EARTHQUAKE HAZARDS ACT

HEARING

BEFORE THE

SUBCOMMITTEE ON OCEANS AND ATMOSPHERE

OF THE

COMMITTEE ON COMMERCE
UNITED STATES SENATE

NINETY-SECOND CONGRESS

SECOND SESSION

ON

S. 3173

TO PROVIDE A SOUND PHYSICAL BASIS AND AN OPERATIONAL SYSTEM FOR PREDICTING DAMAGING EARTHQUAKES IN HEAVILY POPULATED AREAS OF CALIFORNIA AND NEVADA

S. 3392

TO AMEND THE NATIONAL SCIENCE FOUNDATION ACT OF 1950 SO AS TO PROVIDE FOR A PROGRAM RELATING TO EARTHQUAKES

S. 3584

TO PROVIDE FOR A COMPREHENSIVE NATIONAL PROGRAM OF EARTHQUAKE MONITORING, RESEARCH AND ENGINEERING IN ORDER TO REDUCE LOSS OF LIFE AND PROPERTY; TO PROVIDE FOR STUDIES LEADING TO EARTHQUAKE PREDICTION AND CONTROL; AND FOR OTHER PURPOSES

MAY 16, 1972

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EARTHQUAKE HAZARDS ACT

TUESDAY, MAY 16, 1972

U.S. Senate,
Committee on Commerce,
Subcommittee on Oceans and Atmosphere,
Washington, D.C.

The subcommittee met at 11 a.m. in room 1318, New Senate Office Building, Hon. Ernest F. Hollings (chairman) presiding.

Present: Senator Hollings.

OPENING STATEMENT BY SENATOR HOLLINGS

Senator Hollings. We can start a little ahead. Perhaps by the time we have completed the opening statement, Senator Cranston will come along.

Today we begin a series of discussions on the technologies involved in the prediction of earthquakes and the protection of life and property.

Every year hundreds of tremors of varying degrees occur in the United States. Major earthquakes are relatively infrequent but can present an enormous loss of life and property.

The Alaska quake of 1964 alone caused $500 million in damage, the loss of 131 lives, and hundreds of injuries. The San Fernando, Calif., earthquake in February of 1971, caused approximately the same amount of property damage with one-half as many deaths due to the distance of the main tremor from any densely populated area.

Dr. Clarence Allen, professor of geology and geophysics at California Institute of Technology, testified before the Senate Public Works Committee after the California quake that " * * * the pressures of population growth are causing expansion into areas that are more difficult to develop safely than those of past decades * * *. Society is rapidly becoming more complex and interdependent, so that we are becoming increasingly reliant on critical facilities whose loss can create major disasters."

General proposals being looked into by scientists and government alike are:

1. Revision of building code requirements and engineering practices;
2. Detailed evaluation of earthquake hazards in heavily populated seismic areas prior to construction;
3. Development of warning systems; and
4. Arrangements for collection of data and insurance systems.

Staff member assigned to this hearing: John Hussey.

These proposals were suggested by the National Academy of Sciences after its study into the Alaska earthquake, and all are extremely pertinent factors in our discussions today.

At present there is no national, coordinated plan to predict earthquakes or to develop the scientific and technical knowledge which will help us avoid the tremendous damage they can cause. For too long we have lived beneath the threat of earthquakes and their fantastic potential for causing death, human suffering, and millions of dollars' worth of property destruction.

We hope during these hearings to begin developing the direction national policy should take on this matter. My bill, S. 3584, would create within the Department of Commerce, National Oceanic and Atmospheric Administration, the framework for just this kind of interagency cooperation and coordination which must exist before we can succeed in protecting our citizens against earthquakes.

We are pleased to have with us Senator Alan Cranston, of California. Senator Cranston is the author of two bills, S. 3173 and S. 3392, which are before us this morning, along with S. 3584, which I introduced.

(The bills and agency comments follow):

92D CONGRESS
2D SESSION

S. 3173

IN THE SENATE OF THE UNITED STATES

FEBRUARY 15, 1972

Mr. CRANSTON (for himself, Mr. EAGLETON, Mr. GRAVEL, Mr. HATFIELD, Mr. HOLLINGS, Mr. JACKSON, Mr. MANSFIELD, Mr. METCALF, Mr. MOSS, Mr. PACKWOOD, Mr. STEVENS, Mr. THURMOND, and Mr. TUNNEY) introduced the following bill; which was read twice and referred to the Committee on Commerce

A BILL

To provide a sound physical basis and an operational system for predicting damaging earthquakes in heavily populated areas of California and Nevada.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That (a) this Act may be cited as the "Earthquake Prediction Act of 1972".

(b) The Congress hereby finds and declares that the San Andreas fault and closely related faults of California and Nevada are areas of high seismic risk, that 9.8 per centum of the population of the United States lives in California, that the highly developed urban areas of San Francisco and Los

Angeles and their surroundings are especially vulnerable to the dangers of earthquakes, that Japanese scientists have issued earthquake warnings, and that seismic research in the United States is sufficiently advanced that an earthquake prediction capability can be achieved with an earthquake prediction program. To minimize loss of life and property damage, the Congress hereby declares that it is its purpose to establish a program of instrumentation of the San Andreas and closely related faults of California and Nevada; to provide for the collection, analysis, and interpretation of data from such instrumentation; and to provide supporting field, laboratory, and theoretical studies leading to the goal of predictions of earthquakes along the San Andreas fault zone.

SEC. 2. (a) It shall be the function and duty of the Director of the Geological Survey to develop and carry out an earthquake prediction program which shall include—

(1) heavy instrumentation of the San Andreas fault and closely related faults of California and Nevada to obtain detailed records of data useful in developing an earthquake prediction capability;

(2) establishment of facilities for the collection and computerized reduction, analysis, and interpretation of the data flow from such instruments;

(3) supporting field, laboratory, and theoretical studies; and

(4) development and field-testing of additional instruments which are useful in connection with the foregoing provisions of this section.

In carrying out that part of such program involving or relating to research purposes, and in expending a significant portion of the funds appropriated pursuant to this Act for such program, the Director shall utilize the services of research personnel in institutions of higher education and public entities or organizations (other than Geological Survey) and private entities or organizations concerned with seismic research.

(b) (1) There is hereby established an advisory committee for the earthquake prediction program (hereinafter referred to as the "advisory committee"). The advisory committee shall consist of not less than seven nor more than fifteen members who shall be appointed by the Director of the Geological Survey from among individuals recommended by the National Academy of Sciences. The advisory committee shall select a chairman and vice chairman from among its members.

(2) It shall be the function of the advisory committee to advise and assist the Director in developing and carrying out the earthquake prediction program provided for in subsection (a).

SEC. 3. (a) The Director of the Office of Emergency

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Preparedness is authorized to establish and carry out a program to review and assess the current state of knowledge on earthquake prediction and the warning systems, to identify key problem areas for further research and evaluation, and to determine what additional steps may be needed to reduce primary and secondary losses from earthquakes. Such review and assessment shall include—

(1) a forecast of the problems expected to be associated with the issuance of earthquake warnings to the population residing in high seismic risk areas;

(2) an analysis, prepared prior to the issuance of earthquake warnings, of steps which should be taken to make such warnings effective, and of how to make the decision to issue the warnings;

(3) an analysis, prepared prior to the occurrence of an earthquake, of the physical effect of an earthquake; and

(4) an analysis, prepared prior to the occurrence of an earthquake, of the behavioral and psychological effects of an earthquake.

(b) The Director of the Office of Emergency Preparedness is authorized to enter into contracts, agreements, or other appropriate arrangements with the National Academy of Sciences to provide such necessary scientific advisory services as may be required in carrying out the purposes of this section.

SEC. 4. The President of the National Academy of Sciences and the Director of the Office of Emergency Preparedness shall make information developed pursuant to this Act available to the Office of Science and Technology, the Congress, Governors in States of high seismic risk, and other government and private organizations which are concerned with preparations for or reactions to earthquakes or earthquake warnings.

SEC. 5. (a) For purposes of section 2 of this Act, there is authorized to be appropriated for the fiscal year ending June 30, 1973, and for each of the next following four fiscal years, the sum of $12,000,000.

(b) For purposes of sections 3 and 4 of this Act, there is authorized to be appropriated for the fiscal year ending June 30, 1973, and for each of the next following four fiscal years, the sum of $200,000.

92D CONGRESS
2D SESSION

S. 3392

IN THE SENATE OF THE UNITED STATES

MARCH 21, 1972

Mr. CRANSTON (for himself, Mr. DOMINICK, Mr. EAGLETON, Mr. GRAVEL, Mr. MANSFIELD, Mr. STEVENS, Mr. TUNNEY, and Mr. WILLIAMS) introduced the following bill; which was read twice and referred to the Committee on Commerce

A BILL

To amend the National Science Foundation Act of 1950 so as to provide for a program relating to earthquakes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That section 3 (a) of the National Science Foundation Act of 1950 is amended (1) by deleting the word "and" at the end of paragraph (6); (2) by deleting the period at the end of paragraph (7) thereof and inserting in lieu thereof a semicolon and the word "and"; and (3) by adding immediately after paragraph (7) thereof the following new paragraph:

II

"(8) (A) to establish and support a program which shall—

"(i) advance earthquake engineering research;

"(ii) develop more accurate and reliable methods of earthquake resistant analysis and design for all types of structures and for a variety of ground conditions;

"(iii) develop improved minimum criteria of earthquake-resistant construction, measuring the cost of protection against the benefit of damage and loss of life prevented, for all types of structures and for a variety of ground conditions, with priority given to dams, hospitals, schools, public utility and public safety structures, high-occupancy buildings, buildings necessary to emergency operations, and other structures especially needed in time of disaster; and

"(iv) develop improved methods, based upon the seismological characteristics of the area, of assessing the earthquake risk at all types of locations in populated areas of high seismic risk, and of establishing land use priorities designed to reduce the hazards from earthquakes.

"(B) Such program established pursuant to subparagraph (A) shall include—

"(i) measurement and analysis of ground motion during earthquakes;

"(ii) analysis of soil behavior and influence of local geologic features during earthquakes;

"(iii) measurement and analysis of dynamic properties and behavior of structures during earthquakes;

"(iv) development of instruments useful in such program;

"(v) laboratory and field experiments, analytical techniques, and mathematical and computerized methods of analysis which support such program;

"(vi) analysis of tidal wave action and development of appropriate countermeasures;

"(vii) development of a sufficient number of trained personnel to support such program;

"(viii) development of effective means to disseminate the methods of structural analysis and design, criteria of construction, and methods of assessing earthquake risk developed pursuant to such program to public and private groups engaged in engineering construction, architecture, construction planning, and land use planning; and

"(ix) postearthquake studies and investigations of the effects of earthquakes which are relevant to engineering design, earthquake engineering research, or any other purposes consistent with such program.

"(C) The Foundation is directed to report annually to the President and the Congress on the implementation of the program provided for in this paragraph. The Foundation is directed to make the methods of structural analysis and design, the criteria of construction, and the methods of assessing earthquake risk maps developed pursuant to such program available to the Governors in States in seismic risk areas, the General Services Administration, the Department of Housing and Urban Development, the National Bureau of Standards, the Department of Defense, the Bureau of Reclamation, the Atomic Energy Commission, the National Oceanic and Atmospheric Administration, the Forest Products Laboratory, Geological Survey, and other government and private organizations which have an interest in construction and land use planning."

SEC. 2. Section 16 of the National Science Foundation Act of 1950 is amended by adding at the end thereof the following:

"(c) To enable the Foundation to carry out its powers and duties under section 3 (a) (8) of this Act, there is authorized to be appropriated to the Foundation for the fiscal year ending June 30, 1973, the sum of $10,000,000; for the fiscal year ending June 30, 1974, the sum of $10,000,000; and for the fiscal year ending June 30, 1975, the sum of $10,000,000."

92d CONGRESS
2d Session

S. 3584

IN THE SENATE OF THE UNITED STATES

May 9, 1972

Mr. Hollings introduced the following bill; which was read twice and referred to the Committee on Commerce

A BILL

To provide for a comprehensive national program of earthquake monitoring, research and engineering in order to reduce loss of life and property; to provide for studies leading to earthquake prediction and control; and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That this Act may be cited as the "Earthquake Hazards Act".

FINDINGS AND DECLARATIONS

Sec. 2. (a) The Congress finds that—

(1) earthquakes present a severe and continuing threat to the lives and property of the citizens of the United States;

(2) population growth is increasing in areas where earthquakes are likely to cause death, injury, property damage, and disruption of the normal functioning of the local government and community;

(3) human suffering and economic loss caused by earthquakes can be substantially decreased by development of basic information and technology relating to earthquakes and applying such information and technology on the local, State, regional, or Federal level;

(4) special measures to fully identify earthquake risks and to mitigate earthquake effects are urgently needed;

(5) while efforts to predict precisely where future seismic activity is likely to occur on a regional and local basis, to predict the expected maximum effects from earthquakes on surface geological features and on man-made structures, and to design structures more resistant to earthquake damage now exist, this program of efforts should be expanded;

(6) prediction of the magnitude, place, and time of occurrence of individual damaging earthquakes and, ultimately, control of the maximum size of earthquakes would substantially reduce loss of life and property damage; and

(7) scientific and technical information developed

pursuant to this Act are necessary for the development and implementation of hazards reduction actions including zoning, proper building codes, and other measures on a Federal, regional, State, and local basis.

(b) It is hereby declared to be the policy of the Congress, (1) to promote the collection and analysis of data and the development of knowledge with respect to all aspects of earthquakes, seismic events, and other natural tectonic processes; (2) to promote the development of technologies necessary to accomplish the foregoing objectives and to reduce earthquake hazards and mitigate earthquake effects; and (3) to make readily available and disseminate such data, knowledge, and technology to the public and to all appropriate Federal, regional, State, and local agencies authorized to take actions to minimize or mitigate earthquake hazards or earthquake effects.

DEFINITIONS

SEC. 3. As used in this Act, the term—

(1) "earthquake hazard" means the threat of harm from any seismic event or any significant crustal movements such as faulting, uplift, or subsidence due to natural tectonic processes which may cause death or property damage;

(2) "earthquake effects" means changes to ground surface features caused by earthquakes and natural tec-

tonic processes; the effect of these ground surface changes on man and the works of man; the effect of seismicly induced vibrations on structures; seismic sea waves (tsunamis) and the effects thereof; and secondary effects such as earthquake related landslides; and other related damaging phenomena;

(3) "United States" means the fifty States, the District of Columbia, Puerto Rico, the Virgin Islands, Guam, American Samoa, and the Trust Territory of the Pacific Islands;

(4) "State" means any State of the United States, the District of Columbia, Puerto Rico, the Virgin Islands, Guam, American Samoa, or the Trust Territory of the Pacific Islands;

(5) "local government" means any county, city, village, town, district, or other political subdivision of any State, and includes any rural community or unincorporated town or village;

(6) "Federal agency" means any department, independent establishment, government corporation, or other agency of the executive branch of the Federal Government; and

(7) "Secretary" means the Secretary of Commerce.

MONITORING AND ENGINEERING PROGRAM

SEC. 4. (a) The Secretary is authorized—

(1) to collect, analyze, and disseminate data and

information with respect to all aspects of earthquakes, seismic events, and other natural tectonic processes so as to minimize loss of life, injury to persons, and damage to property;

(2) to assess continuously earthquake hazards in the various areas of the United States, and to develop, prepare, and publish maps, reports, and other data needed to describe the type and degree of such hazards in sufficient detail that appropriate Federal agencies and regional, State, and local government authorities can properly plan their activities, make provision, to the extent they are authorized, for appropriate hand use planning, and to take such other actions within their authority as may be advisable to mitigate such earthquake hazards; and

(3) to develop technology to assist in the collection, analysis, and dissemination of earthquake-related data and information and, in collaboration with the Department of the Interior, to investigate and develop the knowledge and technology necessary for the prediction and control of earthquakes, seismic events, and other natural tectonic processes.

(b) In order to carry out the provisions of subsection (a), the Secretary is authorized—

(1) to establish, operate, and maintain seismic

instrument networks in the United States for the purpose of monitoring the occurrence of earthquakes;

(2) to establish, operate, and maintain geodetic systems and networks in the United States for the purpose of monitoring the earth strains;

(3) to establish, operate, and maintain a national strong motion instrument network to monitor and record the effects of earthquakes on the ground surface and on manmade structures in the United States;

(4) to provide centralized national data depositories for the archival, retrieval, and dissemination of seismic, geodetic, strong motion, engineering data, and associated engineering seismology data developed under this Act;

(5) to establish, operate, and maintain warning systems to alert the citizens of the United States to earthquake hazards and earthquake effects (including predictions of impending earthquakes, to the extent practicable according to the then existing state of scientific knowledge and technology); and

(6) to conduct such research, experiments, investigations, and technology development, as are necessary to carry out the provisions of this section and to assist the Secretary of the Interior and the Director of the National Science Foundation in carrying out the provisions of sections 5 and 6.

(c) The Secretary is authorized to conduct such research, experimentation, investigations, and technology development, and such programs of data collection, analysis, and dissemination, as he may deem advisable in order to develop knowledge and criteria for the design of structures to resist earthquake effects and to cause such knowledge and criteria to be made available to all interested Federal, regional, State, and local governmental agencies as well as the general public.

(d) In carrying out his functions under section 4 of this Act, the Secretary shall utilize to the maximum extent practicable the services and facilities of the Department of the Interior, the National Science Foundation, the Atomic Energy Commission, the Department of Defense, the Department of Housing and Urban Development, the Office of Emergency Preparedness, and other appropriate Federal agencies and shall coordinate deployment of instruments by such agencies in order to integrate the instruments effectively into the national networks established pursuant to this section.

SEC. 5. (a) The Secretary of the Interior is authorized—

(1) to collect, analyze, and disseminate data and information necessary to develop techniques for predicting the magnitude, location, and time of occurrence of individual earthquakes, seismic events, and other natural

tectonic processes, including data with respect to changes in measurable geophysical phenomena and their correlation with earthquakes, and to develop such technology as may be required to achieve an earthquake prediction capability;

(2) to conduct appropriate geological surveys to identify and locate earth faults, especially active faults, which may contribute to earthquake hazards;

(3) to conduct field and laboratory experiments to test the thesis that fluid injection and withdrawal or other techniques may be utilized along active faults or elsewhere to release strains nondestructively through a number of small seismic events over a long period of time rather than through potentially destructive earthquakes; and to the extent such experiments indicate practical means of reducing the destructive potential of earthquakes, to develop such technology as may be required therefor.

(b) In order to carry out the provisions of subsection (a), the Secretary of the Interior is authorized, through the United States Geological Survey—

(1) to establish, operate, and maintain such seismic, geodetic, and other geophysical monitoring systems for research purposes in research and experimental areas as may be required, and, to the maximum extent practi-

cable, these research systems shall be integrated into the national networks established under section 201 and copies of resulting data and information shall be deposited in the data centers established under section 4 (b) (4) ; and

(2) to conduct such research, experiments, investigations, and technology development as are necessary to carry out the provisions of this section and to assist the Secretary of Commerce and the Director of the National Science Foundation in carrying out the provisions of sections 4 and 6.

(c) In carrying out his functions under section 5 of this Act, the Secretary of the Interior shall utilize to the maximum extent practicable the services and facilities of the Department of Commerce, the Department of Defense, the National Science Foundation, and other appropriate Federal agencies.

SEC. 6. (a) The Director of the National Science Foundation is authorized to support research in academic institutions, commercial organizations, and Federal agencies—

(1) to promote development of the body of knowledge applicable to sections 4 and 5 of this Act;

(2) to develop a basic understanding of, and criteria for improving, the design of structures to resist earthquake effects, seismic events, and other natural

tectonic processes, measuring the cost of protection against the benefit arising from the reduction of loss of life, injury to persons, and property damage for all classes of structures and for a variety of ground conditions, with priority given to dams, hospitals, schools, public utility and public safety structures, high-occupancy buildings, buildings necessary to emergency operations, structures that, because of their contents or use, may create serious environmental or public health problems if damaged or destroyed, and other structures especially needed in time of disaster.

(b) In carrying out his functions under this section, the Director shall utilize to the maximum extent practicable the services and facilities of the Department of Commerce, the Department of the Interior, the Department of Defense, the Department of Housing and Urban Development, the Atomic Energy Commission, the Department of Health, Education, and Welfare, and other appropriate agencies.

FEDERAL AGENCY COORDINATION; COMPREHENSIVE NATIONAL PROGRAM

SEC. 7. (a) The Secretary shall—

(1) develop, in cooperation with the Department of the Interior, the National Science Foundation, and such other Federal agencies as he may deem appropriate, a comprehensive national program to accomplish the ob-

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jectives of this Act and, in general, to minimize loss of life, injury to persons, and damage to property within the United States resulting from earthquake effects;

(2) establish such coordinating mechanisms and procedures as he may deem necessary or advisable to carry out, in the most efficient and effective manner, the objectives of this Act and the activities authorized thereunder and, to the extent such program can be implemented without additional legislation, such comprehensive national program;

(3) monitor and coordinate the earthquake-related activities of the Federal agencies named in this Act or otherwise participating in earthquake-related activities so as to carry out the objectives of this Act and such comprehensive national plan in the most efficient and effective manner; and

(4) submit to the Congress no later than January 1 in each fiscal year a report in writing setting forth (A) a summary of the actions taken and the results achieved by the Federal agencies named in this Act pursuant hereto during the preceding fiscal year and of other actions taken and results achieved by other Federal agencies in their earthquake-related programs; (B) the progress made during the previous fiscal year in developing the aforesaid comprehensive national plan; and (C)

any proposals which he may deem appropriate for additional legislation to effectuate the objectives of this Act or such comprehensive national program.

(b) To the extent that new data, information, or technologies are developed pursuant to the Act which are capable of practical utilization for the reduction of loss of life, injury to persons, and damage to property, all Federal agencies shall take such data, information, and technologies into account in performing their functions.

AUTHORIZATION OF APPROPRIATIONS

SEC. 8. There are authorized to be appropriated for the fiscal year ending June 30, 1972, and for each of the following nine fiscal years such sums as may be necessary to carry out the objectives of this Act.

U.S. DEPARTMENT OF THE INTERIOR,
OFFICE OF THE SECRETARY,
Washington, D.C., May 15, 1972.

HON. WARREN G. MAGNUSON,
Chairman, Committee on Commerce,
U.S. Senate,
Washington, D.C.

DEAR MR. CHAIRMAN: Your Committee has requested the views of this Department on S. 3173, a bill "To provide a sound physical basis and an operational system for predicting damaging earthquakes in heavily populated areas of California and Nevada."

We do not support enactment of the bill since it does not provide any authority not already available to this Department. We defer to the Office of Emergency Preparedness as to those aspects of the bill which pertain to it.

S. 3173, cited as the "Earthquake Prediction Act of 1972", declares it to be the purpose of Congress to establish a program of instrumentation of the San Andreas and closely related faults of California and Nevada in order to minimize potential loss of life and property damage. The bill directs the Director of Geological Survey to develop and carry out an earthquake prediction program and establishes an advisory committee to assist the Director in formulating such program.

The bill also directs the Office of Emergency Preparedness to carry out a program to review and assess the current state of knowledge on earthquake prediction and warning systems and to determine what additional steps should be taken. The President of the National Academy of Sciences and the Director of the OEP are authorized to make pertinent information available to the Office of Science and Technology, the Congress, Governors of States of high seismic risk and others.

Presently, a number of government agencies, including the Geological Survey, the National Science Foundation, the National Oceanic and Atmospheric Administration, the Bureau of Reclamation, and others, are conducting research programs to find means to reduce losses from earthquakes. The Geological Survey of this Department is the principal agency involved in conducting research on the prediction and control of earthquakes. The Bureau of Reclamation of this Department is concerned with the effects of earthquakes on dams.

Much of the research conducted by Geological Survey is devoted to the geographical area focused on by S. 3173 (California and Nevada). The San Andreas fault is not only the most promising subject on which to carry out the required research and systems development program, but, also, potentially, the most dangerous fault system in the country because of its proximity to major population centers and the large magnitude of the great earthquakes that are known to occur along it.

The level of effort devoted to earthquake research in the past has been too small to yield significant results in prediction or control. A thorough research program should include intensive instrumentation along the fault, fault mapping and tectonic analysis, laboratory rock mechanics experimentation, and computer modeling of faulting. Improved understanding of earthquake mechanics and earthquake effects would provide a more rigorous basis for preparing seismicity maps and earthquake geologic hazards maps. The Administration has recently proposed a dramatic increase in the level of effort in this area to push ahead with these efforts.

The Administration's fiscal year 1973 budget presently before Congress includes requests for an increase of more than 100 percent in total Federal funding for earthquake research, including an increase of $6 million for the Geological Survey and substantial increases for NOAA and NSF.

In February of this year an interagency committee was set up between the Geological Survey and NOAA to coordinate programs. A major function of this committee will be to coordinate earthquake research.

The Office of Management and Budget has advised that there is no objection to the presentation of this report from the standpoint of the Administration's program.

Sincerely yours,

HOLLIS M. DOLE,
Assistant Secretary of the Interior.

OFFICE OF THE SECRETARY OF TRANSPORTATION,
Washington, D.C., May 16, 1972.

HON. WARREN G. MAGNUSON,
Chairman, Committee on Commerce,
U.S. Senate
Washington, D.C.

DEAR MR. CHAIRMAN: Your Committee has asked for the views of this Department concerning S. 3173, a bill "To provide a sound physical basis and an operational system for predicting damaging earthquakes in heavily populated areas of California and Nevada."

S. 3173 would be known as the "Earthquake Prediction Act of 1972."

The bill is intended to minimize the loss of life and property damage through the establishment of a program of instrumentation and to provide for the collection, analysis, and interpretation of data from such instrumentation.

S. 3173 would authorize the Director of Geological Survey to develop and carry out the earthquake prediction program which would (1) obtain detailed records of data, (2) collect and computerize reduction analysis and interpretation of data flow, (3) support field, laboratory and theoretical studies, and (4) develop and field test additional instrumentation. The Director would utilize the services of research personnel in institutions of higher learning, public utilities, organizations (other than Geological Survey) and private entities or organizations concerned with seismic research.

The bill would establish an advisory committee consisting of from 7 to 15 members appointed by the Director from individuals recommended by the National Academy of Sciences. The Committee would select its own chairman and vice-chairman, and assist and advise the Director in developing and carrying out the earthquake prediction program.

The bill would authorize the Director of Emergency Preparedness (1) to establish and carry out a review program and assess the current state of knowledge on earthquake prediction and warning systems, (2) to identify key problem areas for further research and evaluation, and (3) to enter into contracts, agreements or other appropriate arrangements with the National Academy of Sciences to provide such necessary scientific advisory services as may be required.

The bill would require the President of the National Academy of Sciences and the Director of the Office of Emergency Preparedness to make information available to the Office of Science and Technology, the Congress, Governors of those States in the areas of high seismic risk, and other governmental or private organizations which are concerned with preparations for or reactions to earthquakes or earthquake warnings.

The bill authorizes an appropriation of $12,000,000 for fiscal year ending June 30, 1973, and for each of the next four years, for the earthquake prediction program and $200,000 for review and assessment of the current state of knowledge on earthquake prediction and for making available such information.

This Department favors the basic concept embodied in S. 3173 (to enhance the national capability for predicting earthquakes). However, the Department believes that this legislation is unnecessary because sufficient authority now exists to carry out the purposes of the bill. We understand that the President's Budget for FY 1973 provides for the development of an expanded comprehensive earthquake research program which would acomplish the objectives of S. 3173, and would retain responsibility for assignments and coordinating arrangements in the Executive Office of the President. This would enable the utilization of all pertinent Federal resources, and allow greater flexibility to meet changing demands than S. 3173 would allow. In summary, the principal goals of the Administration's program are as follows:

Improve knowledge of the risk of destructive earthquakes in particular locations, and of the nature and extent of the destruction which may result, based on various geologic conditions. Develop detailed seismic risk maps and geologic hazards maps for use in decisions on land use, design of structures, and emergency preparedness.

Develop economically acceptable designs for structures and construction methods to minimize damage from earthquake hazards. It is expected that this research effort will lead to development of improved design criteria, and construction codes and standards for use in areas of seismic risk.

Determine the feasibility of predicting earthquakes. This effort will involve extensive study of micro-earthquakes, ground tilt, earth strain and other geophysical phenomena to determine whether there is a regular pattern of detectable events leading up to an earthquake.

Determine the feasibility of limiting the maximum size of earthquakes by initiating small movements along fault zones to avoid the accumulation of strain which may result in a large earthquake. The research will include an analysis of the costs and benefits of any feasible control methods, as well as analysis of the social and legal implications of such control.

The 1973 Budget requests a total of approximately $25 million for these programs, compared to about $12 million in 1972 for research efforts in these areas.

In view of the above, this Department opposes enactment of S. 3173.

The Office of Management and Budget has advised that, from the standpoint of the Administration's program, there is no objection to the submission of this report to the Congress.

Sincerely,

JOHN W. BARNUM,
General Counsel.

OFFICE OF THE ATTORNEY GENERAL,
Washington, D.C., May 16, 1972.

Hon. WARREN G. MAGNUSON,
Chairman, Committee on Commerce,
U.S. Senate, Washington, D.C.

DEAR SENATOR: This is in response to your request for the views of the Department of Justice on S. 3173, a bill "To provide a sound physical basis and an operational system for predicting damaging earthquakes in heavily populated areas of California and Nevada."

Under the bill it would be the function and duty of the Director of the Geological Survey to develop and carry out an earthquake prediction program. The bill would establish an advisory committee for the program consisting of not less than seven nor more than fifteen members appointed by the Director from among individuals recommended by the National Academy of Sciences. Under the bill the Director of the Office of Emergency Preparedness would carry out a program to review and assess certain problems relating to warning systems and earthquake warnings.

One finding of the first Hoover Commission was that the line of authority from departmental heads through subordinates is often abridged by indepenent authorities granted to bureau heads, and that such bureau autonomy undermines the authority of both the President and the department head. The Commission recommended that, under the President, department heads must hold full responsibility for the conduct of their departments, and that no subordinate should have authority independent from that of his superior. Commission on Organization of the Executive Branch of the Government, *Report on General Management of the Executive Branch*, H. Doc. No. 55, 81st Cong., 1st Sess. 32, 34 (1949). Accordingly, § 2 of the bil shoud be amended to substitute for the references to the Director of the Geoogical Survey references to the Secretary of the Interior.

Whether this legislation should be enacted involves questions as to which the Department of Justice defers to the Department of the Interior.

The Office of Management and Budget has advised that there is no objection to the submission of this report from the standpoint of the Administration's program.

Sincerely,

RICHARD G. KLEINDIENST,
Acting Attorney General.

EXECUTIVE OFFICE OF THE PRESIDENT,
OFFICE OF EMERGENCY PREPAREDNESS,
OFFICE OF THE DIRECTOR,
Washington, D.C., May 18, 1972.

Hon. WARREN G. MAGNUSON,
Chairman, Committee on Commerce, U.S. Senate,
Washington, D.C.

DEAR MR. CHAIRMAN: This is in reply to your request for comments of this Agency concerning S. 3173, 92d Congress, a bill cited as the "Earthquake Prediction Act of 1972."

The objectives of S. 3173 are laudable. However, adequate authorities already exist and the President proposed in his 1973 budget to accelerate substantial efforts in earthquake research. These efforts are to be conducted by several government agencies including United States Geological Survey, National Oceanic and Atmospheric Administration, Advanced Research Projects Agency and the National Science Foundation. Since the President has taken this initiative, we believe that the enactment of S. 3173 would not be useful. The provisions of the bill might conflict with the Administration's initiative, create confusion about program goals and result in undesirable changes in agency responsibilities.

We note that the Office of Emergency Preparedness is already engaged in two of the activities called for in Section 3(a) of the proposed legislation: (a) an assessment of the state of knowledge of all aspects of disaster-related research, including earthquake research, has been requested by OEP from the Advisory Committee on Emergency Planning of the National Academy of Sciences; and (b) at the request of OEP, an analysis of the physical effects of earthquakes of three different Richter magnitudes (6.0, 7.0 and 8.3) occurring on the San Andreas and on the Hayward faults has been brought to an advanced stage of preparation by the National Oceanic and Atmospheric Administration. This analysis will serve as a basis for detailed planning of actions required to respond to an earthquake occurring in the San Francisco Bay Area and as a prototype for similar efforts in other sections of the West Coast and other earthquake-prone areas of the country. The Los Angeles area and the Puget Sound area are scheduled for analysis in the near future.

For the reasons stated above, we do not support enactment of S. 3173.

The Office of Management and Budget advises that it has no objection to the submission of this report from the standpoint of the Administration's program.

Sincerely,

G. A. LINCOLN,
Director.

THE SECRETARY OF HOUSING AND URBAN DEVELOPMENT,
Washington, D.C., May 25, 1972.

Hon. WARREN G. MAGNUSON,
Chairman, Committee on Commerce, U.S. Senate,
Washington, D.C.

DEAR MR. CHAIRMAN: This is in further response to your request for the views of this Department on S. 3173, a bill "To provide a sound physical system for predicting damaging earthquakes in heavily populated areas of California and Nevada."

The bill would establish a program within the Geological Survey and the Office of Emergency Preparedness for the prediction of earthquakes in the area of the San Andreas fault in California and Nevada and for improvement of our earthquake prediction technology.

This Department defers to the Department of the Interior and the Office of Emergency Preparedness as to the need and desirability of S. 3173.

The Office of Management and Budget has advised that there is no objection to the presentation of this report from the standpoint of the Administration's program.

Sincerely,

RICHARD C. VAN DUSEN,
(For GEORGE ROMNEY).

ENVIRONMENTAL PROTECTION AGENCY,
OFFICE OF THE ADMINISTRATOR,
Washington, D.C., June 2, 1972.

Hon. WARREN G. MAGNUSON,
Chairman, Committee on Commerce, U.S. Senate,
Washington, D.C.

DEAR MR. CHAIRMAN: This is in response to your request for the comments of the Environmental Protection Agency with respect to S. 3173, a bill "To provide a sound physical basis and an operational system for predicting damaging earthquakes in heavily populated areas of California and Nevada," and S. 3392, a bill "To amend the National Science Foundation Act of 1950 to provide for a program relating to earthquakes."

S. 3173 would direct the Director of the Geological Survey to develop and carry out an earthquake prediction program including instrumentation of the

San Andreas and closely related faults, establishment of facilities, supporting field and laboratory studies, and development of additional instruments. The Director of the Office of Emergency Preparedness would carry out a program to review and assess the current state of knowledge on earthquake prediction, and to determine needed additional steps.

S. 3392 would direct the National Science Foundation to establish and support a program of advanced earthquake engineering research including development of earthquake prediction methods, criteria for earthquake-resistant construction, and improved methods of earthquake risk assessment. NSF would report annually to the President and the Congress on the implementation of the program.

EPA believes that more knowledge of the risk of earthquake occurrences in particular areas is needed, and that the feasibility of earthquake prediction must be thoroughly investigated. To this end, the President's 1973 Budget provides for an accelerated program of research on earthquakes. With regard to the specific provisions of S. 3173 and S. 3392, however, we defer to other Federal agencies having direct program responsibility in this area.

The Office of Management and Budget advises that there is no objection to the presentation of this report from the standpoint of the President's program.

Sincerely yours,

WILLIAM D. RUCKELSHAUS,
Administrator.

NATIONAL SCIENCE FOUNDATION,
OFFICE OF THE DIRECTOR,
Washington, D.C. June 9, 1972.

Hon. WARREN G. MAGNUSON,
Chairman, Committee on Commerce, U.S. Senate,
Washington, D.C.

DEAR MR. CHAIRMAN: This is in reply to your letter of March 29, 1972, requesting the comments of the National Science Foundation on S. 3173, the "Earthquake Prediction Act of 1972."

The National Science Foundation firmly supports the objectives of strong national support for research in the area of earthquake engineering, earthquake prediction, and related societal problems. As your Committee is aware, the National Science Foundation, the National Oceanic and Atmospheric Administration, the U.S. Geological Survey, and, to a lesser degree, other Federal agencies, have all funded research in one or more areas dealing with earthquakes. The President's 1973 Budget provides for substantially expanded earthquake research programs, requesting a total of approximately $25 million for such programs, compared to about $12 million in FY 1972.

The problem is a national one, and it is by no means certain that our next large damaging earthquake will not occur in Missouri, New England, Washington, South Carolina, or Alaska, rather than in California or Nevada. Consequently, we feel it is unwise to single out a particular area of the country to establish a broad network of earthquake detection instruments, although, admittedly, because of its large population concentration, the California-Nevada area would suffer heavy damage and loss of life from a major earthquake.

The regional limitation of the legislation, however, is not our primary reason for not supporting enactment of S. 3173. Many, if not most, scientists knowledgeable in this area are skeptical about achieving a predictive capability in this century. S. 3173 seems to imply that the envisioned program will provide a sound physical basis and an operational system for predicting damaging earthquakes in California and Nevada within the next five years. Although there has been a very impressive increase in our knowledge of the characteristics of earthquakes and rock properties in recent years, we feel it is premature to suggest that an operational earthquake prediction system can be effectively set up in this time span. Much more must be learned from extensive basic research on the causes and mechanics of crustal movements. The establishment of a very expensive earthquake instrumentation system for the San Andreas and closely related faults and of facilities to handle the data obtained therefrom, while contributing to such research, would do so only in a narrow area and at disproportionate cost. We believe the better course at this point in time would be to support the President's Budget providing for expanded and strengthened programs in the U.S. Geological Survey, NSF, NOAA, and other involved Government agencies.

For the above reasons the Foundation cannot support enactment of S. 3173.

The Office of Management and Budget has advised us that there is no objection to the submission of this report from the viewpoint of the Administration's program.

Sincerely yours,

H. GUYFORD STEVER,
Director,
(For R. L. Risplinghoff).

COMPTROLLER GENERAL OF THE UNITED STATES,
Washington, D.C., June 27, 1972.

B-126965.

Hon. WARREN G. MAGNUSON,
Chairman, Committee on Commerce, U.S. Senate,
Washington, D.C.

DEAR MR. CHAIRMAN: By letter of March 28, 1972, you requested our comments on S. 3173, 92d Congress, which, if enacted would be cited as the "Earthquake Prediction Act of 1972."

S. 3173 is intended to provide a sound physical basis and an operational system for predicting damaging earthquakes in heavily populated areas of California and Nevada.

We have no special information on the subject matter of this legislation which would assist the Committee in considering the merits of its enactment. We offer, however, the following comments on the provisions of the bill.

Section 2(a) provides that, in carrying out the research purposes of the earthquake prediction program, the Director of the Geological Survey shall utilize the services of research personnel in institutions of higher education and public and private entities and organizations concerned with seismic research. The bill does not state the manner in which these services shall be obtained and paid for. We suggest that an appropriate provision be added to the bill including, if so intended, authority to use grants or contracts. Such authority should include a provision requiring the recipients to keep such financial and other pertinent records as the Secretary of the Interior shall prescribe and providing for access thereto by the Secretary of the Interior and the Comptroller General of the United States.

Section 2(b) provides that the Director appoint an advisory committee to assist him in developing and carrying out the earthquake prediction program. The bill does not provide for compensating the members of the advisory committee nor for reimbursing them for travel and other expenses incurred in the course of their duties. The Committee may wish to provide for such compensation as is customary for members of advisory committees serving the Federal Government, setting a maximum rate at which they may be paid, and for the payment of travel expenses for persons employed intermittently for the Government.

Sincerely yours,

R. F. KELLER,
Deputy Comptroller General of the United States.

U.S. DEPARTMENT OF THE INTERIOR
OFFICE OF THE SECRETARY,
Washington, D.C., June 9, 1972.

Hon. WARREN G. MAGNUSON,
Chairman, Committee on Commerce,
U.S. Senate, Washington, D.C.

DEAR MR. CHAIRMAN: Your Committee has requested the views of this Department on S. 3392, a bill "To amend the National Science Foundation Act of 1950 so as to provide for a program relating to earthquakes."

We recommend that the bill not be enacted.

S. 3392 would amend the 1950 Act to establish and support a program to: advance earthquake engineering research, develop more accurate and reliable methods of earthquake resistant analysis and design for all types of structures and for a variety of ground conditions, develop improved minimum criteria of earthquake—resistant construction, and develop improved methods of assessing the earthquake risk at all types of locations in populated areas of high seismic

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risk and of establishing land use priorities designed to reduce the hazards from earthquakes.

On May 16, 1972, Dr. James R. Balsley, Assistant Director of the Geological Survey of this Department, testified before your Subcommittee on Oceans and Atmosphere on S. 3392 and related bills S. 3173 and S. 3584. Dr. Balsley testified in effect that we do not support enactment of this legislation primarily because it does not provide any authority not already available to the Federal agencies involved.

Presently, a number of government agencies, including the Geological Survey, the National Science Foundation, the National Oceanic and Atmospheric Administration, the Bureau of Reclamation, and others, are conducting research programs to find means to reduce losses from earthquakes. The Geological Survey of this Department is the principal agency involved in conducting research on the prediction and control of earthquakes and on geologic hazards mapping. The Bureau of Reclamation of this Department is concerned with the effects of earthquakes on dams.

The Administration's fiscal year 1973 budget presently before Congress includes requests for an increase of more than 100 percent in total Federal funding for earthquake research, including an increase of $6.9 million for the Geological Survey and substantial increases for NOAA and NSF.

The Office of Management and Budget has advised that there is no objection to the presentation of this report from the standpoint of the Administration's program.

Sincerely yours,

HOLLIS M. DOLE,
Assistant Secretary of the Interior.

EXECUTIVE OFFICE OF THE PRESIDENT,
OFFICE OF EMERGENCY PREPAREDNESS,
OFFICE OF THE DIRECTOR,
Washington, D.C., June 19, 1972.

Hon. WARREN G. MAGNUSON,
Chairman, Committee on Commerce,
U.S. Senate,
Washington, D.C.

DEAR MR. CHAIRMAN: This is in reply to your request for comments of this Agency concerning S. 3392, 92nd Congress, a bill, "To amend the National Science Foundation Act of 1950, etc."

The objectives of S. 3392 are worthwhile and its scope comprehensive. However, adequate authorities already exist and the President proposed in his 1973 budget to accelerate substantial efforts in earthquake research. These efforts are to be conducted by several government agencies including United States Geological Survey, National Oceanic and Atmospheric Administration, Advanced Research Projects Agency and the National Science Foundation. Since the President has taken this initiative, we believe that the enactment of S. 3392 would not be useful. The provisions of the bill might conflict with the Administration's initiative, create confusion about program goals and result in undesirable changes in agency responsibilities.

For the reasons stated above, we do not support enactment of S. 3392.

The Office of Management and Budget advises that it has no objection to the submission of this report from the standpoint of the Administration's program.

Sincerely,

G. A. LINCOLN,
Director.

U.S. ATOMIC ENERGY COMMISSION,
Washington, D.C., July 12, 1972.

Hon. WARREN G. MAGNUSON,
Chairman, Committee on Commerce,
U.S. Senate.

DEAR SENATOR MAGNUSON: The Atomic Energy Commission is pleased to reply to your letter of May 5, 1972, and we thank you for your request for our comments on S. 3392, a bill "t[o] amend the National Science Foundation Act of 1950 so as to provide for a program relating to earthquakes."

Although the Atomic Energy Commission supports the bill's general purpose of advancing earthquake engineering research and developing improved criteria of earthquake-resistant construction, we recommend that the bill not be enacted for the following reasons. The authority already exists for activities of the type provided for in this bill, and many such activities have already been undertaken by a number of agencies. Furthermore, the Administration's FY 1973 budget includes requests for an increase of more than 100% in total federal funding for earthquake research programs. Agency responsibilities for carrying out earthquake research programs are being defined by the Executive Office of the President as a part of the expanded earthquake research effort. Therefore, we do not consider this bill necessary or desirable.

As we read the bill, it would authorize and direct the National Science Foundation to establish and support a program which would advance earthquake engineering research; develop more accurate and reliable methods of earthquake-resistant analysis and design for all types of structures and for a variety of ground conditions; develop improved minimum criteria of earthquake-resistant construction; and establish land use priorities designed to reduce the hazards from earthquakes.

The Foundation would be directed to make the methods of structural analysis and design, the criteria of construction, and the methods of assessing earthquake risk maps available to Governors in States in seismic risk areas, a number of Federal agencies including AEC, the Department of Defense, and the General Services Administration, and other interested governmental and private organizations.

The Office of Manageemnt and Budget has advised that there is no objection to the presentation of this report from the standpoint of the Administration's program.

Sincerely,

JOHN A. ERLEWINE,
Deputy General Manager.

OFFICE OF THE SECRETARY OF TRANSPORTATION,
Washington, D.C. July 19, 1972.

Hon. WARREN G. MAGNUSON,
Chairman, Committee on Commerce, U.S. Senate,
Washington, D.C.

DEAR MR. CHAIRMAN: Your Committee has asked for the views of this Department concerning S. 3392, a bill "To amend the National Science Foundation Act of 1950 so as to provide for a program relating to earthquakes."

S. 3392 would establish an earthquake research program under the auspices of the National Science Foundation designed to: advance earthquake engineering research; develop more accurate and reliable methods of earthquake resistant analysis and design for all types of structures and for a variety of ground conditions; develop improved minimum criteria of earthquake-resistant construction, measuring the cost of protection against the benefit of damage and loss of life prevented, with priority given to certain named structures to include "other structures especially needed in time of disaster" and develop improved methods of assessing earthquake risk.

Section (8)(B) of the proposed amendment establishes the various components of such program to include development of effective means to disseminate the methods of structural analysis and design, criteria of construction, and methods of assessing earthquake risk developed pursuant to such program to public and private groups engaged in engineering construction, architecture, construction planning, and land use planning. The Foundation is directed to make the results of the program available to the Governors in States in seismic risk areas, certain government agencies, and "other government . . . organizations which have an interest in construction and land use planning."

Although the Department of Transportation strongly supports the basic intent and scope of this proposed legislation, we recommend that the bill not be enacted for the following reasons. The authority already exists for activities of the type provided for in this bill and many such activities have already been undertaken by a number of agencies. Furthermore, the Administration's FY 1973 budget includes requests for an increase of more than one hundred percent in total Federal funding for earthquake research programs. Agency responsibilities for carrying out earthquake research programs are being defined by the Executive Office of the President as part of the expanded earthquake research effort. Therefore, we do not consider this bill necessary or desirable.

The Office of Management and Budget has advised that, from the standpoint of the Administration's program, there is no objection to the submission of this report to the Congress.

Sincerely,

JOHN W. BARNUM,
General Counsel.

COMPTROLLER GENERAL OF THE UNITED STATES,
Washington, D.C., August 17, 1972.

B-126965.

Hon. WARREN G. MAGNUSON,
Chairman, Committee on Commerce,
U.S. Senate.

DEAR MR. CHAIRMAN: By letter of May 5, 1972, you requested our comments on S. 3392, 92d Congress, which is a bill to amend the National Science Foundation Act of 1950 so as to provide for a program relating to earthquakes.

The stated purpose of S. 3392 is to amend section 3 of the National Science Foundation Act of 1950, 42 U.S.C. 1862 to provide for a program relating to earthquakes. The bill would authorize and direct the National Science Foundation (NSF) to establish and support a program to (1) advance earthquake engineering research; (2) develop more accurate and reliable methods of earthquake-resistant analysis and design of structures; (3) develop improved minimum criteria for earthquake-resistant construction for all types of structures and a variety of ground conditions; and (4) develop improved methods of assessing the earthquake risk at all types of locations in populated areas of high seismic risk.

Section 3 of the NSF Act provides broad authority to NSF to, among other things, (1) initiate and support basic scientific research and programs to strengthen scientific research potential and (2) initiate and support scientific research, including applied research, at academic and other nonprofit institutions. Under this authority, NSF has sponsored earthquake research under several programs including a specific Earthquake Engineering Program. Similar to research areas provided for in the bill, earthquake research areas sponsored by NSF include socio-economic effects and costs, ground motion instrumentation and measurements, effect on solids and foundations, dynamic analysis of structures, tsunami observation and protection, design and dsitribution aspects of public services and utilities, post earthquake inspection and engineering evaluation, and technological transfer, NSF support for earthquake engineering research for fiscal year 1972 is estimated to total about $2.9 million and for fiscal year 1973 such support is budgeted at a level of $6.1 million.

Thus, it would not appear necessary to amend the NSF Act to provide NSF with authority ot support earthquake research as contemplated by the bill. However, we would point out that the bill, if enacted, would require NSF to establish and support an earthquake research program.

Sincerely yours,

E. H. MORSE, Jr.,
(For the Comptroller General of the United States).

U.S. DEPARTMENT OF THE INTERIOR,
OFFICE OF THE SECRETARY,
Washington, D.C., June 12, 1972.

Hon. WARREN G. MAGNUSON,
Chairman, Committee on Commerce,
U.S. Senate,
Washington, D.C.

DEAR MR. CHAIRMAN: Your Committee has requested the views of this Department on S. 3584, a bill "To provide for a comprehensive national program of earthquake monitoring, research and engineering in order to reduce loss of life and property; to provide for studies leading to earthquake prediction and control; and for other purposes."

We recommend that the bill not be enacted.

S. 3584, cited as the "Earthquake Hazards Act", would authorize the Secretary of Commerce to: collect, analyze, and disseminate data and information on earthquakes; assess earthquake hazards in various areas of the country; develop technology in collaboration with this Department for the prediction and control of earthquakes; maintain seismic instrument networks, geodetic systems, warning systems, and data depositories; conduct research on earthquake-resistant structures; and to utilize the services and facilities of other agencies, including this Department, to carry out the purposes of the Act.

S. 3584 also would authorize the Secretary of the Interior to: collect data on the techniques for predicting earthquakes; conduct appropriate geological surveys; conduct field and laboratory experiments; maintain seismic and other geophysical monitoring systems; and to utilize the services of other appropriate Federal agencies.

In addition, S. 3584 would authorize the Director of the National Science Foundation to support research programs in academic institutions to develop criteria for improving the design of earthquake-resistant structures.

On May 16, 1972, Dr. James R. Balsley, Assistant Director of the Geological Survey of this Department, testified before your Subcommittee on Oceans and Atmosphere on S. 3584 and related bills S. 3173 and S. 3392. Dr. Balsley testified in effect that we do not support enactment of this legislation primarily because it does not provide any authority not already available to the Federal agencies involved.

Presently, a number of government agencies, including the Geological Survey, the National Science Foundation, the National Oceanic and Atmospheric Administration, the Bureau of Reclamation, and others, are conducting research programs to find means to reduce losses from earthquakes. The Geological Survey of this Department is the principal agency involved in conducting research on the prediction and control of earthquakes and on geologic hazards mapping. The Bureau of Reclamation of this Department is concerned with the effects of earthquakes on dams.

The Administration's fiscal year 1973 budget presently before Congress includes requests for an increase of more than 100 percent in total Federal funding for earthquake research, including an increase of $6.9 million for the Geological Survey and substantial increases for NOAA and NSF.

The Office of Management and Budget has advised that there is no objection to the presentation of this report from the standpoint of the Administration's program.

Sincerely yours,

HOLLIS M. DOLE,
Assistant Secretary of the Interior.

EXECUTIVE OFFICE OF THE PRESIDENT,
OFFICE OF EMERGENCY PREPAREDNESS,
OFFICE OF THE DIRECTOR,
Washington, D.C., July 10, 1972.

Hon. WARREN G. MAGNUSON,
Chairman, Committee on Commerce,
U.S. Senate,
Washington, D.C.

DEAR MR. CHAIRMAN: This is in reply to your request for comments of this Agency concerning S. 3584, 92nd Congress, a bill cited as the "Earthquake Hazards Act."

The objectives of S. 3584 are worthwhile and its scope comprehensive. However, adequate authorities already exist and the President proposed in his 1973 budget to accelerate substantial efforts in earthquake research. These efforts are to be conducted by several government agencies including United States Geological Survey, National Oceanic and Atmospheric Administration, Advanced Research Projects Agency and the National Science Foundation. Since the President has taken this initiative, we believe that the enactment of S. 3584 would not be useful. The provisions of the bill might conflict with the Administration's initiative, create confusion about program goals and result in undesirable changes in agency responsibilities.

For the reasons stated above, we do not support enactment of S. 3584.

The Office of Management and Budget advises that it has no objection to the submission of this report from the standpoint of the Administration's program.

Sincerely,

G. A. LINCOLN,
Director.

Senator HOLLINGS. We are pleased to hear from Dr. Robert M. White, Administrator of the National Oceanic and Atmospheric Administration, and Mr. James Balsley, Assistant Director of the U.S. Geological Survey.

Senator Cranston, we welcome you to the committee. You are the one who has given the leadership to this particular problem, introducing, of course, the first legislation on this score, and have shown the greatest interest and we are very anxious to hear your thoughts this morning on your two measures and any that you may have on the other bill which was introduced, or any other suggestions.

STATEMENT OF HON. ALAN CRANSTON, U.S. SENATOR FROM CALIFORNIA

Senator CRANSTON. Thank you very much.

I am very grateful to you, Mr. Chairman, and to this committee for providing the opportunity for consideration of the various bills, mine and others, that have been introduced to deal with this very serious problem of earthquakes in a way that modern technology now makes possible.

I have a fairly long statement which I would like simply to have placed in the record, and I will just briefly make a few points verbally at this point.

S. 3173 provides for a program to acquire the ability to scientifically predict earthquakes. I am convinced, based upon studies that I and my staff have made in consultation with many experts in this field, that we can develop the capacity to predict where earthquakes will come.

Experiments conducted in connection with developing our capacity to detect underground atomic blasts have in part brought the technology to the point where we can make major breakthroughs here. Based on discussions with a number of officials, a number of experts in this field, I believe that if the procedures suggested in my bill were followed, we would develop a capacity, in not too many years, to predict where and when earthquakes will come.

I can believe we can predict, within a few days, when they will strike and within 20 miles of the center of the earthquake.

If we do develop this capacity we can then do a number of things to reduce the loss of lives and the damage to individuals in earthquakes. People in buildings that might be considered dangerous can be asked to leave. We can turn off gas and electric to reduce the danger of fire. We can let water out from behind dams to reduce the danger of floods.

The program would be directed by the U.S. Geological Survey under this bill. I chose USGS because they have done extensive work in the field of basic seismological research and, of all the experts that I have talked to in many, many places on this topic, virtually everyone recommended the USGS direct the program.

It would be a 5-year program. The National Academy of Sciences has called for full-scale research in earthquake prediction. The program this bill provides would implement that recommendation.

The bill does more than just continue sporadic research in seismology, which I think is what is now occurring. It provides also for an Office of Emergency Preparedness program to determine the best way to use the warning. There are many problems connected with how you tell people. You don't want to create a panic.

There should be some study in the best way to advise people in advance.

The bill calls for spending $61 million over 5 years; $60 million to USGS, $1 million to OEP.

The bill provides a distinct program in earthquake prediction which would be funded at $12 million for fiscal 1973, rather than the $1.5 million for earthquake prediction that the administration has requested, which is totally inadequate to prepare to deal with the problem.

I would like to add, Mr. Chairman, that I and my staff worked extremely closely with the USGS in drafting this bill. Many of their people were involved.

Senator HOLLINGS. Did the people you worked with at the USGS approve and support your bill?

Senator CRANSTON. They most certainly did approve, because we designed the bill on lines that they suggested.

Specifically, Jerry Eaton, who heads their project in California was consulted, and his staff was.

I fully expected that the USGS would formally support the bill. Now I gather that some work done by the OMB has resulted in a different viewpoint. But I think it is very shortsighted in terms of the money and lives to be saved if this program is undertaken.

On the other bill, S. 3392, it is designed to provide for a program in earthquake engineering research. It is the objective of earthquake engineering to develop structural designs and code standards to avert massive death due to collapsing structures during an earthquake, obviously every structure experiences stresses and strains. Well-designed structures can stand up under them.

The San Fernando earthquake that we had quite recently in California calls into basic question the assumption of today's building code. As I am sure you know, one brandnew hospital that had just barely been dedicated, collapsed in that quake. It had passed all the requirements as of that time.

The National Academy of Engineering's earthquake engineering report in 1969 called for major efforts in earthquake engineering.

The National Science Foundation would direct a 3-year program in engineering research under the bill. The bill provides for an authorization of $10 million each year for 3 years for a total of $30 million.

I would like to add one point, Mr. Chairman. This work is already being undertaken, but again, inadequately and sporadically.

In northern California, under the auspices of the University of California, there is an earthquake—what we in amateur language might call a shaking table. They can, on a concrete steel reinforced slab, various structures and various materials used in those structures can be felt.

Then you turn on the table so it shakes like an earthquake at various degrees on the Richter scale, and you see how the structures stand up, and you learn by that experiment what will stand up in what degree earthquake, and what will not.

I believe it is very important for the people not only of my State, but for the people of all States—all States can be hit by earthquakes, and all have had earthquakes—to have these programs undertaken.

It is important not only to the people who will suffer the loss of life, or the damage to their bodies, or to their property, it is also important to all the citizens of the country who become involved in the expense after an earthquake occurs in trying to help those who have suffered.

This is a tremendous investment in the well-being of all the people of our country, Mr. Chairman.

Senator HOLLINGS. Senator, your statement in its entirety will be included in the record.

As you know, I join in the cosponsorship of your S. 3173. I am mindful of the fact that there is hardly a home or building in my hometown of Charleston that does not have these tie rods to hold the building together in case of earthquake.

Additionally, we have the AEC trying to sneak around and do some permanent storage of spent fuel elements, and high-level nuclear waste at the Savannah River plant. The Tuscaloosa Aquifer, which provides much of the drinking water for South Carolina and Georgia, lies below this plant.

We had a tremor of a minor nature in February. So this is of vital importance, not only to California and Nevada, but to the entire country. And as I say, the committee commends you for giving leadership to the issue. That is why I want to try to extend it beyond California and Nevada, and try to obtain a comprehensive approach to it, segmenting the areas of responsibility between the Geological Survey, the National Academy of Sciences and NOAA.

You realize that I introduced S. 3584 only a week ago. Do you have any comments or criticisms of that measure? Because I want to try to bring it all into focus.

Senator CRANSTON. I would like to say that generally, there should be a national program. Work has centered to some degree in California, because we have suffered along with Alaska, the most recent damage from quakes.

We have experienced some of the worst, and we have one of the most active faults in the San Andreas Fault. It is felt, that by developing, as my bill would suggest, a series of instruments along that fault, we can learn in California—because we have this active fault where we can measure what is going on and gain experience very rapidly—we can learn there what needs to be done in the rest of the Nation to help people in all the States and I hope we can carry on that particular program.

Senator HOLLINGS. I would think so. I think the best testing—we can ask Dr. White and some of the experts from the Geological Survey to testify later—would be in the California area. It would be the best test tube, so to speak, for the entire country.

But the fact remains that we have this problem on the east coast and in other sections of the country as well. Study S. 3584, if you can, please, Senator Cranston, and let us have your comments, not necessarily for the record, but I want to hear from you.

I would like your comments on my bill so we can get every agency into the picture which belongs, and they all will know where their responsibility lies.

That has been one of the problems. Everybody wants to continue on in their own little phase of it, but there is no coordinated program within the country.

Senator CRANSTON. I think one particular thing is all I would like to say at this point about your bill. I think that a specific sum should be authorized, not what will be needed, but a specific sum. I have come up with specific sums in both my bills, and let us see if they stand up under scrutiny and attack.

But eventually we should arrive at a program that we can really authorize and count on, a substantive, accepted figure being spent, invested.

Senator HOLLINGS. I think that suggestion is well taken. Is there anything else you wish to add at this time?

Senator CRANSTON. I think that is all at this point.

Senator HOLLINGS. Thank you very much, Senator Cranston, we appreciate your testimony.

Senator CRANSTON. Thank you very much for the opportunity.

(The statement follows:)

STATEMENT OF HON. ALAN CRANSTON, U.S. SENATOR FROM CALIFORNIA

Mr. Chairman and members of the Subcommittee, I have the privilege of appearing before you to testify on two bills which I introduced earlier this year. S. 3173 is concerned with achieving the ability to predict earthquakes, and S. 3392 is concerned with achieving the ability to build structures which are more earthquake-resistant.

Earthquakes are not limited to California and Alaska. Every State in the Union has at some time suffered earthquake damage. Twenty States have suffered major damage, and according to scientific projections, are likely to suffer major earthquake damage again. Besides California and Alaska, these States are South Carolina, Nevada, Kentucky, Washington, Illinois, New York, Idaho, Massachusetts, New Hampshire, Tennessee, Mississippi, Montana, Wyoming, Utah, Maine, Indiana, Missouri, and Arkansas.

The most severe earthquake to occur in the United States was centered in New Madrid, Missouri, in 1812. No loss of life or recorded damage to structures occurred because the area was unsettled at the time. However, more recent earthquakes have struck populated areas leaving death, injury, and property damage in their wake. The 1906 San Francisco earthquake resulted in devastating fires which destroyed much of the city. An estimated 700 persons died in that earthquake and fire. The 1964 Alaska earthquake caused extensive damage, virtually destroying the port area of Seward, Alaska. Docks and warehouse facilities disappeared, transportation facilities were destroyed, and oil tanks were set afire. The 1886 Charleston, South Carolina earthquake resulted in at least 60 persons being killed, many buildings being severely damaged, 14,000 chimneys of houses destroyed, and rail and telegraph service to the city cut. Fortunately there was no wind so the fires that occurred did not spread disastrously.

In 1971 a medium-sized earthquake hit the San Fernando Valley in California. Due to the dense population and extensive development of that area, the earthquake damage reached catastrophic proportions. Sixty-four persons lost their lives, many more were injured, and between $500 million and $1 billion in property damage occurred. Most of the lives were lost because of collapsing structures.

The San Fernando earthquake registered only 6.6 on the Richter Scale—the 1906 San Francisco earthquake registered 8.2; the 1964 Alaska earthquake, 8.4. An earthquake measuring 8.0 on the Richter scale releases almost 1,000 times the amount of energy as an earthquake registering 6.0.

If another earthquake of the magnitude of the 1906 San Francisco earthquake were to strike California, 500 times the energy of the San Fernando earthquake

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would be released. A 1968 report prepared by a group of the Nation's top earthquake experts for the President's Office of Science and Technology, estimates that an earthquake registering 8.2 in California today could cause up to $50 billion damage and take thousands of lives. There is a 75 percent chance that an earthquake of that magnitude will occur along the San Andreas fault in California within the next 30 years, according to testimony by the former director of the California Earthquake Office before the Senate Public Works Committee last year. An earthquake of magnitude 7.0 or greater is likely to occur at least once a decade, according to an earthquake engineering report prepared for the National Science Foundation in 1969.

If the ability to predict the earthquake has existed, the gravest crisis of the San Fernando earthquake could have been averted altogether. When the concrete apron of the lower Van Norman Dam gave way, only 5 feet of soil separated the San Fernando Valley from 3.6 billion gallons of water behind the dam. More than 80,000 persons were evacuated and estimates warn that up to 10,000 persons would have been killed if the dam had given way. Experts say the dam would have collapsed if the water had been 4 feet higher. Only by merest chance were those thousands of lives saved. Earthquake prediction will take from the hands of chance and place in the hands of science the responsibility to save those lives. If the earthquake had been predicted scientifically, the water in the dam would have been lowered and the danger to those thousands of lives prevented.

S. 3173 provides for a program to acquire the ability to scientifically predict earthquakes. The U.S. Geological Survey will direct the research program which should achieve earthquake prediction ability. The U.S. Geological Survey was recommended to me by virtually all of the persons in the field whom I contacted when formulating this legislation. I was told USGS was the agency with the greatest ability to direct a program such as the one I am proposing. USGS has done extensive work in the field of basic seismological research, as well as doing some initial work in the area of earthquake prediction. They operate a network of seismographs, tiltometers, creepometers, and other instrumentation of the type useful and necessary for work in earthquake prediction.

The U.S. Geological Survey has proposed a plan which within 5 years should enable them to predict medium and major earthquakes in California and Nevada, giving the day the earthquake will occur within 3 days. Prediction will come up to 3 months before the earthquake actually occurs.

The possibility of this prediction ability exists because of the tremendous breakthroughs in seismology in the past few years. Japanese seismologists were able to give earthquake warnings at Matsushiro in 1966. Russian scientists plan to be able to issue their first formal earthquake warnings this year if one should occur in the Tadzhik Republic in Siberia where they have been conducting extensive experiments. The Russians expect to be able to predict the location of a quake 5 days in advance and to guage its magnitude to within plus or minus 0.5 on the Richter Scale. The United States currently has no such capability.

Both the National Academy of Sciences and the U.S. Geological Survey call for full-scale research by the United States in this important field. Research up to the moment in earthquake prediction has found that certain movements such as previously random foreshocks begin to behave in a systematic fashion and a change occurs in the conductivity of the rocks in the region of an imminent earthquake. These "signal" an upcoming earthquake. Future research should be along the lines of the program embodied by the bill, the U.S. Geological Survey states.

The program authorized by this legislation provides for instrumentation that will be comprised of more than 1,000 geophysical measuring devices along the 600 mile length of the San Andreas fault system. Some of the research would be aimed at creating more efficient and more reliable instruments to work under the condition required. These instruments would be linked to a computer that would gather the data and interpret the movements of the earth over a period of time. Further studies to learn the patterns that precede earthquakes, and the many factors that can aid in earthquake prediction, will be part of the program. Other aspects of it include use of the satellite network to help in the study of volcanic forces, earth movements, and other relevant data.

The San Andreas fault system provides the best opportunity for testing an instrumentation network leading to prediction. There are 3 major reasons for this. First, the U.S. Geological Survey states that the best accumulation of information to date on any U.S. fault exists in the data from studies of the San Andreas fault. Second, the San Andreas is the most active fault in the North

American Continent and is the contact line between 2 of the earth's major lithospheric plates. Thirdly, because it is an active fault near major population centers basic seismological research on earthquake prediction is already under way there. Some of the instrumentation required for a program in earthquake prediction such as seismographs and creepometers has already been stationed on the fault. For these reasons, I urge that whatever bill is finally acted upon by the Subcommittee, it include a provision that instrumentation for the earthquake prediction program be established first on the San Andreas fault.

The first 3 years of the 5-year program would be devoted mainly to producing and deploying instruments known to be useful in earthquake prediction, and for developing and testing new devises.

Within 5 years, the plan should enable American scientists to predict an earthquake of a magnitude of Richter 5 or greater up to 3 months in advance, to estimate its severity to within 1 unit of magnitude, and to locate it within a 3–20 mile area. While beginning research would concentrate on faults in California and Nevada, the knowledge gained would be sufficient to predict an earthquake anywhere in the country when the necessary instrumentation has been established.

Once the ability to predict earthquakes exists, knowledge of the best way to warn people is required. It is not known precisely how earthquakes affect people's behavior and psychological reactions. A study of mass behavior may show that it is best to warn people several months in advance, or it may show that a general public warning should only be issued a few days before the coming earthquake. Problems like this will be studied by the portion of the program directed by the Office of Emergency Preparedness.

A plan determining what steps should be taken before the earthquake will be developed. This plan would include evacuating particularly vulnerable buildings, lowering water levels behind dams to prevent flooding, and turning off gas and electricity to structures likely to be heavily damaged, to prevent fires like the one that followed the San Francisco earthquake in 1906. Emergency supplies of water, food, and medicine will be readied. Such a plan is necessary to best utilize the ability to predict earthquakes.

The earthquake prediction bill, S. 3173, provides an authorization of $12.2 million a year for 5 years. The U.S. Geological Survey will direct use of $12 million a year for instrumentation, and supporting field and theoretical studies. Additionally, the Office of Emergency Preparedness will utilize $200,000 each year to study the problems of issuing an earthquake warning, the physical effects of earthquakes, and the behavioral and psychological effects from earthquakes.

The ability to predict earthquakes will greatly reduce the loss of life and injuries earthquakes cause. It will also reduce the large amounts of property damage earthquakes now are able to inflict, thus making the authorization this bill calls for a very sound financial investment.

The earthquake engineering bill, S. 3392, will also prevent many financial losses. Buildings which are more earthquake-resistant will not collapse except under the most severe earthquake stress. Thus, much property damage will be avoided when buildings are built to resist major earthquakes.

During an earthquake, every structure or object in contact with the earth, every piece of equipment in contact with a structure, even the ground that supports the structure, all experience stresses and strains. Whether the structure collapses will depend largely on the original engineering design.

It is the objective of earthquake engineering to develop structural designs and code standards to avert massive death and destruction during an earthquake. The advanages of such construction designs were demonstrated during the 1923 Tokyo earthquake. Some 74,000 persons died, 54 percent of all brick buildings collapsed, and 10 percent of all reinforced concrete structures collapsed. Frank Lloyd Wright's Imperial Hotel was the only large building that offered safety because of its revolutionary, floating cantilever construction.

Current minimum construction standards are determined throughout the United States by city and county building codes. The Uniform Building Code published by the International Conference of Building Officials and based on testing done by the Structural Engineers Association of California, is preeminent in the field. However, the San Fernando earthquake has raised serious questions about the adequacy of the code provisions. Earthquake engineers call the San Fernando earthquake the first comprehensive test of American earthquake codes. That earthquake tragically demonstrated the inadequacy of existing building codes.

The $24 million Olive View Medical Center was dedicated in November 1970. Three months later, the second floor of the psychiatric center collapsed to the ground in that earthquake; the facility is a total loss. The San Fernando earthquake caused the collapse of a freeway interchange under construction at the time of the quake. It was designed in late 1966.

Many other buildings, bridges, and utility structures which sustained serious damage under the earthquake stress, had been built to meet current code requirements. Clearly, we must reevaluate the assumptions on which the codes are based. A critical and comprehensive review is needed. Earthquake engineering research, which will use new methods such as computer analysis of structural reaction to earthquakes, will enable earthquake resistant structures to be built. The new knowledge gained from a program in earthquake engineering research will be translated into revised building codes.

Several major Government studies over the past decade have called for greater investment in earthquake engineering research. The National Academy of Engineering issued an "Earthquake Engineering Research" report in 1969 calling for a program of safe and economical seismic design criteria, new methods of design, and guidelines for decreasing potential earthquake disaster. The National Academy recommended a 10- to 20-year research effort in earthquake engineering to compensate for past under-investment in the field.

One major earthquake in the Los Angeles area could cause $50 billion in damage, according to the National Academy of Engineering report. Dr. George Housner, a professor at the California Institute of Technology and chairman of the Committee on Earthquake Engineering Research of the National Academy of Engineering, states that the Academy's proposed 10-year research program would produce data that could reduce losses to 10 percent in an earthquake of the magnitude of the San Fernando earthquake. Dr. Ray Clough, professor of structural engineering at Berkeley, estimates that the cost of building multistory office buildings to withstand an earthquake of the San Fernando magnitude would be only 1.5 to 2 percent higher. The increase would be less for hospitals whose structural cost is a smaller portion of the total cost of the building.

The program in earthquake engineering which my bill will launch provides for research along the lines of that proposed by the National Academy of Engineering. The research will be funded for the first 3 years at a level of $10 million each year. After 3 years, the program will be reevaluated to determine at what level the program should be further funded, or whether the desired results have already been achieved.

The proposed program is similar to one recommended by the National Science Foundation. In preparing the bill, I have worked closely with the National Science Foundation and with Dr. George Housner.

The bill seeks to improve earthquake engineering knowledge using known and new techniques. By amending the National Science Foundation Act of 1950, the bill directs the National Science Foundation to support a program to advance earthquake engineering research; to develop improved minimum construction standards for resistance of structures to the ground shaking during quakes; and to develop improved methods of making maps to indicate the degree of earthquake hazard to be expected for a variety of locations with a variety of soil conditions. The National Science Foundation would administer the earthquake engineering research program. The NSF has directed most earthquake engineering research in the past, and has done an excellent job. Earthquake engineers I spoke with feel the National Science Foundation should continue to administer earthquake engineering research.

The ability to build structures capable of withstanding earthquakes and the ability to predict coming earthquakes will drastically reduce the loss of life, the injuries, and the large amounts of property damage earthquakes are now able to inflict. To alleviate these disastrous losses in the future, we should invest now in the programs I am proposing.

Senator HOLLINGS. The committee will next hear from Dr. Robert M. White, the Administrator of the National Oceanic and Atmospheric Administration.

I see that you have with you, I believe, Dr. John W. Townsend, your Associate Administrator; Mr. Raud E. Johnson, the General Counsel; and Wilmot N. Hess, Director of the Environmental Research Laboratories.

You have already built yourself up a hierarchy, have you not?

STATEMENT OF DR. ROBERT M. WHITE, ADMINISTRATOR, NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION; ACCOMPANIED BY JOHN W. TOWNSEND, ASSOCIATE ADMINISTRATOR; JAMES BRENNAN, GENERAL COUNSEL'S OFFICE; AND WILMOT N. HESS, DIRECTOR, ENVIRONMENTAL RESEARCH LABORATORIES

Dr. White. We think it is a rather streamlined one, Mr. Chairman.

Senator Hollings. That is good. We are glad to hear from you and your associates at this time.

Dr. White. Mr. Chairman, I have one correction to make. My General Counsel, Mr. Raud Johnson, is not here, and in his place, I have Mr. James Brennan, from our General Counsel's office—on my far left, here.

It is with great pleasure, Mr. Chairman, that I appear before your subcommittee again today to discuss the national need for an earthquake hazard protection program.

As you have pointed out and as Senator Cranston has pointed out; earthquakes pose a serious and growing threat to many people of this Nation and throughout the world. The disasters in recent years in areas as far apart as Turkey, Peru, Iran, and California well illustrate the level of loss of life, human suffering, and property damage which can be caused by earthquakes.

Senator Hollings. You do not mind, Doctor, if, from time to time, I interrupt you?

Dr. White. No, sir.

Senator Hollings. When you talk about Turkey, Peru, Iran, and California—I know you had a weather prediction program, worldwide, and a hotline, even before the White House started talking about it.

I think you had one from Suitland, Md., into the Soviet Union, to call and communicate predictions. Now, on a weather basis, we have it. Do we have anything similar to it on earthquakes, or could it be developed from your experience along this line, the same type of system used to assist in the prediction of earthquakes?

Dr. White. There is an international system that has some aegis with the international weather system. There is maintained, a worldwide, standardized seismological network. This network has instruments located in many countries in the world.

They are jointly funded and operated by the United States and the host country. In this particular case, the National Science Foundation and NOAA, jointly, are responsible for it on our side. It is this worldwide network of standardized instruments which enable us to locate an earthquake and determine its magnitude, wherever it occurs in any part of the world.

Senator Hollings. Now, as to earthquakes, can you educate me about the possibility of predictions? Or is that just totally fanciful, the fact that you have one at a certain location, you could not predict its effect anywhere else, or does it have an effect?

Dr. White. Well, earthquakes do not move, in the sense that hurricanes move, from one part of the world to another.

Senator Hollings. The tremors at one place would not cause a reaction in another?

Dr. WHITE. Well, that we do not quite know, if there is a connection in one part of the world with an earthquake in another. There is some indication that there is some connection. But the earthquake itself, does not move. What moves, of course, is the wave through the earth, which is the result of the earthquake, and these waves can be sensed at almost any part of the earth, provided you have adequately sensitive instrumentation. And that is what the worldwide seismic network does do, that I talked about, this international one.

It is able to sense the location of an earthquake, no matter where it occurs on the basis of this international network. It provides other information too, of course. It gives us information on the number, frequency, and location of earthquakes at various parts of the world, so that remedial measures that need to be taken in various parts of the world on the basis of seismic risk can be taken.

This network is also essential for other problems. Seismic sea waves, which are called tsunamis, and which occur principally in the Pacific Ocean, are triggered by submarine earthquakes. Now, the tidal wave, of course, does travel in the same sense that a hurricane travels. And in order to locate and predict when a seismic sea wave, or as commonly called, a tidal wave, will arrive, one has to know where the earthquake is occurring, and one has to know something about its magnitude.

And, as I indicated later in my testimony, the responsibility for operating the international Tsunami Warning System in the Pacific Ocean area is the responsibility of our organization, which does maintain, in collaboration with the other nations around the Pacific Basin, a network of seismic stations, and the necessary communications to transmit data very rapidly to Hawaii, where the predictions of the occurrence of tidal waves are made, or to local areas, such as in Alaska, or the Northwestern part of the United States, where local predictions of possible tidal waves are made.

So, in that sense, there is an analogy between a hurricane, in the sense that the actual physical phenomena does move.

Senator HOLLINGS. Do we learn anything from the history of these seismic disturbances? In other words, if you had so many in Iran, I guess periodically, let us hypothetically use that as a case, every 5 or 10 years, does it have a consequent effect in other parts of the globe?

For example, when we have one in Iran, can we count on, within a given number of days, a similar reaction on some consequent reaction as a result of it?

Dr. WHITE. No.

Senator HOLLINGS. Can we learn anything from that? Or that does not occur that way?

Dr. WHITE. I do not think it occurs that way; although there have been studies of triggering effects of earthquakes, none have shown positive results.

Senator HOLLINGS. All right, sir.

Dr. WHITE. In the United States as in other countries, the pressure of increasing population in major urban centers is causing development in areas considered to have substantial susceptibility to servere earthquake damage.

Many people in this country recognize that Alaska and California are "earthquake country." Not so well understood by the public, however, is the fact that portions of Washington, Idaho, Montana, Utah, Nevada, Illinois, Indiana, Kentucky, Tennessee, Missouri, Massachusetts, Mississippi, New York, Maine, and of course, your State of South Carolina, have all been subjected to significant earthquake damage. In fact, only portions of Texas, Florida, Alabama, and Mississippi have no history of earthquake damage.

Senator HOLLINGS. Well, we have found four potential places for that AEC material. Thank you. We have got something out of these hearings, all right.

Dr. WHITE. Earthquakes and related phenomena such as landslides and seismic sea waves (tsunamis), impact every segment of our economy from the individual endagered from falling debris; the homeowner faced with partial or complete destruction of his home; commerce and industry faced with destruction of facilities and equipment; utilities concerned with destruction of facilities and interruption of essential services; to State and local organizations concerned with disaster relief and the impact on local economic well-being.

In addition to these public perils, the Federal Government is intimiately concerned with earthquakes in connection with large volume of construction carried out or supported by Federal agencies and with such other activities as the mortgage insurance programs of FHA and VA and the licensing of nuclear reactors by the AEC. The Federal Government is concerned with physical and economic reconstruction following a disastrous earthquake.

Since 1900, this Nation has experienced 10 particularly destructive earthquakes, and many other smaller shocks which in total have taken 1,350 lives and caused property damage of approximately $1.8 billion. It should be noted that the property damage estimates just mentioned are in contemporary dollars.

Damage based on current construction costs would, in every case, be much higher. For example, the $525 million damage due to the 1906 San Francisco earthquakes would be comparable to almost $3 billion today.

The 65 lives taken and estimated property damage of over $550 million from the February 9, 1971, San Fernando earthquake—a moderate seismic event near a major metropolitan area—demonstrate all too clearly the potential threats from earthquakes.

If the epicenter or source of this particular earthquake had been just a few miles closer to Los Angeles, or if it had occurred when the freeways and buildings had been fully occupied, the death toll and property damage could easily have been larger by a factor of 10 or more.

As severe as the threat from earthquakes is today, the potential for loss of life and property damage is growing larger every year. Poorly planned urban expansion is increasing the risk by developing areas of artificial land fill, such as in the San Francisco Bay area, or scenic bluffs, and unstable slopes, such as the Turnigan Arms area in Anchorage, Alaska, and other geologic areas of high potential earthquake risk.

It is estimated that within the next 30 years, approximately 40 million people will be living in the high risk areas in California, alone. Additionally, NOAA estimates the U.S. population potentially endangered from tsunamis, which, as we have discussed, is the result of submarine earthquakes, at 500,000 to 1 million coastal residents in 500 cities and towns in Hawaii, Alaska, Washington, Oregon, and California.

Some of this Nation's leading earthquake experts feel that deaths in the thousands and damage in the $20 to $50 billion range could occur in the next few years if severe quakes occur.

They feel that the chances are good for such earthquakes along the San Andreas Fault in the next 10 to 30 years. No one can say with absolute certainty when or exactly where severe earthquakes will occur, but there is strong evidence that a major event will happen along the San Andreas Fault.

Senator HOLLINGS. To what degree do we know that? You know we get these predictions from your agency, wherein NOAA says there is a 30 percent chance of rain or 70 percent chance. What is the percent of chance for an earthquake?

Dr. WHITE. The statement is really based on the past occurrence of major earthquakes along this fault.

Senator HOLLINGS. If you had to put it in weather terms, what would you say? What percent?

Dr. WHITE. Dr. Hess suggested it may be as high as 100 percent, if you take a period as long as 30 years.

Senator HOLLINGS. I see. All right, sir.

Dr. WHITE. We cannot prevent these earthquakes, but we can substantially reduce the devastation. We can consider earthquake risk in land use planning. We can establish and enforce proper building codes to govern design and construction to improve the earthquake damage resistance of structures.

We can identify existing hazardous structures so that they may be properly modified or torn down. These types of hazards abatement actions can be achieved in the next 5 to 10 years.

For the longer term, it is possible that earthquake prediction technology will evolve to the point where warnings of individual earthquakes can be given. The utility of such warnings will depend on the precision, timeliness, and reliability that can be achieved.

Our experience with weather warnings indicates the need to achieve a high measure of credibility before the public will act. No one can, at this time, tell whether adequate precision and reliability can be developed. Nevertheless, we must push our research forward. Once reliable forecasts are available, many steps can be taken to protect the public.

Water levels in critical reservoirs could be lowered. Public utilities could be put on alert to contend with ruptured water and gas mains, fallen wires, and other threats. Particularly hazardous buildings could be evacuated. Disaster relief resources could be mobilized. These are just a few examples of hazards mitigation actions that would result from a credible prediction capability.

Senator HOLLINGS. At this point, Dr. White, can you comment a little about it more fully, when you say, "No one can, at this time, tell whether adequate precision and reliability can be developed."

What do we know and what is lacking in the computer area that has not gone into determining this? What have we not done that can be done, so we know whether or not it can be developed?

Dr. WHITE. I think, fundamentally, our basic understanding of the mechanics of earthquakes is poor, at the present time. And that is the first thing that needs to be attacked. There are indications, based upon studies carried out in the Soviet Union, and Japan; that there may very well be certain precursors of an earthquake, that is, there may very well be certain indications in the everyday seismic record of the possibility of a major event, sometime in the future.

Now, if you talk to scientists, you will get different views as to whether it will, or will not, be possible to develop a sufficiently precise earthquake prediction technique over a certain period of time.

You asked me the question, what is the percent chance of having an earthquake on the San Andreas Fault; and I indicated that over a period of 30 years, if you were to take that long for your prediction, why, your probability of having a successful prediction goes up to about 100 percent.

This is based upon certain kinds of evidence. Now, I do not know exactly what kind of precision would be required of an earthquake prediction in order to bring about the need for certain kinds of disaster preparedness. One of the things that we have found in the warning systems that we operate, and as you know, we operate many of them, not just for the weather phenomena, but for floods, and for tsunamis—is that you can "cry wolf," too often.

Senator HOLLINGS. Yes.

Dr. WHITE. If the public begins to believe that your forecasts are not reliable, they will not pay any attention to them.

Senator HOLLINGS. Along that line, how fast does an earthquake occur? Is that a sensible question, or you just cannot tell? In other words, I have never been in one, but I have been in hurricanes, and we have experts who can give all the warnings, but many stubborn people will be blown all over the beach before they will abandon their home, and then we have to send emergency crews out to get them.

Now, is it possible to develop the ability to warn about earthquakes in time for evacuation? Or do they just occur and you do not have that time?

Dr. WHITE. The earthquake occurs almost instantaneously. A prediction of an earthquake would be a statement that an earthquake would occur, let us say 24 hours from now, or 3 days from now, or something of that nature.

And, if we could develop a technique that woud allow us to do that, then you could take the kinds of actions that I have indicated. Now, if your prediction frequency said an earthquake will occur sometime in the next 3 months, then the kinds of actions that you might take would be quite different than if you said the earthquake is going to occur 3 days from now; and with great precision in that statement.

That is, it is going to occur within 3 days, plus or minus, let us say, 6 hours or so. The decisionmakers in the community that would be affected by such an earthquake would take very, very specific actions. But, if you made a statement, that an earthquake was going to occur sometime over the next 3 months, what actions would you take?

Would you evacuate buildings for a 3-month period? So, your action and your decisionmaking mechanisms would be totally dependent upon the kind of precision you could achieve in that prediction capability.

Senator HOLLINGS. In other words, you have to build in credibility or it just would not be heeded at all?

Dr. WHITE. That is right. It would have to be a well-tested system, otherwise if you had prediction on, let us say, three or four occasions which did not work out, and the public and the decisionmakers became used to the idea that they did not have much confidence in these predictions, they would not pay any attention to them. So, this is really a critical part of developing a prediction capability.

Senator HOLLINGS. All right, sir.

Dr. WHITE. Now, what about preventing earthquakes? Recent theoretical and field experiments indicate that fluid injection and withdrawal or other techniques may offer hope of reducing the magnitude of earthquakes. By injecting fluids it is thought that the slowly accumulating strain energy could be reduced under controlled conditions.

This technique, if proven might be used in densely populated, very active seismic regions to release earth strain through a large number of small, nondestructive earthquakes rather than allowing the strain to accumulate to the point where a devastating earthquake occurs.

Senator HOLLINGS. Specifically as to that San Andreas Fault. Please elaborate a little more on that injecting of fluid? How do you do that?

Dr. WHITE. It is essentially a——

Senator HOLLINGS. Do you recommend it, considering there is a 100-percent chance of an earthquake in the next 30 years?

Dr. WHITE. As I will indicate in my testimony, Mr. Chairman, I believe it is important for the United States to investigate this kind of technique. There are some indications that, for example, by fluid injection, one can have some effect on earthquakes. We really do not know the extent to which we can have an effect, and that is only going to be known if we carry out a program of research and development on this kind of a technology.

And, I think it is very worthwhile doing. To sum up, there is a broad range of steps that may be taken to mitigate earthquake hazards. Some of them are within the present state of knowledge. Some of them require additional research and engineering to convert the present state of technology into specific information and tools needed by Federal, regional, State and local officials to reduce hazards.

No one should be misled that our knowledge is now, or likely in the future, able to produce a foolproof method of controlling earthquakes. There is a long hard road of research and engineering required—and assurance of success is not guaranteed. I believe, however, an investment in such control techniques should be made.

As the President pointed out in his March 16, 1972 message to the Congress of the United States on science and technology, now is the time to provide a strong new effort to marshal science and technology in the work of strengthening our economy and improving the quality of our life.

One specific area emphasized by the President was to marshal our science and technology to reduce loss of life and property damage from natural hazards, among them earthquakes. In the President's budget, there are substantial increases in funding to enable the Nation to move ahead in this technological front.

These funds are in NOAA's budget, as well as that of the Geological Survey, the National Science Foundation, and others.

The following table is a comparison of the funding for fiscal year 1972, and the funding requested from the Congress for fiscal year 1963 by NOAA, the Geological Survey, and the National Science Foundation.

The table in my testimony, Mr. Chairman, is a comparison of funding. As you can see, this is more than a doubling of the present earthquake hazards program, and this represents a significant increase for the Federal Government in attacking this problem.

Senator HOLLINGS. You have seen the figures which were worked out by Senator Cranston in his bill, S. 3173? They were substantially more than you mention. He recommeded $12 million for prediction, $200,000 for OEP and the National Academy of Sciences.

And, under his S. 3392, it was a $10 million figure. I was told in trying to work on my bill—I introduced, S. 3548—that these amounts were inadequate.

Could you not really do, as the President indicates, a much better job of strengthening and improving our quality of life by marshalling the science and technology in a much more effective way by even an increase over the Cranston measure?

I am trying to seek a question that expects an answer, of "yes."

Dr. WHITE. Well, I believe a program such as this, Mr. Chairman, could be funded at various levels of course. The decision ultimately has to come down on investments in this program versus a variety of other competing things.

Senator HOLLINGS. What is competing with an earthquake?

Dr. WHITE. There are other natural hazards. There are many other programs that the President has to decide upon in allocating his funds. I believe that the increase proposed by the Persident of about $13 million for these three agencies is a substantial step forward in the earthquake hazards area.

It may not be as much as many people would like to see. It may not even be as much as one could fruitfully use in such a program. But it is a significant step forward.

Senator HOLLINGS. I understand.

Dr. WHITE. Following is the table of the funds.

EARTHQUAKE HAZARDS FUNDS

Agency	Fiscal year— 1972 total	1973 increase	1973 total
NOAA	$4,860,000	$2,935,000	$7,795,000
GS	2,400,000	6,900,000	9,300,000
NSF	2,900,000	3,200,000	6,100,000

It is our view that earthquake hazards can be reduced only if we follow a comprehensive approach that addresses all aspects of the earthquake problem—not just prediction and not just control. Such a comprehensive national effort, or program, in my view should deal with four broad categories of problems.

The first porblem is to carefully and precisely locate, describe and define the areas of the United States particularly susceptible to earthquake hazards in sufficient detail that appropriate Federal agencies, and regional, State, and local government authorities can take corrective or preventive measures on the basis of the best estimates of a seismologist.

This effort should stress continual assessment of the degree and specific type of hazard as our understanding of natural and man-made tectonic processes evolves. To do this requires a major monitoring and mapping program. It necessitates seismic monitoring, monitoring of earth strains on a regional basis and monitoring the effects of earthquakes. It requires geologic hazards mapping and the careful mapping of active faults. It also requires the preparation of seismic risk maps, earthquake hazards maps, and establishment of appropriate data centers.

The second problem is to develop the basic understanding of the response of various classes of man-made structures to earthquake-induced ground motions, and to develop design and construction methodology to insure more effective damage resistance. To do this requires examining the benefits to be derived—saving of lives, reduction of damage, continued functional utility during and after an earthquake—and balancing them against the increased costs of design, construction and materials.

The third problem is to determine the feasibility and, if warranted, to develop the capability needed to predict the time, location, and magnitude of individual damaging earthquakes. This effort involves extensive study of microearthquakes, ground tilt, earth strain, and other geophysical phenomena to determine whether there is a regular pattern of detectable events leading up to an earthquake.

The fourth problem is to determine the feasibility of limiting the maximum size of earthquakes through earthquake control techniques. Research in this area requires field testing of the techniques and an analysis of the cost and benefits of any feasible control methods.

Finally, of course, a comprehensive approach to earthquake hazards requires effective monitoring and coordination.

A national program which did not address all these elements would be deficient. Description and assessment of the degree and type of earthquake hazards will not, alone, reduce the effect of earthquake on the public. Community action, based on land use planning, improved building codes, and response to specific warnings are needed. Improved structural design will not, alone, economically reduce hazards because costs for earthquake-resistant design and construction are 3 to 10 percent higher depending on the type of structure, intensity of earthquake designed for, and degree of protection provided. Successful earthquake prediction will reduce loss of life, but, alone, it will not substantially reduce property damage, and disruption of industrial, social, and governmental functions unless community actions, based on detailed description of hazardous areas and identification of particularly hazardous structures have been taken in advance.

The problem we face is not a new one. It has always been with us. The Federal Government already possesses virtualy all the basic elements needed for the comprehensive national program to reduce earthquake hazards which I have described, and work is being conducted on each of the broad categories of problems indicated.

There are many Federal agencies involved in either development of the scientific and technical information related to earthquakes, or in the utilization of this information in terms of their in-house programs or their involvement with regional, State, or local organizations and the general public. The principal scientific and technical agencies are NOAA and NBS in the Department of Commerce, the Geological Survey in the Department of Interior, and the National Science Foundation.

The Geological Survey has the knowledge of the geological structure of the earth. NOAA is, by statute and practice, an agency with fine capabilities in geophysics and the operation of warning systems; and the National Science Foundation has, for many years, supported within our universities, a strong program in the basic science of seismology, as well as engineering studies of structural damage from earthquakes. With its new charter in applied research, and its new research applied to national needs (RANN) programs, it is substantially expanding its efforts to develop economically acceptable designs for structures to minimize damage from earthquakes.

I would like to turn now to the role I see for NOAA in this comprehensive national program.

Here, Mr. Chairman, I would like to summarize the remainder of my testimony, and I would like to submit it all for the record, because it is a description in some detail of the programs that NOAA has developed in earthquake activities.

Senator HOLLINGS. We will include it in its entirety.

Dr. WHITE. NOAA through its predecessor organizations has been involved in earthquake studies for over 65 years. Our involvement in seismology dates from 1905 when the U.S. Coast and Geodetic Survey (U.S.C. & G.S.) began operating seismographs at its magnetic observatories.

Seismological investigators were formally recognized by statute in 1914 when the Weather Bureau was given authority to collect and disseminate seismological data. By act of the Congress (H.R. 8308) this function was transferred to the U.S.C. & G.S. in 1925. From 1925, the U.S.C. & G.S. had a major Federal responsibility for making earthquake and seismological investigations in the United States. The Bureau's statutory authority for earthquake investigations was broadened by Public Law 573 enacted by the 80th Congress in 1947 to include the whole range of related geophysical studies. NOAA conducts a broad program of earthquake investigations and supporting services with emphasis on reducing the hazardous effects of earthquakes and providing the data base for a broad national research effort.

To alert the public of approaching tsunamis frequently generated by earthquakes around the rim of the Pacific Ocean, NOAA operates the Pacific tsunami warning system. This system is operated cooperatively through joint agreements with many nations that border the Pacific Ocean. A regional warning system is operated in Alaska to give rapid warning to the state of tsunamis generated by earthquakes in the Aleutian Islands. Efforts are constantly being made to upgrade both the Pacific and the Alaska warning services through further research on such things as the mechanism of tsunami generation and theorotecial studies of runup, and further development of technology to detect tsunamis.

To provide a data base for seismological research throughout the world, NOAA determines the precise location of most significant earthquakes in the world, an average of about 6,000 per year, and all significant earthquakes in the United States, an average of about 1,600 per year. These raw data are distributed to all researchers and are used for a wide range of studies including earthquake zoning and earthquake prediction studies.

Since 1925, NOAA has routinely gathered damage and intensity data for all damaging earthquakes in the United States. These raw data are distributed to all researchers four times each year through the "Quarterly Seismological Reports" and summarized annually in the series "U.S. Earthquakes."

These data were the bases for the first national seismic risk map of the United States developed by NOAA in 1948, as well as the revised map published in 1969. Since the early 1950's, the major building codes in the country have relied on these seismic risk maps as the basis for earthquake-resistant design.

NOAA's Earth Sciences Laboratories operate a network of strong-motion seismographs that currently numbers almost 1,000 instruments. Approximately 700 of these are in California. Instruments are installed in buildings, dams, bridges, and other engineered structures, and in a wide range of geological environments throughout the United States and in Central and South America. These instruments write a time record of the response (acceleration or displacement) of structures or geological environments to earthquake generated motions. Copies of the recordings are routinely distributed to all researchers. They are the basis of research in earthquake-resistant design of structures and are thus critical to the improvement of the earthquake provisions of local and national building codes.

NOAA also conducts a multidisciplinary program in regional and local seismic risk mapping in the United States, which depends heavily on data from the strong-motion seismograph network, earthquake damage surveys, soil amplification studies, and other related research projects.

NOAA's geodetic survey program along the San Andreas fault system dates from 1855. Following earthquakes in this area in 1868, it was recognized that significant information about deformation in earthquake zones could be obtained from repeat measurements of the movement of the geodetic monuments. The geodetic network spanning the length of the San Andreas fault system was completed before 1900. Repeat measurements in selected areas were made following the San Francisco earthquake of 1906, and the network covering the overall system was reobserved in 1922–23. Since then the network has been expanded into subregions of the fault system, and the systematic repeat surveys have been made at intervals ranging from 1 to 15 years. These measurements, coupled with periodic measurement of vertical changes, continous polar motion measurements, and research studies of plate tectonic and global geophysics, provide a suite of measurements ranging from annual fault slippage at specific locations through regional changes in fault subsystems. Under OMB Circular A–16, NOAA has the responsibility for coordinating all geodetic surveys of other Federal agencies, including the crustal movement studies made by or funded by Federal agencies.

The Earth Sciences Laboratories (ESL) also conduct special earthquake research studies related to the San Andreas Fault at its Earthquake Mechanism Laboratory (EML). EML, previously known as

Advanced Seismac Experiments Group, was formed in February 1964, and has occupied its present quarters in San Francisco since December 1964. Its function includes the study of the earth's internal structure and the mechanisms that cause earthquakes. ESL conducts extensive research on creep along the San Andreas Fault and a broad program in measuring strain fields in Nevada, California, and particularly in the Aleutian Islands. The strain program is in cooperation with the AEC and some universities.

NOAA provides seismological information needed by other Federal agencies, State agencies, and regional and local regulatory authorities in the conduct of their programs and conducts research in support of their programs. An an example, NOAA recently developed a method of computing economic losses in earthquakes that served as the technical basis for the Department of Housing and Urban Development report to the Congress of the feasibility of a national program of earthquake insurance.

NOAA has also cooperated with OEP in the development of its emergency preparedness plan by estimating the likely effects of large earthquakes in various parts of the United States.

NOAA also provides expert advice to AEC in its nuclear reactor siting program. NOAA operates the strong ground motion measurement program for AEC both at its Nevada test site and more recently at the testing area in the Aleutian Islands.

Geodetic, seismic, and engineering seismology data are used for research within NOAA and they are made available to other agencies having direct interest, as well as to universities and private research groups. Such data, in the form of special services and published reports, provide the parameters required for programs such as the California aqueduct system, the San Francisco Bay Rapid Transit System, and urban development in regions of extreme subsidence.

In adidtion to its working agreements with public agencies NOAA collaborates with universities and nonprofit groups such as the Earthquake Engineering Research Institute to focus its research on both the immediate and long-range public needs.

I have mentioned several of NOAA's resources in discussing our problems, but I would like to list a few others. NOAA operates a network of 14 seismological observatories and cooperates with academic institutions and other Federal agencies in operating 35 other observatories.

In cooperation with the NSF and a number of foreign organizations, NOAA maintains and operates a network of 120 stations in 60 nations which make up the World Wide Standardized Seismograph Network. We have one of the Nation's finest seismic instrument development and calibration facilities at Albuquerque, N. Mex. The tsunami warning system draws on information from NOAA's seismological observatories, plus information from observations in other nation sand a network of 47 tide gauges.

For your information, I have provided copies of NOAA's Seismic Risk Map of the Conterminous United States and a list of major U.S. earthquakes since 1900.

To recapitulate, for a truly sound approach to the reduction of earthquake hazards, a comprehensive national program must be followed. We already possess most of the basic building blocks of such a program and are attacking the broad categories of problems which such an approach dictates.

Of course, our efforts could be strengthened and improved in a variety of ways. Given the enormity of the task, additional funding is a major consideration, and, indeed, the President's budget for fiscal 1973 has taken an important step in this regard by requesting a total of approximately $25 million for earthquake-related research, compared to about $12 million in fiscal year 1972.

In addition, improvements in the coordination and direction of the activities of the various Federal agencies involved is appropriate. To do this requires first that the individual agencies themselves perfect their means of consultation and coordination with other agencies.

In addition, the Executive Office of the President, particularly the Office of Science and Technology, can play an important role in assisting coordination efforts.

It may also be desirable to establish an advisory group independent of the Federal Government to provide advice to the Executive Office of the President and the concerned agencies regarding such matters as changes in national goals, improvements in coordinating efforts, or improvements in agency activities.

Mr. Chairman, in conclusion I would like to turn very briefly to three bills now under consideration by your committee. I refer to S. 3173, S. 3392, and S. 3584.

S. 3173, among other things, identifies areas of high seismic risk in California and Nevada and assigns managerial responsibility for a program leading to the goal of prediction of earthquakes along the San Andreas Fault to the new director of the Geological Survey.

It also appropriates substantial funds for carrying out activities in this regard. We would opose enactment of this legislation because of its limited nature. Geographically it fails to recognize that earthquake hazards are severe in many other parts of the United States besides California and Nevada.

Likewise, it tends to be counterproductive in that it disregards the comprehensive approach to earthquake hazards which we have been describing and concentrates funds and efforts on the single problem of achieving an earthquake prediction capability.

S. 3392 would authorize the National Science Foundation to establish and support a program of engineering research to improve design of earthquake-resistant construction criteria; and to develop improved methods of assessing earthquake risks at all types of locations in populated areas and establish land use priorities designed to reduce hazards.

We would also oppose enactment of this bill for a number of reasons. First, like S. 3173, it concentrates on only one facet of the comprehensive national program which should be followed.

Second, it completely disregards and duplicates long-standing programs, substantial research and service capability that now exists in or is carried on by NOAA and NBS with the Department of Commerce and other Federal agencies, as I have described in my earlier testimony.

S. 3584 would provide for a comprehensive national program of earthquake monitoring research and engineering by clarifying the authority and roles of the three major Federal agencies involved in earthquake activities, namely, NOAA, the Geological Survey, and the National Science Foundation.

It would further provide for Federal coordination of this program through the Office of the Secretary of Commerce and would authorize additional appropriations for earthquake work.

We believe that this bill has considerable merit in many of its features. It does seek to insure that a comprehensive effort toward earthquakes is undertaken, and it recognizes the need for coordination of activities. However, we would oppose this bill on the grounds that supervision of coordination activities should be lodged with the Office of Science and Technology.

In addition, we believe that provision should be made for some form of independent advisory body to assist the work of the Federal agencies.

Mr. Chairman, I have presented here only a brief statement of NOAA's views on earthquake hazards reduction and a brief description of NOAA's programs. I would be pleased to supply for the record a more comprehensive description of the role of NOAA in earthquake legislation.

Let me reiterate, it has been a great pleasure for me to be here with you. If you wish, I would attempt to answer any questions, or provide more information that you may wish.

To summarize, Mr. Chairman, our organization has been involved in earthquake studies for over 65 years. It dates back to 1905. The first statutory authority given to deal with seismological problems goes back to 1914 when the authority was assigned to the Weather Bureau.

As I indicated in our opening discussion, NOAA operates the Pacific tsunamis warning system. This system operates throughout the Pacific Basin and has regional warning setups in Alaska and along the west coast.

We are responsible now for providing the data base for much seismological research in the United States and internationally, through our responsibility to determine the precise location of the most significant earthquakes in the world. These average about 6,000 a year, incidentally.

Since 1925, we have routinely gathered damage and intensity data for all damaging earthquakes in the United States; and on the basis of such data, we are responsible for preparing the seismic risk maps of the country.

And incidentally, there is appended to my testimony a copy of such a seismic risk map, indicating the probability of occurrence of damage from earthquakes of various intensities. And these are the risk maps which have been used in designing major building codes throughout the United States.

We also maintain a network of what are called strong-motion seismographs, about 1,000 of these instruments throughout the Nation, about 700 of them being in California. These are located in buildings, dams, bridges, and other structures, and it is from these instruments that we can measure the forces of earthquakes and use this information to design structures.

We are responsible, as an organization, for the national geodetic aspects of earthquakes. This goes back many years to 1855, in this particular case. This is a program for measuring the motion along the San Andreas Fault, and what you do is you go back and make very, very precise geodetic measurements on a repeat basis so you can measure movement along the fault.

We have been conducting for a number of years special earthquake research studies along the San Andreas Fault in our Earthquake Mechanisms Laboratory in San Francisco, and have been carrying out similar work in the Aleutian Islands.

Initially, you mentioned that California in your earlier testimony, was a very good test bed for trying out many of these things because it is so active. There is also another excellent test bed up in Alaska, especially along the ocean, which is an extremely active sesimic area, and we believe it makes another fine test area.

Senator HOLLINGS. In the Aleutians?

Dr. WHITE. Yes, sir.

We provide much of the seismological information required by other Federal agencies, State agencies, and so forth; and we have been developing methods of computing the economic losses from earthquakes, for example, that are used by the Department of Housing and Urban Development.

We work closely with the AEC on its nuclear reactor program, in doing a lot of the seismic work for them.

Senator HOLLINGS. Do you have any input into their disposal plans? Radiation waste, the permanent storage?

Dr. WHITE. We have worked with the AEC on many of their nuclear shots but not worked closely with them on the disposal problem.

Senator HOLLINGS. You have not worked with them.

Do you know, or do your other experts know, if drilling of the bedrock does have any effect on the crust which could cause a tremor itself? I have heard plans, and at one time they said it was safe. Another time the National Academy of Sciences said it was unsafe to even drill into the bedrock for permanent storage, even for testing purposes. That in itself may cause a tremor or cracking within the crust; and in attempting to have found it could be safe, you have already destroyed its safety factor by a cracking of the crust from the drilling.

Mr. HESS. Yes, Mr. Chairman, if you introduce material down the drill hole at high pressure to try to store; by pushing the liquid down into the ground, we know that that is a possible device for triggering earthquakes. That occurred in the Denver area from disposal of waste material from local facilities.

If you do not inject it at high pressure, I do not think it would have the same probability of creating earthquakes.

Senator HOLLINGS. Excuse me; go right ahead.

Dr. WHITE. Just to finish up, Mr. Chairman, our operations operate a network of 14 observatories, in cooperation with others.

We operate, as we mentioned earlier, the international worldwide standardized seismographic networks. This consists of 120 stations in 60 different nations.

Senator HOLLINGS. What effort do other countries have, Dr. White, to supplement this? Is it coordinated? What does the Soviet Union have? Do they have stations around the world or in the Soviet Union or in Iran or any of these other countries that have experienced earthquakes?

Dr. WHITE. There are enormously active programs in seismology both in the Soviet Union and in Japan where they have suffered great damage from earthquakes, and we work very closely, both with our Japanese and Soviet colleagues, on seismic problems. And we have had exchanges with them on these problems.

Senator HOLLINGS. The experssion has been used that they are ahead of us in this field. Is that a correct statement?

Dr. WHITE. I did not hear you, Mr. Chairman.

Senator HOLLINGS. That the Japanese and Soviets are ahead of us in this field of earthquake prediction research.

Dr. WHITE. I think it would be fair to say that the Japanese and Soviets have put more focus on the earthquake prediction problem than we have, and have results from some of their studies which are advanced over ours. I think that is a fair statement.

Senator HOLLINGS. Are those studies available to us?

Dr. WHITE. Yes; they are, sir.

Senator HOLLINGS. Very good.

Dr. WHITE. To comment, Mr. Chairman, just on the bills now before us, on S. 3173, which among other things identifies areas of high seismic risk in California and Nevada and assigns responsibility for a program leading to the goal of prediction of earthquakes along the San Andreas fault to the U.S. Geological Survey, our concern with this bill would be the fact that it is not a comprehensive program, and we would not be in favor of that bill for that reason.

S. 3392 which would authorize the National Science Foundation to support a program of engineering research to improve the design of earthquake-resistant construction criteria, and develop improved methods of assessing risk in all types of areas and establish land use priorities designed to reduce hazards, we would also oppose enactment of this bill for a number of reasons.

First, we do not feel it is comprehensive. We would oppose it on the same grounds as we would S. 3173, for that reason.

Second, however, in the case of that bill, it does disregard and duplicate longstanding programs. As I have indicated in my testimony, substantial research and service capability now exists in or is carried on by NOAA and other agencies of the Department of Commerce and other Federal agencies. So, I think that would tend to duplicate things already in existence.

S. 3584 which would provide for a comprehensive national program of earthquake monitoring research and engineering by clarifying the authority and roles of the three major Federal agencies involved in earthquake activities, namely NOAA, the Geological Survey and the NSF, would provide for Federal coordination through the office of the Secretary of Commerce, and would authorize additional appropriations. We believe this bill has considerable merit in many of its features.

First, it is important that this bill does insure that a comprehensive effort towards earthquakes is undertaken. As I indicated in my testimony, we believe that is strongly needed. And it does recognize the need for the coordination in other agencies' activities in this field.

We would, however, oppose this bill, Mr. Chairman, on the grounds that the coordination of these activities would more properly be lodged in the Office of Science and Technology.

Senator HOLLINGS. More properly be lodged in the Office of Science and Technology? How does Congress get at that group?

Dr. WHITE. I believe it is possible, Mr. Chairman, for the Director of the Office of Science and Technology to appear before the Congress.

Senator HOLLINGS. Yes; but that is really in the White House itself, is it not?

Dr. WHITE. It is part of the White House structure; yes, sir.

Senator HOLLINGS. I think we have enough over there now. Let them just handle the war and I will be satisfied.

What we are trying to do is have continuity in this program, and the continuity changes and the comprehensiveness of the approach is altered somewhat by putting it over there just in that Office.

In fact, we have had no recommendations from the Office of Science and Technology relative to earthquakes. The leadership has to come, say from Senator Cranston, and as for me, I know very little other than the fact that one occurred in my backyard. That is how I got interested in it. That is pretty good evidence that we need this thing more or less coordinated through your own office, or the National Science Foundation, or in the Geological Survey, rather than the Office of Science and Technology.

The President has not asked for any increases in the Office of Science and Technology to handle this?

Dr. WHITE. No, Mr. Chairman. The Office of Science and Technology, through the Federal Council for Science Technology has coordinating mechanisms now set up for dealing with many scientific and technical programs in the Federal Government, and they are coordinated through that mechanism. It would seem to us that this kind of program could very well be coordinated through that mechanism.

Senator HOLLINGS. Well, the President just in his Executive order the year before last gave you the role of coordinating the entire oceans program, rather than the Office of Science and Technology.

After studying the issues and listening, and really laboring over the matter for some time, I think it is significant that under Reorganization Plan No. 4, you were selected as the coordinator.

If you can handle all of that, why couldn't you handle this?

Dr. WHITE. You are right, Mr. Chairman, that as the Administrator of NOAA, I have been asked to take on the role of coordinating efforts of the Federal agencies in oceanography, but as a chairman of a Federal Council of Science and Technology Committee—in other words, the structure through which the coordination actually takes place is the Federal Council for Science and Technology, and a similar mechanism could be used here.

Senator HOLLINGS. If we gave you the role and responsibility as is designated under S. 3584 and it passed both Houses, would you recommend that the President veto it?

Dr. WHITE. Well, sir; I would certainly try to convince you that this kind of program ought to be coordinated from a more central body than my own organization.

It is of course difficult when this kind of assignment is offered as a demonstration of the respect and belief that you and other Members of the Congress have in our agency to turn this down, but I honestly believe that, in the best interests of the earthquake hazards program, our efforts are best coordinated at a level above all of the departments; above the Department of Commerce, the National Science Foundation, or the Department of Interior.

Senator HOLLINGS. All right, sir.

Go right ahead. Is there any other comment or suggestion you have as to S. 3584?

Dr. WHITE. As I have indicated, Mr. Chairman, we think that it is very sound in the approach it takes to a comprehensive program. We support that.

Our reservations are with the coordination part and the lack of an advisery board.

I think that pretty well completes my statement, Mr. Chairman. It has been a great pleasure for me to be here with you, and I will be glad to answer any questions you may have that we have not already covered, sir.

Senator HOLLINGS. Well, we had to start a little late this morning and there are many, many more things I have learned about earthquakes, and I want to learn from you and the other experts and colleagues who have appeared here today, but we want these other witnesses to have a chance before lunch, so Dr. White, we are very grateful to you and your colleagues here, and we will be in touch with you.

If there are further comments about these bills from time to time, let us know.

Dr. WHITE. Thank you, sir.

(The attachments follow:)

PROPERTY DAMAGE AND LOSS OF LIFE CAUSED BY STRONG U.S. EARTHQUAKES IN THIS CENTURY[1]

Earthquake	Damage (millions in contemporary dollars)	Lives lost
1906—San Francisco, Calif	$524	700
1933—Long Beach, Calif	40	115
1946—Hawaii (tsunami from Aleutian earthquake)	25	173
1949—Puget Sound, Wash	25	8
1952—Kern County, Calif	60	14
1959—Hebgen Lake, Mont	11	28
1960—Hawaii and West Coast U.S. (tsunami from Chile earthquake)	26	61
1964—Prince William Sound, Alaska and resultant tsunami	500	131
1965—Puget Sound	13	7
1971—San Fernando, Calif	553	65

[1] From ESSA's "Earthquake Investigation in the United States," C. & GS special publication No. 282, 1969 edition (updated to inc ude information on the 1969 Santa Rosa and 1971 San Fernando, California Earthquakes).

Note: Not listed in the above are many smaler earthquakes in California, Montana, New York, Pennsylvania and New Mexico which took 50 lives and caused almost $62 000,000 damage.

Senator HOLLINGS. The next witness is Dr. James Balsley, Assistant Director of the U.S. Geological Survey. Mr. Balsley, we welcome you to the committee.

STATEMENT OF JAMES BALSLEY, ASSISTANT DIRECTOR, U.S. GEOLOGICAL SURVEY; ACCOMPLISHED BY DR. C. B. RALEIGH

Dr. BALSLEY. I would like to introduce Dr. C. B. Raleigh, of our National Center for Earthquake Research.

Senator HOLLINGS. Good, sir. You heard Senator Cranston testify that he drafted S. 3173 with the advice and consent of the U.S. Geological Survey, and gave the impression that they were very much in favor of what he was doing. Is that a right impression? Are you going to support his bill?

Dr. BALSLEY. We are in support of the philosophy involved in the three bills dealing with earthquakes, S. 3173, S. 3392 and S. 3548. It is our opinion that we cannot support the enactment of these bills, primarily because they do not provide any authority not already available to the departments involved. But as I said, we believe very strongly that the chief objective of the bills, earthquake prediction, is of great national importance and should be a key part of a comprehensive national program for earthquake hazards reduction.

Senator HOLLINGS. Good.

Dr. BALSLEY. I believe much of the next part of my testimony has already been discussed by Dr. White. His review of the situation with respect to the Japanese and the Russians is——

Senator HOLLINGS. Do you work closely with them, Dr. Balsley?

Dr. BALSLEY. We do. We have for years worked closely with originally the U.S. Coast and Geodetic Survey, later ESSA, and now NOAA, and at the present time, there is a coordinating committee that works directly with them in establishing working relationships in many areas in which we interface.

For years, as Dr. White indicated, we have been primarily dealing with geology. The interest of the Coast and Geodetic Survey has been in geophysics, which is by definition also a part of geology. So we have worked closely with them in many, many areas. As you know, the mapping program of the Geological Survey and of the Coast and Geodetic Survey, now NOAA, have been integrated also for many years.

Senator HOLLINGS. Do you find any gaps in the line where perhaps the problem is not being administered or gaining the attention it deserves? Suppose you were the President, what would you change tomorrow, other than giving it all to the U.S. Geological Survey?

Dr. BALSLEY. I wouldn't even support that. Each of us has our areas of expertise. As Dr. White testified they have for many years been responsible for the network of seismic stations all over the world. These are important data which we use.

On the other hand, we combine these data with our geological expertise and are involved with studies of the nature and causes of earthquakes and faults. Geologists have studied faults for many, many years and we have the record that goes back through hundreds of millions of years of the effects of faults which are the actual features which produce earthquakes. So to properly understand these, we have to have the very recent record, which we have through the seismic observatories operated by NOAA and also by the Geological Survey. We have been involved with studies on the San Andreas Fault using very detailed seismic observatories which record micro earthquakes, tiny little shakes that are not obvious even if you're standing right on the fault. So we have developed this kind of a working relationship over the years.

Senator HOLLINGS. Very good, sir. Go right ahead. Your statement in its entirety also will be included, and you can highlight it or summarize it, if you wish.

Dr. BALSLEY. I would like to reenforce Dr. White's statement that this whole matter of earthquake prediction is at a very important stage. The work of the Japanese and the Russians has developed some leads that we don't quite understand. In the Garm region, in the south-central part of the Soviet Union, changes in the characteristics of seismic signals emanating from small earthquakes have been observed repeatedly a few months prior to moderately large earthquakes. The nature of the changes is so clearly definitive that Soviet scientists now plan to implement an earthquake warning system based on their observations.

Although the physical basis for the changes observed is not yet understood, the measurements are straightforward, involving conventional seismological tools. The necessary instrumentation for such an observational system could be installed within a few months in this country and tests of the Soviet technique could be conducted within 1 year.

Senator HOLLINGS. Do you have plans for that?

Dr. BALSLEY. Yes, sir.

Senator HOLLINGS. Do you have enough money?

Dr. BALSLEY. Well, as Dr. White reported, the 1973 budget includes a very large increase for all of the agencies involved in this kind of work and we will be beginning these programs.

Senator HOLLINGS. What you are saying is you just have enough money for beginning.

Dr. BALSLEY. That is correct, sir.

Senator HOLLINGS. You would like to have more to complete it?

Dr. BALSLEY. And it is going to take a longer time, of course, yes.

Senator HOLLINGS. What is the estimated time?

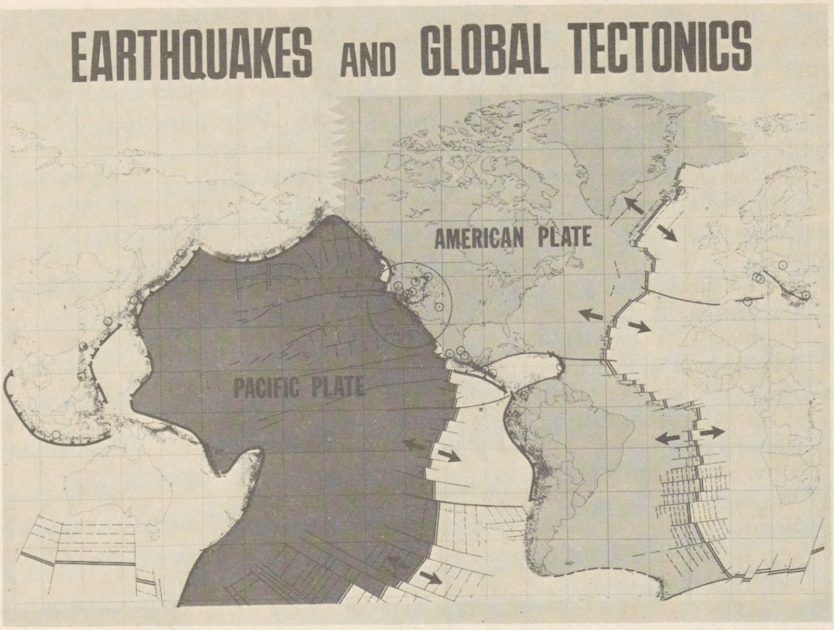
Dr. BALSLEY. Well, I would say that certainly within a 10-year period we ought to be very well along the way. We have great hopes that within 5 years, we can arrive at results which will have direct benefit to the Nation.

Senator HOLLINGS. I did not ask, and should have, of Dr. White, when you make on that San Andreas Fault a 30-year prediction, does he mean from now to the next 30 years, or are we at the end of the 30-year period he had in mind from the last one.

In other words, I am trying to fit it into perspective with your 5 to 10 years. If I am on the end of his 30-year projection, I can not wait around 10 years. I have to move to 5 years or even quicker.

Dr. BALSLEY. Perhaps I could show you somebackground on this. This is the forefront of our understanding now of the processes that formed the surface of the earth. Just recently, in the past approximately 10 years, we are beginning to get an understanding of the forces that alter the surface of the earth. There are major crustal plates which are rather rigid. These plates are generated by mid-ocean ridges where material apparently moves to the surface and the plates move out more or less as conveyor belts. Along these mid-ocean ridges, there are earthquakes, but because of their location, they are generally not significant. The mid-ocean ridge in the Atlantic does intersect Iceland and is the cause of earthquakes in that area. Most of the earthquakes that we have been concerned with are where the two plates intersect and it has now been established that the Pacific plate is moving northwest with respect to the American plate and the San Andreas Fault is where there two plates intersect.

Exhibit No. 1



Much earthquake activity in the western conterminous U.S. and in Alaska is concentrated along the contacts separating the six mobile plates that make up the outer layer of the earth. The contact between the Pacific and American plates comes ashore in California and is known as the San Andreas Fault; differential movement along this fault causes horizontal displacement of about 1.5 inches per year. Base map showing worldwide distribution of earthquakes prepared by NOAA.

Dr. BALSLEY. Now, these motions have been going on for as long as the earth has been here, or since the crust was formed, for 4 billion years approximately. The rate of the motion is about 1 to 2 inches a year, more or less; the American plate moving with respect to the Pacific plate.

The San Andreas Fault has had earthquakes on it for certainly at least tens of millions of years. Geologists, by mapping particular rock formations on one side and comparing them on the other side, have found the displacement has been, over that period of time, at least 200 miles.

During the San Francisco earthquake, which occurred on the San Andreas Fault, the displacement was a maximum of 22 feet. It is the actual movement of one block of the earth, or the crust, past another, that produces the earthquake. So we can predict with 100 percent probability that there are going to be earthquakes along the San Andreas Fault; just exactly when they will occur, and just exactly where they will occur, is the attempt of earthquake prediction.

At the San Andreas Fault, the two blocks do not move entirely rigidly. At the northern end, near San Francisco, there has been no major motion since 1906. At the southern end down in Los Angeles, this has similarly been locked for a long period of time. In between, particularly near Hollister, the motion is going on by what we call creep—very slow motions. The energy is released in very small parcels. The classic place that seismologists visited for many years is a winery built right across the San Andreas Fault and, over the year, the two halves of the building have slowly moved apart.

Now, this kind of action is the kind of action we would like to see on all faults, because this is not accompanied by major earthquakes. Yes, there are little microearthquakes, we call them, which cause no damage. This is basically the idea behind earthquake control.

If we could have that chart on earthquake control——

Senator HOLLINGS. On these charts, Dr. Balsley, it would be very helpful to the committee if you could reproduce those for the record, if it is easily done.

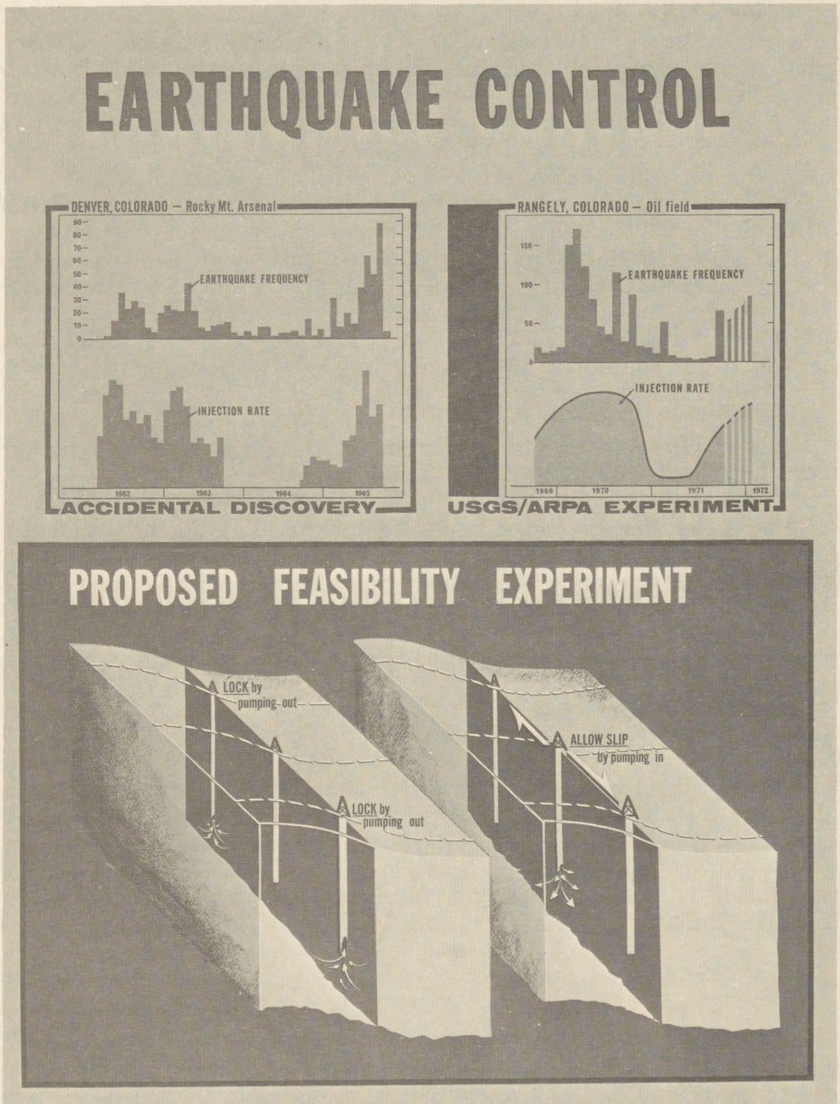
Dr. BALSLEY. Yes, sir.

Senator HOLLINGS. Your testimony relating to them will be far more legible if we can have those reproduced.

Dr. BALSLEY. Thank you.

This is the idea behind earthquake control. This is the accidental discovery that was mentioned in Dr. White's testimony. In Denver, where in pumping underground wastes, a well was drilled down into the ground crossing the major fault that uplifts the Rocky Mountains just west of Denver. Soon after they began pumping, people began to notice earthquakes in Denver, small earthquakes, enough to rattle dishes.

Exhibit No. 2



Experiments can be carried out along an active fault in a remote area to test the feasibility of controlling the maximum size of earthquakes. It has been demonstrated at the Rocky Mountain Arsenal and at Rangely, Colo. that earthquakes can be triggered artificially by increasing the underground fluid pressure. It is suggested that large earthquakes on active faults can be avoided by the controlled release of elastic strain in the form of many smaller earthquakes.

Dr. Balsley. This was a classified activity, but one of the men working at the area knew of the injection rate and put together this kind of a document which shows the number of earthquakes related to the injection rate in that well.

This is, of course, an accidental discovery, and there was nothing that could be done about it. But Dr. Raleigh here, who can give us more detail if you wish, has been working with the Chevron Oil Co. in an oilfield near Rangeley, Colo., which is also transected by a fault.

Any time you pump water underground, under pressure, if your pressure is high enough, you can fracture the rocks. This process of hydrofracturing is used by the petroleum industry to crack the rocks when a well is not delivering enough oil. The immediate assumption in the Denver case was that the energy that was going into the ground through pumping was the energy that was being transferred—was coming back in the little earthquakes. But when you calculate the amount of energy involved in the pumping, it was discovered that the energy coming back was greater. The only explanation of this was that this high pressure, by essentially supporting of the weights of the rocks overlying the fault, reduced the friction on the fault, and allowed some of the stored energy to be released.

Now, this is the stored energy that is stored by the relative motions of the two plates that I referred to. So, to prove this, with the cooperation of the Chevron Oil Co., Barry Raleigh has studied pressuring and depressuring the field. This is the pressuring phase, and there were many earthquakes. When they depressured the field, then the earthquakes stopped, and now we are back again in the pressuring phase, hoping to turn on the small earthquakes. We have demonstrated that you can turn off this kind of earthquake, and hope to show we can turn them on and off at will.

Theoretically—and this is the sort of thing that we are beginning our experiments on—you would be able to take a fault like the San Andreas and lock it by removing the high pressure which now exists there. And then having locked two ends of it, to pump down water under pressure to produce this kind of effect, so that we would release the accumulated energy slowly over a small area. We wouldn't dare do that kind of a thing without making sure that the locking mechanism worked, because we might trigger a major earthquake. This would have to be avoided at all costs.

Senator Hollings. Were you familiar with the Tuscaloosa Aquifer, Dr. Raleigh or yourself? And would you carry on such experimentation there, where you have radiated elements already stored? Do you recall that hydrogen bomb that landed off Spain in the Mediterranean? They dug up about 600 tons of soil. If you want to go see a little of Spain, all you have to do is go down the Savannah River plant of AEC because they dug it up and hauled it all the way across the Atlantic and buried it there.

Now you can see what I am getting at. Do you monkey around with drilling, once you have these dangerous materials present?

Dr. Raleigh. As I understand that disposal project, they don't plan to inject the waste fluid under pressure. And as Dr. Hess pointed out, if you are not injecting the fluid under high pressure, the likelihood of triggering a slip on a fault would be fairly small. That doesn't mean that you shouldn't take careful measures to assure that the rocks aren't highly loaded, because if you increase the fluid pressure even a small amount in that case, you might produce a fracture and possibly an earthquake. I would assume, however, that they are going to take careful measures to avoid that.

Senator HOLLINGS. What about as a place for permanent storage of spent or radiated elements? Do you think that is an ideal place to store it, in an earthquake strata?

Dr. RALEIGH. I would defer that question to Dr. Balsley.

Dr. BALSLEY. Our comments on the environmental impact statement presented to us by the AEC for our review states that we believe they should make a careful analysis of the seismic background in that area. It is a seismic area, as you know. There was a severe earthquake in 1886. It shows on the seismic risk maps of NOAA. To maintain a large opening, leak free, in a seismic area, is something that will have to be investigated with great care.

Senator HOLLINGS. Very good, sir.

Dr. BALSLEY. In the last 3 years the development of very large digital computers in the United States has made it possible to produce numerical models of earthquake faulting. The physical properties of the models can be adjusted with the advent of new data to provide increasingly closer correspondence between the model and the real world. Ultimately, perhaps within a very few years, such models should become the critical element in arriving at a predictive understanding of the earthquake mechanism.

That is to be able to see actually what is occurring in the fault and through this understanding, then be able to predict when and where an earthquake would occur.

In light of this combination of favorable developments, a well-planned and coordinated program of research on earthquake prediction can now be implemented with a very reasonable likelihood of success. The essential elements of such a program include intensive instrumentation of the most seismically active areas of the United States, theoretical and experimental investigations of the earthquake mechanisms, and synthesis of the data gathered into a comprehensive model of the earthquake generating system.

The tools and techniques for testing prediction theories are presently available or within reach given only minimal time for development. The promising results of Japanese and Soviet Russian scientists and our own studies indicate that a breakthrough may be reasonably near at hand. Scientists in the United States generally believe that earthquakes are predictable phenomena, and that the benefits to humanity accuring from the development of the capability to predict earthquakes makes it an extremely important national objective.

Dr. Raleigh has given us a report on our own studies of earthquake prediction and control. I would like to include that with my statement.

Senator HOLLINGS. Very well, it will be included.[1]

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[1] See p. 69.

Dr. BALSLEY. Now to discuss the details of the bill, as I mentioned before, we oppose enactment of S. 3392 and S. 3584, because they, for the most part, do not provide authority not already available to any of the departments or agencies involved, and because it appears to us that in S. 3584 earthquake hazards mapping, traditionally a function of the Geological Survey, has been confused with seismic risk mapping, a traditional function of NOAA.

Senator HOLLINGS. What is the difference between the seismic risk map and the earthquake hazards map?

Dr. BALSLEY. The seismic risk map deals with the probability of a given size earthquake occurring in a given region based primarily on a historical seismic record. This is traditionally the function of NOAA. They have been accumulating these data for many years. They have, as Dr. White has presented in his testimony, prepared a seismic risk map of the United States. This is the most current and up-to-date map now available. They have classified the various zones of seismic risk, from those in which there are none, to minor, moderate, and major.

Now, this is a seismic risk map.

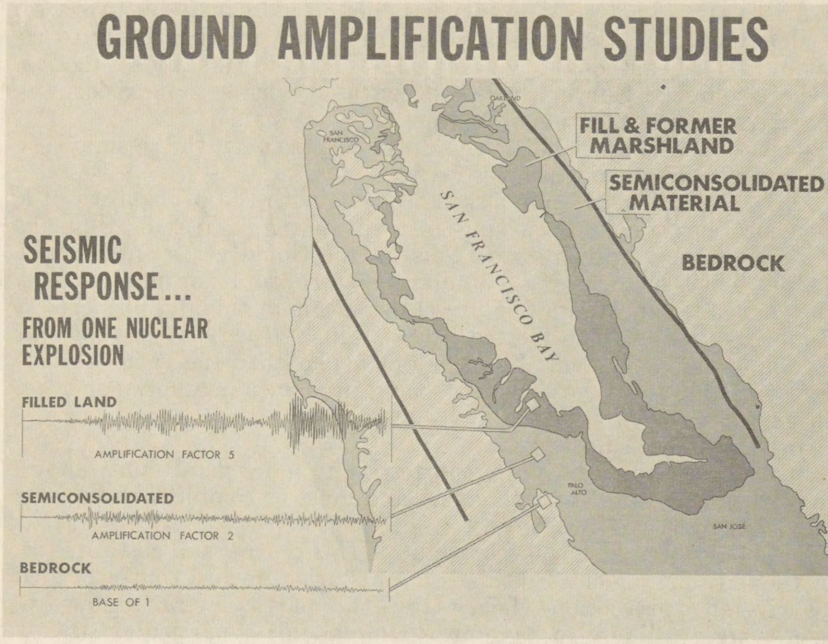
But this map, as Dr. White can testify in more detail, only shows the intensity of historic earthquakes and must be combined with some knowledge of their frequency.

There have been large ones here and in this central and eastern area, but they are infrequent. So this is the historical record that is needed to arrive at a prediction when, within this particular area, how frequently we are likely to have an earthquake of a particular size.

Now, an earthquake hazards map uses this information as its foundation but moves on to look at the particular materials.

This is the ground amplification work that has been referred to. This is in the San Francisco Bay Area, where seismographs have been located quite close together, but on different kinds of bedrock. You can see here the seismic record from each different seismograph for the same earthquake—it wasn't an actual earthquake in this case, it was a nuclear explosion, but the instruments would record it as an earthquake. You can see that in the bedrock, you get a base ground motion of 1, whereas in fill material you get 10 times as much effect from the same earthquake. This is due to the ground response of different kinds of geologic materials. The bedrock is the strongest and reacts least.

Exhibit No. 3

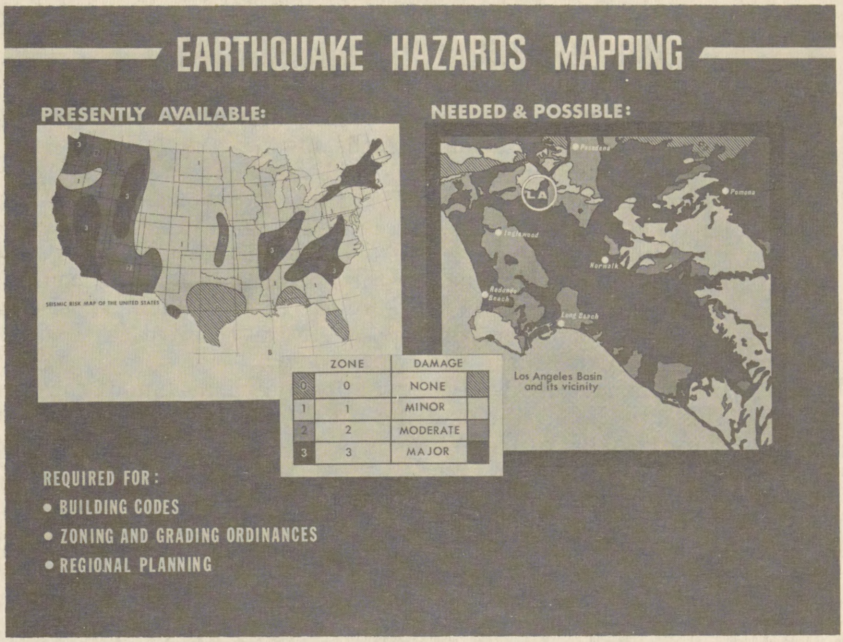


The ground motion expected from earthquakes is much greater on filled land than on bedrock. The steady encroachment of urban areas onto filled land around San Francisco Bay poses an extreme hazard in the event of a large local earthquake. Such areas can be delineated to define more accurately the location and extent of earthquake hazard.

The filled land is weakest, and is the most reactive. This is the source of the Biblical injunctive about not building your house on the sand. They were in a seismic area and they discovered these effects empirically without instruments.

Using this technique then, it is possible to study a region from a knowledge of the geologic materials, and then predict what the reaction will be in each particular area within it. Thus here within this red area of major damage, in Los Angeles, there are places where the reaction of the ground is going to be just like it is in North Dakota. In other words, in an earthquake, in California there will be practically no reaction at some places, whereas in the red areas there will be major effects. This has been demonstrated in the San Fernando earthquake recently, which occurred at this place (pointing). The data from this map were confirmed by the results of the earthquake, because particular areas received considerably more seismic effect, and therefore more damage to the buildings.

Exhibit No. 4



The seismic risk map prepared by NOAA shown on the left is a valuable representation of the nationwide hazard, but it is too generalized for use by local communities. Detailed hazards maps of the type shown on the right provide a more precise guide to local decisionmakers.

Senator HOLLINGS. Very good, sir.

You say S. 3584, I think, confuses those two roles?

Dr. BALSLEY. Yes, sir.

Earthquake hazard mapping deals with the anticipated damaging effects of an earthquake and is based primarily on a knowledge of the distribution and physical properties of the geologic units in a particular area and the characteristic response of these units to strong ground motion.

Hence, earthquake hazard maps have a predictive capacity in that the method permits extrapolation beyond the limits of recorded events. Possibly through a misunderstanding of the distinction between the two kinds of mapping, the responsibility for essentially all earthquake hazards mapping is delegated to NOAA under S. 3584, and seismic risk mapping is not mentioned.

This is more or less a traditional breakdown of these two functions, and they are mutually supportive. Actually, we couldn't do this kind of thing without the seismic risk mapping prepared by NOAA.

Furthermore, under S. 3584, the Secretary of Commerce is authorized to develop and coordinate a national earthquake program in cooperation with the Department of the Interior, the National Science Foundation, and such other Federal agencies that he may deem appropriate.

We oppose the establishment of such authority because the President's budget for fiscal year 1973, which was formulated by the Executive Office of the President, partly on the basis of joint presentations to OST by the USGS, NOAA, and NSF, has already provided for the development of a comprehensive earthquake hazards reduction research program. Coordination of this program is the chief responsibility of the Executive Office of the President, through the OST and OMB, and in close consultation with the agencies involved.

It is our understanding that the OST is already taking steps to assess the capabilities and competence of the various agencies, universities, and other organizations currently engaged in earthquake research. We applaud this action and understand that OST and OMB are taking the lead in coordinating the implementation of a comprehensive earthquake hazards reduction research program so as to reduce the threat to lives and property posed by destructive earthquakes throughout large parts of the Nation.

For your information, I have also appended a résumé of the long history of studies of earthquakes by the NOAA and the Geological Survey, similar to that of Dr. White.

Thank you, sir.

Senator HOLLINGS. Thank you very much.

Do you have any additional comments, Dr. Raleigh?

Dr. RALEIGH. I have talked to some extent to our colleagues in the universities who are also working on the question of earthquake——

Senator HOLLINGS. By the way there are some questions here for you and Dr. Balsley from the St. Louis University. I will submit them to you and you can submit the answers in writing.

Go right ahead. Excuse me.

Dr. RALEIGH. Rather than submit anything formal to you, they simply said to me that they felt this was an extremely hard problem to work on and they are excited about it and anxious to participate. They have asked me, since I am representing seismology here for this committee, to point out that the time scale by which predictions are likely to be made in the future can't be known right now.

In fact that is one of the objects of the research.

There is a statement in the record from Senator Cranston's office which says that 3 months in advance of the earthquake the earthquake could be predicted to within 3 days. That statement is based on the results of Soviet investigators who have seen changes in the seismic velocities from small earthquakes near the region where the large earthquake was going to occur several months in advance of the event and they see a characteristic signal that permits them to predict the time of the event within a few days.

Now we don't know definitely that those Russian results would be applicable to studies in the United States. We are going to investigate that. But we are not able to make any promises regarding the exact time scale within which our predictions will be made.

I wanted to clarify that point.

Senator HOLLINGS Very good.

You gentlemen have given some very interesting testimony. I was about to say I didn't know I had introduced such an interesting piece of legislation. I have learned a lot from it. But I have also learned the confidence you have in OMB raises questions in our minds from actual experience. When we went into the oceans program—I am sorry Dr. White is not here—but we wouldn't have an oceans program. We brought that OMB crowd around kicking and screaming. They put every clog in the wheel they could possibly conceive of.

Sometime we will have to tell the full story. We had to go through the Attorney General to get an oceans program.

Now the President is very proud of us, in spite of OMB. And OMB has the poor President on TV vetoing programs one month, and 7 months later, recommends for this particular program. You know, it is Government of "stop and start." There is no continuity to OMB, because they are looking just solely at the budgetary aspect. They are not looking to promulgate a basic program relative to earthquakes, education, public works in America, or anything else.

So we understand the constrictions on your testimony and you do perform well. And we do appreciate very much your presentation here this morning. We want to look very seriously at the criticism and comments that you do have, because you are the ones that we are trying to get behind to really develop, for the good of everyone, a comprehensive program of prediction and control, if there can be such.

Thank you both very much.

Dr. BALSLEY. Thank you sir.

(The article referred to follows:)

THE SCIENTIFIC BASIS FOR EARTHQUAKE PREDICTION

(By Dr. C. B. Raleigh, U.S. Geological Survey)

Most U.S. seismologists from universities and the U.S. Geological Survey believe that intensive investigations leading to the prediction of the approximate time and place of great earthquakes are both appropriate and timely. There are several reasons for this optimistic view. Some remarkable discoveries by earth scientists over the past few years have led to a clear understanding of the fundamental cause of earthquakes. It is now known that the earth's surface is divided into several large plates, 50 miles or so in thickness, which move past one another at rates of a few inches per year. Where the plates are in contact, this relative motion is accommodated by periodic, sudden displacements which give rise to earthquakes. The vast majority of earthquakes take place along these plate boundaries. Because rates of plate motion appear to be constant over millions of years, we can safely anticipate that great earthquakes will occur repeatedly in the future where they have happened in the past. The time interval between such earthquakes will be determined largely by the rate of relative motion of the plates.

Seismologists have long recognized that some major earthquakes are accompanied by premonitory phenomena, including anomalous deformations of the land surface and heightened seismic activity in the focal region. Repeated observations of such phenomena led Japanese seismologists in 1962 to formulate a blueprint for earthquake prediction based on a program of extensive and detailed measurements of land-deformation and seismicity. The program in Japan was formally launched in 1965, and in 1966 moderately large earthquakes in the vicinity of Matsushiro were successfully predicted on the basis of intense foreshock activity.

Seismologists in the U.S.S.R. have been engaged in a program of research on earthquake prediction for the past decade. They have pursued several lines of attack on the problem, one of which has recently met with considerable success. In the region of Garm, changes in the characteristics of the seismic signals emanating from small earthquakes have been repeatedly observed a few months prior to moderately large earthquakes. The nature of the change is so clearly definitive that Soviet scientists now plan to implement an earthquake warning system based on their observations. Although the physical basis for the change observed is not yet understood, the measurements are straightforward, involving only conventional seismological tools. The necessary instrumentation for such an observational system could be installed within a few months in this country, and tests of the Soviet technique could be conducted within one year.

The possibility of predicting earthquakes has been greatly enhanced in recent years by developments in instrumentation, telemetry and digital data processing and analysis. Although a national program for earthquake prediction was called for in the report of an ad hoc Presidential Panel (the Press Panel) as early as 1965, economical implementation of the Panel's recommendations has only recently become possible.

Theoretical predictions and empirical observations both have indicated the need for stable instruments capable of measuring displacements in the earth of the order of the wavelength of light. Such instruments have now been developed and are available at reasonable cost. The techniques for real-time acquisition and processing of data from large numbers of seismometers, tilt and displacement sensors have developed rapidly and can now be put to work at the same time as the instruments are deployed in the field. In the last 3 years, very large digital computers have made it possible to develop numerical models of faulting. The physical properties of the models can be adjusted with the advent of new data to provide increasingly closer correspondence between the model and the real world. Ultimately, perhaps within a very few years, such models should become the critical element in arriving at a predictive understanding of the earthquake mechanism.

In light of this combination of favorable developments, a well-planned and coordinated program of research on earthquake prediction can now be implemented with a reasonable likelihood of success. The essential elements of such a program include intensive instrumentation of the most seismically active areas of the United States, theoretical and experimental investigations of the earthquake mechanism and synthesis of the data gathered into a comprehensive model of the earthquake generating system. The scientific rationale for such a large-scale program is documented in more detail in the following discussion.

THEORY OF PLATE TECTONICS AND THE ORIGIN OF EARTHQUAKES

The ultimate cause of most earthquakes lies at great depths in the very hot, slowly flowing rocks of the earth's mantle. Motions, possibly due to convective overturn, are transmitted from the mantle's viscous asthenosphere into less plastic and finally brittle rocks at progressively shallower levels in the earth's lithosphere. The lithosphere, about 50 miles thick, is uppermost shell of relatively rigid rock which constitutes the plates whose motions give rise to earthquakes. From detailed studies of the distribution of microearthquakes in California we know that the earth's crust in the western United States behaves in a brittle fashion only at depths less than about 10 miles. From steady, slow motions in the asthenosphere, deformations are transferred through to the thin brittle crust, where finally rupture occurs as stresses accumulate due to friction between the boundaries of the moving plates.

The numbers and magnitudes of earthquakes along plate boundaries are related to the relative velocity of the plates moving past one another. On the average, the slip rate calculated from the earthquake magnitudes agrees well with the rates calculated from other lines of evidence. The historic record is short, however, and there are segments of the plate boundaries where the slip due to earthquakes has lagged behind that required by the overall plate motion. These are the so-called "seismic gaps" where the largest earthquakes can be expected soon. The concept of seismic gaps provides a basis for concentrating seismological studies of earthquake prediction where they will do the most good.

It may well be impractical to concentrate research efforts on all the seismic gaps, particularly where these are in remote areas, although there appears to be at least one such gap in Alaska where a reasonable effort could be carried out. However, the plate theory provides another important clue to the problem of earthquake prediction.

Enough is known about the viscous flow of rock at different temperatures so that at least qualitative statements regarding the mechanism of transfer of strains generated within the asthenosphere to the brittle crust can be made. At the base of the lithosphere, it appears likely that rock flows much as water—the rate of flow is directly proportional to the stresses at that depth. Within the still plastic but cooler lithosphere the properties of the rocks are such that this simple proportionality no longer holds. For rocks at these lower temperatures, a small increment of stress produces a disproportionately large increase in the rate of deformation. It is, therefore, most unlikely that the accumulation of stress in the brittle crust increases linearly, in direct proportion to steady state displacements within the asthenosphere. This conclusion from plate theory provides a rational basis for the observation that large earthquakes are preceded by a rapid buildup in strain rather than an almost imperceptible, steady rate of deformation prior to the seismic event.

PREMONITORY PHENOMENA—STRAIN

If great earthquakes are to be predicted on a scale of time which is short compared to the interval between their recurrence, the measurable quantities of land deformation and seismicity should ideally show rapid changes prior to the earthquake. There are several, well-documented examples of such changes. One of the most dramatic instances of land upheaval prior to a great earthquake occurred at Ajikabazawa in the northern part of Japan in 1792. The local inhabitants awoke to find a remarkable retreat of the sea from the bay nearby. Terrified of the possibility of a tsunami, or seismic sea wave, they ran into the mountains, where at 2:00 p.m. they felt a strong earthquake. They returned to their village only to be inundated by a tsunami resulting from the earthquake. At least 9 hours before the earthquake the local shallow water areas had been uplifted to above sea level, a change in elevation of at least a few feet.

Most of the other well-recorded premonitory deformations in Japan involve vertical displacement of the ground near the earthquake source region. For this reason, detailed first-order leveling networks are basic elements in the present day Japanese program of earthquake prediction. The recent discovery, through leveling, of anomalous elevation changes in the South Kanto region near Tokyo has led to that area being designated as one of intensive study. Because of the possible danger to Tokyo from a great earthquake, Japanese scientists are being asked to make actual predictions even though the methodology of earthquake prediction is not quite established.

If earthquakes are to be predicted days to months in advance, continuous monitoring of deformation is required. Precise leveling, triangulation and trilateration are important techniques for measurement of earth strains, but the repetition interval for observations is necessarily long. For this reason, instruments designed to measure tilting of the land surface and horizontal strain in rocks have been developed over the past few years. The U.S. Geological Survey has in operation some 20 tiltmeters of the pendulum type installed in shallow boreholes. The devices are sensitive to tilts induced by solid earth tides and appear to be stable over long periods of time. An anomalous tilt was recorded by U.S.G.S. instruments prior to a recent earthquake near Danville, California. Tiltmeters having similar sensitivity and a comparable price are also now available commercially. In a new program of earthquake prediction research at least 200 such instruments could be installed in earthquake-prone regions of the United States within the first year.

In California, fault slips giving rise to earthquakes are predominantly horizontal. Prior to failure, the deformations can be expected to be horizontal compression or extension of the land surface. Tilting will undoubtedly accompany these deformations but may be of second-order importance. Devices for continuous measurement of horizontal strains are available but are more costly at the present time. There is no doubt, however, that adequate instruments can be developed and produced at prices comparable to tiltmeters if called for under a national program of earthquake prediction.

Predictions based on repetition of premonitory events alone will never be a satisfactory method unless the nature of the phenomena is well-understood. Local, instrumental measurements of tilt and strain are taken at a point, and though most important for short-term predictions, they are less informative regarding the mechanism of accumulation of strain in the brittle crust. Geodetic surveying methods, principally leveling and trilateration, are presently in use in the United States and elsewhere to measure the distribution and rate of strain accumulation on a large scale. The use of laser ranging devices has improved the measurement of strain over large distances by nearly 2 orders of magnitude over triangulation methods. Although costly measurement of air temperature along the past length of the laser beam is now required to achieve this level of accuracy, recent developments in laser ranging technology will eliminate the need for the temperature measurements. Given these developments, a major extension of existing trilateration networks along the major active faults of the U.S. can be installed and measurements begun within a year. Within 3 years, the accuracy of distance determination is such that the pattern and rate of strain build-up should begin to emerge.

SEISMICITY

In California alone, damaging earthquakes occur at intervals of about 10 years. Great earthquakes such as the San Francisco earthquake of 1906 appear to occur within the United States about every 50 years. Although the evidence is not clear, many of these shocks appear to be preceded over several years time by a heightened level of seismic activity. Moreover, if the results obtained by Soviet seismologists are applicable here, a change in the character of the small earthquakes takes place a few months prior to the large event. Equally important, the locations, magnitudes and numbers of small earthquakes, along with the character of their seismic signal, provide the fundamental data on the mechanism of earthquake generation. A program of research on and, ultimately, the implementation of an earthquake prediction scheme will depend on our ability to operate and analyze the data from a dense network of seismic stations in earthquake-prone regions.

Efforts on the part of the U.S. Geological Survey over the past 6 years have led to the construction of a prototype seismic network embodying most of the necessary elements. In central California, some 100 seismic stations with their associated telemetry equipment have been installed at a unit cost of about $2500. The data presently are recorded on film and magnetic tape and are processed manually within 48 hours. The locations and magnitudes of all earthquakes above Richter magnitude 1 within the network are available for study within a few days of their occurrence. Research has been conducted by the U.S.G.S. on techniques for automatic processing of the data through use of digital computers, and it now appears possible to carry out real-time automatic processing of seismic data from an expanded network of stations.

Other special purpose seismic instrumentation for the study of the earthquake mechanism and to measure seismic velocity changes related to buildup of stress in the fault will be needed. Although some development will be required, installation of most equipment for such studies can be accomplished within a year of the beginning of an earthquake prediction program.

OTHER STUDIES

Some of the most important advances in understanding earthquakes and identifying likely premonitory effects have come out of experimental deformation of rocks in the laboratory. The specimens are placed under confining pressures and temperatures appropriate for rocks in the earth's crust and are then loaded to failure. The processes operating at the earthquake focus apparently can be approximated in the laboratory and observed in great detail.

Among the observations pertinent to earthquake prediction, the property of dilatancy observed in experiments may be the most important. During loading, small-scale fracturing takes place with an accompanying increase in the volume of the rock specimen at stresses near the point of rupture. The volume increases rapidly with nearness of approach to the failure stress, where the specimen finally ruptures generating a laboratory earthquake. This effect is important because it is readily observable in the field and occurs only when stresses have approached the dangerous level. Other than producing large strains of a characteristic type, dilatancy of fault zone materials might be expected to have a profound effect on the electrical conductivity of the rock and on the velocity of seismic waves traveling through it. The techniques for field measurement of these parameters are currently being developed and preliminary tests are under way.

Earthquakes take place when the stresses exceed the frictional strength along the fault. The frictional strength is generally well known so that if the state-of-stress were measurable and the rate of increase of stress determined, prediction of the approximate time and place of forthcoming earthquakes should be possible. Changes in stress may be calculated from measurements of surface strains or possibly from indirect effects such as magnetic variations or changes in seismic velocity. The absolute level of stress is presently meaurable only approximately and at considerable expense. The importance of the measurement is so great, however, that a determined effort to develop techniques should be conducted at the earliest possible stages of an earthquake prediction program. The difficulties at the moment are principally technological rather than of a fundamental scientific nature, and it is reasonable, therefore, to hope for success in the development of the necessary instrumentation.

A less revolutionary although equally important facet of earthquake prediction involves the recognition and delineation of areas within which, given the occurrence of a damaging earthquake, the damage and effects will be most severe. Intensive study of past earthquakes throughout the world has clearly shown the intimate relationship between the distribution of certain soils and rocks and the distribution of intensive damage caused by fault displacement, slope failures, landslides, foundation failures and amplification of strong ground motion. The type of earthquake geologic hazard mapping made possible by the application of the knowledge of these relationships represents a valid form of prediction which has enormous implications in the field of earthquake hazard reduction and safe land use planning.

Augmented research efforts can profitably be applied to the development of more quantified criteria for earthquake hazard mapping and to the development of better graphic methods of data presentation which will be of immediate use to a wider group of potential users.

EARTHQUAKE CONTROL

It may be possible in the future not only to predict earthquakes but also to control their occurrence. Important in the possible control of earthquakes is the concept of fluid pressure. The role of excess fluid pressure on rock strength was first proposed to explain giant thrust faults that could not have moved unless some method was introduced to reduce the coefficient of friction. The basic concept of the role of fluid pressure is quite simple. The frictional forces resisting sliding along a fault plane are greater if the opposite sides of the fault are being pressed toward each other. Fluid pressure in the fault plane pushes in the opposite direction and reduces friction. These observations have led to the conclusion that changes in fluid pressure may have some control over the timing of earthquakes and have opened the door to the possibility that natural earthquakes could be actively controlled.

The role of fluid pressure in earthquakes was first observed accidentally at a deep disposal well near Denver, Colorado. Over a period of about 10 years, the time-space correlation of earthquake activity compared with rates of fluid injection into the well clearly demonstrated a causative relation between earthquakes and fluid injection at this site.

This and similar observations at other areas prompted the U.S. Geological Survey in cooperation with the Chevron Oil Company to carry out an active experiment in earthquake generation in an oil field at Rangely, Colorado. During this experiment earthquakes were successfully "turned on" and "off" by a program of raising and lowering the fluid pressure in the oil field.

We believe that the results of the experiment at Rangely, Colorado, demonstrate the feasibility of earthquake control under some circumstances. The question that we now face is how to apply this knowledge to active faults in the western United States.

Seismic activity along these faults show that most of the earthquake activity occurs at depths shallower than 10 km and practically no earthquakes take place at depths greater than 15 km. This shallow depth of seismic activity offers the possibility of drilling into the active seismic zones and attempting to control the activity by controlling the fluid pressure. There are many strategies for modifying seismic behavior along a fault without creating a large earthquake. All of these involve the concept of first locking portions of the fault so that there is no possibility of a great earthquake resulting from the control efforts, and then allowing controlled slip to take place between the locked points by increasing the fluid pressure.

No one at this time can predict whether practical earthquake control will be feasible. Before any reasoned judgment on this matter can be reached, it will be necessary to have detailed information about the physical properties within the fault zone. Such information can only be obtained by drilling a number of holes along the fault to be controlled.

RESEARCH CAPABILITIES IN THE EARTH SCIENCES

Given a program of the magnitude proposed, are there sufficient numbers of qualified scientists willing and able to devote the measure of effort required for its success? The state of seismological and geophysical sciences is particularly healthy at the present time. The challenge posed by the Vela Uniform program for nuclear test detection has drawn a large number of extremely capable and brilliant young scientists into these fields. With a solution to the detection problem close at hand, a national program on the equally challenging problem of earthquake prediction should have no difficulty in enlisting their full support.

There are upwards of 150 PhD-level scientists in the United States whose talents could be brought to bear on earthquake prediction. Of these, at least half are employed by universities, the remainder working in governmental and industrial laboratories. Some of the most imaginative research on earthquake seismology in the past decade has come from university research scientists. A program so designed as to ensure the full participation of all these scientists stands a great change for success.

SUMMARY

In summary, earthquake prediction is a valid concept and a subject worthy of a concerted research effort. The tools and techniques for testing prediction theories are presently available or within reach given only minimal time for development. The promising results of Japanese and Soviet Russian scientists indicate that a breakthrough may be reasonably near at hand. Scientists in the U.S. generally believe that earthquakes are predictable phenomena and that the benefits to humanity accruing from the development of the capability for earthquake prediction make it an extremely important national objective.

Appendix to the Statement by Dr. James R. Balsley, Assistant Director, U.S. Geological Survey

The following material elaborating the long history of NOAA and the USGS in studies of earthquakes and the solid earth is taken from the response prepared jointly by both agencies to the GAO Draft Report "Need for a National Earthquake Research Program."

NOAA—DEPARTMENT OF COMMERCE

U.S. Coast & Geodetic Survey (USC&GS, predecessor to NOAA) involvement in seismology dates from 1905 when, as an unofficial program, the Bureau began operating seismographs at its magnetic observatories.

Seismological investigations were formally recognized by statute in 1914 when the Weather Bureau was given authority to collect and disseminate seismological data. By Act of the Congress (H.R. 8308) this function was transferred to the USC&GS in 1925. Since 1925 the USC&GS (NOAA) has had a major Federal responsibility for making earthquake and seismological investigations in the United States. The Bureau's statutory authority for earthquake investigations was broadened by PL–573 enacted by the 80th Congress in 1947 to include the whole range of related geophysical studies. NOAA conducts a broad program of earthquake investigations and supporting services with emphasis on reducing the hazardous effects of earthquakes and providing the data base for a broad national research effort. To alert the public of approaching tsunamis frequently generated by earthquakes around the rim of the Pacific Ocean, NOAA operates the Pacific Tsunami Warning System. This system is operated cooperatively through joint agreements with all nations that border the Pacific Ocean. A regional warning system is operated in Alaska to give rapid warning to that state of tsunamis generated by earthquakes in the Aleutian Islands. Efforts are constantly being made to upgrade both the Pacific and the Alaska warning services through further research and development on the mechanism of tsunami generation, theoretical studies of runup, etc.

To provide a data base for seismological research NOAA determines the hypocenters of most significant earthquakes in the world (an average of about 6,000 per year) and all significant earthquakes in the United States (an average of about 1,600 per year). These raw data are distributed to all researchers and are used for a wide range of studies including earthquake zoning and earthquake prediction studies.

Since 1925 NOAA has routinely gathered damage and intensity data for all damaging earthquakes in the United States. These raw data are distributed to all researchers four times each year through the "Quarterly Seismological Reports" and summarized annually in the series "United States Earthquakes." These data were the basis for the first seismic risk map of the United States developed by NOAA in 1948, as well as the revised map published in 1969. The first map was adopted as the basis for earthquake resistant design by the Uniform Building Code in 1952; it was replaced by the revised map in 1970.

The Earth Sciences Laboratories operate a network of strong-motion seismographs that currently numbers almost 1,000 instruments. Approximately 700 of these are in California. Instruments are installed in buildings, dams, bridges, and other engineered structures, and in a wide range of geological environments throughout the United States and in Central and South America. These instruments write a time-record of the response (acceleration or displacement) of structures or geologic environments to earthquake generated motions. Copies of the recordings are routinely distributed to all researchers. They are the basis of research in earthquake resistant design of structures and thus are critical to improvement of the earthquake provisions of local and national building codes.

NOAA also conducts a multidisciplinary program in seismic risk mapping of the United States which depends heavily on data from the strong motion seismograph network, earthquake damage surveys, soil amplification studies and other related research projects.

NOAA's geodetic survey program along the San Andreas Fault System dates from 1855. Following earthquakes in this area in 1868, it was recognized that significant information about deformation in earthquake zones could be obtained from repeat measurements of the movement of the geodetic monuments. The geodetic network spanning the length of the San Andreas Fault System was completed before 1900. Repeat measurements in selected areas were made following the San Francisco earthquake of 1906, and the network covering the overall system was reobserved in 1922–23. Since then the network has been expanded into sub-regions of the fault system, and systematic repeat surveys have been made at intervals ranging from one to 15 years. These measurements coupled with periodic measurement of vertical changes, continuous polar motion measurements, and research studies of plate tectonic and global geophysics, provide a suite of measurements ranging from annual fault slippage at specific locations through regional changes in fault subsystems.

These data are used for research within NOAA and are made available to other agencies having direct interest, as well as universities and private research groups. Such data, in the form of special services and published reports, provide the parameters required for programs such as the California Aqueduct System, the San Francisco Bay Rapid Transit System, and urban development in regions of extreme subsidence. NOAA has the responsibility for coordinating all geodetic surveys of other Federal agencies, including the crustal movement studies made by or funded by Federal agencies.

The Earth Sciences Laboratories also conduct special earthquake research studies related to the San Andreas fault at its Earthquake Mechanism Laboratory (EML). EML, previously known as Advanced Seismic Experiments Group, was formed in February 1964, and has occupied its present quarters in San Francisco since December 1964. Its function includes the study of the earth's internal structure and the mechanisms that cause earthquakes. EML conducts extensive research on creep along the San Andreas fault and a broad program in the Aleutian Islands. The strain program is in cooperation with the AEC and some universities.

NOAA provides seismological information needed by other Federal agencies, state agencies, and regional and local regulatory authorities in the conduct of their programs and conducts research in support of their programs. As an example, NOAA recently developed a method of computing economic losses in earthquakes that served as the technical basis for the Department of Housing and Urban Development report to the Congress of the feasibility of a national program of earthquake insurance. NOAA has also cooperated with OEP in the development of its Emergency Preparedness Plan by estimating the likely effects of large earthquakes in various parts of the United States. NOAA also provides expert advice to AEC in its Nuclear Reaction Siting Program. NOAA operates the strong ground motion measurement program for AEC both at its Nevada test site and more recently at the testing area in the Aleutian Islands.

In addition to its working agreements with public agencies, NOAA collaborates with universities and nonprofit groups such as the Earthquake Engineering Research Institute to focus its research on both the immediate and long-range public needs.

USGS—DEPARTMENT OF THE INTERIOR

The USGS was created in 1879 by an act of Congress and was charged, among other things, with examining the geologic structure of the national domain. Since then the USGS program has spanned the whole realm of earth sciences, and it interfaces with the area of earthquake engineering. The seismic and geodetic aspects are components of an integrated program encompassing geophysics and geology. The study of geologic hazards, including those of earthquakes, has been a long-standing concern of USGS programs, and the talents of research scientists in many different fields of earth science are directed towards solution of a broad spectrum of problems that range from earthquake prediction to the defining of the effects of earthquake shock in specific areas. Early efforts in seismology by USGS scientists included investigations on the great earthquake of Charleston S.C., in 1886, the 1906 earthquake in California, the 1811–12 earthquake at New Madrid, Missouri (investigated and reported on in 1912), and many significant earthquakes in the United States have been reported on by USGS scientists since then.

Since the turn of the century scientists of the USGS have played a major role in the geologic and geophysical analysis of active tectonic belts of Western North America, including such active earthquake faults as the San Andreas Fault. Many of the early fundamental studies of the San Andreas Fault were started by USGS scientists shortly after the first World War. The work continued and expanded, leading to present concepts of large earth shifts, estimates of earthquake probability and recurrence, and preparation of maps of active fault strands for land use planning.

Studies of the earth's crust and upper mantle by refraction seismology, heat flow studies concerned with earthquake-driving mechanisms, landmark studies of the reversals of the earth's magnetic poles as revealed by paleomagnetism, laboratory studies of rock mechanics, and aeromagnetic mapping, all contributed fundamentally to the great breakthrough in the earth sciences in the 1960's known as the "New Global Tectonics."

The USGS was responsible for synthesizing and publishing the tectonic map of North America, possible only by employing the vast accumulation of geological and geophysical information gathered over the decades by the USGS.

Subbottom accoustical profiling within the marine geology program of the USGS has been employed to map active faults on the continental shelf so as to provide data for evaluating seismic hazards of coastal sites for nuclear reactors.

In 1924 the USGS took over the research program of the Hawaiian Volcano Observatory (HVO) and employed seismic instruments with tiltmeters to analyze volcanic activity and related seismicity. Since then, the study of microearthquakes has been a technique commonly employed by USGS scientists to analyze geologic structures and processes ranging from active faults, sources of geothermal energy, mine tunnel failures, to volcanism. In the mid-1950's techniques of employing local seismic nets and tiltmeters at HVO were improved by the USGS and led to successful prediction of eruptions of Kilauea volcano.

The seismic and related geophysical studies of the USGS were expanded in the 1960's to serve the Vela Uniform program of ARPA, and after a successful completion of that program, the expanded capabilities were refocused on studies of the earth's upper mantle and natural earthquakes. Geophysical staff was moved from Denver, Colorado, to Menlo Park, California, to be brought together with geologic staff and the combined effort became the National Center for Earthquake Research (NCER) by proclamation of the Secretary of the Interior in 1965.

The geologic hazards of earth failure including landslides, mudflows, liquefaction, land spreading, and differential subsidence are greatly amplified during earthquakes, and have been subjects of continuing research in the engineering geology program of the USGS, aimed at developing techniques and criteria for the recognition of hazards and at delineating on maps the areas underlain by such hazardous deposits. The first major physical environmental study of an urban area to be concerned with delineating geologic hazards for urban and regional land use planning was launched in 1969 by the USGS with partial support by the Department of Housing and Urban Development.

The seismological and geological capabilities of the Survey have been increasingly utilized during the past 10 years by many other agencies, including the Atomic Energy Commission, Department of Housing and Urban Development, Advanced Research Projects Agency, Veterans Administration, Office of Emergency Preparedness, National Aeronautics and Space Administration, and state and local governments. USGS scientists have examined the results of many earthquakes in other parts of the world in collaboration with international organizations such as CENTO and UNESCO. Close involvement with universities, including part-time employment of professors, has been traditional, and programs of post-doctoral fellowships and visiting scientists have perpetuated strong liaison with scientific research throughout the world. The strength of the Survey program in earthquake research, and the reason the Survey is called upon by other agencies, rest basically on the wide diversity of research talent in the earth sciences available to attack all aspects of the problem.

Senator HOLLINGS. The committee will be in recess, subject to the call of the Chair.

(Whereupon, at 12:30 p.m., the committee was recessed, subject to the call of the Chair.)

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