## COMPLETE REPAIR AND RESTORATION

### Introductory Remarks

The purpose of complete repair and restoration is to rebuild the water and sewer system to its original form. The decision concerning complete repair and restoration of a damaged system should be based on the following considerations:

1. The intensity and character of damage to pipes
2. The intensity and character of damage to manholes
3. The intensity and character of damage to inlets
4. Comparison of functional operations before and after the earthquake
5. The expected life and plan of usage of the facility
6. The expected life of the structures
7. Soil properties, ground water level and buried depth
8. Construction environment
9. Special characteristics of the stricken area
10. The effect on users
11. The effect on roads
12. The effect on surrounding facilities
13. Restoration method and its application

### Methods of Restoration and/or Repair

Repair/restoration work for water and sewer pipelines can be categorized as follows:

1. Repair/restoration to original pipeline strength
2. Repair of cracks to stop leakage
3. Restoration of pipeline axis alignment

The methods of repair/restoration for the above three categories are outlined as follows:

1. Methods of Repair/Restoration to Original Pipeline Strength
   - Replacement of pipes
   - Reuse of old pipes

- Adding of concrete around pipe
- Injection of epoxy
- Welding of steel plate
- Caulking
- Encasement of pipe

2. Methods of Repair for Leakage
   - Caulking
   - Use of super joint glue
   - Sealing
   - Grouting chemically
   - Use of rubber band on outside surface of pipe
   - Use of rubber band on inside surface of pipe
   - Use of water-stopping flexible joint
   - Replacement at bottom of pipe by special frame
   - Injection of epoxy
   - Encasement of pipe
   - Steel plate connection

3. Methods of Correcting Misalignment of Pipeline
   - Injection of epoxy
   - Grouting with cement
   - Replacement with new pipe
   - Leveling techniques

## RETROFITTING ISSUES

Since a seismic design code for buried pipelines is not available at this time, existing pipelines, either sewer or water, are probably not designed for seismic resistance. Retrofitting of existing lines for seismic resistance is definitely one of the desires that the owner of the utility may wish to consider. However, retrofitting of existing water or sewer pipelines is a very expensive, if not impossible, task. The difficulty lies in the facts that (1) most water and sewer lines are buried under congested streets and (2) so many lines are in need of retrofitting. The opening of a street for repair at an isolated location is very difficult and expensive; the opening of all street for retrofitting of all existing lines is out of question.

Other important facts are that so many uncertainties (e.g., exact soil properties, seismic intensities) are involved in a retrofitting project and no effective retrofitting method has been yet developed. Therefore, retrofitting of all existing buried pipelines is not recommended by most experts in the lifeline earthquake engineering field.

What one can do at the present time is to upgrade the existing system during routine maintenance or disaster repair works. The following items should be considered:

1. Replace current brittle pipe with more ductile pipe

2. Replace current rigid joints with more flexible and/or restrained joints

3. Replace current pipes that have been weakened by corrosion

4. Repair cracks with strong epoxy

For an important project such as a nuclear power plant, retrofitting, repair, and/or replacement of pipelines may be necessary. The methods are as follows:

1. Add drainage around existing pipes at regions of possible soil liquefaction

2. Inject chemical (or epoxy) or cement into soil liquefaction region

3. Drive piles at junction between pipeline and interconnected structures

4. Densify soils surrounding the pipeline

5. Add anchorage to pipeline

## SCIENTIFIC AND ENGINEERING INFORMATION NEEDS AND RECOMMENDATIONS

For the mitigation and/or prevention of an earthquake disaster, repair and/or restoration of earthquake damage as well as the development of an aseismic code for segmented and jointed pipelines, much scientific and engineering information is needed in the following areas:

- Understanding of earthquake damage behavior
- Pre-earthquake preparation
- Repair and restoration strategy during and after an earthquake
- Development of aseismic design code for new systems
- Further research

### Understanding Earthquake Damage Behavior

An earlier section of this paper described damage from recent earthquakes in the United States, Japan, and China. Some types of damage to be expected are now known. However, the influence of many parameters are known only qualitatively (e.g., soil resistance characteristics, joint resistance characteristics). Detailed or quantitative information regarding these parameters will be needed. The effects of other geological parameters (e.g., ground strain variations, liquefaction potential) are still relatively unknown. Therefore, monitoring of pipeline damage should be continued. When possible, seismometers and strain and displacement gauges should be installed.

### Pre-earthquake Preparation

Pre-earthquake preparations and measures also were discussed above. For this task, a complete inventory and map of the pipeline system should be prepared for emergency use. It is necessary to identify the most vulnerable regions for quick reference. It is also necessary to set up communication networks in advance. Parametric studies of analytical response behavior will be helpful in identifying weak areas.

### Repair and Restoration Strategy During and After Earthquake

For efficiently repairing and/or restoring buried pipelines during and after an earthquake, effective repair and restoration strategies must be developed. Emergency survey/inspection measures already have been presented. One must now assess the various methods and their applicability to various conditions for use in a strategy plan.

The strategy plan should identify the method, procedure, and priority for repair and/or restoration under different intensities of an earthquake disaster. The manpower and materials or parts needed for the repair/restoration should be estimated. The organization of the repair/restoration team and an inventory of material/parts should be prepared accordingly.

## ONGOING AND RECOMMENDED FUTURE RESEARCH ACTIVITIES

As indicated above, an aseismic code for buried pipeline has not been developed and many uncertainties remain. Research and development work is being diligently pursued in many countries, including the United States and Japan, by many researchers and engineers. The major topics of current and recommended research investigations are summarized below.

### Ground Motion Measurement

Seismic behavior of buried linear structures, such as pipes and tunnels, is strongly influenced by the relative displacement of the surrounding soil. This concept has been implemented in the design considerations for buried pipelines, but observation data on soil strain are limited and fragmentary. Recently, several strong-motion network arrays to study ground motion characteristics have been established around the world, particularly in Japan, the United States and Taiwan.

Using the strong-motion data recorded from the dense network arrays, the ground displacement/strains can be calculated. As a result, the correlation of ground strains with local seismological, geological, and geotechnical conditions can be studied.

For the correlation between ground motion characteristics (ground displacement/strains) and the buried pipeline seismic behavior, the Institute of Industrial Science, University of Tokyo, has instrumented

two L-shape buried pipelines at its Chiba Site Experimentation Station. Preliminary results have been obtained from several actual earthquake records. The field observation of buried pipeline response to actual earthquakes is a long-term project.

Similar projects are being proposed by several investigators. Once the correlation between ground motion characteristics and the pipe responses in terms of local site conditions has been confirmed, the design of buried pipelines for seismic resistance would be more effective.

## Pipeline Under a Soil Liquefaction Environment

There has been heavy damage to buried pipelines under soil liquefaction environments, particularly at the junction of heavy structures and pipelines, as observed and reported in Japan and China. Although both analytical and experimental studies on the behavior of buried pipelines under soil liquefaction environments have been initiated, results obtained are only preliminary and limited.

The importance of uplift and soil movement upon pipelines during liquefaction have been recognized. Analytical correlation and prediction of pipeline responses are of interest. Most of all, methods to mitigate damage and improve site environments are under development. Some of the ongoing Japanese research activities on buried pipeline responses under soil liquefaction environments are listed below:

1. Experimental study of buried pipeline including manhole by shaking table tests

2. Experimental study of improved measures for buried pipelines including manholes under soil liquefaction environment

3. Dynamic response study of buried pipelines including manholes under soil liquefaction environments

To complement and/or supplement the Japanese investigation, similar research with common objectives but a different scope and approach should be initiated and implemented under the U.S.-Japan Cooperative Research Program. This may be done from the U.S. side by one or more academic and/or research institutions. A budget of $300,000 is estimated.

## Dynamic Soil Resistant Characteristics

The seismic response of buried pipelines is greatly influenced by the dynamic soil resistant characteristics. Without accurate information, the analytical prediction of the dynamic response behavior would not be accurate. Using inaccurate results, the design of buried lifelines will not be satisfactory. Therefore, the complete understanding of the dynamic soil resistant characteristics is necessary for development of an aseismic design code for buried pipelines.

Under a seismic shaking environment, the dynamic axial soil resistant characteristics are most important. Under a soil liquefaction environment, the dynamic lateral soil resistant characteristics also are important because both uplift and lateral motion would become dominant under a liquefaction condition.

For a buried pipeline under large fault movement, the static axial and lateral soil resistant characteristics would be of interest. Because Japan has much new and sophisticated equipment (e.g., shaking tables with multiple degrees of freedom, reaction walls), this task should probably be carried out by Japanese investigators or under a U.S.-Japan joint research program using Japanese equipment. This task may be accomplished in two years with a budget of $200,000.

### Joint Resistance Characteristics

For segmented and jointed pipelines, joint resistance characteristics play a major role in the seismic resistance of pipelines. Currently, the conventional joints and seals have not been studied thoroughly for performance during an earthquake.

Furthermore, in order to allow larger displacements and to absorb more energy during seismic shaking, liquefaction and fault movement, new types of flexible-restrained joints should be developed. It is recommended that such development work be carried out in the near future. The pipe joint industry should be encouraged to cooperate in this task by contributing their pipe-joint specimens. The budget is about $150,000 without including equipment and specimen costs.

### Development of Tentative Manual of Practice

While research is being carried out and/or proposed toward the development of a comprehensive seismic design code for buried segmented and jointed pipeline for future applications, it is necessary, in the mean time, to develop a tentative manual of practice for immediate application using the current state of knowledge. This manual should be refined continuously as new information or knowledge becomes available.

The development of such a manual of practice would be best done by a group of academic researchers and practicing engineers in the field. Currently, the Water and Sewerage Committee of the American Society of Civil Engineers' Technical Council on Lifeline Earthquake Engineering (TCLEE), which consists of both academic researchers and practicing engineers, has initiated a proposal to undertake the task. It is recommended test funds be sought to sponsor the project. A budget of $150,000 to $200,000 is estimated.

### ACKNOWLEDGEMENTS

The authors wish to thank Dr. Makoto Kawamura, Associate Professor of Civil Engineering, Mr. Yui, Research Associate and several graduate

students at the Toyohashi University of Technology and Mr. Yuean-Chen Lau, a doctoral student, and Mrs. Sue Smith, administrative secretary at Old Dominion University, for assisting the preparation of this manuscript. The authors also wish to acknowledge the comments from Mr. James R. Smith, Executive Director, and Mr. Allen Israelsen, Technical Consultant, of the Building Seismic Safety Council and members of the BSSC Water and Sewer Panel, of which Mr. Holly A. Cornell is the chairman.

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# APPENDIX A

## WORKSHOP AGENDA

# Workshop on
# Abatement of Seismic Hazards to Lifelines
# Denver, Colorado
# November 5, 6, and 7, 1986

| | Session | Activity | Presenter/Speaker |
|---|---|---|---|
| **Wednesday, Nov. 5** | | | |
| 7:30 - 8:30am | Registration | | |
| 8:30 - 10:00am | Plenary | Introductory Remarks | James R. Smith, BSSC |
| | | Goals for the Workshop | Roy G. Johnston, Session Ch. |
| | | FEMA Interest in Lifelines | Ugo Morelli, FEMA |
| | | Overview of Seismic Hazards in the U.S. | Walter Hays, USGS |
| 10:00-10:15am | Break | Refreshments | |
| 10:15am - noon | Plenary | Presentations of Draft Action Plans/Category | |
| | | o Water & Sewer | Holly Cornell |
| | | o Transportation | James Gates |
| | | o Communications | John Foss |
| | | o Power | Otto Steinhardt |
| | | o Gas & Liquid Fuel | Douglas Nyman |
| | | o Seismic Risk | Ronald Eguchi |
| Noon - 1:30pm | Plenary | Luncheon - Guest speaker on "The 1906 San Francisco Earthquake - A New Perspective" | David Fowler |
| 1:30 - 5:00pm | Concurrent | Final Review & Discussion of Authored Papers | |
| | | o Water & Sewer | Individ. authors |
| | | o Transportation | Individ. authors |
| | | o Communications | Individ. authors |
| | | o Power | Individ. authors |
| | | o Gas & Liquid Fuel | Individ. authors |
| | | o Political/Social/Economic | Individ. authors |
| | | o Legal/Regulatory | Individ. authors |
| 6:30 - 7:30pm | Plenary | Banquet | |
| 7:30 - 8:15pm | Plenary | Presentations of Global Issues, Problems and Related Action Plans | |
| | | o Political/Social/Economic | William Petak |
| | | o Legal/Regulatory | Morton Remmer |
| 8:15 - 9:30pm | Plenary | Discussion and Critique of, Reaction to Presentations | Roy G. Johnston (Moderator) |
| 9:30pm | | ADJOURNMENT | |

| | Session | Activity | Moderator/Speaker |
|---|---|---|---|
| **Thursday, Nov 6** | | | |
| 8:30am - noon | Concurrent | Discussion of Action Plans Per Category | |
| | | o Water & Sewer | Holly Cornell |
| | | o Transportation | James Gates |
| | | o Communications | John Foss |
| | | o Power | Otto Steinhardt |
| | | o Gas & Liquid Fuel | Douglas Nyman |
| | | o Seismic Risk | Ronald Eguchi |
| Noon - 1:30pm | Plenary | Luncheon - Guest Speaker on "Fire Following Earthquakes - Lifeline Interactions" | Charles Scawthorn |
| 1:30pm - 5:00pm | Concurrent | Rewrite and finalize Action Plans per Category | |
| | | o Water & Sewer | Holly Cornell |
| | | o Transportation | James Gates |
| | | o Communications | John Foss |
| | | o Power | Otto Steinhardt |
| | | o Gas & Liquid Fuel | Douglas Nyman |
| 5:00pm | ADJOURNMENT | (Evening open) | |

| | Session | Activity | Moderator/Speaker |
|---|---|---|---|
| **Friday, Nov. 7** | | | |
| 8:30am - noon | Plenary | Presentations and Discussion of Final Draft Action Plans | Roy G. Johnston |
| 10:00-10:15am | Break | Refreshments | |
| Noon | ADJOURNMENT | (with exception of Action Plan Committee) | |
| Noon - 1:30pm | Committee | Luncheon | |
| 1:30 - 4:30pm | Committee | Action Plan Committee meeting to: | |
| | | o finalize plans for completion | |
| | | o make assignments | |

# APPENDIX B

## LIST OF WORKSHOP PARTICIPANTS

**BSSC Lifelines Program Management Committee**

Roy G. Johnston, Brandow and Johnston Associates, Los Angeles California (Ex-Officio member of the BSSC Board of Direction)
Neal Houghton, Building Owners and Managers Association, Phoenix, Arizona (BSSC Vice Chairman)[1]
William R. Moore, Dames and Moore, San Francisco, California

**Panel on Water and Sewer Facilities**

Chairman

Holly A. Cornell, CH2M Hill, Inc., Corvallis, Oregon

Members

Donald H. Babbitt, Division of Safety of Dams, Sacramento, California
Donald B. Ballantyne, Kennedy/Jenks/Chilton, Federal Way, Washington
Martin Jaffe, University of Illinois, Chicago
Le Val Lund, Department of Water and Power, Los Angeles, California
James E. McCarty, Oakland, California
Michael J. O'Rourke, Rensselaer Polytechnic Institute, Troy, New York
Lawrence D. Reaveley, Reaveley Engineers and Associates, Inc., Salt Lake City, Utah
Charles H. Trautmann, Cornell University, Ithaca, New York
Leon R. L. Wang, Old Dominion University, Norfolk, Virginia

**Panel on Transportation**

Chairman

James H. Gates, Department of Transportation, Sacramento, California

Members

Peter Engelmann, Preinvest, Inc., Bethesda, Maryland
Edward S. Fratto, Massachusetts Civil Defense Agency and Office of Emergency Preparedness, Framingham
Peter Gordon, University of Southern California, Los Angeles
Roy A. Imbsen, Imbsen and Associates, Sacramento, California
Geoffrey R. Martin,[2] The Earth Technology Corporation, Long Beach, California

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[1]Could not attend workshop.

[2]C. B. Crouse, The Earth Technology Corporation, participated in the workshop for panel member Martin.

Ronald L. Mayes,[3] Computech Engineering Services, Inc., Berkeley, California
Irving J. Oppenheim, Carnegie-Mellon University, Pittsburgh, Pennsylvania
Joy M. Pauschke, Impell Corporation, Lincolnshire, Illinois
Stuart D. Werner, Wiss, Janney, Elstner Associates, Inc., Emeryville, California

**Panel on Communications**

Chairman

John W. Foss, Bell Communications Research, Morristown, New Jersey

Members

Leon Faynsod, General Telephone Company of California, Thousand Oaks
Jeremy Isenberg, Weidlinger Associates, Palo Alto, California
Gordon L. Laverty,[4] Laverty Associates, Oakland, California
Saeed S. Mirzad, Pacific Bell Company, San Ramon, California
Joanne Nigg, Arizona State University, Tempe
Masanobu Shinozuka, Columbia University, New York, New York
Alex Tang, Northern Telecom Canada, Ltd., Brampton, Ontario

**Panel on Power**

Chairman

Otto W. Steinhardt, ASCE TCLEE, Clearlake Park, California

Members

H. Crane Miller, Attorney at Law, Washington, D.C.
Dennis K. Ostrom, Southern California Edison, Los Angeles, California
Anshel J. Schiff, Stanford, California
Richard T. Sylves, University of Delaware, Newark
Joseph V. Tyrrell, Naval Facilities Engineering Command, Alexandria, Virginia
Peter I. Yanev, EQE, Incorporated, San Francisco, California

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[3]Ian Buckle, Computech Engineering Services, Inc., participated in the workshop for panel member Mayes.

[4]D. J. Stief, Pacific Bell Company, participated in the workshop for panel member Laverty.

**Panel on Gas and Liquid Fuels**

Chairman

Douglas J. Nyman, Nyman Associates, Houston, Texas

Members

Ronald T. Eguchi, Dames and Moore, Los Angeles, California
Marjorie R. Greene, Bay Area Region Earthquake Preparedness Project, Oakland, California
William J. Hall, University of Illinois, Urbana
Lincoln E. Malik, URS John A. Blume and Associates, San Francisco, California
Thomas D. O'Rourke, Cornell University, Ithaca, New York
Dennis G. Row, SSD Incorporated, Berkeley, California

**Overview Group on Legal and Regulatory Issues**

Chairman

Norton S. Remmer, Worcester, Massachusetts

**Overview Group on Political, Economic, and Social Problems**

Chairman

William J. Petak, University of Southern California, Los Angeles

**Overview Group on Seismic Risk**

Chairman

Ronald T. Eguchi, Dames and Moore, Los Angeles, California

**Guest Participants**

James E. Beavers, Martin Marietta Energy Systems, Oak Ridge, Tennessee
James D. Cooper,[5] Defense Nuclear Agency, Alexandria, Virginia, and member of the Executive Committee, ASCE-TCLEE
Rudolf E. Elling, Clemson University, Clemson, South Carolina
Lorie Hoffman, Bonneville Power Administration, Portland, Oregon
Leo A. Kinney, U.S. Bureau of Reclamation, Denver, Colorado
Edgar V. Leyendecker, U.S. Geologic Survey, Denver, Colorado
R. Michael McCafferty, Western Area Power Administration, Golden, Colorado

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[5]Absent from workshop; reviewed and contributed to Chapter 6, the action plan for transportation lifelines.

Frank E. McClure, Lawrence Berkeley Laboratory, Berkeley, California
Robin K. McGuire, Risk Engineering Inc., Golden, Colorado
Harry H. Mejdell, CH2M Hill, Inc., Corvallis, Oregon
James R. Morgan, Texas A&M University, College Station
Michael Purdy, Bell Northern Research, Ottawa, Ontario
Charles F. Scheffey, Federal Highway Administration, McLean, Virginia
Arie B. Schuurman,[6] Pacific Gas and Electric Company, San Francisco, California
Craig Taylor, NTS Corporation, Long Beach California
Curtis A. Thompson, PRC Engineering, Englewood, Colorado
Felix Y. Yokel, National Bureau of Standards, Gaithersburg, Maryland

**Observers**

Jane Bullock, Federal Emergency Management Agency, Washington, D.C.
Gary D. Johnson, Federal Emergency Management Agency, Washington, D.C.
Ugo Morelli, Federal Emergency Management Agency, Washington, D.C.

**Workshop Speakers**

David Fowler, California Academy of Sciences, San Francisco Earthquake Research Project, San Francisco, California
Charles Scawthorn, Dames and Moore, San Francisco, California
Walter Hays, U.S. Geological Survey, Reston, Virginia

**Workshop Recorders**

David Bessy, CH2M Hill, Inc.
David Diggs, University of Colorado
Neil Heywood, University of Colorado
Lynn Highland, U.S. Geological Survey
Peter Morrisette, University of Colorado
Larry Reasch, CH2M Hill, Inc.
Sara Rhoades, CH2M Hill, Inc.
Susan Tubbesing, Natural Hazards Research and Applications Center
Mary Jo Vobjeda, CH2M Hill, Inc.
John Wiener, University of Colorado

**BSSC Staff**

James R. Smith, Executive Director
O. Allen Israelsen, Consultant
Claret M. Heider, Consulting Technical Writer-Editor

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[6]Participated in development of Chapter 9, the action plan for power lifelines.

# APPENDIX C

## BIOGRAPHIES OF WORKSHOP PARTICIPANTS

**James E. Beavers** is manager of civil and architectural engineering for Martin Marietta Energy Systems, Oak Ridge, Tennessee.

**Donald H. Babbitt** is chief of the Field Engineering Branch, California Division of Safety of Dams. He has been employed by the state of California since 1957. He has designed or supervised the design of eight dam embankments including the 390-foot-high Pyramid Dam and the 120-foot-high, 11,600-foot-long Perris Dam, both in southern California. Mr. Babbitt received a B.S. degree in civil engineering from the University of California at Berkeley.

**Donald B. Ballantyne** is a sanitary engineer with Kennedy/Jenks/Chilton, Federal Way, Washington, where he has worked since 1981. He is responsible for the design of seismic-resistant pipe support systems for four Kennedy/Jenks/Chilton wastewater treatment plants. He also provided seismic vulnerability analyses for the 10 mgd/125 mgd DWF/PWWP CMSA Wastewater Treatment Plant, priority ranking unit processes and evaluating systems. He currently is vice chairman of the American Society of Civil Engineers Technical Council on Lifeline Earthquake Engineering (ASCE TCLEE). Mr. Ballantyne holds a B.S. degree in civil engineering from Rensselaer Polytechnic Institute and a M.S. degree in civil/sanitary engineering from the State University of New York.

**Ian G. Buckle** is director of research and development for Computech Engineering Services, Berkeley, California. He came to Computech in July 1984 from the faculty of the University of Auckland where he had been involved in bridge and earthquake engineering research for the previous 15 years. He is an international expert in base isolation technology and currently is principal investigator for several research contracts funded by the National Science Foundation (NSF) and the Federal Emergency Management Agency (FEMA). He holds B.E. and Ph.D. degrees from the University of Auckland, New Zealand.

**James D. Cooper** is a civil engineering staff specialist concentrating on structural and geotechnical engineering with the Defense Nuclear Agency (DNA). He is manager of the DNA technology-based program to advance the state of the art concerning understanding of structural response to seismic loads. Mr. Cooper also serves on the Executive Committee of ASCE-TCLEE and is chairman of the ICSSC Subcommittee on Lifelines.

**W. Gene Corley**, Portland Cement Association, Skokie, Illinois, is secretary of the BSSC Board of Direction.

**Holly A. Cornell** is senior consultant for CH2M Hill, Corvallis, Oregon, and was a founding partner of the firm in 1946. He served as president from 1974 to 1978 when he became chairman of the board. He retired from that position in 1980 and now serves as senior advisor to management, acts as consultant to project teams, and is actively engaged in assignments on major projects. Mr. Cornell is an honorary member of the ASCE and past chairman of the Engineering and Construction Committee of the Technical and Professional Council of the American Water Works Association (AWWA). He holds a B.S. degree in civil engineering

from Oregon State University and a M.E. degree in structural engineering from Yale University.

**C. B. Crouse** is a principal engineer with The Earth Technology Corporation, Long Beach, California. He recently completed a NSF-funded study on dynamic soil-structure interaction of bridges and is an associate editor of the *Bulletin of the Seismological Society of America*. Dr. Crouse is a member of various local, state, and national committees in earthquake engineering and has published over 30 papers in this field.

**Ronald T. Eguchi** is an associate with Dames and Moore in Los Angeles, California. He has over 12 years of experience in risk analysis, earthquake engineering, and natural hazards engineering and has directed major research and application studies in these areas for government and industry. He currently is chairman of the ASCE TCLEE Committee on Seismic Risk and serves as a member of the ASCE TCLEE Committee on Gas and Liquid Fuels and Committee on Water and Sewage and the Earthquake Engineering Research Institute (EERI) Seismic Risk Committee. He also has been appointed to the newly formed editorial board of EERI's technical journal, *Spectra*.

**Rudolf E. Elling** is a member of the faculty at Clemson University, Clemson, South Carolina.

**Peter Engelmann** is president of Preinvest, Inc., Bethesda, Maryland, and a civil engineer/planner. He has over 20 years experience in a variety of positions for the World Bank, 1 year with the U.S. government, and 19 years with consulting firms on domestic and international projects related to transportation, ports, and industrial development. His expertise lies in concept formulation and planning of preinvestment work, related budgeting, preparation of study programs, and contract management.

**Leon Faynsod** is senior network engineering supervisor for General Telephone Company of California, Thousand Oaks, where he has worked since 1968. He is a member of the ASCE TCLEE Electric Power and Communications Committee, the EERI, the Colegio de Ingenieros Civiles de Mexico, Camara Nacional de la Industria de la Construccion, the State of California Governor's Earthquake Task Force Telecommunications Subcommittee, and the State of California Public Utilities Commission Subcommittee on Earthquake Resistance of Public Utilities. He holds a B.S. degree in engineering from the Colegio Franco Espanol and a M.S. degree in engineering from the Universidad Nacional Autonoma de Mexico.

**John W. Foss** is district manager for Bell Communications Research, Inc., Morristown, New Jersey.

**David Fowler** is an associate of the California Academy of Sciences, San Francisco Earthquake Research Project, San Francisco.

**Edward S. Fratto** is manager of the Massachusetts Civil Defense Agency and Office of Emergency Preparedness Earthquake Hazard Mitigation Program. His professional activities have focused primarily on earthquake hazard mitigation and he has been responsible for the management

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# APPENDIX D

## CONTENTS OF WORKSHOP PROCEEDINGS VOLUMES

## VOLUME 1[1]

### PAPERS ON WATER AND SEWER LIFELINES



## VOLUME 2

### PAPERS ON TRANSPORTATION LIFELINES



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[1]All volumes contain appendixes presenting the workshop agenda, list of workshop participants, biographies of workshop participants, and this list of the contents of the proceedings volumes.

Seismic Retrofit for Geotechnical Components of Transportation System
*Geoffrey R. Martin, Ignatius (Po) Lam, and C. B. Crouse*

Conventional and Seismic Isolation Retrofit Techniques for Bridges
*Ronald L. Mayes*

Seismic Risk to Transportation Systems
*Irving J. Oppenheim and Chris Hendrickson*

Seismic Hazard Abatement of Railroad Facilities
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Engineering Research Needs for Seismic-Resistant Transportation Lifeline System Elements
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**VOLUME 3**

**PAPERS ON COMMUNICATION LIFELINES**

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*Leon Faynsod*

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Survey of Ongoing Activities in the Abatement of Seismic Hazards to Communications Systems
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Scientific and Engineering Information Needs in Abatement of Seismic Hazards to Telecommunications Systems
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**VOLUME 6**
**PAPERS ON POLITICAL, SOCIAL, ECONOMIC, LEGAL, AND REGULATORY ISSUES AND GENERAL WORKSHOP PRESENTATIONS**

**Papers on Political, Social, and Economic Issues**

**Papers on Legal and Regulatory Issues**



**General Workshop Presentations**

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Building Officials and Code Administrators, International
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