to location and source mechanism studies. Should a major event occur, the rapid and strong sequence of aftershocks could quickly (within hours) saturate the recording film capacity, and immediate service to replace the film magazines would be called for. USC's laboratory is located practically in the middle of the proposed array and is within minutes of any array element. Sufficient manpower will be organized to cope with such an emergency situation.

The preliminary results and description of the array will be presented at scientific and professional meetings and widely distributed to earthquake engineering and seismology groups. Visitors will be invited to come to U.S.C. to work on and to further develop the proposed array system.

Analysis of Optimal Strong-motion Instrument Location in Building Structures; *F. E. Udwadia,* University of Southern California, Department of Civil Engineering, Los Angeles, CA 90007; $74,056 for 12 months beginning March 1, 1978.

This project is directed at the development of a scientific methodology for optimal sensor location. Over the past several years, a major improvement in our understanding of the dynamic response of structures during earthquakes has been gained from instrumental data obtained during strong ground shaking. Such data have revealed several general aspects of the dynamic behavior of structural systems and have lead to improved design criteria and safer designs. To acquire data more and more structures built in seismically active regions of the world are being instrumented with strong motion accelerographs. Such instrumentation programs involve large outlays in capital as well as maintenance costs. Little attention has been paid to the development of any methodology for determining which buildings should be instrumented, how many instruments should be used, and where the instruments should be located.

Both the number and the position of instruments will be studied in relation to the amount of information that can be gathered from such data as well as the economic costs involved in their installation and maintenance. Such a study is significant, since instrument location, if properly assigned in a building structure, could yield a wealth of information about the structure and reduce the unnecessary instruments.

The Effects of Earthquake Input Motion Phasing on Structural Response Characteristics; *Stuart D. Werner,* Agbabian Associates, 250 North Nash Street, El Segundo, CA 90245; $137,801 for 12 months beginning July 1, 1978.

In most analyses of the response of complex structures to earthquake ground motion, the seismic input is defined either from a family of damped response spectra or as one or more time histories of ground ac-

celeration. This input is applied simultaneously along the entire base of the structure, regardless of its dimensions and dynamic characteristics, the properties of the underlying soil material, or the nature of the ground motions themselves. In reality spatial variations and different velocities of propagation of the seismic waves actually cause different portions of the structure foundation to be subjected to different phased amplitudes of motion at a given time. The extent of these traveling wave effects on the structure's response is dependent on the type, frequency, and angeles of incidence of the seismic waves; the properties of the soil profile; and the materials properties and geometry of the structure and its foundation.

Results from previous studies have indicated that traveling wave effects are most pronounced when the wavelength of the incident waves is comparable to or less than the structure length, and become negligible when the ratio of the wavelength to the foundation length is large.

Two main deficiencies still exist regarding the assessment of wave effects. The first is the lack of ground motion measurements at closely-spaced locations that would provide guidance for improved quantitative representation of spatially-varying ground motions. The second main deficiency is the one to which this overall research program is addressed: the lack of information that can be directly used by engineers to assess potential traveling wave effects during the design of earthquake-resistant structures. This information will consist of two parts. First, it will include a general methodology that is applicable to a wide variety of structure types and can be readily applied by the practicing engineer. Second, it will contain generalized structure response data, presented in a form that provides quantitative guidelines for considering traveling wave effects in design and analysis applications.

In previous study the response of structures on an elastic half-space subjected to traveling shear waves was considered. This work will be extended to investigate the response of various types of structures supported on an elastic half-space and subjected to traveling P, SV, and Rayleigh waves. Of particular interest are structural types covering large areas, or having foundations widely spaced, such as long-span bridges. This methodology will be applied to the analysis of typical structures to determine the importance of input motion phasing on the structural response and on soil-structure interaction. Analysis will be carried out with computer programs based on the methodology developed in this research. These programs and supporting documentation will be made available through the National Information Service for Earthquake Engineering.

Earthquake Strong-Motion Instrumentation and Array Design; *Francis T. Wu,* SUNY State University at Binghamton, Department of Geological Sciences, Binghamton, NY 13901; $41,464 for 12 months beginning August 7, 1978.

Up to now, the gathering of strong motion data has been performed by the fixed station technique. Only in rare cases is there an array suitably located to record strong motions systematically around a fault. Also until recently, the timing on these records was not tied to real time. This made it difficult to decipher the precise nature of the waves recorded and to generalize the obtained results for future earthquakes, since the contribution of the source and that of the path could not be easily separated.

The technology of seismic recording has advanced recently. It is now possible to record the data digitally using a self-contained portable system, use a "pretrigger" digital loop to retain the complete strong motion data, including the triggering signal, use a low-drain accurate crystal clock for coordinated time and use a non-linear amplifier to increase the dynamic range of the recording system.

In this project two such new systems will be studied to increase the efficiency of ground motion data recordings. Optimum design of local and regional instrument arrays will be investigated to minimize the total cost and maximize the return. The objective of this project is threefold: (1) to develop more efficient strong-motion instruments with wider dynamic range and versatility, (2) to develop criteria for reliable and cost-effective network design, and (3) to study the dynamic seismic source mechanism by using near field data.

Response of Nonlinear Saturated Soils to Seismic Disturbances; *E. B. Wylie,* University of Michigan, Department of Civil Engineering, Ann Arbor, MI 48109; $57,831 for 12 months beginning March 15, 1978.

A satisfactory analytical procedure to calculate the potential for liquefaction of a particular site during a seismic disturbance remains an important unresolved goal of geotechnical specialists. This research will develop a numerical model to evaluate the tendency of saturated porous media to liquefy. This model will include a coupled nonlinear shear and pressure wave, with the physical nonlinear behavior of the soil being characterized through standard soil testing procedures.

A recently developed model which is based upon the application of the method of characteristics to handle the equations for transient motion in saturated soils will be modified to incorporate a more realistic description of material properties. Parametric studies will be used to qualitatively evaluate results from the model, while comparisons with large-scale laboratory results reported in the literature will be utilized to demonstrate the quantitative behavior. The concepts developed in the one-dimensional model will be extended to a two-dimensional spatial domain.

Nonlinear material behavior is utilized both in the shearing stress-shearing strain and in the volumetric deformation portions of the model. These two subsets of the total model are interactively coupled so that the shearing strength of the material varies with transient pore pressure. As the pore pressure develops, the effective stress reduces, and the shear modulus and shear strength reduce, thereby permitting larger shearing strains for the same transient shear excitation. Leakage of excess pore water in response to transient pressure gradients is permitted. The one-dimensional distributed parameter model can handle layered soils with variable soil properties. Various surface and base boundary conditions can be used. The two-dimensional model will provide the opportunity to incorporate lateral variations in material properties for *in situ* studies in addition to the vertical layering treated by the one-dimensional model.

DESIGN

The analysis and design of buildings, dams, pipelines, and other civil structures requires information from the basic physical and natural sciences to determine the functional, economic, and performance requirements necessary to maintain the integrity of a structure throughout its intended life. For natural hazard loadings such as earthquake or wind forces, these processes involve the formulation of loadings, study of the behavior of materials and structural components under stressed conditions, formulation and development of conceptual and mathematical representations for structural systems (including computer modeling), and validation of design procedures through observation of and tests on real structures.

Earthquakes and related natural hazard effects pose two significant problems: that of developing design procedures for new projects, and that of developing practical and cost-effective ways to deal with existing structures and facilities which were constructed with inadequate dynamic load resistances. Initiatives to upgrade existing, hazardous structures have been limited by costs which seemed too high in view of the chance of damage. As our ability to accurately predict the location and magnitude of earthquakes improves, an effort to upgrade structures to improve their seismic performance in areas of known high seismic risk may be undertaken. In FY 1978 the *Design* program supported research on hazard assessment, upgrading and reinforcement of existing structures, particularly unreinforced masonry structures in the high-risk Western states.

By observing actual earthquake damage we have learned that, even if the primary structure of a building withstands earthquake damage, the cost of replacing or repairing damage to its secondary building elements such as glass, claddings, ceilings and interior partitions, and electrical and mechanical systems which may not have received dynamic design consideration can amount to more than one-half of the original cost of the structure. In FY 1978, the *Design* subelement stressed techniques to predict loadings which occur on secondary structures and elements, and design methods to improve their performance under dynamic loadings.

Simulation of Strong Earthquake Motion with Contained Explosive Line Source Arrays; *G. R. Abrahamson,* SRI International, 333 Ravenswood Ave., Menlo Park, CA 94025; $283,992 for 12 months beginning June 21, 1978.

The objective of this program is to continue the development of an explosive method to develop ground motion with the required control and versatility to test *in-situ* full-scale structures at strong earthquake level to observe vibration modes and explore potential damage mechanisms. This approach utilizes an array of vertical line sources that produce ground motion through an expandable rubber bladder rugged enough to withstand repeated tests with expansions to roughly twice the initial bladder diameter. Such tests demonstrate the feasibility of producing ground motions needed to study behavior in *in-situ* soils under strong ground motions, the propagation of strong motions through soils, soil-structure interaction effects, and the dynamic behavior of full-scale structures.

The explosive is detonated inside a steel canister through vent holes to pressurize the bladder at a controlled rate. Pressure pulse rise times are controlled by the size of the vent holes in the pipes, and decay time can be controlled by venting the upper end assembly to

the surface. The explosive used is Primacord strands, an inexpensive and convenient form of PFTN. There are several advantages to the use of line sources. A minimum amount of explosive is required because containing the explosion products eliminates the high ground shocks associated with freely expanding explosions; therefore the line source array can be located close to the structure. The duration of the simulated earthquake motion can be controlled by delayed multiple detonations. Contained explosions are more advantageous for seismic ground-motion simulation because they produce lower pressures and hence local ground motions, and they can be used closer to test structures, require small amounts of explosive, and produce no surface eruptions.

In previous work reasonable ground accelerations and frequencies were obtained in single reusable ⅓-scale line sources. This program consists of a series of array tests using these ⅓ scale sources, design and testing of a single full-scale line source, theoretical analysis and calculations of simulation performance, and further developmental investigations.

Seminars on Earthquake Criteria and Design; *M. S. Agbabian,* Earthquake Engineering Research Institute, 2620 Telegraph Ave., Berkeley, CA 94704; $77,820 for 12 months beginning September 15, 1978.

Practicing engineers, architects and state, Federal and local government officials are becoming increasingly concerned about earthquake hazards mitigation. The need has arisen to disseminate research findings as rapidly as possible in order to implement the application of the results. This project will present seminars and videotaped lectures designed for practicing engineers and government officials who wish to enhance their ability to evaluate and resolve earthquake engineering problems. They will provide, in capsule form, the important areas of recent progress in research and experience and the procedures for utilization of the newly developed earthquake engineering technology.

The project will consist of two phases: presentation of seminars and preparation of videotapes of these seminars. The seminars will consit of a series of lectures by engineers and scientists in various areas of seismology, geophysics, and earthquake engineering. Attention will be focused on engineering rather than seismological aspects of strong motion data acquisition and utilization in design. Regional problems of earthquake design criteria and performance of structures will be emphasized. The videotapes will be made available through EERI to all groups interested in earthquake hazards mitigation, such as engineering and architectural schools, local professional groups of all disciplines, academic short courses, local, state and Federal agencies.

Safety Evaluation of Structures to Earthquakes and other Natural Hazards; *H. S. Ang,* University of Illinois—Urbana, Department of Civil Engineering, Urbana, IL 61801; $271,000 for 24 months beginning December 15, 1977.

The safety of a structure depends on structural adequacy for resisting the maximum force that it may be subjected to over its useful life. Because of the uncertainty that underlies the prediction of the lifetime maximum force, as well as in the estimation of the resistance of a structure, any assurance of safety is realistically possible only in terms of probability.

This project is to conduct a coordinated analytical program to develop a methodology based on probabilistic techniques. Specific tasks to be conducted are development of a random vibration method for nonlinear-hysteretic structures; development and computerization of models for the determination of the lifetime intensities of extreme hazards; analysis of the extremes of combined random loads; safety evaluation of specific structures; and formulation of probabilistic bases for hazard-resistant design. The methodology will be tested by application to real structures and will serve to advance the basis for safety evaluation and reliability design to resist natural hazards. The research will also enhance the engineer's ability to evaluate the risk of existing buildings and to construct regional hazard maps for specified damage levels.

Conference on Stability Problems of Mixed Steel Concrete Structures, Boston, Massachusetts, May 1978; *Lynn S. Beedle,* Lehigh University, Department of Engineering, Bethlehem, PA 18015; $9,000 for 12 months beginning April 15, 1978.

This grant will provide partial support for a technical meeting on the static and dynamic stability problems associated with mixed steel-concrete construction. Engineers have used steel and concrete as constructional material for a long time. The strength and behavior of steel or concrete (reinforced and prestressed) members and structures acting independently have been investigated thoroughly and have become well understood. However, there are two methods of combining structural steel with plain or reinforced concrete such that the unique characteristics of these two components may be used most effectively.

One method is called "composite construction" and the other may be referred to as "mixed systems". In composite construction, structural steel and concrete interact with each other in individual members in resisting the load by means of shear transfer, mostly through mechanical shear connectors. Composite girders, beams, slabs and walls have become widely accepted in construction practice. Mixed systems, on the other hand, do not involve the casting of concrete on steel members; rather, the two systems are mixed to act in combination. A steel frame with infilled precast panels would be one example. The application of the mixed steel-concrete construction system has gained popularity the last decade. Several mixed steel-concrete structural systems have been developed, for example: concrete encased steel frames, composite tubular systems, and mixed systems, plate clad buildings, panel braced steel frames, and mixed systems with precast concrete members. The mixed steel-concrete construction method provides a flexible means for designers to obtain the optimum usage of materials since several choices of combining structural steel with concrete members and assemblies may be selected. One of the areas of interest is in the damping characteristics of these systems, both prior to cracking and after the initial cracking that can occur under extreme lateral load. The latter influences earthquake response.

It is anticipated that this meeting on the subject of Mixed Steel-Concrete Construction will provide the opportunities for leading firms and organizations to discuss and exchange the up-to-date knowledge and information in this field. Specific areas of research needs and priorities, particularly for the aspects related to safety and behavior of mixed steel-concrete structures subjected to sever seismic loading, can be examined. This will provide the impetus to discuss the steps to be taken for organizing future research, the results of which will be used as the basis of revisions by specification writing bodies.

Reliability Assessment of Linear Lifelines for Natural Hazards; *Jack R. Benjamin,* Engineering Decision Analysis Co., Inc., 480 California Street, Suite 301, Palo Alto, CA 94306; $41,775 for 12 months beginning July 15, 1978.

This proposal is concerned with the mitigation of socioeconomic losses brought about by the loss of function of civil engineered lifelines exposed to natural hazards such as earthquake ground motion. If key facilities of an energy supply, water supply, transportation or communications lifeline are destroyed, then the lifelines as a whole will not function. The losses to society from the loss of function of a lifeline are potentially far greater than simply the loss of the facility itself. For example, the breakdown of water supply lifelines during an earthquake due to the loss of function of a pumping station could result in fires from broken gas lines spreading uncontrolled and causing socioeconomic losses on the order of several magnitudes greater than the loss of the pumping station.

This research is aimed at developing a practical methodology for reliability assessment of linear lifelines subjected to natural hazards. The models to be developed in this program will fit linear assemblies of segments of highways, bridges, railroads, transmission lines, pipelines, etc. Emphasis will be on the development of reliable and practical techniques to solve very complex theoretical problems. The type of reliability assessment to be employed in this program consists of estimating probabilities of attaining of various levels of functional goals (gains and losses) rather than simply the probability of success on a single trial. The techniques fit directly into a cost-benefit methodology.

Three models will be considered in this research. One model deals with continuous discrete spans with dependent properties such as pier-supported pipelines, bridges (both continuous and simply supported), transmission lines, and others in which individual segments can be identified and evaluated. A second model deals with uniform support continuums with dependent properties, and includes uniform support continuum problems in which the properties considered are random and dependent from point to point. This model similarly fits the response characteristics of continuously-supported pipelines. Spatially-varying support continuums and loading with dependent properties extends the third model to include systematic spatial variation of random loads such as attentuation of earthquake ground motion. Response properties of areas with systematic spatial variation such as residential and commercial districts are also included in the model. The research plan is to employ the case method with practical lifeline problems in order to ensure that the results of the studies are of practical value and directly of interest to potential users of the methodology.

Seismic Investigation and Design Criteria for Industrial Storage Racks; *John A. Blume,* John A. Blume & Associates, 130 Jessie Street, San Francisco, CA 94105; $43,130 for 12 months beginning April 11, 1978.

The objective of this project is to develop rational design criteria and procedures for industrial storage racks, incorporating realistic seismic resistance in their design and construction at minimal cost to reduce the risks of potential earthquake damage and losses. The types of racks include standard pallet racks and their subassemblies, drive-in and cantilever racks.

Portal type racks involving beam-to-column connections of various types have been tested and analyzed. Design procedures and criteria are currently in progress. In the second phase of this award, the analysis and testing of stacker-type racks rather than cantilever type will be conducted.

Objective and Subjective Seismic Safety Considerations; *Colin B. Brown,* University of Washington, Department of Civil Engineering, Seattle, WA 98195; $52,000 for 12 months beginning January 1, 1978.

One of the most important tasks in earthquake engineering research is the development of improved methods for evaluating the seismic safety of both existing and new structures. To date the probabilistic approach, which treats the ground motion input and the structural response and capacity as random, has been generally used. Probabilistic statements are appropriate for measurable, objective information, but the real design of structures for seismic effects requires that subjective information and understanding be readily included. This probabilistic approach fails to properly address the effects on the safety evaluation that might be caused by subjective features in a structural design process, such as numerical errors, simplification, and omissions in the modeling, analysis, design and construction stages.

This study addresses the problem of rationally including both objective and subjective considerations in seismic safety evaluations. The objective information will be treated as statistical moments and limits. Unbiased distributions will be obtained by maximizing the entropy in the manner of Jaynes. Subjective information in the form of linguistic statements will be accomodated within the mathematical theory of Zadeh's fuzzy sets. This ensures a measure and a calculus for the quantification of subjective matters. The final result will be a unique estimate of seismic safety which includes both objective and subjective parts. A four-part research plan will be developed in this project to obtain quantitative safety estimate by combining the results from separate objective and subjective analyses.

Research on Seismic Hardening of Unreinforced Masonry Walls Through a Surface Treatment; *James R. Cagley,* Martin and Cagley, 6000 Executive Boulevard, Rockville, MD 20852; $25,000 for 6 months beginning October 1, 1977.

This award is for the first year of a two year project to develop an economical and simple method of reinforcing masonry to resist seismic forces through the use of a coating. This will be accomplished by assembling available information on methods of reinforcing masonry which are now in use, by reviewing

available test data of unrienforced masonry, by research available products, by determining necessary structural requirements and by establishing a test program that will be proposed to be carried out in the second year to verify the methods and procedures.

Optimum Design of Three-Dimensional Building Systems for Multicomponent Earthquake Motions; *Franklin Y. Cheng,* University of Missouri, Rolla, Department of Civil Engineering, Rolla, MO 65401; $20,165 for 4 months beginning June 1, 1978.

Conventional methods of seismic design are usually based on calculations of response due to one single horizontal component of the earthquake ground motion and are without consideration of the economic consequences of the design. The knowledge of structural behavior subjected to three components of earthquake excitation has progressed greatly and has made it possible for researchers to develop more rational, reliable and cost-effective methods of seismic design using computers.

This project is intended to investigate the optimum design of three-dimensional building systems subjected to static loads, wind forces, and three orthogonal components of earthquake ground motion. The research aims at developing computer programs for practical use for optimum seismic structural design by design engineers.

Research will include mathematical formulation of optimization and structural models, investigation of seismic forces and structural systems, development of computer programs for optimum design, computer analysis of design options, and assessment of critical structural parameters and systems. This will lead to a practical method of seismic design which is more rational and reliable than those methods commonly used today.

Earthquake Response of Dams Including Hydrodynamic and Foundation Interactions; *Anil K. Chopra,* University of California—Berkeley, Department of Civil Engineering, Berkeley, CA 94720; $70,700 for 12 months beginning December 8, 1977.

This research program will develop reliable and effective techniques for earthquake analysis of dams including effects of hydrodynamic and foundation interaction, and will develop a fundamental understanding of the effects of interactions and their significance in the response of dams to earthquake ground motions. Studies will be made of concrete gravity, concrete arch, and earth dams. General procedures for dam analysis will be formulated and the computer programs needed to implement the design procedures will be developed. The significance of interaction effects in earthquake response of dams will be evaluated and the results interpreted in relation to assessing the safety of existing dams and of designs proposed for dams to be constructed. Results generated in this study will be made available through NISEE.

Collaborative International Research on Earthquake Response of Structures, U.S.—Yugoslavia; *Ray W. Clough,* University of California—Berkeley, College of Engineering, Berkeley, CA 94720; $59,278 for 24 months beginning May 15, 1978.

The purpose of this project is to coordinate ongoing research at the University of California, Berkeley in the U.S. and in Yugoslavia concerned with the dynamic behavior and earthquake resistance of high rise residential buildings, considering large-panel precast concrete construction in Yugoslavia and poured-in-place monolithic concrete construction in California. The vibration properties of four such structures, three in Yugoslavia and one in California, are being measured by both ambient and rotating mass shaker techniques. Of particular interest in these studies are the foundation and surrounding soil deformations because soil-structure interaction can contribute significantly to the dynamic response of such relatively stiff buildings.

In addition, pseudo-static cyclic tests are being performed in the laboratory to determine the stiffness, strength, and energy absorption mechanisms of typical structural components, such as joint details

and shear wall segments. The laboratory tests in Skopje deal with precast concrete components. Additional experiments will be performed in Yugoslavia on the dynamic behavior of foundation systems embedded in soil, to provide detailed information on actual soil-structure interaction.

Computer program development is proceeding in parallel with the experimental studies, primarily by the Berkeley investigators. These programs will serve in analytical correlation with the experimental results, and will be based on mathematical models derived from the experiments. One specific subject of these program developments will be the nonlinear behavior of concrete components (both monolithic and precast assemblies) and also of complete concrete buildings of both types. Another topic of analytical development is soil-structure interaction, and the experimental data obtained in this project will serve to refine and verify current analytical procedures. Research is also in progress on techniques of system identification as an efficient means of defining the mathematical models to be used in analytical correlation with experimental results.

Seismic Behavior of Complete Structural Systems; *Ray W. Clough,* University of California—Berkeley, Department of Civil Engineering, Berkeley, CA 94720; $454,400 beginning November 14, 1977.

One of the major goals of earthquake engineering is predicting the inelastic response of structures subjected to severe earthquake excitation. Considerable effort has been devoted to development of computer programs for performing such analyses; however, very early in the development of these programs, it became apparent that the ability to perform nonlinear structural analyses greatly exceeded the understanding of the seismic behavior mechanism of structural elements and components. Much more detailed information on the actual damage performance of such components was needed before reliable computer predictions could be made.

Accordingly, in 1965 a faculty group of the Department of Civil Engineering, University of California, Berkeley, submitted a proposal to NSF for a five-year program of research under the title "Energy Absorption Characteristics of Structural Systems Subjected to Earthquake Excitation". The first grant in support of this proposed research program was made in November 1966, and subsequent grants have provided continuous support to the research effort. This project is one of four independent programs: "Behavior of Complete Structures", proposed to continue the research.

This project represents a continuation of five of the 16 sub-programs which constituted the previous project. Its objectives are to develop techniques for shake table tests of large sized structural systems, to measure the simulated earthquake response of such systems, to correlate the measured seismic behavior with results of digital computer analyses, and to make improvement in the mathematical models and analyses procedures.

The research plan consists of the following tasks: (1) Earthquake Simulator Studies — to perform extensive dynamic tests on steel concrete frames to gain an understanding of their behavior and to improve the techniques for mathematical modeling; (2) System Identification — to evaluate system identification procedures with respect to their suitability for application to nonlinear seismic response of structures, and to develop computer programs which make efficient use of the most promising algorithms; (3) Computer Program Development — to continue the development and application of computer programs for predicting the inelastic earthquake response of structures; (4) Energy Absorbing Devices — to investigate the feasibility and effectiveness of energy-absorbing devices to reduce and control building response; (5) Field Measurements — to carry out measurements of the dynamic properties of existing structures to supplement the studies of structural tests; and (6) Post-Earthquake Damage Analyses — to assess the reliability of various analytical models and techniques for predicting response, and to assess possible improvements in design and construction practices.

Seismic Resistance of Buildings with Reinforced Concrete Structural Walls; *W. G. Corley,* Portland Cement Association, Engineering Development, Old Orchard Road, Skokie, IL 60076; $490,125 for 12 months beginning February 1, 1978.

The behavior of multistory reinforced concrete structures during recent earthquakes has clearly demonstrated that both protection of human life and superior damage control can be achieved if the buildings are stiffened by properly proportioned and detailed structural walls. In spite of this observation, engineers have been reluctant to use reinforced concrete structural walls for earthquake resistance because they lack adequate information on their deformation capacity in relation to likely demands under strong ground motions.

The ultimate objective of this investigation is the development of reliable and practical design procedures for earthquake-resistant reinforced concrete structural wall (shear wall) systems. Included under this broad category of structures are isolated walls, coupled walls and frame-wall systems.

Realistic estimates of the strength and deformation requirements in critical regions of structural wall systems will be established through dynamic inelastic analyses. These estimates will correspond to different combinations of the significant structural and ground motion parameters. Laboratory tests on large-size specimens are planned. Results of these tests and correlation with theory will be used to develop methods of predicting the available strength and deformation capacities of properly proportioned and detailed structural walls.

Nondestructive Dynamic Testing of Three Highway Bridges; *Bruce M. Douglas,* University of Nevada, Reno Campus, Department of Civil Engineering, Reno, NV 89557; $80,123 for 24 months beginning September 1, 1978.

This research addresses the lack of full scale dynamic tests on highway bridge structures. Under this project a five span reinforced concrete box girder bridge and a six span composite girder bridge will be subjected to dynamic testing for both the lateral and vertical directions of motion. A third bridge, a three span composite girder structure having variable depth sections, will be subjected to vertical motion analysis only. The structures selected for study are representative of the more typical structures of their class. In all experiments, complete identification of the structural dynamic properties — natural frequencies, mode shapes, and modal damping will be performed. The method of quick release pullback testing, which has successfully been used in the past for bridge structures, will be extensively employed.

Analytical studies will be conducted to confirm the validity of all experimental results obtained and the methodology used in the theoretical modeling process. Analytical seismic analyses will be performed to identify the seismic resistance of the principal structural features of the bridges selected for study.

Methodology for Mitigation of Seismic Hazards in Existing Unreinforced Masonry Buildings; *Robert D. Ewing,* ABK, A Joint Venture, 250 N. Nash Street, El Segundo, CA 90245; $461,962 for 12 months beginning October 1, 1978.

Building construction using unreinforced masonry predates the development of the seismic criteria which guide the design and construction of present day buildings. Many of these buildings are still in use and pose a potential hazard to life when subjected to seismic forces. Concern for the safety of these buildings is increasing because of potential liability in the event of injury or loss of life.

This project will evaluate the current state-of-the-art for mitigating the seismic hazards of existing unreinforced masonry buildings, categorize nationwide existing masonry construction, evaluate current methods for selecting earthquake ground-motion input, categorize the damage from past earthquakes, review strength data, assess analytical methods to evaluate these buildings, and evaluate retrofit methods. In a second effort, a program for analytical verification and testing, including retrofit, will be conducted. Both quasistatic and dynamic tests will be performed on wood and metal diaphragms and on walls

subjected to out-of-plane forces. Wall sections subjected to in-plane forces, simulating existing masonry walls, and anchorages will be tested. The results of both efforts will be integrated in the development of the required methodology.

The results of this research should be of use in the design of new unreinforced masonry buildings.

Research on the Response of Existing (Masonry Buildings) Systems to Earthquake Motions; *Robert D. Ewing,* Agbabian Associates, 250 N. Nash Street, El Segundo, CA 90245; $25,000 for 6 months beginning October 1, 1977.

Practical and reliable analysis methods are needed to determine the response and failure mechanisms of existing unreinforced masonry structures and to verify the effectiveness of methods for strengthening the structures against seismic hazard. This is a Phase I effort to identify improved methods for analyzing the earthquake response of existing systems and to develop methods for strength retrofitting.

Analytical study will be undertaken to categorize and evaluate analysis methods appropriate for determining the response of unreinforced masonry structures, for analyzing the response of strengthened structures, and for verifying the retrofitted strengthening. Data necessary for accurate modeling of physical and material properties would be identified and the adaption of available computer programs would be considered. The study will produce a list of candidate methods for response analysis of existing structures, both unreinforced and reinforced by retrofitting; will lead to improved seismic-resistance evaluation of existing structures; and has a potential for incorporation of more reliable standards in the building codes.

Formulation and Expression of Seismic Design Provisions; *Steven J. Fenves,* Carnegie Mellon University, Department of Civil Engineering, Pittsburgh, PA 15213; $5,177 for 6 months beginning April 14, 1978.

The National Bureau of Standards and the Applied Technology Council (ATC) have conducted an NSF-funded project on the development of comprehensive seismic design provisions. A preliminary draft of the design provisions was released to a wide range of professional, business and industrial groups. The draft represented the work of a multidisciplinary team to resolve the major technical issues involved and to express the technical content of the provisions on a consistent basis.

The objective of this project was to assist the ATC project to the maximum extent possible in the preparation of the final document, and to provide domumentation of the logic of the final text by publication of the formal representation of the provisions embodied in the ATC final report. A systematic study of the ATC draft was undertaken to insure that the basic premises of the entire development, suitability for adoption, ease of updating, and consistency of provisions are truly reflected in the final document. This documentation provides a reference for those who may adopt or update the Design Provisions. The study also provides alternate organization of the provisions to accommodate specific categories of users from various federal, state and local regulatory agencies and model code organizations.

Progressive Collapse of Transmission Line Structures Due to Dynamic Loads; *John F. Fleming,* University of Pittsburgh, Department of Civil Engineering, Pittsburgh, PA 15260; $74,445 for 24 months beginning April 15, 1978.

An electric transmission line is a structural system composed of individual towers connected together by conductors and ground wires. Unlike the commonly encountered structural systems for bridges and buildings, the force deformation relationship for such a system is highly non-linear under initial loading. This non-linearity results primarily from three factors. First, the individual conductors and ground wires exhibit a non-linear sag tension relationship which results in a changing axial stiffness with displacement of their ends. The actual deformed shape of any conductor, under the applied axial load,

is governed by its weight, length and applied tensile force. Second, the conductors are usually attached to the towers by means of suspension insulators which exhibit a non-linear change in angle of inclination with applied force. Third, the towers themselves can undergo large displacements, particularly since many utility companies are now introducing flexible steel poles as a replacement for the familiar stiff latice towers in both new and existing lines. The computed displacement at the top of a typical 130 foot high steel pole structure, under the static unbalanced loads due to broken conductors in the adjacent span, is on the order of eight feet. Changes in geometry of this magnitude could produce significant changes in the stiffness of the towers.

In order to perform a dynamic analysis of an electric transmission line, longitudinal impact forces it is necessary to develop force-deformation relationships for the individual components which must then be combined to form the stiffness for the total system. Since the system is non-linear, the stiffness will not be a constant but must be developed as a function of the deformed system.

This research will consist of an investigation to determine the displacements and forces in electric transmission line structures resulting from loss of support of the wires in a span. A typical cause of this loss of support could be a foundation failure in a tower due to localized consolidation, slippage or other earth movements during wind or seismic disturbances. The actual cause of the localized failure is not significant; the important consideration is its effect upon the total system and in particular the possibility of a cascading failure.

The study will consist of the development of a mathematical model for determining the displacements and forces induced in the system; a parametric study to determine the effect of system variables upon the behavior; and the establishment of design criteria and procedures for electric transmission line structures for the longitudinal impact resulting from the breaking of any number of wires in a span and in particular for the total collapse of a support structure as a result of wind loads or seismic ground motions.

Research on the Use of Structural Foams to Improve Earthquake Resistance in Buildings; *Bernard L. Gabrielsen,* Scientific Services, Inc., 1536 Maple Street, Redwood City, CA 94063; $24,517 for 6 months beginning October 1, 1977.

Many buildings in areas of earthquake risk — at least 20,000 in Los Angeles alone — are not sound enough to withstand even a moderate earthquake. The problem is a national one, in that such structures occur throughout the U.S., and there is a reasonable probability that as many as 28 states can experience moderate earthquake accelerations.

This project will investigate the feasibility of using polyurethane foams to increase the shear capacity of timber stud walls and timber joist floors and ceilings, a technique that promises to be inexpensive relative to replacement costs. The work could lead to the development of inexpensive new building systems and elements incorporating foams.

The research will concentrate on developing foam placement techniques, documenting increases in strength due to foam, and determining the feasibility of developing new building systems and elements. The foams could effectively be incorporated into new building systems and elements and could provide many benefits at less cost than conventional construction materials and practices.

Scale Modeling and Testing of Structures for Reproducing Response to Earthquake Excitation; *James M. Gere,* Stanford University, Department of Civil Engineering, Stanford, CA 94305; $89,722 for 12 months beginning March 1, 1978.

Structural tests on dynamic earthquake simulators generally have been of two classes. Either the aim was to verify integrity for a small component or mechanical subsystem which could be excited at its full scale, or the data were intended to validate theoretical methods so as to improve the accuracy of analyses of civil engineering structures of various kinds.

Conventional methods for structural tests are generally expensive. Experience suggests that if a common material can be identified to construct scale models and to reproduce the elastic and inelastic behavior of structures, great savings can be achieved. In the case of expensive major structures, such replica model tests would provide a valuable and relatively in-

expensive complement to theoretical analyses. The objective of this proposal is to achieve a routine capability for simulating and reproducing on existing small-scale test facilities the earthquake response history of large structures. In view of the hazards posed by earthquakes to existing and future structures in many parts of the United States, successful completion of the proposed project on scale modeling tests could lead to avoidance of accidental deaths and injuries, savings in costs of repair or replacement and in earthquake insurance, and to improved reliability of service delivery systems.

Six interrelated research elements will be continued: (1) a comprehensive literature search, (2) synthesis and extension of modeling theory, (3) assembly of data on metallic construction techniques, (4) model construction techniques, (5) instrumentation methods development, and (6) construction and testing of prototype structures. This project will generate useful information for the engineering community regarding possibilities and limitations of replica modeling, and model construction and testing techniques.

Design of Splices in Reinforced Concrete Frames for Earthquake Effects; *Peter Gergely,* Cornell University, Department of Structural Engineering, Ithaca, NY 14850; $199,548 for 24 months beginning September 1, 1978.

Recent investigations have shown that reversed cyclic loading seriously affects the behavior of bar anchorages, but practically no information is available on the behavior of lapped splices subjected to this type of loading. Considering that recent studies have pointed out the strong similarity between splice and anchorage requirements for static loading, the strength and behavior of lapped splices will certainly be affected by reversed cyclic loading. These effects are probably even greater for splices than for straight bar anchorages.

This project will address the capacity of beam and column splices in reinforced concrete frames during seismic loading. The energy absorption capacity and increased flexibility produced by splice distress will be studied in detail. At the end of the two-year program the effects of the most important variables will be evaluated and design recommendations formulated. The performance of splices under high-level cyclic reversed loading will be compared with results of static monotonic loading.

The primary variables in the research program will include: splice length, cycle load level, loading rate, number of load cycles, reversal of load, distance between reinforcing bars, amount of transverse reinforcement, and bar size. Exploratory tests involving high shear and axial column forces and lightweight concrete will also be included near the end of the two-year period to assess the importance of these factors.

The research will mainly be experimental because the effects of loading rate, load cycling, and other variables cannot yet be evaluated analytically. Beam and column tests will be conducted but the loading conditions for them are not greatly different, therefore much of the information obtained for one type of test will be useful in the study of the other type of experiment. The main differences are the cross section of the members and the moment gradient. The sequence of loading will also be different in most tests.

Analytical studies will accompany the experimental program. These will include nonlinear dynamic analysis to aid in the design of load histories and evaluation of test results. A model of behavior will be formulated and design recommendations will be developed.

This investigation will also examine current code design provisions and will make new design recommendations in the light of the experimental research results.

Earthquake Resistant Design of Braced Steel Frame Structures; *Subhash C. Goel,* University of Michigan, Department of Civil Engineering, Ann Arbor, MI 48109; $152,500 for 24 months beginning December 8, 1977.

Braced multistory steel frame structures have gained popularity among engineers in recent years. Bracing members are considered to be effective earthquake-resistant elements because they provide necessary stiffness to help prevent non-structural damage due to moderate shaking and are a source of

energy dissipation during severe earthquake motions. The need for an understanding of the cyclic inelastic response of braced frame structures is not limited to earthquake resistance, but also to tornado winds and sea storms. The hysteresis behavior of bracing members is quite complex because it is influenced by buckling and yielding; thus, the computation of realistic inelastic dynamic response is more difficult for braced frames than for unbraced frames.

This project will perform an analitical study of braced frame systems subjected to earthquakes. Practical structural configurations will be investigated to determine their advantages and disadvantages utilizing an improved understanding of bracing behavior. Based upon these and past studies, design recommendations will be formulated and analytical procedures for the design of earthquake-resistant braced frame structures will be developed.

An analytical and experimental study of the hysteresis behavior of steel members subjected to combined cyclic bending and axial forces will be conducted. The results will help define the conditions under which the bending action is a primary effect and axial force is a secondary effect. The case when buckling dominates the member behavior and bending is secondary will be investigated as well as the intermediate range of conditions under which the member behavior may be significantly influenced by both types of action. The experimental program will be conducted to verify the theoretical results and to develop an understanding of the mechanisms and limits of failure for these types of members.

A Summer Institute on Multiprotection Design; *George T. Goforth,* Department of Defense, Defense Civil Preparedness Agency, Washington, D.C. 20301; $50,000 for 11 months beginning May 15, 1978.

The project consists of four independent one-week courses in seismic engineering, fire engineering, wind engineering, and energy conservation in building design. Attendees will be faculty from engineering and architectural schools. The objective is to disseminate research results to the faculty who are expected to include the material into the curricula at their institutions, and are encouraged to present similar short courses for the professional practitioners in their region of the country.

Influence of Nonstructural Cladding on Dynamic Properties and Response of Highrise Buildings; *Barry J. Goodno,* Georgia Institute of Technology, Department of Civil Engineering, Atlanta, GA 30332; $96,906 for 12 months beginning January 1, 1978.

In the past little attention has been paid to the effect of exterior cladding in multi-story buildings subjected to seismic forces. Recent studies have shown that the cladding may actually provide a considerable amount of resistance to low level excitation and thus help control interstory drift and building motion. Reports of cladding failures prompt us to ask whether or not the stiffness and energy absorption capacity of these elements can be used to advantage in modern building designs.

This research program is designed to assess the role of cladding systems in the structural performance of modern highrise buildings subject to earthquake forces. The research involves a balanced combination of analytical and experimental studies aimed at identifying the influence of heavy precast concrete and lightweight glass curtain wall systems on the dynamic properties and response of multistory buildings. A building will be studied during construction to determine its properties before, during, and after installation of the cladding. Analytical models for the cladding will be developed. Experimental results will be compared on a rational basis in order to calibrate the analytical models and to develop reliable data.

These studies represent an initial study at the problem of cladding-structure interaction, and are designed to put future follow-on studies on a firm analytical and experimental basis. The findings are expected to be of immediate use to designers in integrating the cladding into the structural design, but are also directly applicable to the problem of low level response which is largely linear. With experience gained in the linear problem, future studies of cladding-structure interaction which encompass both material and geometric nonlinearities and strong motion excitation are anticipated.

Urban Environmental Factors and Personal Well-being; *Robert M. Griffin,* Pennsylvania State University, Department of Human Development, University Park, PA 16802; $55,200 for 14 months beginning January 1, 1978.

Little is known about the effects of different urban environments on mental illness. Current research with regard to the relationship of urban environment to illness indicates that further advancement of knowledge may result from the use of the concept of "settings" to define urban environments, and inclusion of the concept of "predispositions" to explain variations in behavioral response to settings. An understanding of the causal process requires investigation of the psychological effects of interaction of behavior with urban settings, and the effects of psychological states on psychological and other responses.

The first working hypothesis of the proposed research is that individuals with predispositions to conformity seek support from their environment, while individuals with predispositions to self-direction seek control over their environment. This is only a working hypothesis; the research will determine whether or not predispositions to conformity and self-direction are the best concepts of behavior which is directed to obtaining support from or control over one's environment. It is possible that conformity and self-direction are only situation-specific manifestations of fundamental predispositions common to several traits. If so, concepts of predispositions will be substituted for those of conformity and self-direction.

The second working hypothesis is that a predisposition to conformity mediates between experiences with urban behavior settings and the psychological experience of social *support* or "social isolation", and that a predisposition to self-direction mediates between experiences with urban behavior settings and the psychological experiences of social *control* or "social press."

The third working hypothesis is that if individuals with predispositions to conformity experience frequent difficulties with social supports in their interaction with urban behavior settings, then they are likely to have a high sense of social isolation. If individuals with predispositions to self-direction experience frequent difficulties in social control in their interaction with these settings, then they are likely to have a high sense of social press.

The methods of research will consist of laboratory simulations of urban settings to develop measures of predispositions, followed by pilot studies to develop concepts and measures of objective attributes of environment. If these working hypotheses are supported by the research, the specific aim of the research will have been achieved.

This research is designed to lead directly to the identification of attributes that can be modified or created by urban planning and design. It may also indicate the relative importance of settings for the promotion of health. Thus, urban planners may be provided with new ways to conceptualize the environment at the level of organization most relevant to personal well-being.

Engineering Design for Natural Hazards; *William J. Hall,* University of Illinois, Urbana, Department of Civil Engineering, Urbana, IL 61801; $493,355 for 24 months beginning November 15, 1977.

This program of research is aimed at the development of simplified and improved methods of structural design to provide protection against natural hazards with special emphasis on protection against earthquakes. Design professionals are in dire need of simplified, conventionally applicable methods to analyze and design building structures for dynamic loads caused by earthquakes, wind, and other sources. This research has as its goal the development of such new and/or improved, simplified methods of design. The three interrelated areas in which work is planned are simplified methods of analysis and design for excitation arising from earthquake and wind, including consideration of ground motions and interaction effects; response of subsystems to dynamic forces and motions; and design of multi-degree-of-freedom systems subjected to dynamic loads and motions with special attention to inelastic behavior.

In-depth research will be conducted to improve knowledge in the foregoing areas with the goal of developing improved design approaches of a simple form that will be safe and economical. During the past few decades the attention of designers has been devoted to developing separate and distinct methods for approaching the design of structures and equipment subjected to earthquakes, winds, and other specific types of hazards. Many of these methods are

interrelated. Another goal of the proposed research is to develop consistent design methods for the various dynamic hazards.

In order to expedite the technology transfer, the information obtained as a result of the research will be translated into the form of criteria and techniques of direct practical usefulness to designers in industry, private practice and government, and made available to them as quickly as possible through papers, reports, presentations and code activities.

Behavior of Buildings to Wind and Seismic Forces; *Gary C. Hart,* University of California—Los Angeles, Department of Mechanics and Structures, Los Angeles, CA 90024; $183,814 for 36 months beginning March 15, 1978.

There is a scarcity of data on the response of high rise buildings to wind and seismic forces. This project will acquire data from several previously instrumented high rise buildings in Century City, Los Angeles. In this way we can obtain wind and seismic effects on a continuous basis and develop an understanding of the response of the building to each type of motion. Project objectives include response data collection, preparation and analysis, and harmonic testing and system identification of soil-structure interactions. The research will consist of several tasks involved with collecting the response data and analyzing it for practical application and code recommendations.

Tasks include conversion of recorded analog data to a digitized form, conversion of digital magnetic tape data from recorded kinemetrics format to IBM magnetic tape, cataloging each data event by number and description of the event, storing of master tapes, and providing for loan copies to practitioners and researchers. Analysis of data with respect to time and frequency domains will also be undertaken.

Harmonic Testing and System Identification of Soil-Structure Interaction will be conducted in three parts:

- a harmonic vibration test program will be conducted to measure soil-structure interaction;
- a literature search will be conducted of computer programs suitable for the required modeling, and the best existing model selected for this study; and
- a system identification problem consistent with the analytical model to correlate the harmonic test results with predicted model response will be formulated.

Contribution of Floor Systems to Earthquake Resistance of Steel and Concrete Building Frames; *Ti Huang,* Lehigh University, Department of Civil Engineering, Bethlehem, PA 18015; $151,865 for 12 months beginning January 24, 1978.

This study will investigate and evaluate the contribution of floor systems to the earthquake resistance of building structural frames. The cyclic behavior of various floor systems under in-plane shear and gravity loads will be studied. Since the results of this research are to be applied to the design of both concrete and steel tier buildings, the floor systems selected will be those which are most suitable (and frequently used) for these buildings. Based on a survey of current construction practice, they are:

For Concrete Buildings:

Flat slab directly supported on columns, including capitals,

Slab supported on edge and intermediate beams,

Slab with closely spaced joints in one or both directions;

For Steel Buildings:

Solid concrete slab with and without composite action with steel girders,

Concrete slab on metal deck, with and without composite action with steel girders.

Both analytical and experimental studies will be included:

Specific objectives include a critical review of the present state-of-the-art of our understanding of the behavior of floor systems in multistory building frames under earthquake loading; definition of the effectiveness (stiffness, strength, energy absorption capacity, etc.) of floor systems as load-transmitting diaphragms between vertical lateral load resisting systems; definition of the effectiveness of the floor

system as a main component in the lateral load resisting system where staggered systems are used; identification of the primary parameters controlling the behavior of floor systems subjected to repeated and reversing lateral loads; and development of improved design recommendations for building frames taking into account the contribution of floor systems in earthquake resistance.

Operation of the Universities Council for Earthquake Engineering Research; *Wilfred D. Iwan,* California Institute of Technology, Department of Engineering & Applied Science, Pasadena, CA 91125; $127,615 for 36 months beginning January 1, 1978.

This research project is for the support of the activity of the Universities Council for Earthquake Engineering Research (UCEER). UCEER was formed in 1965 to provide a vehicle for the free exchange of information on Earthquake Engineering-related university research plans, priorities and programs; and to assist in the coordination of university research efforts. UCEER organizes periodic national meetings of research investigators in Earthquake Engineering. These meetings consit of reports on current university research, panel discussions and working sub-group discussions on directions for future research. The proceedings of these national meetings are made available to all interested parties.

UCEER's principal activity is a national conference held every two years which provides a mechanism for the exchange of information in university research activities, plans, priorities, and programs. The Council also assists in coordination of university research efforts wherever possible.

All University research investigators with an active interest in Earthquake Engineering are welcome to participate in UCEER activities.

Behavior of Reinforced Concrete Frame Elements Under Biaxial Lateral Loadings; *James O. Jirsa,* University of Texas at Austin, Department of Civil Engineering, Austin, TX 78712; $492,051 for 36 months beginning March 1, 1978.

Research into the behavior of structural elements subjected to simulated seismic loading has concentrated almost exclusively on behavior under unidirectional lateral loading and compressive axial loads. The direction of lateral load coincided with a principal axis of the structure or structural elements. Some very limited recent studies indicate that the seismic response of structures may be quite severely influenced by biaxial lateral motions, as compared with uniaxial motions. In order to assess realistically the significance of biaxial lateral forces of movements on structural response, experimental studies are required.

A review of reported work on the behavior of structural elements, particularly columns and beam-column joints, indicates that data are limited to specimens subjected to alternating unidirectional lateral forces and to compressive column loads. There is a growing need for an evaluation of the importance of bidirectional loadings on seismic behavior. The limited data available from Japan on the influence of biaxial loadings indicates clearly that such loadings must be considered in the response of reinforced concrete structures. More experimental data is needed if the design and analysis of reinforced concrete frame structures is to include the effects of complex load histories.

This study is intended to lead to the development of design criteria for reinforced concrete members subjected to bidirectional lateral deformations and axial forces. Tests are proposed to evaluate the influence of constant levels of axial compression or tension as well as cyclic axial load in the presence of various lateral loading paths on the shear strength and hysteretic response of reinforced concrete members. The investigation is aimed toward providing information in areas in which data are currently not available. The objectives will be accomplished by evaluating the importance of the path of lateral deformation and sequence of application of bidirectional lateral loads on the shear strength and response of columns and beam-column joints; evaluating the influence of axial load variations on the behavior of columns and beam-column joints; developing design recommendations for such members; and developing behavioral models to be used in analysis of structures and to predict behavior for members subjected to large shear forces.

Comprehensive Building Analysis Computer Program for Earthquake Response; *Lindsay R. Jones,* Computech, Inc., 2150 Shattuck Avenue, Berkeley, CA 94704; $97,512 for 12 months beginning September 1, 1978.

The objective of this research is the development and dissemination of a comprehensive building analysis computer program for static and dynamic loads. Existing programs for building analysis fail to satisfy many of the practical requirements of the structural engineering profession. This is particularly true in seismic areas where current codes require the dynamic characteristics of a building to be considered in its design process. Most of the developments in structural analysis have been oriented toward more general, complex finite element programs that are not always suitable for building design.

To ensure that this computer program is relevant to the needs of the engineering profession, emphasis will be placed on gathering feedback from users of existing programs to determine the types of features which should be included.

Program features will be selected on the basis of their potential usefulness to practicing engineers. Those having little more than academic interest will not be included. To ensure practicality the user manual will be developed and the input/output designed before programming commences. The newly developed program will be as simple as possible. The content and format of the analysis results will be such that an engineer will perform a minimum number of additional calculations in the design process. The computer printout will be in such a form as to be readily included as part of a set of design calculations. The program will be presented in standard fortran which can be adapted to large computers of various makes. The input, calculations, and output will conform to the language and format of existing or proposed building codes. Computer programming techniques will be employed which allow flexibility to add new features and incorporate new code requirements at a later date. Finally, the cost of performing the computer analysis will be reasonable.

The computer program and relevant documentation will be made available for distribution through the National Information Service for Earthquake Engineering (NISEE) at the University of California, Berkeley. All firms that have obtained other building analysis programs through NISEE will be notified of its availability.

Research on a Rational Approach to Damage Mitagation in Existing Structures Exposed to Earthquake; *Ben Kacyra,* Earthquake Engineering Systems, Inc., 88 First Street, San Francisco, CA 94111; $20,095 for 6 months beginning October 1, 1977.

Earthquakes can cause many deaths and injuries and major property damage. Other natural disasters have seasonable characteristics or accepted permonitory signs which permit credible warnings to be issued, saving both injury and loss of life as well as lessening property loss. Recent developments in earthquake prediction indicate that during the next quarter century, and possibly sooner, earthquake prediction will become a useful technique in our society. The degree of usefulness will depend on society's ability to utilize the prediction to decrease potential loss from the forecasted earthquake. At present, individuals responsible for structures exposed to earthquakes are without the tools necessary to decide how and what to do to mitigate their expected loss due to a predicted earthquake.

This project will undertake a feasibility study of developing a rational desision analysis methodology for evaluating possible modification schemes for existing buildings exposed to a predicted earthquake. The research tasks include determination of the reliability of earthquake prediction, classification of types and extent of damage, and evaluation of possible structural modification schemes. The study will be focused on older, low-rise commercial, industrial and residential buildings.

Research on Mitigation of Seismic Hazards in Existing Unreinforced Masonry Wall Buildings; *John Kariotis,* Kariotis Kesler & Allys, Inc., 1414 Fair Oaks Avenue, South Pasedena, CA 91030; $24,391 for 6 months beginning October 1, 1977.

Existing buildings with unreinforced masonry walls constitute a major hazard to life is seismic areas. Many of these structures were constructed prior to adoption of building codes which required seismic resistance to be considered in design. Some were constructed in geographical areas which did not require seismic design and are now shown to have the potential for significant ground shaking.

Research will be directed toward analysis and assessment of the performance of existing structures incorporating undesigned elements and reinforced masonry walls. It will develop simple analytical methods for identifying response to ground motion of construction materials and methods used throughout the United States. Changes in response caused by modification of structural elements will be investigated. Performance of currently used strengthening modifications will be evaluated. New methods for revising performance of undesigned and unreinforced elements will be proposed.

It is anticipated that this research will provide a means to identify buildings which require strengthening, evaluate the performance of strengthened structures, and identify existing buildings that will have adequate performance with minimal retrofitting. This research will provide technical information for urban areas now attempting to mitigate the hazard of existing buildings using unreinforced masonry, and if such recommended retrofit programs can be shown to be cost effective it will encourage general acceptance of these programs.

Summer Seismic Institutes for Architectural Faculty; *Earle W. Kennett,* American Institute of Architects, 1735 New York Avenue, N.W., Washington, D.C. 20006; $141,000 for 10 months beginning April 15, 1978.

The AIA Research Corporation will organize, administer and conduct two one-week summer seismic institutes for architectural faculty. The goal of the institutes is to educate faculty from architectural school in those design elements which impact the seismic safety of buildings and other architectural features.

Each institute will be conducted for approximately fifty faculty members from architectural schools during August, 1978. Two separate institutes will be held. A West Coast institute is proposed to be held at Stanford University in California. The second institute will be held at the University of Illinois in Urbana, Illinois.

Dynamic Wind Loads on Buildings; *Bernard M. Leadon,* University of Florida, Department of Engineering Sciences, Gainesville, FL 32611; $59,611 for 12 months beginning June 1, 1978.

The objectives of this research are to obtain full-scale dynamic wind measurements and to compare these with predictions of theories for the interaction between turbulent winds and obstacles; to examine the relation between small-scale wind tunnel studies and full-scale structures to estimate the dynamic response of structures under lateral loadings of low frequency; and to estimate the convective film heat transfer coefficient for smooth surfaces in curtain walls.

The plan for achieving these objectives consists of three parts: (1) measurements on a full-scale building and on a nearby TV tower, (2) ¼-scale model tests of the effects of external mullions upon curtain wall pressures and skin fraction, and (3) theoretical analysis of random lateral loads and resulting structural deflections. Three years were spent in developing a velocity, pressure, strain and deflection data acquisition system which monitors the building's surface pressures in real time and at many points on the building's surface simultaneously and collects these data on magnetic tape.

The building which is under study is the Independent Life Tower (ILT) in Jacksonville, Florida. The location of ILT is excellent in that two entirely different terrain roughnesses exist immediately to its north and south. ILT has an entirely glass curtain wall exterior. The geometry and surface finish of ILT are ideal from the standpoint of making an accurate wind tunnel model.

The results of this research will be made available to the American Society of Civil Engineers, the

American Meteorological Society, the American Institute of Architecture, the American Society of Heating, Ventilating and Air Conditioning Engineers as well as various pollutant control organizations and, of course, to the Wind Engineering Research Council and the American National Standard Institute's code revision committee.

Sequential Optimization of Structural Geometry; *Ovadia E. Lev,* Merritt Cases, Inc., 710 Brookside Avenue, P.O. Box 1206, Redlands, CA 92373; $49,901 for 15 months beginning September 1, 1978.

This investigation is aimed at determining the validity and correctness of a basic procedure in design for optimum geometry of structures — that of sequential optimazation with fixed and variable node coordinates. Conclusions drawn from this study will clarify the nature of geometry interaction with other design variables, thus opening the way to a unified approach to other important aspects of optimum design.

The problem of shape optimization is a complex one. While a backlog of accumulated research exists, very little has been utilized by the practicing engineer. This fact may be attributed to the highly theoretical results obtained, to unfamiliarity with sophisticated techniques, high costs and the difficulties in programming many important, nonquantifiable design factors. Nevertheless, certain features and results of optimization have proved successful and are slowly being accepted in professional practice, especially as guides in preliminary design.

The investigation of sequential optimization, involving the basic interaction of geometry, will be a main objective of this research. Optimum design of trusses and frames under single and multiple loading conditions will be analyzed. It is hoped that the results will lead to a unified and integrated approach to optimum design.

United States/Republic of China Cooperative Research in Earthquake Engineering; *Le-Wu Lu,* Lehigh University, Department of Civil Engineering, Bethlehem, PA 18015; $42,000 for 12 months beginning August 14, 1978.

This cooperative research program in the field of earthquake engineering between the United States and the Republic of China is under the sponsorship of the United States — Republic of China Cooperative Science Program, which is administered jointly by the National Science Foundation and the National Science Council. The cooperative program is divided into two parts, Part I, a program between the University of California, Berkeley (UCB) and the National Taiwan University (NTU) and Part II, a program between Lehigh University (LU) and the National Taiwan University. The objective of this cooperative program is to study fundamental subjects in both siting and design and to obtain technical information which will benefit both countries.

This project between LU-NTU deals with earthquake resistance and strengthening of concrete buildings with foundation settlement and partial structural damage. This problem has become a major concern to engineers because of the increase in height of new buildings. Both analytical and experimental studies will be conducted to investigate the earthquake response and the strength, stiffness, and damage characteristics of such structures in an effort to develop useful information to improve engineering design and practices.

Workshop on Wood Diaphragms and Development of a Wood Manual; *Ronald L. Mayes,* Applied Technology Council, 171 Second Street, San Francisco, CA 94105; $132,871 for 18 months beginning July 1, 1978.

A horizontal construction carrying forces in its own plane is referred to as a diaphragm. Diaphragms are used in virtually all types of construction but are especially important for wood buildings where the structural systems are principally assemblies of diaphragms in the form of joist floors, raftered roofs, and stud walls. Although diaphragms are utilized to carry gravitational as well as lateral in-plane forces, they are used primarily to resist the horizontal forces resulting from wind and earthquake action. If

diaphragms are properly designed and fabricated, they can eliminate much of the diagonal bracing that would otherwise be required.

The objective of this project is to develop a comprehensive, nationally applicable document summarizing current technology and practice for the design of horizontal wood diaphragms. The project will summarize current knowledge and practice in horizontal wood diaphragm design through implementation of three tasks: compilation of a bibliography and summarization of all literature on test results and design recommendations presently available; development of a report summarizing the technology of wood diaphragm design practices including engineering analysis methods, example analyses, and typical construction details; and, identification of additional research that might be conducted to improve wood diaphgram analysis and design practice.

A second objective will be to identify and outline additional research that might improve horizontal wood diaphragm design and performance. This objective will be met by conducting a workshop to develop current standards of practice and to enumerate areas requiring additional research.

Reliability of Existing Buildings in Earthquake Zones — Part II; *Hugh D. McNiven,* University of California — Berkeley, Department of Civil Engineering, Berkeley, CA 94720; $46,900 for 24 months beginning November 18, 1977.

One of the major concerns in Earthquake Engineering is to develop means by which existing buildings in earthquake zones can be appraised in terms of how they might respond during an earthquake. The first step to make the problem tractable is to study not an existing building but an experimental frame that includes many of the characteristics of an existing building. The frame can be subjected to any simulated earthquake motions that might be appropriate.

This project is addressing this latter task, that is, the development of a realistic method to evaluate the seismic reliability of existing structures. The method consists of constructing mathematical models truly representing the linear and nonlinear behavior or building structures by performing shaking tests and utilizing the System Identification techniques, establishing the "limit states" or "failure criteria" of structures, and determining the reliability of structures by subjecting the structural models to a family of earthquake excitations. The project requires a joint effort by the University of California, Berkeley and Purdue University. Berkeley's effort will be in the development of mathematical models by the System Identification approach and testing the physical frame models on the shaking table. Purdue's effort will be on the formulation of reliability criteria and the analysis of test results in terms of damage probability and other probabilistic response measures.

The user group that will benefit from the proposed research is the structural engineering profession, especially those who practice in seismic regions. Engineers have long been aware that partitions have significant influence on the response of a structure to earthquakes, but have been unable or reluctant to assign numerical evaluation to this influence. The System Identification program should assist greatly in this evaluation. A second benefit pertains to knowledge of the beginning and progress of damage that could imperil safety. The proposed research should be immensely helpful in predicting under what loading and conditions danger to safety begins.

Seismic Behavior of Multistory Masonry Structures; *Hugh D. McNiven,* University of California— Berkeley, Department of Civil Engineering, 1301 So. 46 Street, Richmond, CA 94720; $102,300 beginning November 21, 1977.

Masonry construction is used extensively for housing and office buildings. Such structures are particularly susceptible to earthquake damage because of their relatively low shear strength and moment resistance as compared to steel or reinforced concrete structures. To reduce the potential life loss and property damage associated with masonry structures due to earthquakes, research will be performed to gain better understanding of the seismic behavior of masonry structures and to develop improved design methods for such structures.

The principal subject of the experimental work is the seismic shear resistance of window piers in multistory masonry buildings. Both single and double pier test program and diagonal splitting tests will be conducted to study the stiffness and strength of the piers and their parametric variation. Correlation study of these data will be performed, and the behavior of typical spandrel girders in multistory construction will also be investigated.

The purpose of the project's analytical research effort is to correlate the experimental results with predictions of various mathematical models. Work during the project period will be aimed toward further refinement of the modelling technique to better represent masonry as a periodic material, and then toward evaluation of effective material properties which may be used in the design of masonry structures.

A series of technical reports including computer programs will be published by the Earthquake Engineering Research Center, University of California. The technical series will be disseminated to the researchers and practicing engineers through NTIS, NISEE, EERI, and other channels. Technical papers will also be prepared for publication in various professional journals. Means and ways to interact with practicing engineers to implement the research results in seismic testing, design and construction of structures will be actively pursued. The research results will be provided to ATC code provisions development teams for incorporation in the proposed seismic design provisions.

The Masonry Institute of America (MIA) fully endorses this project and has provided partial support of labor and materials for construction of the test specimen. The research findings of the project will be channeled directly to MIA, so that revised design and construction practices of masonry structures can be made.

Wind Load Provisions for Safe Design of Structures; *Kishor C. Mehta,* Texas Tech University, Department of Civil Engineering, Lubbock, TX 79409; $81,780 for 18 months beginning July 15, 1978.

Buildings and other facilities can be subjected to severe dynamic lateral loads from winds and possibly earthquakes during their service lives. These effects should be considered in a coordinated way, as design decisions related to one type of loading may have an important effect on response due to other types of loads.

The purpose of this project is to develop design guidelines for wind load provisions for buildings and other structures. The basic wind load provisions contained in the American National Standards Institute A58.I-1972 standards are currently being revised and updated and will be republished in 1980. The guidelines are intended to explain the methodology utilized in the American National Standards Institute Wind Load Provisions, to explain the wind-structure interaction phenomena covered by the standard, and to provide concise and easy to read examples showing how to apply the A58 standard to the design of different types of structures. The availability of the design guidelines will promote the use of improved wind design procedures and will help mitigate building damage due to wind.

A Symposium on the Structural Use of Wood in Adverse Environments to be held in Vancouver, British Columbia: May, 1978; *Robert W. Meyer,* Washington State University, Society of Wood Science and Technology, Materials Science and Engineering, St. Louis, MO 63130; $28,233 for 12 months beginning January 15, 1978.

This research will support a symposium to bring together available published information about effects of extreme environments on the structural use of wood, design considerations for using wood in extreme environments and methods for analyzing residual strength of wood members and wood structures following severe loading or environmental conditions that have caused or are suspected to have caused reduced strength.

Information presented at the symposium included literature reviews by invited speakers, practical experience of wood technologists and engineers in meeting design problems or analyzing behavior of wood members and wood structures subjected to extreme environmental conditions, new research on topics outlined in the symposium organization plan, and ideas gathered from symposium attendees on where to go next — additional research, value of a

subsequent symposium on a particular topic, etc.

To ensure maximum availability of information generated at the symposium a proceedings volume which includes discussion questions and answers in addition to papers presented at the symposium was compiled. The symposium volume should be of great value to designers of wood structures, particularly for natural hazard considerations such as wind, earthquake, flood and snow loads.

Dynamics of Structures with Localized Nonlinearity; *Richard K. Miller,* University of California—Santa Barbara, Department of Mechanical and Environmental Engineering, Santa Barbara, CA 93106; $35,000 for 24 months beginning November 15, 1977.

Nonlinear structural behavior is of primary concern in the design and analysis of structures subjected to strong ground motion. In the most general case the nonlinear behavior is distributed throughout the structure. However, in some important applications the nonlinear behavior is restricted to one location within the structure. Examples of such locally nonlinear systems include adjacent structures with a flexible seismic connection, buildings with a flexible first story, and equipment mounted on flexible supports. In this project, analytical studies will be conducted to investigate the dynamic behavior of structures with localized nonlinearity.

The objectives of this project are to:

- formulate a simplified analytical model for a class of locally nonlinear structures,
- extend and apply feasible existing approximate methods,
- study the steady-state and stationary stochastic responses of such structures,
- develop methods for determining the transient response of such systems, including wave propagation effects, and
- perform numerical analysis and illustrate the practical applications.

Approximate analytical techniques which are made tractable by the localization of nonlinear behavior will be used. By isolating and analyzing the nonlinear element separately from the remaining linear system, the equations of force balance at the connections may be written. By using well-known properties of linear systems, either transfer function or impulse function representations may be used to decompose the linear system forces into the sum of passive, receptance-like forces and active, loading-dependent forces. The approximation enters by replacing the nonlinear restoring force by an appropriately-chosen equivalent linear force. The particular choice of equivalent linear force will depend on whether the excitation is harmonic, stochastic, or transient. The response of the resulting equivalent linear system is then determined by standard techniques. For a system containing one linear element, the response is governed by H single nonlinear algebraic y standard techniques. For a system containing one linear element, the response is governed by a single nonlinear algebraic equation which may either be solved numerically in specific examples or analyzed mathematically to reveal general conclusions concerning the response. This general procedure may also be applied to the case of wave propagation through a nonlinear boundary condition between elastic bodies.

The results of the proposed research will be of interest primarily to researchers in earthquake engineering and structural dynamics, but also to designers and practicing engineers.

Unified Approach to the Design of Window Glass Subjected to Dynamic Loads; *Joseph E. Minor,* Texas Tech University, Institute for Disaster Research, Lubbock, TX 79409; $113,012 for 12 months beginning April 15, 1978.

The process which produces glass window designs in 1977 is based upon tests and methodology that were developed in the late 1950's and early 1960's. The dramatic increase in the use of glass panels in curtain walls, much improved understandings of wind effects on buildings, and the availability of new, computer related analytical methods combine to suggest that the 20-year old window glass design process should be reviewed and modified where appropriate.

Initial assessments of the problem suggest the appropriateness of a program of research and profes-

sional education/extension in the window glass design area. The objectives of this proposed program are: the utilization of windloads on buildings to develop a tractable approach to the design of glass windows for dynamic hazards; relation of new approaches to the design of glass windows to current professional practice; assessment of potentials for integrating newly developed understandings into practice; and appropriate initial steps toward exposing new approaches to the profession and integrating new understandings into the glass design process.

Research objectives will be addressed through theoretical formulations and experimental work directed toward the development of a tractable design process. Theoretical formulations which treat relationships between load, stress, and failure for a wide range of plate geometries form the basis for the first part of the research plan. Experimental work will provide input data to theoretical formulations, as well as data for verification of the analytical processes. The results of theory and experiment will be used to produce a new design process that is based upon relevant aspects of glass response.

The objectives of this project include the important task of moving research results to professional practice. Forums for information exchange will include technical meetings, extension courses, publications, academic programs, symposiums and seminars.

Conference on Masonry Design and Construction for Seismic Effects; *James L. Noland,* Atkinson-Noland and Associates, Inc., P.O. Box 3611, Boulder, CO 80303; $36,047 for 9 months beginning June 1, 1978.

Research and development in masonry design and construction has been inhibited due to the lack of a forum dedicated to the objective and impartial discussion and advancement of masonry technology. This project will organize and conduct a conference for the exchange of concepts, information, and experience in areas related to masonry usage including materials, design, construction, quality control, codes and standards, education and training, manufacturing, energy considerations and other topics at the levels of research, current practice, and future needs. Conference participants will include professional engineers and architects, state, Federal and local government officials, and representatives of universities, industry, trade organizations and others. The utilization of the conference results will be extended through the publication and dissemination of copies of the conference proceedings. Copies will be distributed to engineering and architectural schools, national and local trade organizations, building officials, state and federal agencies, and other interested organizations.

National Information Service for Earthquake Engineering; *Joseph Penzien,* University of California—Berkeley, College of Engineering, Berkeley, CA 94720; $401,377 for 16 months beginning December 14, 1977.

The National Information Service in Earthquake Engineering (NISEE) is a national focus for information on earthquake engineering data, projects and research reports. The success of NISEE during its first years affirms that a center of this type is urgently needed, and is bieng effectively used by the professions. NISEE provides for the transfer of earthquake and other hazards information generated through research to the public users. Collected and assessed information from many different sources provided by a single, efficient source to researchers and users in the field, NISEE is geared to meet the needs of both academic researchers and design engineers at the national level. Its computer program distribution service now has a total of 33 programs, each fully developed and suitable for use in professional engineering offices. New programs will be added to the library and made available for distribution as they are developed. The Earthquake Engineering Research library will maintain collections of reports (both published and unpublished), site visit records, data acquired from various seismic regions, and provides an abstracting service and a technical journal directed to the needs of earthquake engineers.

The NISEE project has now entered a new performance period after the successful initial development and experimental services stage. The emphasis will be on service expansion covering a much broadened users group concerning the natural hazards and on more dynamic pursuit of research utilization.

Seismic Behavior of Structures: Analysis and Design; *Joseph Penzien,* University of California—Berkeley, Department of Civil Engineering, Richmond, CA 94720; $260,300 for 24 months beginning November 14, 1977.

Advanced experimental and analytical investigations are needed to provide a better understanding of seismic performance and modes of failure of structures. Such investigations will be directed toward the development of improved seismic analysis and design methods and application of these methods in practical situations.

This project will develop improved seismic analysis capabilities and apply them in structural design to achieve increased reliability of controlling seismic damage and costs. In this project, concentrated efforts will be devoted to a number of needed analytical areas in order to increase the reliability of controlling seismic damage according to acceptable criteria. The research findings from two other Berkeley projects, i.e., "Seismic Behavior of Complete Structures" and "Seismic Behavior of Structural Components", will be used and synthesized in this project to develop improved analysis and design capabilities for earthquake-resistant steel and reinforced concrete structures.

The following specific research tasks will be conducted: Analytical Studies of Building Response; Soil-Structure Interaction Effects in Building Response; Development of Nonlinear Structural Analysis Techniques; Probabilistic Studies of Seismic Response; and Analytical Methods for Design. These tasks are technically interrelated and each will supplement the others so that the overall project objectives can be achieved.

The United States-Japan Cooperative Research Program on Large-Scale Structural Systems: A Planning Study; *Joseph Penzien,* University of California—Berkeley, Department of Civil Engineering, Richmond, CA 94720; $65,700 for 24 months beginning November 16, 1977.

Traditionally engineers have relied heavily on technical capabilities with theory and computers to develop concepts for design of structures to resist earthquake forces. Many of these concepts have evolved from post-inspections of earthquake damage and laboratory simulations. As beneficial as these concepts are there are many factors which cannot be evaluated by inspection or small scale tests.

The results of these small scale tests could be verified by full size structural tests to evaluate the time behavior in a structural system. A program to extend the tests to full size structures to determine the parameters which can not be evaluated otherwise would be most desirable and beneficial to the engineering profession.

This project has developed an effective research program of maximum benefit to both United States and Japan on large-scale test of structural systems. A task committee established under the U.S.-Japan Panel on Wind and Seismic Effects, U.S.-Japan Natural Resources Program is responsible for making detailed plans and recommendations on such a program.

Plans include a cooperative research program in earthquake engineering with emphasis on large-scale testing which concentrates on controlled dynamic testing of full-scale buildings in the field and laboratory testing of large-scale building systems to ensure the maximum benefit to both countries.

Seismic Behavior of Precast Curtain Walls in High Rise Buildings; *Dale C. Perry,* Washington State University, Department of Civil/Environmental Engineering, Pullman, WA 99163; $73,332 for 18 months beginning May 1, 1978.

This research will provide direct insight into design procedures, analytical modeling techniques, and full-scale performance evaluations of curtain wall assemblages subjected to earthquake loadings. Emphasis of this investigation will be placed on the generation of full-scale static and dynamic characteristics of curtain wall assemblages essential to the development of analytical models suitable for predicting curtain wall and structural frame interaction for high rise buildings subject to earthquake excitation. An extensive survey of the types of connections most commonly employed in contemporary

buildings to attach precast curtain wall panels to the primary structure will be made. Full-scale laboratory studies of selected connection details will be conducted to determine static and dynamic characteristics and susceptibility to low-cycle fatigue. Full-scale laboratory test of "selected" curtain wall assemblages will quantify dynamic response characteristics. Analytical models suitable for predicting curtain wall participation with the structural frame for various levels of excitation will be developed. Comparison will be made of reported full-scale building response measurements with mathematical model predictions.

Results will be presented at the completion of the study in a special seminar hosted by the investigators for members of the architectural, engineering and academic communities, along with persons from local government and the building construction industry.

Research on Methodology for Mitigation of Seismic Hazards in Existing Unreinforced Masonry Buildings; *C. W. Pinkham,* S. B. Barnes & Associates, 2236 Beverly Boulevard, Los Angeles, CA 90057; $25,000 for 6 months beginning October 1, 1977.

Unreinforced masonry buildings in seismically active areas have been singled out by building officials as particularly hazardous, due to their record of damage in even moderate earthquakes. Most were built before the development of seismic design criteria. This project will review past work on this subject and plan the additional research, analysis and testing required to determine the need for hazard mitigation and methods to retrofit existing unreinforced masonry buildings.

To assist the building official and building owner in their attempts to mitigate the hazard posed by unreinforced masonry buildings within economical limits, the need exists for design methods for determining the need for hazard mitigation and methods of retrofit where feasible. The design methods must be applicable to the particular structural conditions of unreinforced masonry buildings, their earthquake response, and to the seismicity of the particular area. These variables along with the risks and economic factors would be formulated for the use of those administering the safety requirements of a community.

Fire Resistance of Epoxy Repaired Concrete Structures; *Joseph M. Plecnik,* California State University at Long Beach, Engineering Research, Long Beach, CA 90840; $91,816 for 24 months beginning May 1, 1978.

Reinforced concrete and masonry structures which have been damaged by earthquakes and/or wind are usually repaired by filling the cracks with one of several epoxy materials. Structures thus repaired are essentially restored to original strength levels. However, preliminary fire exposure tests indicate that thermal degradation and charring may occur. More data on the extent of the degradation is required.

This research will determine the data required for the proper use of epoxy materials for repair of structures, with concentration on behavior of epoxy adhesives at elevated temperatures, behavior of epoxy repaired structures during and after fire exposure, analytical studies to correlate with test data, and structural analysis and computer catalog of repaired structures in California.

An experimental program has been developed using small-scale specimens and culminating with standard fire tests. The experimental results will be used to develop appropriate fire ratings for epoxy repaired structures.

The results of this research program will be useful to government agencies such as the U.S. Navy, VA, and Corps of Engineers in determining the behavior of epoxy repaired structures during and after fire exposure.

Seismic Behavior of Structural Components; *Egor P. Popov,* University of California—Berkeley, Department of Civil Engineering, Berkeley, CA 94720; $482,800 for 24 months beginning November 14, 1977.

One of the major goals of earthquake engineering is predicting the inelastic response of structures subjected to severe earthquake excitation. Considerable effort has been devoted to development of computer

programs for performing such analyses; however, very early in the development of these programs, it became apparent that our ability to perform nonlinear structural analyses greatly exceeded our understanding of the seismic behavior mechanisms of structural elements and components. Much more detailed information on the actual damage performance of such components is needed before reliable computer predictions can be made.

A general approach to structural response analysis is to model each of the members of components comprising the complete structure and then to mathematically assemble these component models so that they simulate the behavior of the complete structure. Toward this end experimental and analytical studies of the behavior of structural components are needed. This proposal will continue the experimental work on relatively large-scale components of structural systems, will incorporate the experimental results into the mathematical modeling development efforts, and will correlate the experimental results with calculated results to develop broadened capabilities for analyzing the inelastic behavior of structural components under seismic conditions.

This project consists of five interrelated study programs. All studies will proceed independently and simultaneously. Study tasks include (1) Braced steel frames — evaluate the ductility and load resistance of simple K-Braced frames, (2) Reinforced concrete walls and infilled frames — develop practical methods for earthquake design of combined ductile frame and infilled frame/wall systems (3) Reinforced concrete ductile frame — obtain additional knowledge on the behavior of reinforced concrete beams, beam-column components, and (4) correlation computer program — develop and apply computer programs for analyzing the inelastic behavior of isolated structural components. The results of the experimental work will be used as the basis for the construction and verification of mathematical modeling of structural components. The analytical work and experimental efforts are complementary so that the capabilities for analyzing the inelastic behavior of structural components can be broadened.

Seismic Behavior and Design of Buildings; *Jose M. Roesset,* Massachusetts Institute of Technology, Department of Civil Engineering, Cambridge, MA 02139; $264,835 for 24 months beginning January 15, 1978.

This project will improve our knowledge of the nonlinear dynamic behavior of buildings subject to earthquake excitation and the effectiveness of various design procedures. The nonlinear behavior of structures under dynamic loading has been a topic of renewed interest recently. The emphasis of this work has normally been to obtain a better understanding of the characteristics of inelastic response and to develop procedures to assess the potential damage to a structure for a given class of motions.

This project performs a more comprehensive evaluation of various definitions of ductility used at present in dynamic analysis programs, assessing their physical meaning and their relation to expected structural damage. Two different definitions of ductility are commonly used, one based on rotations, the other on moments. Both definitions yield the same result for a member in bending (without axial forces) loaded in an antisymmetric fashion. When the moments at both ends are not equal, which will happen in particular if one accounts for gravity loads, the results are no longer identical. When the member has in addition axial loads the meaning of these ductilities is even more questionable.

The effect on nonlinear structural response of earthquake characteristics such as duration of strong motion and intensity, measured by the maximum ground acceleration, will be studied. Different design procedures, particularly those recommended by present codes, in terms of the behavior of the resulting frames and the expected level of damage under various earthquake motions will be evaluated. If alternate design procedures or recommendations to ensure the adequacy of the behavior are required, they will be developed. Researchers will evaluate further some of the complex models used at present for special structures, such as nonlinear finite element models for reinforced concrete structures.

Seismic Behavior of Precast Curtain Walls in High Rise Buildings; *Ronald L. Sack,* University of Idaho, Department of Civil Engineering, Moscow, ID 83843; $63,692 for 18 months beginning May 1, 1978.

This investigation consists of a broad program of full-scale laboratory studies and companion analytical investigations to explore the nature of curtain wall participation in the total structural response characteristics of high-rise buildings subjected to seismic excitation. Primary emphasis of this effort will be placed on the generation of full-scale test data for specific curtain wall assemblages in order to quantify the constitutive relationships for precast concrete cladding systems commonly employed in comtemporary structures.

Objectives include an extensive survey of the types of connections most commonly employed in contemporary buildings to attach precast curtain wall panels to the primary structure; full-scale laboratory studies of selected connection details to determine static and dynamic characteristics and susceptibility to low-cycle fatigue; full-scale laboratory tests of selected curtain wall assemblages to quantify dynamic response characteristics; development of analytical models suitable for predicting curtain wall participation with the structural frame for various levels of excitation; and comparison of reported full-scale building response measurements with mathematical model predictions.

It is anticipated that completion of the research will provide direct insight into design procedures, analytical modeling techniques, and full-scale performance evaluations of curtain wall assemblages subjected to earthquake loadings. Special attention will be given to developing channels of communication for the continual exchange of information and ideas with other researchers and practitioners.

Feasibility of Force-Pulse Generators for Earthquake Simulators; *Frederick B. Safford,* Agbabian Associates, Experimental Mechanics, 250 N. Nash Street, El Segundo, CA 90245; $420,594 for 24 months beginning May 15, 1978.

The objective of this research is to support the mitigation of earthquake hazards of existing and new structures by providing a new type of dynamic structural testing system. In seismically active areas, potential structural damage represents a significant hazard that could be reduced through an improved understanding of dynamic structural response. This new testing system will allow dynamic tests of full-scale structures, three-axes excitation, validation of computer models by direct tests, direct examination of structural response to a spectrum of dynamic loads, and proof testing of real structures.

This new simulation method consists of an array of force-pulse generators that are placed on a structure with each pulse unit programmed to produce a particular series of force pulses. A different set of excitation forces is applied at each of several different locations, driving the structure to match a precalculated response. By replacing continuous earthquake-type excitation with an equivalent waveform, the structure can be induced to respond as closely as possible to the criterion response.

This objective will be accomplished by a comprehensive program in which laboratory test systems will be constructed and then validated by simulation of earthquake motions on structures. Validation will move progressively from linear single-axis response to three-axes response in the nonlinear/structural damage range of structures.

Improving Earthquake Resistance of Elevators; *Anshel J. Schiff,* Purdue University, Department of Mechanical Engineering, Lafayette, IN 47907; $143,882 for 24 months beginning February 15, 1978.

The purpose of this project is to provide information needed to improve the earthquake resistance of elevators through an improved elevator code. Through comprehensive research current safety codes commonly used by the elevator industry can be improved. The proposed research will lead to improved understandings of elevator guide rail performance, the seismic loads on elevator systems and the dynamics of elevator cable systems.

The proposed work consists of an analytical investigation of three key problem areas concerning elevator safety: guide rail design of elevator cars and counter weights; determination of seismic forces on

elevator systems, and analysis of cable dynamics. In addition, a study on the evaluation of the best location of seismic trigger location and on the minimization of false triggers will be conducted.

This research is being done in conjunction with industry through the code-writing body, so that results of the research will be available to users as they become available.

Distribution of ATC-3 Report, Tentative Seismic Design Recommendations for Buildings; *Roland L. Sharpe,* Applied Technology Council, 480 California Avenue, Suite 205, San Francisco, CA 94105; $22,476 for 18 months beginning April 1, 1978.

This project distributed approximately 5000 copies of the report, "Tentative Recommendations for the Use in Development of Seismic Regulations," to professional organizations, libraries of engineering and architectural schools, model code agencies, trade associations, and local and state building officials for their application and to generate comments, suggestions, revisions, and additions.

The document is a concensus of current knowledge in the aseismic design of buildings, and therefore introduces many new concepts of analysis, design, and construction. The document represents the efforts of 85 participants throughout the United States and is the result of approximately three years of intensive effort.

Testing of Tentative Provisions for Seismic Regulations for Building; *Roland L. Sharpe,* Applied Technology Council, 480 California Avenue, Suite 205, San Francisco, CA 94105; $56,720 for 6 months beginning August 1, 1978.

The development of a report on tentative provisions for seismic design of buildings will bring together in one document extensive material concerning seismic risk, seismic analysis and design of buildings. The report will include structural and nonstructural components, evaluation of potential hazards in existing buildings, assessment of earthquake damage to buildings, abatement of hazardous conditions, and repair and/or strengthening of earthquake damaged buildings. The report will form the basis for an orderly, continuing updating of seismic provisions and development of earthquake engineering research.

There are many new and/or modified concepts in the tentative provisions which are significantly different from those in existing seismic building codes. This project will test the understanding and applicability of the provisions by engineers and architects. Because of the many new concepts and procedures involved, the provisions should not be offered for code adoption until detailed comparative designs of actual buildings are made to test their workability, practicability, enforceability, and potential economic impact.

ATC will conduct a study to develop and plan a program for making comparative test designs of buildings and for testing the viability and applicability of seismic hazard abatement and building repair and strengthening procedures presented in the ATC-3 tentative provisions. The test designs will be made by practicing engineers who were not participants in the development of the provisions. The study group will coordinate with counterparts from Canada who are planning a parallel effort to make comparative designs of a representative group of buildings using the new Canadian Building Code and the ATC-3 tentative provisions.

The results of testing will be submitted to the ATC-3 project steering group, and necessary changes and revisions to the ATC-3 document will be issued to code promulgating groups, governmental agencies, professional organizations, and industry for their review, use and/or comments.

Workshop on Seismic Resistance of Highway Bridges, San Francisco, California, October, 1978; *Roland L. Sharpe,* Applied Technology Council, 480 California Avenue, Suite 205, San Francisco, CA 94105; $83,685 for 6 months beginning August 1, 1978.

Highway bridges are vital elements of transportation systems and their commercial, industrial, educational, recreational, municipal, health and welfare and other activities or services. When an earthquake occurs, a bridge may be damaged or destroyed, causing disruption of the transportation system. The loss of vital links during the time required to repair or replace the disrupted area can magnify the effects of the disaster.

As a result of the 1971 San Fernando earthquake, the Department of Transportation of the State of California revised its earthquake design criteria in 1973. The resulting document with modifications was adopted in 1975 as an Interim Specification by the American Association of State Highway and Transportation Officials (AASHTO). In 1977, the Applied Technology Council (ATC) evaluated the 1975 AASHTO Interim Specification and developed new and improved seismic design criteria.

The objectives of this workshop were to evaluate the current state of knowledge and practice for the seismic design of bridges and to determine needs and priorities for future research and development. The workshop also provided an opportunity to define the current state of knowledge and seismic research needs on an international basis as well as providing an opportunity for collaborative code development work between Japan and ATC. A definition of future research needs will be of use in establishing research priorities. International definition of the current state of knowledge will ensure that code development efforts consider all the research data currently available.

Seismic Behavior of Irregularly-Shaped Low-Rise Buildings; *David T. Tang,* SUNY State University at Buffalo, Department of Civil Engineering, Buffalo, NY 14260; $52,034 for 24 months beginning February 15, 1978.

Low-rise unsymmetric buildings such as hospitals, schools, industrial plants as well as apartment and office complexes can undergo inelastic, coupled translational and torsional motion when subjected to earthquakes excitations. The precise nature of seismic behavior of such buildings still is not yet adequately understood because past research efforts were concentrated on high-rise structures. As a result there is currently little analytical basis from which design guidelines for low-rise buildings of arbitrary shape can be established for practicing engineers.

This project will conduct a comprehensive investigation of the inelastic, coupled earthquake behavior of low-rise buildings by establishing the mathematical models characterizing such behavior and the interaction with building members. Finite element computer programs will be developed based on such models and dynamic analysis will be performed to identify the governing seismic design parameters and to establish the design and analysis guidelines for such structures. Design recommendations will be made to aid the engineers and building officials who are concerned with implementation of codes of practices concerning low-rise buildings in active seismic regions.

Automatic Digitization of Accelerograph Records; *Mihajlo D. Trifunac,* University of Southern California, Department of Civil Engineering, Los Angeles, CA 90007; $40,500 for 24 months beginning September 27, 1978.

This program represents the final phase of a continuing research effort in earthquake engineering instrumentation during the period from June, 1973 to the present. It is hoped that this project will revolutionize the speed and accuracy of digitizing strong-motion accelerograms.

An automation digitization system consisting of a rotating drum scanner and a complete computer interactive system will be built at the University of Southern California. This capability will provide an accurate, convenient and fast way to digitize accelerograph film records. Implementation of such a system will significantly extend the life of the simplicity and reliability of this accelerograph type.

Plans will be made to coordinate work with efforts at USGS so that a broad base enabling wider deploy-

ment of the complete digitization system in this country and over the world can be established. The program will accomplish the major goals of the original grant and will also provide a platform for further developments and contributions to the national earthquake engineering research as well as to international efforts toward a more complete and expedient data collection and exchange arrangement.

Evaluation of Seismic Safety of Buildings; *Erik H. Vanmarcke,* Massachusetts Institute of Technology, Department of Civil Engineering, Cambridge, MA 02139; $112,617 for 12 months beginning January 27, 1978.

This research will evaluate and compare possible ways of representing predicted ground motion and three associated methods of seismic analysis, each utilizing a different representation of the ground motion: (1) time-integration analysis, using one or more real or artificial earthquake motions; (2) the response spectrum approach utilizing modal analysis and an envelope of possible ground motion effects on one-degree oscillators; and (3) random vibration analysis in which the entire problem is treated statistically. In all cases there are uncertainties both in the specification of input and the evaluation of the computed response. Within the profession there is disagreement as to which of the three approaches is most appropriate for design purposes. Although the emphasis will be on linear analysis, nonlinear systems will also be considered. The aim is to identify and fill in gaps of knowledge as needed to accomplish the principal objective, which is, to establish procedures to determine the overall safety provided by seismic design, considering the variability in both the prediction of ground motion and in structural analysis and design. The study is expected to yield valuable practical information on the required variation in load factors to provide a consistent seismic safety by different procedures, and also on the effect of load factors on safety.

Prediction of Earthquake Resistance of Structures; *Ping Chun Wang,* Polytechnic Institute of New York, Department of Electrical Engineering and Electrophysics, Brooklyn, NY 11201; $68,060 for 12 months beginning May 3, 1978.

When a structure is designed for earthquake resistance, the first major problem is to select an appropriate time history of ground acceleration as the design load. One way is to select the worst possible excitation from a class of admissible functions for the specific structure under consideration. The theory of worst or "critical" excitation, and methods of analysis for elastic structures have been developed in previous studies. This project will convert the critical excitation method into a fully implemented design tool. The research will enhance the usefulness of the method and make it applicable to structural design and analysis problems that can now be solved only with considerable difficulty.

This project is directed at full implementation of current methodologies for elastic structures, and with complete development of theories and design methods for inelastic structures. The research tasks to be carried out include development of critical response spectra; development of computer programs; establishment of procedures for the choice of representative design variables; and design implementation for elastic and inelastic structures. Design charts, computational aids and computer programs will be developed in forms that can be directly used by the practicing engineer.

Four fundamental methods are being pursued to specify the ground motion input at a site. These are: (1) the build-up of a catalogue of measurements, (2) the construction by use of seismologic models, (3) the application of stochastic modeling to form classes, and (4) the minimax procedure dependent on the type of structure. This project is the only undertaking to date under the fourth concept.

Earthquake Design Criteria for Water Supply and Wastewater Systems; *Leon W. Weinberger,* Environmental Quality Systems, 1160 Rockville Pike, Rockville, MD 20852; $99,961 for 8 months beginning April 1, 1978.

Water supply and wastewater disposal are two elements of the "lifeline" network of systems which sustain life and welfare in populated areas. Water supply is directly related to life support, and wastewater disposal in an effective and efficient manner will minimize the hazard to public health and the spread of disease during the after earthquakes. Earthquake resistive design and siting of such lifeline facilities has been recognized as a critical national need. This area has received little attention in the past from the research community. It is necessary to develop appropriate planning and design criteria and to test these in future earthquakes for efficacy in mitigating hazards.

The objective of this project is to analyze and assess past earthquake events with a view to developing a set of interim design and engineering analysis criteria to be used in the water supply and wastewater control fields in two ways: first, to reduce or eliminate damage to water supply and wastewater disposal systems during earthquake events, and second, to promote rapid recovery from damage to these vital systems, and to minimize interruption to their functions after an earthquake event. Both pre-quake and post-quake analysis will be conducted.

The primary task of this project is to develop a set of earthquake planning and design criteria for the following major elements: (a) wastewater treatment plants and appurtenances, (b) water supply treat ment plants and appurtenances, (c) sewers and water collection systems, (d) water supply distribution systems and pumping stations, (e) subsurface waste disposal systems, and (f) land disposal systems.

The study is expected to result in the following: a listing of the key or critical components in water supply and wastewater systems; a discussion of the fuctional aspects of each of the components in terms of the operational integrity of the whole system, and an estimate of the relative impact of failure of each component on the integrity of the system; and an analysis on how the component may be re-planned or redesigned for hazards reduction. A handbook or manual will be prepared containing the results of each of the analyses. The result of this project will be of interest to practicing engineers, public works managers and regulatory agencies. The results of this study are expected to have national significance and a widespread impact on the planning and design of water supply and water pollution control systems.

Analysis of Cape Ann Earthquake from Building Damage; *Robert V. Whitman,* Massachusetts Institute of Technology, Department of Civil Engineering, Cambridge, MA 02139; $94,159 for 18 months beginning February 1, 1978.

In New England, the largest historical seismic event has been the earthquake of 1755 which occurred off Cape Ann, Massachusetts. Seismologists have studied the damage caused by the 1755 earthquake and have rated the intensities along the Massachusetts coast in terms of the modified Mercalli scale — and have disagreed as to the maximum intensity. Estimates of this maximum intensity have ranged from VII to IX.

Though there are numerous accounts of damage resulting from the earthquake, this damage must be interpreted in terms of the structures and materials present in 1755. This program of research intends to address that problem in three phases:

- assessment of damage reports, location and identification of representative buildings;
- evaluation of contemporary 1755 construction which sustained damage; and
- establishment of the relationship of damage reported to the estimation of actual ground motion at specific sites.

The estimation of seismic risk in the eastern United States is complicated by the lack of recorded ground motion data from significant historical events. The detailed study of damage experienced by contemporary structures will allow for better estimates of probable ground motion parameters. By clarifying the intensity of shaking experienced in 1755, the research will lead to substantially improved confidence in estimates for seismic risk in New England. At a later date, the same approach may be applied to other earthquakes — such as that in South Carolina in 1886 — which have occurred prior to the use of earthquake recording devices.

Development of Earthquake and Other Natural Hazard Damage Assessment Procedures for Existing Structures; *John H. Wiggins,* J. H. Wiggins Company, 1650 So. Pacific Coast Highway, Redondo Beach, CA 90277; $146,543 for 15 months beginning March 1, 1978.

The objective of this research is to provide a computerized method for evaluating the damageability and consequent life safety of existing as well as new structures under earthquake, wind and tornado loads. A particular objective of the research will be to provide engineers with a three-dimensional program which will allow assessment of potential damage under earthquake, wind and tornado loads from input parameters obtained from a simple building survey.

The starting point for the research will be an existing program based largely on two-dimensional analysis. The program will be upgraded, updated and "checked" by a group of experts working in the earthquake and wind fields. The program will model the seismicity of the geographic region in which the structure is located, the soil conditions, the framing and non-structural portions of the building. For wind the program will model tornado, hurricane and extreme wind probability as a function of geographic location. Factors such as shape, height, and structural resistance capacity by floor will be included. The program and associated manuals and documentation will be made readily available to all interested parties.

Summer Institute on Design for Protection Against Natural and Man-Made Hazards; *Bernard Wobbeking,* American Society for Engineering Education, One Dupont Circle, Suite 400, Washington, D.C. 20036; $8,000 beginning March 15, 1978.

A two week summer Institute was conducted to orient and qualify selected architectural and engineering faculty participants to teach university faculty and practicing engineers and architects concerning the technical aspects of analysis and design methods to mitigate the losses due to natural hazards such as earthquakes, extreme winds, fire, and effects of nuclear blasts as they affect soil and structure response. The institute was held for 50 students at the Defense Civil Preparedness Staff College, Battle Creek, Michigan, August 15-26, 1977.

The objective of the Institute was to disseminate current research data and developments in the design of structures to resist the effects of earthquakes and other natural hazards.

Reliability of Existing Buildings in Earthquake Zones — Part I; *James T. Yao,* Purdue University, Department of Civil Engineering, Lafayette, IN 47907; $45,200 for 12 months beginning November 18, 1977.

One of the major activities in Earthquake Hazards Mitigation is to develop means by which existing buildings in earthquake zones can be appraised in terms of how they might respond during an earthquake. The subject of reliability is a general one and there are many criteria for reliability. The first step to make the problem tractable is to study not an existing building but an experimental frame that includes many of the characteristics of an existing building. The frame can be installed on the Earthquake Simulator at the Earthquake Engineering Research Center at the University of California, Berkeley and subjected to any simulated earthquake motions that might be appropriate. The intensity of the motion can be gradually increased. The measured response of the frame will demonstrate the earthquake-resistant capacity of the frame, and therefore the "reliability" of the building which the frame represents.

This project will investigate the earthquake reliability of existing buildings by constructing accurate mathematical models (both linear and nonlinear) based on System Identification techniques, testing the mathematical models using shake-table experiment data, and studying the reliability of existing buildings both analytically (based on the mathematical models) and experimentally (based on the physical frame model and shake-table tests).

The project requires a joint effort by the University of California, Berkeley and Purdue University. Berkeley's effort will be in the development of mathematical models by the System Identification approach and testing of physical frame models on the shaking table. Purdue's effort will be on the formulation of reliability criteria and the analysis of test results in terms of damage probability and other probablistic response measures.

The proposed research represents a workable first step in gaining insight into the seismic reliability problems of existing structures. This research will provide the basis for formulating effective and realistic counter measures to mitigate damage and losses associated with non-engineered existing buildings in seismic areas.

POLICY

Communities differ significantly in their planning for and response to earthquakes and other natural hazards. Some have undertaken few or no protective measures, while others have adopted useful preparedness, land-use and building construction strategies. The *Policy* program in Fiscal Year 1978 supported research on the social, political, economic, and legal adjustments units of society and government can make to earthquakes and other natural hazards. Research was supported on protective measures such as disaster planning and preparedness, land-use planning, insurance, building codes and standards, and relief and rehabilitation programs and services. In addition, public information and education efforts were developed and evaluated so that relevant knowledge could be effectively diseminated to user groups and decisionmakers.

Longitudinal and Cross Cultural Study of the Post Impact Phases of a Major National Disaster: the February 6, 1976, Guatemalan Earthquake; *Frederick L. Bates,* University of Georgia, Department of Sociology, Athens, GA 30602; $223,520 for 12 months beginning June 23, 1978.

In 1974 the U.S. Government spent $135.5 million on twenty-two foreign disasters, which affected 14 million people. In the following year the comparable outlay was $156.4 million on twenty-seven foreign relief operations that affected 50 million people.

The February 6, 1976 earthquake which occurred in Guatemala killed more than 22,000 people, injured in excess of 76,000 and rendered about a fifth of the nation homeless. Damages were estimated to be about a third of the nation's gross national product. More than 30 nations responded with various forms of relief. U.S. A.I.D. spent $25 million on disaster relief for Guatemala, during the first twelve month period, and voluntary contributions exceeded $36 million. Informed judgments on the need for better coordination of these and other humanitarian responses is needed.

The project is designed to answer these general questions: How successful has the delivery of disaster relief in meeting the immediate emergency? How did the manner in which U.S. aid was delivered affect the recovery process? How have disaster relief and rehabilitation programs affected and been affected by ongoing development programs and projects sponsored by the U.S., as well as local efforts? How have cultural differences affected the success of the relief, and how can the research findings on these questions, and others be used to develop guidelines for use by U.S. public and private agencies concerned with present and future disaster mitigation, and to improve the delivery of disaster relief?

Dynamic Response Analysis of Offshore Platforms; *Jack G. Bouwkamp,* J. G. Bouwkamp, Inc., 1930 Shattuck Avenue, Berkeley, CA 94704; $109,624 for 12 months beginning March 1, 1978.

Oil and gas exploration and production offshore the U.S. has long been confined to water depths of not more than a few hundred feet. Production platforms were commonly designed as steel, trussed, multi-legged towers built from circular tubular members. In the design of these structures the dynamic forces due to waves and currents were typically represented as a set of equivalent static loads.

As offshore exploration moved into deeper waters and into regions with high seismicity, analyses assuming static equivalent load conditions were no longer appropriate. The proposed study addresses itself specifically to evaluating the joint stiffnesses and incorporating them into an effective accurate model formulation for three-dimensional dynamic response analysis. This research project will develop a com-

puter program for the three-dimensional analysis of the dynamic response of tubular framed offshore platforms to earthquake and/or wave loads taking account of the flexibility of the tubular joint regions. The effect of joint flexibility can have a substantial influence in the behavior of the structure and, in the past, this effect has been generally ignored in practice in each of the analytical techniques used in the solution of such problems.

The results will improve the safety design of offshore structures, which will benefit the entire structural engineering profession as a whole and the oil industry in particular. The research will also provide the much needed information for government regulatory bodies concerning the environmental and engineering design safety aspects of offshore exploration activity by the oil industry.

Invitational Workshop on Comprehensive Emergency Preparedness to be held in Denver, Colorado: April, 1978; *A. Berry Crawford,* Institute for Policy Research, 3333 Quebec Street, Denver, CO 80207; $14,632 for 6 months beginning March 1, 1978

There is at present a heightened interest in emergency preparedness in this country. Local and State officials have identified a need for the Federal government to examine its approach to emergency preparedness and the provision of emergency services to disaster-struck communities. Senators Percy and Proxmire have introduced a bill which would centralize Federal emergency preparedness and disaster programs. The Office of Management and Budget has undertaken a study of the key Federal disaster agencies for the purpose of identifying needed organizational and task changes. This workshop will provide an opportunity to take advantage of this interest in preparedness.

The three co-sponsors of this workshop — the Institute for Policy Research (IPR) of the Western Governors' Policy Office, the National Governors Conference (NGC), and the Council of State Planning Agencies (CSPA) — see this as a forum to enable the states to strengthen their capacity for managing emergencies and for interfacing more effectively with local and Federal disaster Officials.

Four case studies of emergencies will provide the background for the workshop on comprehensive emergency preparedness which will be held in Las Vegas, Nevada in January, 1978. The selected case studies are the 1976-77 drought, the 1971 San Fernando earthquake, the 1976 Big Thompson Flood and the 1977 winter fuel shortage.

Workshop participants will examine the concept of comprehensive emergency preparedness, define local, State and Federal emergency preparedness roles and responsibilities, and develop recommendations and follow-up actions for strengthening local, State and Federal emergency preparedness capabilities.

Study of the Role of the Mass Media in Disaster Reporting; *Charles E. Fritz,* National Academy of Sciences, 2101 Constitution Avenue, N.W., Washington, DC 20418; $147,549 for 12 months beginning September 1, 1978.

The mass media play a key role in influencing the behavior of the public and responsible officials with regard to disaster mitigation and preparedness programs, disaster predictions and warning, rescue, and relief and rehabilitation activities. Sometimes news media coverage provides people outside an impacted area with the only information on which they can make decisions about the provision of disaster aid and relief. On the negative side, the media have been a major source of myths about disaster response. In spite of the importance of the mass media, up to now no comprehensive effort has been made at integrating research findings and policy issues or at assessing the potential of the mass media's role in programs aimed at mitigating the effects of disasters, promoting disaster preparedness, and helping in the recovery and rehabilitation stages.

The specific objectives of this study are to

- review and analyze existing knowledge on the role of the mass media in disaster reporting, especially as it refers to hazard reduction and mitigation, warning, impact, emergency operations, recovery, rehabilitation and reconstruction, and to different types of natural and man-made disasters;
- to trace and interpret the sequence of steps taken by different media for gathering, selecting, and disseminating information about pre- and post-

disaster activity;

- to increase our understanding of the existing relations between news media, scientific organizations (private, governmental, and university), governmental agencies, and the public;
- to describe and assess the potential of the mass media's role in educating the public concerning programs aimed at mitigating the effects of disasters, promoting disaster preparedness, and helping in relief and rehabilitation;
- to suggest possible changes in media strategies and operations to contribute to a better understanding by the population of the essential characteristics of pre-and post-disaster activities, and to assist disaster-related organizations in the dissemination of information about programs for coping with various kinds of hazards during different pre-and post-disaster time periods; and
- to identify the research topics that need to be given priority attention and to propose the most effective ways in which such research should be executed.

This study will be conducted under the supervision of the Commission on Socio-Technical Systems, National Academy of Sciences — National Research Council over a two-year period. The work will be carried out by a committee selected for their professional and scientific expertise in fields related to the mass media, disaster preparedness, relief and rehabilitation, and disaster research. This interdisciplinary committee will include representatives from the various mass media of communication, experts in the field of communication policy, social scientists, and disaster research and operations specialists. The first year's activity will focus on the review of existing knowledge on the role of the mass media of communication in disaster reporting, the organization of a workshop, the construction of a model on the structure and policies of news organizations in different media, and on the identification of research priorities and relevant methodologies. The second year's activity will be based on the issues identified and on the priorities defined in the initial year. After completion of the first six month's activity, the committee will specifically identify and define projects to be undertaken during the second year and the appropriate methodologies to utilize research results.

Community Response to Natural Hazard Warnings; *Robert K. Leik,* University of Minnesota, Department of Sociology, Minneapolis, MN 55455; $492,899 for 12 months beginning April 25, 1978.

Prompt and appropriate responses of individuals, families, organizations and communities to disaster warnings are essential if lives are to be saved, injuries minimized and property losses reduced. This three year project will provide information on how families and organizations in communities at risk to hurricanes, tornadoes, floods and earthquakes perceive, prepare for, make decisions on, and respond to disaster warning.

This research is designed to clarify how warning responses are related to content and timing of message; interorganizational relations; incongruity between normal and emergency relations; predisaster planning; individual decisions, and social and economic constraints.

This first phase of the research involves development and pretesting of interview data from households and organizations in four communities. Controlled laboratory experiments are an integral part of the project. First, experiments will determine the adequacy and appropriateness of questions to be asked in field interviews; later experiments will aid in interpretation of field data. Twenty-one communities will be studied during the second year. Community households and organizations will be studied prior to each hazard season and studies of the same will be restudied after a warning/impact has been received.

Earthquake Risk and Damage Functions — An Integrated Preparedness and Planning Study for Central USA; *Ben Chieh Liu,* Midwest Research Institute, Department of Economics, Kansas City, MO 64101; $105,493 for 12 months beginning January 15, 1978.

Earthquakes are truly a nationwide hazard. Thirty-nine states are in seismic zones of either moderate or major risk, although California and a few other Western States recieve most of the attention. Little

research, either by seismologists, earthquake engineers or social scientists, has been conducted on many of the very high risk areas east of the Rocky Mountains. This is true, for example, of the New Madrid seismic zone, even though it has experienced some of the most severe earthquakes ever recorded in this country.

This 12 month study focuses upon the seismic threat in the Central or Midwestern Region of the United States where the New Madrid seismic zone is located. On the basis of historical seismicity, four sites of potential earthquakes have been selected for study. Three are in the New Madrid zone and the fourth is in Central Oklahoma, near the site of a 1952 earthquake. The objectives of this research are to develop a body of information on major earthquakes in the Central Region, particularly for the sites selected as case studies; to develop intensity on isoseismal maps for the four sites so that intensity valves can be related to damage values; to construct a simulation model so that various physical damage functions can be estimated and converted into economic damage values; to evaluate existing preparedness policies and programs in the regions, and to make recommendations for more effective decisions for coping with earthquakes and other natural disasters.

Because of its focus on the Central Region of the United States, this study promises to broaden our understanding of the scope of the earthquake hazard in the country and to move us closer to the development of a national earthquake mitigation plan.

Seismic Safety Preparedness by Local Governments in California; *Dean E. Mann,* University of California—Santa Barbara, Department of Political Science, Santa Barbara, CA 93106; $118,265 for 12 months beginning June 13, 1978.

Earthquakes are a major threat in California. Estimates suggest that earthquake losses in the state could reach as high as $20 billion and thousands of deaths by the end of the century. Government officials in California need to develop seismic safety measures, including regulations, which govern the construction and location of structures, and which minimize property damage and human loss from earthquakes. They must also prepare to respond to community-wide disasters in the aftermath of serious earthquakes.

This study focuses on California because it is a seismically active area, and the state has taken some steps which offer significant opportunities to understand seismic safety planning. California has written several landmark pieces of earthquake legislation. For example, the Field Act, adopted in 1933, requires public schools to meet certain earthquake resistant standards; hospitals must meet special standards; and, since 1974, every California city and county must have a "Seismic Safety Element" as part of its general plan. Many local governments have also passed measures such as building codes to promote structural safety.

Still, the need for seismic safety must compete with other interests. Very real incentives exist for local governments to avoid enactment or enforcement of stringent earthquake-related laws. Little systematic research has addressed this import issue, although such research offers the possibility of substantial policy payoff. This project will focus on the following question: How do local governments address seismic safety issues when there may be serious economic, social and political pressures working against enactment and enforcement of potentially life saving and property protection laws? The specific objectives of the study are to understand the ways in which selected California cities differ in planning for the implementing seismic safety, and to define more effective strategies for planning and implementing programs for reducing seismic hazards in local communities.

Four communities in California, two with recent earthquake experience and two without, will be examined to ascertain the sources of resistance to adequate seismic safety planning. The two basic sources of information for the study will be interviews with key individuals and organizations in the four communities, and documentary data. Because of the exploratory nature of this study, the data obtained from such sources will be subject primarily to qualitative analysis and descriptive statistical analysis. This will lay the groundwork for future studies which will hopefully be able to establish statistically valid relationships between factors effecting seismic safety preparedness.

In addition to local decision makers, the involvement of the national, state, and regional governments in local planning will also be examined. The study will provide officials at all levels of government and in the private sector with improved understanding of the social, political and economic incentives for action or inaction, and alternative strageties for overcoming resistance to effective seismic safety planning.

Liabilities of Local Governments for Earthquake Hazard Reduction; *Terry R. Margerum,* Association of Bay Area Governments, Hotel Clairmont, Berkeley, CA 94705; $125,200 for 12 months beginning January 1, 1978.

Little is known about the incentives and disincentives for local governments to invest time and resources in hazard mitigation. We know very little about the extent to which existing laws facilitate or hinder the development of sound earthquake-mitigation strategies and programs by local governments in threatened areas.

Ambiguity and uncertainty about potential liability may inhibit the willingness of local governments to engage in certain types of hazard-mitigation activities. Such uncertainty results in part from a lack of clear precedents and a concern that earthquakes, because of their relative magnitude and infrequency, may be a special case. In addition to the issue of the liability of local governments, there is the question of the personal liability of public officers.

This project will address three major objectives: clarification of the nature and extent of local government's liability for property damage and personal injury resulting from failure to eliminate or mitigate known earthquake related hazards, failure to implement adopted policies designed to eliminate or mitigate earthquake-related hazards, and actions taken or not taken as a result of an officially certified earthquake prediction or warning; assessment of the impact of tort liability (currently and potentially) on the willingness of local governments to mitigate earthquake-related hazards; and, definition of alternative legislative and administrative strategies which help local governments better understand and deal with their potential liabilities in a manner supportive of their responsibilities to protect their citizens.

An interdisciplinary team with expertise in geology, planning, economics and law will be assembled to conduct the research over a twelve-month period in California and other selected states. Existing statutory law and relevant case precedents will be investigated and a survey will be conducted on current activities and strategies of local governments with regard to their perceived liability for earthquake-related hazards. Prior research and existing law on other natural disasters such as tsunamis, hurricanes and floods will be studied. Also, contacts will be made with key officials and organizations in areas which have experienced a recent earthquake.

The following types of groups have been identified as potential users of the findings and products of this project: local governments, especially those in highly earthquake-prone areas; state leagues of cities and counties; legislators from earthquake-prone states; state emergency services agencies; professional associations of architects, planners, structural engineers, geologists and lawyers; Federal agencies such as the Federal Disaster Assistance Administration; and state organizations such as the California Seismic Safety Commission.

Extensions and Utilization of Community Flood Model; *Louis W. Miller,* University of Pennsylvania, Department of Decision Sciences and Finance, Philadelphia, PA 19104; $192,930 for 12 months beginning March 15, 1978.

A computer-based community disaster model was developed to provide decision-makers with a sound basis for understanding the benefits and costs of alternative mitigation and recovery policies. The model takes advantage of modern interactive computing technology and was fashioned so that it could be modified for new situations and types of analyses. Individual homeowners are the basic units of analysis upon which the model operates. Attributes of homeowners can be acquired through field survey data or by sampling. The model focuses on financial implications of disaster and has modules dealing with damage production and financial characteristics of homeowners.

The general objective of the research is to extend the development and utilization of the model. The specific objectives of the study are to extend the specification of the financial impact of natural disasters on households. The role of financial institutions in disaster mitigation and recovery will be studied. With this information, data will be developed to determine effective ways to minimize the consequences of disaster. Also, the model will specify the relationships among various entities of a region in order to determine the impact of a natural disaster on the region's economy. This will permit regional planning for disaster mitigation and recovery.

The results of this project should be of interest to government agencies and private sector disaster-related groups charged with the establishment of disaster policy.

Dissemination of Information on Natural Hazards in the Urban Area; *Risa Palm,* University of Colorado, Department of Geography, Boulder, CO 80309; $104,397 for 18 months beginning September 1, 1978.

California has decided that real estate agents have a responsibility to inform buyers about earthquake hazards which are associated with a particular piece of property. In 1975, the Alquist-Priolo legislation was passed in California which requires that realtors or sellers disclose to buyers the location of property within the seismic study area, if it is so located. The legislation provides a suggested approach for the disclosure statement, but does not require that this particular approach be utilized nor that disclosure be offered at a definite time during the purchase process. This research will address two general issues: the effectiveness of the disclosure legislation and the relative merits of disclosure plans which vary in terms of method of presentation as well as timing in the signing of the purchase contract and the actual closing.

Specifically, the research will focus on the effects of alternative disclosure methods, how realtors respond to the disclosure requirement, and the effects of the behavior of real estate agents on decision-making by prospective home buyers. Real estate agents and recent home buyers will be surveyed within one of the board of realtor jurisdictions in the San Francisco Bay area. An initial group of home buyers will be interviewed on a face-to-face basis and the rest will be interviewed by telephone. Face-to-face interviews will be conducted with real estate agents. A monitored disclosure program will be set up in California to test the effectiveness of various presentation strategies.

The results of this research should prove useful to both state and Federal bodies which might want to consider legislation which requires real estate agents to disclose the existence of seismic, flood and other hazards to prospective buyers of a piece of property. In addition to the public officials and agencies, boards of realtors and real estate companies should also find the results of the study useful.

Factors Affecting the Design and Implementation of Community Disaster Evacuation Plans; *Ronald W. Perry,* Battelle Memorial Institute, Human Affairs, 4000 N.E. 41 Street, Seattle, WA 98105; $233,829 for 18 months beginning February 15, 1978.

Although evacuation can be an effective tool for saving lives, minimizing personal injury, reducing property losses, and minimizing social and economic disruption after a natural disaster, insufficient research has been conducted on individual decisions to evacuate prior to the impact of a disaster. The major objectives of this project are to integrate existing research findings on human behavior in evacuation into a theoretical model of social and psychological determinants of evacuation; operationalize the model and evaluate it on the basis of data on evacuation secured in three communities; examine policy issues in evacuations through feedback from evacuees; assess the role of community characteristics in the success of evacuation; and, identify factors that contribute to different degrees of community change following disaster.

Data will be collected in three communities and a model will be developed of the social and psychological determinants of pre-impact evacuation. The public policy implications of the model for natural hazards response will be determined and evacuee reactions to official evacuation programs will be assessed. Intended specific outcomes of the study include production of a theoretically and empirically grounded model of the factors effecting evacuation; development of guidelines for designers of community emergency plans; development of information regarding evacuee feedback which can be incorporated into future evacuation planning; and, establishment of data on the optimal use of evacuation as a management tool in response to natural hazards.

Social Behavioral Responses to Chemical Hazards; *E. L. Quarantelli,* Ohio State University, Department of Sociology, Columbus, OH 43210; $213,915 for 12 months beginning August 7, 1978.

Chemical disasters represent a serious threat to populations in the United States today. Tens of thousands of different chemicals are produced in this country each year. This creates major problems in the storage, transport, use and disposal of such products. It is likely that chemical disasters will increase in both frequency and magnitude in the future. In spite of the increasing threat of chemical disaster, little social science research has been conducted on the social, political, economic and other behavioral factors which effect emergency plans for responding to and recovering from chemical disasters. This study will be a first step in the specific investigation of the socio-behavioral aspects of technological disasters and the general study of the socio-behavioral aspects of technological disasters.

The research will involve three principal tasks: extensive exploration of organizational and community preparations for sudden chemical disasters in vunerable localities; in-depth study of the emergency time responses and problems in catastrophic events, major accidents, acute hazardous episodes and severe chronic events of a chemical nature; and longitudinal examination of selected cases of recovery from episodic and recurrent chemical disasters. As the study moves from one phase to another, findings will be reviewed with potential users.

This research should provide needed information on the socio-behavioral aspects of chemical disasters and identify policy, planning and procedural options with regard to chemical disasters. Groups which should find the results of this research useful include organizations with a major interest in health hazards related to the handling of chemicals, disaster planners, citizen organizations and scientific researchers.

State Government Policy Options for the Utilization of Earthquake Prediction Technology; *Hirst Sutton,* Council of State Governments, 1776 Massachusetts Avenue, N.W., Room 102A, Washington D.C. 20036; $86,930 for 7 months beginning August 23, 1978.

This project will examine public policy, legal, legislative and administrative issues related to the evolving technology of earthquake prediction, and will translate the results of this comprehensive examination for use in state and local government programs as well as programs for the private sector. Work on such programs must begin now so that there is a reasonable chance that the results will be in place and operational before the technology for earthquake prediction is developed and employed for a real event. The project will include consideration of programs and policies for the secondary effects of earthquakes, such as fire, flood, and tsunami.

There are seven component parts or tasks to the project: (1) determine the general nature of responsibility of state and local governmental bodies, officials, and agencies for validating earthquake predictions; (2) determine responsibility of governmental bodies, officials, and agencies for issuing public warning, including appropriate terminology and procedures; (3) identify and examine the legal, political, administrative, social and economic issues relating to the utilization of earthquake predictions; (4) analyze and evaluate the opportunities and need for policies and programs for hazard mitigation and for increased response readiness; (5) formulate alternative policies, programs, and planning guidelines, also approaches to developing possible state legislation relating to the utilization of earthquake prediction; (6) prepare documentation to aid consideration of suggested policies and actions by state and local executive and legislative officials; (7) based on the results of the work on the foregoing six components, determine the need for follow-up technical assistance to state and local governmental bodies, and officials, including the need for further research on policy and administrative issues, as well as establishing a continuing means for exchange of knowledge between the scientific community, public officials, and others dealing with earthquake prediction and related hazard mitigation programs.

The project staff will perform these tasks by convening a general conference of state and other public officials for the purpose of informing the conferees and exchanging views on such related issues as the state of the art of earthquake prediction and responsibilities and procedures for issuing earthquake warnings. Prior to the conference, three select committees will be established: (1) state Attorneys General, to address legal questions and possible present or future

need for state legislation; (2) state planning officials, to give special attention to mitigation opportunities and recovery programs; (3) state directors for disaster preparedness, to examine operational issues related to earthquake hazard warning and response. Policy position papers will be drafted and submitted for the consideration of the Council of State Governments, the National Governors' Conference, the National Conference of State Legislators, the National Association of State Attorneys General, the Council of State Planning Agencies, and the National Association of State Directors for Disaster Preparedness. A final report will be prepared summarizing findings, conclusions and recommendations applicable to state government actions and programs.

Community Response to Earthquake Threat in Southern California; *Ralph H. Turner,* University of California — Los Angeles, Department of Sociology, Los Angeles, CA 90024; $191,511 for 12 months beginning January 17, 1978.

The scientific community is on the verge of developing the capability to predict destructive earthquakes. In anticipation of this, there is a need to understand how people will respond to predictions so that effective public policy can be developed. This research attempts to meet this need by focusing on the community response to the Mojave Uplift along the San Andreas fault and other possible premonitory signs of a destructive earthquake. A sample survey of 1600-1800 residents of Los Angeles County will be conducted with periodic follow-up telephone interviews, direct monitoring of the mass media, and interviews with public and private leaders. The research will produce a history of community response to a prediction or near prediction, identify people's reception and understanding of reports of earthquake danger, coping steps they are willing to take, extent of their altruistic concern for others, their disposition to cooperate with hazard reduction programs, the process by which people decide about these matters, and the changing patterns of community response.

Natural Hazards Research and Applications Information Center; *Gilbert F. White,* University of Colorado, Department of Behavioral Science, Boulder, CO 80309; $130,394 for 12 months beginning April 12, 1978.

A Clearinghouse on Natural Hazards Research and Applications has been established and will greatly accelerate the exchange and use of information on natural hazards research, publications, findings, continuing and emerging research needs, meetings, conferences, primary and secondary data sources, and the responsibilities and the interests of disasters agencies and organizations at all levels in both the public and private sectors. Information on all of the above, as well as the identification of those who are supporting or conducting or expecting to conduct or support research on natural hazards, will be periodically disseminated through the publication and free distribution of a quarterly newsletter. The staff of the Clearinghouse will also provide quick turnaround responses to requests for information on the above. The staff director will maintain contacts with and keep informed on the information needs and interests of the senior staff and policy level officials of the various public and private disaster agencies and the relevant public interest groups. When urgent special needs and trends are established, conferences and symposia will be initiated. The Clearinghouse staff will plan and conduct an annual workshop on natural hazards for public and private disaster agency officials, their staffs, and the research community. At the end of the first eighteen months of the activity, the clearinghouse experience will be evaluated and recommendations for its future formulated.

Quick Response to Natural Disasters; *Gilbert F. White,* University of Colorado, Department of Behavioral Science, Boulder, CO 80309; $24,800 for 16 months beginning January 24, 1978.

This award provides support for the Natural Hazards Research and Applications Information Center in Boulder, Colorado. The purpose of the Information Center is to accelerate the exchange and use of information on natural hazards research, publications, findings, continuing and emerging research

needs, meetings, conferences, and data sources in the public and private sectors. Information on the above, as well as the identification of those who are supporting or conducting research on natural hazards will continue to be periodically disseminated through the publication and distribution of a quarterly newsletter, *The Natural Hazards Observer.* The staff of the center will continue to provide quick turnaround responses to requests for disaster related information. The Staff Director, Dr. Gilbert F. White, will keep informed on the information needs and interests of senior staff and policy level officials of the public and private disaster agencies, and of public interest groups. When urgent special needs and trends are identified, conferences and symposia will be initiated.

The Center's staff will plan and conduct an annual workshop and special seminars on natural hazards for public and private disaster agency officials, their staffs, and the research community. Before the end of this year the Center's experience will be evaluated and recommendations for the future of the program formulated.

In its third year, the Center began an experiment which provided for travel funds and per diem for researchers who wanted to carry out quick response on-site investigations of hazardous events. It is hoped that this quick response research will give new sociological insights into post-disaster decisionmaking and behavior.

NEW FISCAL YEAR 1979 PROGRAMS FOR PFRA

PFRA will initiate two applied research programs in Fiscal Year 1979.

Science and Technology to Aid the Physically Handicapped will support research on the use of the best available scientific and engineering developments to improve defective speech, visual, tactile, and hearing systems in those persons afflicted with these impairments, and also to find ways to overcome locomotion and manipulatory limitations. The program will involve researchers from any disciplines including biomedical engineering, medicine, law, and the social sciences working with the active participation of handicapped persons on these problems.

The second new program, *Human Nutrition,* will address some important nutritional concerns. An estimated 70 percent of the food consumed in the United States is derived from highly refined ingredients and is processed during manufacture with various additives and supplements. However, effects on human health and performance of the life-long consumption of such processed foods have not been determined. PFRA will support research on the assessment of the nutrient value of processed foods through investigations of the physical, chemical and biochemical changes which occur in these foods during cooking, processing, packaging and storage.

APPENDIX

THE DIVISION OF PROBLEM-FOCUSED RESEARCH APPLICATIONS — FY 1978 AWARDS*

Principal Investigator/ Institution	*Project Title*	*Amount**	*Effective Date/Award Duration*	*Page*
ALTERNATIVE BIOLOGICAL SOURCES OF MATERIALS				
	Program Total* $3,865,240			
Billy R. Allen Battelle Memorial Institute	Pretreatment Methods for the Degradation of Lignin	$85,730	9/1/78 9 months	5
A. W. Anderson Oregon State University	Semisolid Fermentation of Grass Straw	$13,145	5/8/78 12 months	6
Gary C. April University of Alabama	Chemicals from Wood by Organic Solvent Treatment	$129,800	6/15/78 24 months	6
Martha D. Berliner Simmons College	Fusion, Regeneration and Development of Algal Protoplasts	$53,995	4/1/78 12 months	7
Daniel M. Bragg Texas A & M University	Feasibility of Producing Natural Rubber from the Guayule	$130,874	9/15/78 15 months	7
Winston J. Brill University of Wisconsin, Madison	Enhancing Plant Productivity with Nitrogen-Fixing Bacteria	$216,600	4/13/78 12 months	8
Donald L. Crawford University of Idaho	Conversion of Lignocellulose by Actinomycetes Microorganisms	$99,076	9/15/78 24 months	8
Alexander Cruickshank Gordon Research Conferences, University of Rhode Island	Conference on Chemicals and Materials from Renewable Resources	$3,560	6/15/78 3 months	8
Irving S. Goldstein North Carolina State University, Raleigh	An Integrated Approach to the Conversion of Lignocellulose from Wood into Useful Chemicals	$159,205	6/12/78 12 months	9
Edward A. Grula Oklahoma State University	Insecticidal Activity of *Beauveria Bassiana*	$41,855	8/7/78 12 months	9
John Hachmann Collaborative Research, Inc.	Synthesis and Applications of Nucleic Acids to Biological Nitrogen Fixation	$229,967	9/26/78 18 months	9
Philip L. Hall Virginia Polytechnic Institute	Enzymatic Transformations of Lignin	$142,900	11/14/77 24 months	10
George P. Hanson California Arboretum Foundation	Breeding Improvement of Rubber Yield in Guayule	$90,390	3/1/78 12 months	10
George P. Hanson California Arboretum Foundation	Chemical Stimulation of Rubber Synthesis in Guayule	$55,896	5/1/78 12 months	17
Donald R. Helinski University of California San Diego	Enhancement of Biological Nitrogen Fixation by Genetic Manipulation of *Rhizobium*	$111,062	6/11/78 12 months	11
Bessel Kok Martin Marietta Laboratory	Biological Solar Energy Conversion: Approaches to Overcome Yield, Stability, and Product Limitations	$74,312	4/15/78 12 months	11
Marvin Lamborg Charles F. Kettering Research	A Multifaceted Approach to Enhancing Biological Nitrogen Fixation	$199,956	7/1/78 12 months	12

*NOTE: Dollar amounts refer only to funds provided by NSF in Fiscal Year 1978. Funding actions excluded from this Summary are Purchase Orders, Awards made using funds from other Federal agencies, and International Travel awards.

Principal Investigator/ Institution	*Project Title*	*Amount**	*Effective Date/Award Duration*	*Page*
Thomas A. Larue Boyce Thompson Institute of Plant Research	Workshop on Selecting and Breeding Legumes for Enhanced Nitrogen Fixation	$13,340	9/1/78 6 months	12
Gilbert V. Levin Biospherics, Inc.	Bioconversion of Saline Water	$25,000	10/1/77 6 months	13
James M. Lyons University of California, Davis	Enhancing Biological Production of Ammonia from Atmospheric Nitrogen and Soil Nitrate	$818,237	6/27/78 12 months	13
Akira Mitsui University of Miami	Production of Hydrogen by Marine Blue-Green Algae	$153,724	6/22/78 12 months	13
Dale M. Norris University of Wisconsin, Madison	Isolation of Lignocellulose — Transforming Microorganisms	$97,777	2/15/78 12 months	14
Peter J. Reilly Iowa State University of Science and Technology	The Conversion of Agricultural By-Products to Sugars	$119,735	4/11/78 12 months	14
Peter Schauffler Bio-Energy Council	Capturing the Sun Through Bioconversion — Conference II	$170,000	9/1/78 24 months	15
Karel R. Schubert Michigan State University	The Enhancement of Biological Nitrogen Fixation	$35,000	8/15/78 24 months	15
Fred Shafizadeh University of Montana	Pyrolytic Conversion of Lignocellulosic Materials	$177,000	7/15/78 24 months	15
James F. Shepard Kansas State University	Regeneration, Selection and Evaluation of Plants from Protoplasts of Potato	$99,600	2/15/78 12 months	16
Harry Sobel NEUS, Inc.	Renewable Resources — Enzyme Technology Digest	$93,600	4/15/78 36 months	16
Arthur A. Theisen Soil & Land Use Technology, Inc.	Feasibility of Introducing Food Crops Better Adapted to Environmental Stress	$24,919	10/1/77 9 months	16
Leo P. Vernon Brigham Young University	Incorporation of a Nitrogen-Fixing Organelle into Plant Cells	$125,062	5/31/78 12 months	17
Demetrios M. Yermanos University of California, Riverside	Development of Superior Cultivars of Jojoba	$113,585	7/1/78 12 months	17
Henry Yokoyama California Arboretum Foundation	Chemical Stimulation of Rubber Yield in Guayule (see George P. Hanson)			17

CHEMICAL THREATS TO MAN AND THE ENVIRONMENT

Program Total $3,183,966

Silverio P. Almeida Virginia Polytechnic Institute	A Water Pollution Monitoring Laser Systems	$93,711	11/1/77 12 months	19
Steven D. Aust Michigan State University	Workshop on Scientific Aspects of Polybrominated Biphenyls to be held in East Lansing, Michigan During October 1977	$9,100	10/15/77 12 months	20
John M. Bremner Iowa State University of Science and Technology	Natural and Fertilizer-Induced Emissions of Nitrous Oxide from Soils	$129,083	2/15/78 12 months	20

Principal Investigator/ Institution	*Project Title*	*Amount*	*Effective Date/Award Duration*	*Page*
Albert A. Caretto Carnegie Mellon University	The Development of a Method for the Detection of Sources of Organic Pollutants Using Carbon-Isotope Ratios	$115,000	10/1/78 18 months	20
David Chang Environmental Research and Technology, Inc.	Field Measurements of Biogenic Sulfur Emissions	$117,883	5/1/78 12 months	21
John M. Duxbury Cornell University	Soils as a Source or Sink of Atmospheric Nitrous Oxide	$110,112	8/15/78 12 months	22
David H. Fine Thermo-Electron Corp.	N-Nitroso Compounds in the Environment	$226,317	1/23/78 12 months	22
Paul O. Fromm Michigan State University	Effects of Pollutants on Gills of Freshwater Fishes	$26,311	5/17/78 12 months	23
Anil C. Ghosh Sisa, Inc.	Mycotoxins as a Potential Human Health Hazard	$25,000	10/1/77 6 months	23
Patrick E. Guire Kallestad Labs, Inc.	Enzyme Monitored Receptor Assay System for Industrial Organic Chemicals	$47,016	9/15/78 12 months	23
Delbert D. Hemphill University of Missouri, Columbia	Twelfth Annual Conference on Trace Substances in Environmental Health to be Held in Columbia, Missouri: June 6-8, 1978	$18,350	6/1/78 12 months	24
A. J. Hopfinger Case Western Reserve University	Quantitative Structure Activity Relationships in Toxic Substances	$144,903	3/1/78 24 months	24
T. C. Hsu Anderson Hospital and Turner Institute, University of Texas	Cytogenetic Effects of Mutagens and Mitotic Poisons on Mammalian Cells	$79,307	1/24/78 12 months	25
Gregory L. Kok Harvey Mudd College	Chemiluminescent Analysis of Hydrogen Peroxide in the Ambient Atmosphere	$3,612	6/22/78 6 months	25
John C. Kolojeski Clement Associates, Inc.	Technical Assistance to the TSCA Interagency Testing Committee	$144,287	12/1/77 6 months	26
H. R. Lukens IRT Corporation	Research on an Immunochemical Assay for Asbestos in the Environment	$24,280	10/1/77 6 months	26
Walter J. Maier University of Minnesota	Characterization of Aquatic Organics and Complexes	$160,530	5/9/78 12 months	26
David P. Martinsen Fein-Marquart Associates, Inc.	Approaches for the Acquisition of Mass Spectral Data for Inclusion in the NIH/EPA Mass Spectral Data Base	$24,874	10/1/77 6 months	27
Michael B. McElroy Harvard University	Nitrous Oxide Environmental Measurement Program	$140,428	7/19/78 12 months	27
G. D. Mendenhall Battelle Memorial Institute	Isotopic Labeling Techniques to Study the Photooxidation of Hydrocarbons in Air	$80,000	9/1/78 12 months	28
Larry D. Nichols Moleculon Research Corp.	Reactive Tapes for Automatic Environmental Analyses	$24,805	10/1/77 6 months	28
Tihomir Novakov Lawrence Berkeley Laboratory	The Role of Primary Particulates in Urban Air Pollution	$185,700	8/18/78 14 months	28
Kent Painter Western Chemical Research Corp.	Development of Antisera to Benzo [A] Pyrene and its Metabolites	$81,872	10/1/77 6 months	29
James N. Pitts University of California Riverside	Atmospheric Transformations and Mutagenic Activity of Primary and Secondary Air Pollutants	$253,240	2/1/78 12 months	29

Principal Investigator/ Institution	*Project Title*	*Amount*	*Effective Date/Award Duration*	*Page*
Robert L. Seecof City of Hope Medical Center	Development of Screening Methods for Developmental Abnormalities	$177,020	7/1/78 12 months	30
Henry J. Segall University of California, Davis	The Detection of Pyrrolizidine Alkaloids and their Metabolites	$117,470	1/1/78 12 months	30
John H. Seinfeld California Institute of Technology	Chemical and Physical Characterization of Submicron Aerosols	$118,608	7/11/78 12 months	31
Robert E. Sievers University of Colorado	Development of Procedures for the Analysis of Organic Compounds in the Atmosphere	$135,500	2/1/78 24 months	31
James H. Smith SRI International	Prediction of Volatilization Rates of Chemicals in Water	$79,589	8/1/78 12 months	32
Benjamin L. Van Duuren New York University	Chemical Structure, Reactivity and Carcinogenicity of Halohydrocarbons	$300,000	5/8/78 24 months	32
David Young Southern California Coastal Water Resources	Pollutant Flow Through the Marine Food Web	$69,980	2/15/78 12 months	33

COMMUNITY WATER MANAGEMENT

Program Total $2,278,822

Anne M. Blackburn Interstate Commission on the Potomac River Basin	The Thames/Potomac Seminars: A Comparative Study of River Basin Management	$17,800	4/1/78 8 months	34
Stanley A. Changnon University of Illinois, Urbana	Hydrometeorologic Studies of Urban Water Resource Problems	$131,200	9/1/78 12 months	35
P. C. Cheo California Arboretum Foundation	Mechanism of Plant Virus Inactivation in Soil Injected with Municipal Wastewater and Treatment Plant Sludges	$37,766	6/6/78 12 months	35
Jack E. Collier Colliers Earthworm Compost Systems, Inc.	Conversion of Municipal Wastewater Treatment Plant Residual Sludges into Earthworm Castings for Use as Topsoil	$15,620	9/11/78 12 months	36
William J. Cooper U.S. Army Bioengineering Research & Development Laboratory	Symposium on Water Reuse	$10,000	9/1/78 12 months	36
Grant Cottam University of Wisconsin, Madison	Efficacy and Impact of Intensive Plant Harvesting for Lake Management	$164,124	3/1/78 14 months	36
Arun K. Deb Roy F. Weston, Inc.	Wastewater Reuse for Regional Management of Water to Meet Urban Needs	$9,067	2/14/78 6 months	37
Richard I. Dick Cornell University	Process Integration for Optimum Management of Municipal Wastewater Treatment Sludges	$77,181	1/15/78 12 months	37
Charles Finance Media-Four Productions	Synthesis of a Municipal Wastewater Sludge Management System	$2,375	4/1/78 3 months	38
Walter R. Fritz Boyle Engineering Corp.	Advanced Treatment of Community Wastewater by Flow-Through Cypress Strand Wetlands	$163,759	9/1/78 24 months	38
Haynes C. Goddard University of Arizona	Feasibility of Obtaining Public Cooperation for Source-Separation in Management of Solid Wastes	$25,000	5/1/78 12 months	39

Principal Investigator/ Institution	*Project Title*	*Amount*	*Effective Date/Award Duration*	*Page*
Harris Gold Water Purification Associates	Water Management in New England: A Method for Integrating Short-Run Operational and Long-Range Investment Strategies	$130,782	9/1/78 12 months	40
Carlos R. Guerra Public Service Electric and Gas Company	Utilization of Waste Heat from Power Plants in Aquaculture	$115,000	1/16/78 24 months	40
Roy C. Hartenstein SUNY College of Environmental Sciences & Forestry	Stabilization of Community Wastewater Sludges by Soil Invertebrates	$150,739	6/1/78 12 months	41
Robert L. Irvine University of Notre Dame	Application of Sequencing Batch Reactors for Treatment of Municipal and Industrial Wastewater	$8,396	8/25/78 12 months	41
Robert H. Kadlec University of Michigan	Wetland Utilization for Management of Community Wastewater	$141,744	2/15/78 12 months	42
Judith F. Kitchens Atlantic Research Corp.	Evaluation of Coliform Bacteria and Bacteriophage Relationships in Assessment of Water Quality	$69,616	10/1/78 12 months	43
Eriks Leitis Westgate Research Corp.	An Investigation into the Chemistry of the UV—Ozone Water Purification Process	$107,099	8/14/78 12 months	43
Steven J. Marcus Energy Resources Co., Inc.	Public Health and Nuisance Aspects of Community Wastewater Sludge Management	$126,407	8/1/78 8 months	44
Theodore G. Metcalf University of New Hampshire, Durham	Disinfection of Enteric Viruses in Sludge by Use of Energized Electrons	$16,948	6/1/78 6 months	44
Howard T. Odum University of Florida	Utilization of Cypress Wetlands for Management of Municipal Wastewater Treatment Plant Effluents	$20,800	8/30/78 24 months	45
Wesley O. Pipes Drexel University	Workshop on Water Quality and Health Significance of Bacterial Indicators of Pollution	$9,800	2/7/78 6 months	45
Bernard P. Sagik University of Texas, San Antonio	Potential Health Risks Associated with Injection of Residual Domestic Wastewater Sludges into Soils	$87,477	6/12/78 12 months	46
Jeffrey C. Sutherland Williams and Works, Inc.	Utilization of Wetlands for Management of Pond Stabilized Domestic Wastewater	$85,103	5/1/78 19 months	46
Ben Tencer Roy F. Weston, Inc.	On-Shore Impacts of Off-Shore Oil and Gas: Methodology, Development and Tests	$21,914	4/17/78 3 months	47
John G. Trump Massachusetts Institute of Technology	High Energy Electron Irradation of Municipal Wastewater Liquid Residuals	$27,159	7/11/78 12 months	47
George D. Ward George D. Ward & Associates	Research on Controlled Soil Microbial Detoxification of Herbicide Residues	$208,445	10/1/78 24 months	48
Leon W. Weinberger Environmental Quality Systems	Prediction and Control of Heavy Metals and Toxic Organic Materials in Sludges	$199,364	9/1/78 12 months	48
Flora M. Wellings Florida Department of Health and Rehabilitation	Mobility and Survival Characteristics of Viruses in Cypress Dome Wetlands	$48,072	4/15/78 12 months	49

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	EARTHQUAKE HAZARDS MITIGATION Program Total $17,689,081			
	Siting Subtotal $5,860,123			
William M. Adams University of Hawaii, Manoa	Prediction of Conditional Expected Tsunami Inundation on Hawaiian Shorelines	$30,943	8/1/78 12 months	51
Keiiti Aki Massachusetts Institute of Technology	A New Approach to the Prediction of Earthquake Strong Motion	$47,610	5/15/78 8 months	51
Keiiti Aki Massachusetts Institute of Technology	An Experimental Investigation of the Earthquake Response of Sediment-Filled Valleys in Garm, USSR	$196,018	2/16/78 24 months	51
Teoman Ariman University of Notre Dame	Earthquake Response and Aseismic Design of Underground Piping Systems	$135,213	2/15/78 24 months	52
Dimitrios Athanasiou-Grivas Rensselaer Polytechnic Institute	Reliability Analysis of Slopes During Earthquakes	$125,400	1/15/78 24 months	52
Melvin L. Baron Weidlinger Associates	Underground Lifelines in a Seismic Environment, Phase II	$370,313	5/1/78 12 months	53
Jack R. Benjamin Engineering Decision Analysis Co., Inc.	Optimal Design of Earthquake Strong-Motion Networks	$50,416	8/1/78 12 months	53
Bruce A. Bolt University of California, Berkeley	Seismological Analysis of Strong Motion Records	$47,723	5/1/78 24 months	54
James N. Brune University of California, San Diego	A Strong Motion Seismograph Array in Northern Baja California	$36,800	11/21/77 12 months	54
James N. Brune University of California, San Diego	Numerical and Experimental Study of Earthquake Strong Motion	$159,672	3/15/78 24 months	55
Mary B. Bullock National Academy of Sciences	Committee on Scholarly Communication with the People's Republic of China: Earthquake Hazards Mitigation	$41,300	7/1/78 12 months	55
Ahmet S. Cakmak Princeton University	Earthquake Waves in Soil Deposits	$72,900	1/25/78 12 months	55
Allen T. Chwang California Institute of Technology	Seismic Response of Three-Dimensional Dam-Reservoir Systems	$110,774	3/15/78 18 months	56
Gautama Dasgupta Columbia University	Modeling of Foundations for Embedded Structures	$59,563	2/1/78 24 months	56
Thomas C. Hanks U.S. Geological Survey	Collaborative Research: Processing and Analysis of Oroville Earthquake Aftershock Ground Motion Records	$114,033	7/19/78 12 months	57
Donald V. Helmberger California Institute of Technology	Collaborative Research: Processing and Analysis of Oroville Earthquake Aftershock Ground Motion Records, Part II	$40,395	7/19/78 12 months	57
Robert B. Herrmann Saint Louis University	Earthquake Ground Motion Modeling for the Central United States	$93,200	5/31/78 12 months	58

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George W. Housner California Institute of Technology	Seismic Response of Structures and Strong-Motion Instrumentation	$448,360	2/15/78 12 months	58
Li-San Hwang Tetra Tech, Inc.	Workshop on Tsunami Research to be Held in Los Angeles, California, October, 1978	$53,412	4/15/78 12 months	59
Paul Ibanez Applied Nucleonics Co., Inc.	Research on a Portable Vibrating Structure for Soils Investigations	$24,282	10/1/77 6 months	59
Wilfred D. Iwan California Institute of Technology	Analysis of Strong-Motion Data Network Programs	$35,854	6/1/78 36 months	59
Wilfred D. Iwan California Institute of Technology	International Workshop on Strong Motion Earthquake Instrument Arrays	$66,871	11/15/77 12 months	60
Paul C. Jennings California Institute of Technology	Strong Motion Seminar-Workshop, California Institute of Technology, January, 1978	$14,350	1/15/78 12 months	60
Leon Knopoff Institute of Geophysics and Planetary Physics, University of California, Los Angeles	Statistical Investigation of Engineering Seismology	$46,960	4/1/78 8 months	60
Denny R. Ko Dynamics Technology, Inc.	Response of Submerged Structures to Seismic Excitation	$87,325	7/15/78 12 months	61
Jiin-Jen Lee University of Southern California	Distant and Local Tsunamis in Coastal Region	$135,865	11/15/77 24 months	62
Kenneth L. Lee University of California, Los Angeles	Earthquake Stability of Reinforced Earth Structures	$19,000	1/27/78 12 months	62
Y. K. Lin University of Illinois, Urbana	Structural Response Under Random Wind Loading	$54,671	6/21/78 12 months	62
John Lysmer University of California, Berkeley	Soil Structure Interaction with Arbitrary Seismic Environment	$43,700	11/21/77 24 months	63
R. B. Matthiesen U.S. Geological Survey	Operation of the National Program in Strong-Motion Instrumentation	$956,524	2/17/78 12 months	63
Chiang C. Mei Massachusetts Institute of Technology	Structure-Fluid Interaction Due to Earthquakes	$87,000	11/15/77 24 months	64
William A. Nash University of Massachusetts, Amherst	Seismic Effects in Liquid Storage Tanks	$85,014	2/15/78 24 months	64
Joseph Penzien University of California, Berkeley	US/ROC Cooperative Research in Earthquake Engineering	$44,094	8/1/78 12 months	64
Fredric Raichlen California Institute of Technology	An Experimental Study of Tsunamis: Their Generation, Propagation and Coastal Effects	$279,558	2/1/78 36 months	65
Jose M. Roesset Massachusetts Institute of Technology	Dynamic Soil Structure Interaction	$172,473	3/1/78 24 months	65

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Adel S. Saada Case Western Reserve University	The Dynamic Response of Anisotropic Clay Soils with Application to Soil Structure Analysis	$69,876	1/25/78 12 months	66
Roger E. Scholl John A. Blume & Associates	Earthquake Engineering of Large Underground Structures	$78,600	4/1/78 18 months	66
H. B. Seed University of California, Berkeley	Influence of Site Characteristics on the Damage During the October 1974 Lima Earthquake	$36,242	1/1/78 12 months	67
Haresh C. Shah Stanford University	A Generalized Study on Seismic Risk Analysis	$300,000	1/1/78 36 months	67
Mehmet A. Sherif Applied Engineering Resources, Inc.	Second International Conference on Earthquake Microzonation for Safer Construction-Research and Application, November 1978 — San Francisco	$85,830	2/15/78 18 months	68
D. W. Simpson Columbia University	Induced Seismicity at Nurek Reservoir, Tadjikistan, USSR	$207,125	1/31/78 21 months	68
Ta-Liang Teng University of Southern California	Strong Motion Accelerograph Network in the Los Angeles Basin	$383,712	3/15/78 24 months	69
F. E. Udwadia University of Southern California	Analysis of Optimal Strong-Motion Instrument Location in Building Structures	$74,056	3/1/78 12 months	69
Stuart D. Werner Agbabian Associates	The Effects of Earthquake Input Motion Phasing on Structural Response Characteristics	$137,801	7/1/78 12 months	69
Francis T. Wu Suny State University, Binghamton	Earthquake Strong-Motion Instrumentation and Array Design	$41,464	8/7/78 12 months	70
E. B. Wylie University of Michigan	Response of Nonlinear Saturated Soils to Seismic Disturbances	$57,831	3/15/78 12 months	71
	Design Subtotal $8,796,121			
G. R. Abrahamson SRI International	Simulation of Strong Earthquake Motion with Contained Explosive Line Source Arrays	$283,992	6/21/78 12 months	72
M. S. Agbabian Earthquake Engineering Research Institute	Seminars on Earthquake Criteria and Design	$77,820	9/15/78 12 months	73
H. S. Ang University of Illinois, Urbana	Safety Evaluation of Structures to Earthquakes and Other Natural Hazards	$271,000	12/15/77 24 months	73
Lynn S. Beedle Lehigh University	Conference on Stability Problems of Mixed Steel Concrete Structures, Boston, Massachusetts, May 1978	$9,000	4/15/78 12 months	74
Jack R. Benjamin Engineering Decision Analysis Co., Inc.	Reliability Assessment of Linear Lifelines for Natural Hazards	$41,775	7/15/78 12 months	74
John A. Blume John A. Blume & Associates	Seismic Investigation and Design Criteria for Industrial Storage Racks	$43,130	4/11/78 12 months	75
Colin B. Brown University of Washington	Objective and Subjective Seismic Safety Considerations	$52,000	1/1/78 12 months	75
James R. Cagley Martin and Cagley	Research on Seismic Hardening of Unreinforced Masonry Walls Through a Surface Treatment	$25,000	10/1/77 6 months	75
Franklin Y. Cheng University of Missouri, Rolla	Optimum Design of Three-Dimensional Building Systems for Multicomponent Earthquake Motions	$20,165	6/1/78 4 months	76

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Anil K. Chopra University of California, Berkeley	Earthquake Response of Dams Including Hydrodynamic and Foundation Interactions	$70,700	12/8/77 12 months	76
Ray W. Clough University of California, Berkeley	Collaborative International Research on Earthquake Response of Structures, U.S. — Yugoslavia	$59,278	5/15/78 24 months	76
Ray W. Clough University of California, Berkeley	Seismic Behavior of Complete Structural Systems	$454,400	11/14/77 months	77
W. G. Corley Portland Cement Association	Seismic Resistance of Buildings with Reinforced Concrete Structural Walls	$490,125	2/1/78 12 months	78
Bruce M. Douglas University of Nevada, Reno	Nondestructive Dynamic Testing of Three Highway Bridges	$80,123	9/1/78 24 months	78
Robert D. Ewing ABK, A Joint Venture	Methodology for Mitigation of Seismic Hazards in Existing Unreinforced Masonry Buildings	$461,962	10/1/78 12 months	78
Robert D. Ewing Agbabian Associates	Research on the Response of Existing (Masonry Buildings) Systems to Earthquake Motions	$25,000	10/1/77 6 months	79
Steven J. Fenves Carnegie Mellon University	Formulation and Expression of Seismic Design Provisions	$5,177	4/14/78 6 months	79
John F. Fleming University of Pittsburgh	Progressive Collapse of Transmission Line Structures Due to Dynamic Loads	$74,445	4/15/78 24 months	79
Bernard L. Gabrielsen Scientific Services, Inc.	Research on the Use of Structural Foams to Improve Earthquake Resistance in Buildings	$24,517	10/1/77 6 months	80
James M. Gere Stanford University	Scale Modeling and Testing of Structures for Reproducing Response to Earthquake Excitation	$89,722	3/1/78 12 months	80
Peter Gergely Cornell University	Design of Splices in Reinforced Concrete Frames for Earthquake Effects	$199,548	9/1/78 24 months	81
Subhash C. Goel University of Michigan	Earthquake Resistant Design of Braced Steel Frame Structures	$152,500	12/8/77 24 months	81
George T. Goforth Department of Defense, Defense Civil Preparedness Agency	A Summer Institute on Multiprotection Design	$50,000	5/15/78 11 months	82
Barry J. Goodno Georgia Institute of Technology	Influence of Nonstructural Cladding on Dynamic Properties and Response of Highrise Buildings	$96,906	1/1/78 12 months	82
Robert M. Griffin Pennsylvania State University	Urban Environmental Factors and Personal Well-Being	$55,200	1/1/78 14 months	83
William J. Hall University of Illinois, Urbana	Engineering Design for Natural Hazards	$493,355	11/15/77 24 months	83
Gary C. Hart University of California, Los Angeles	Behavior of Buildings to Wind and Seismic Forces	$183,814	3/15/78 36 months	84
Ti Huang Lehigh University	Contribution of Floor Systems to Earthquake Resistance of Steel and Concrete Building Frames	$151,865	1/24/78 12 months	84
Wilfred D. Iwan California Institute of Technology	Operation for the Universities Council for Earthquake Engineering Research	$127,615	1/1/78 36 months	85
James O. Jirsa University of Texas, Austin	Behavior of Reinforced Concrete Frame Elements Under Biaxial Lateral Loadings	$492,051	3/1/78 36 months	85

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Lindsay R. Jones Computech, Inc.	Comprehensive Building Analysis Computer Program for Earthquake Response	$97,512	9/1/78 12 months	86
Ben Kacyra Earthquake Engineering Systems, Inc.	Research on a Rational Approach to Damage Mitigation in Existing Structures Exposed to Earthquake	$20,095	10/1/77 6 months	86
John Kariotis Kariotis, Kesler & Allys, Inc.	Research on Mitigation of Seismic Hazards in Existing Unreinforced Masonry Wall Buildings	$24,391	10/1/77 6 months	87
Earle W. Kennett American Institute of Architects	Summer Seismic Institutes for Architectural Faculty	$141,000	4/15/78 10 months	87
Bernard M. Leadon University of Florida	Dynamic Wind Loads on Buildings	$59,611	6/1/78 12 months	87
Ovadia E. Lev Merritt Cases, Inc.	Sequential Optimization of Structural Geometry	$49,901	9/1/78 15 months	88
Le-Wu Lu Lehigh University	United States/Republic of China Cooperative Research in Earthquake Engineering	$42,000	8/14/78 12 months	88
Ronald L. Mayes Applied Technology Council	Workshop on Wood Diaphragms and Development of a Wood Manual	$132,871	7/1/78 18 months	88
Hugh D. McNiven University of California, Berkeley	Reliability of Existing Buildings in Earthquake Zones — Part II	$46,900	11/18/77 24 months	89
Hugh D. McNiven University of California, Berkeley	Seismic Behavior of Multistory Masonry Structures	$102,300	11/21/77	89
Kishor C. Mehta Texas Tech University	Wind Load Provisions for Safe Design of Structures	$81,780	7/15/78 18 months	90
Robert W. Meyer Society of Wood Science and Technology, Washington State University	A Symposium on the Structural Use of Wood in Adverse Environments to be Held in Vancouver, British Columbia: May, 1978	$28,233	1/15/78 12 months	90
Richard K. Miller University of California, Santa Barbara	Dynamics of Structures with Localized Nonlinearity	$35,000	11/15/77 24 months	91
Joseph E. Minor Institute for Disaster Research, Texas Tech University	Unified Approach to the Design of Window Glass Subjected to Dynamic Loads	$113,012	4/15/78 12 months	91
James L. Noland Atkinson-Noland and Associates, Inc.	Conference on Masonry Design and Construction for Seismic Effects	$36,047	6/1/78 9 months	92
Joseph Penzien University of California, Berkeley	National Information Service for Earthquake Engineering	$401,377	12/14/77 16 months	92
Joseph Penzien University of California, Berkeley	Seismic Behavior of Structures: Analysis and Design	$260,300	11/14/77 24 months	93
Joseph Penzien University of California, Berkeley	The United States-Japan Cooperative Research Program on Large-Scale Structural Systems: A Planning Study	$65,700	11/16/77 24 months	93
Dale C. Perry Washington State University	Seismic Behavior of Precast Curtain Walls in High Rise Buildings	$73,332	5/1/78 18 months	93

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C. W. Pinkham S. B. Barnes & Associates	Research on Methodology for Mitigation of Seismic Hazards in Existing Unreinforced Masonry Buildings	$25,000	10/1/77 6 months	94
Joseph M. Plecnik California State University, Long Beach	Fire Resistance of Epoxy Repaired Concrete Structures	$91,816	5/1/78 24 months	94
Egor P. Popov University of California, Berkeley	Seismic Behavior of Structural Components	$482,800	11/14/77 24 months	94
Jose M. Roesset Massachusetts Institute of Technology	Seismic Behavior and Design of Buildings	$264,835	1/15/78 24 months	95
Ronald L. Sack University of Idaho	Seismic Behavior of Precast Curtain Walls in High Rise Buildings	$63,692	5/1/78 18 months	96
Frederic B. Safford Agbabian Associates	Feasibility of Force-Pulse Generators for Earthquake Simulators	$420,594	5/15/78 24 months	96
Anshel J. Schiff Purdue University	Improving Earthquake Resistance of Elevators	$143,882	2/15/78 24 months	96
Roland L. Sharpe Applied Technology Council	Distribution of ATC-3 Report, Tentative Seismic Design Recommendations for Buildings	$22,476	4/1/78 18 months	97
Roland L. Sharpe Applied Technology Council	Testing of Tentative Provisions for Seismic Regulations for Building	$56,720	8/1/78 6 months	97
Roland L. Sharpe Applied Technology Council	Workshop on Seismic Resistance of Highway Bridges	$83,685	8/1/78 6 months	98
David T. Tang Suny State University, Buffalo	Seismic Behavior of Irregularly-Shaped Low-Rise Buildings	$52,034	2/15/78 24 months	98
Mihajlo D. Trifunac University of Southern California	Automatic Digitization of Accelerograph Records	$40,500	9/27/78 24 months	98
Erik H. VanMarcke Massachusetts Institute of Technology	Evaluation of Seismic Safety of Buildings	$112,617	1/27/78 12 months	99
Ping Chun Wang Polytechnic Institute of New York	Prediction of Earthquake Resistance of Structures	$68,060	5/3/78 12 months	99
Leon W. Weinberger Environmental Quality Systems	Earthquake Design Criteria for Water Supply and Wastewater Systems	$99,961	4/1/78 8 months	100
Robert V. Whitman Massachusetts Institute of Technology	Analysis of Cape Ann Earthquake from Building Damage	$94,159	2/1/78 18 months	100
John H. Wiggins J. H. Wiggins Co.	Development of Earthquake and Other Natural Hazard Damage Assessment Procedures for Existing Structures	$146,543	3/1/78 15 months	101
Bernard Wobbeking American Society for Engineering Education	Summer Institute on Design for Protection Against Natural and Man-Made Hazards	$8,000	3/15/78 months	101
James T. Yao Purdue University	Reliability of Existing Buildings in Earthquake Zones — Part 1	$45,200	11/18/77 12 months	101

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	Policy Subtotal $2,515,888			
Frederick L. Bates University of Georgia	Longitudinal and Cross Cultural Study of the Post Impact Phases of a Major National Disaster: The February 6, 1976, Guatemalan Earthquake	$223,520	6/23/78 12 months	103
Jack G. Bouwkamp J. G. Bouwkamp	Dynamic Response Analysis of Offshore Platforms	$109,624	3/1/78 12 months	103
A. Berry Crawford Institute for Policy Research	Invitational Workshop on Comprehensive Emergency Preparedness to be held in Denver, Colorado: April, 1978	$14,632	3/1/78 6 months	104
Charles E. Fritz National Academy of Sciences	Study of the Role of the Mass Media in Disaster Reporting	$147,549	9/1/78 12 months	104
Robert K. Leik University of Minnesota	Community Response to Natural Hazard Warnings	$492,899	4/25/78 12 months	105
Ben Chieh Liu Midwest Research Institute	Earthquake Risk and Damage Functions — An Integrated Preparedness and Planning Study for Central USA	$105,493	1/15/78 12 months	105
Dean E. Mann University of California, Santa Barbara	Seismic Safety Preparedness by Local Governments in California	$118,265	6/13/78 12 months	106
Terry R. Margerum Association of Bay Area Governments	Liabilities of Local Governments for Earthquake Hazard Reduction	$125,200	1/1/78 12 months	107
Louis W. Miller University of Pennsylvania	Extensions and Utilization of Community Flood Model	$192,930	3/15/78 12 months	107
Risa Palm University of Colorado	Real Estate Agents and Dissemination of Information on National Hazards in the Urban Area	$104,397	9/1/78 18 months	108
Ronald W. Perry Battelle Memorial Institute	Factors Affecting the Design and Implementation of Community Disaster Evacuation Plans	$233,829	2/15/78 18 months	108
E. L. Quarantelli Ohio State University	Social Behaviorial Responses to Chemical Hazards	$213,915	8/7/78 12 months	109
Hirst Sutton Council of State Governments	State Government Policy Options for the Utilization of Earthquake Prediction Technology	$86,930	8/23/78 7 months	109
Ralph H. Turner University of California, Los Angeles	Community Response to Earthquake Threat in Southern California	$191,511	1/17/78 12 months	110
Gilbert F. White University of Colorado	Natural Hazards Research and Applications Information Center	$130,394	4/12/78 12 months	110
Gilbert F. White University of Colorado	Quick Response to Natural Disasters	$24,800	1/24/78 16 months	110