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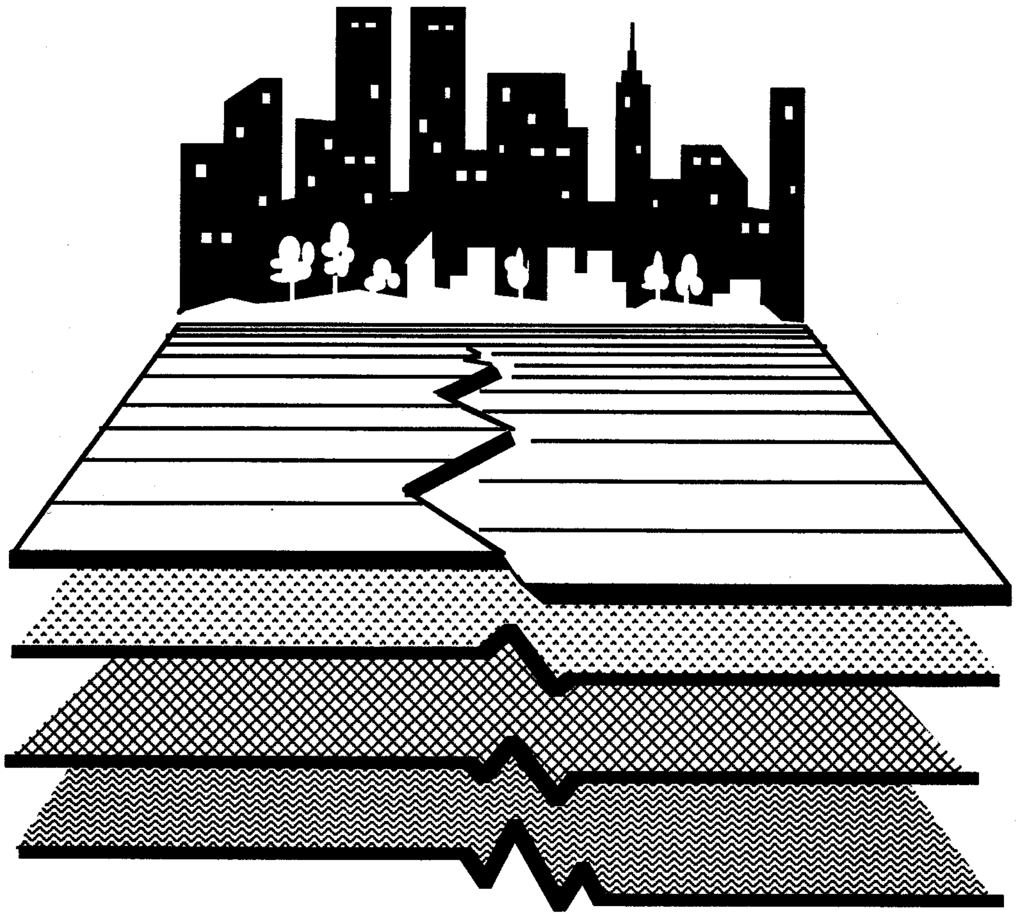
A Benefit-Cost Model for the Seismic Rehabilitation of Buildings

Volume 2: Supporting Documentation



EARTHQUAKE HAZARDS REDUCTION SERIES 63

Issued by FEMA in furtherance of the Decade for Natural Disaster Reduction.

NATIONAL EARTHQUAKE HAZARDS REDUCTION PROGRAM

A BENEFIT-COST MODEL FOR THE SEISMIC REHABILITATION OF HAZARDOUS BUILDINGS

VOLUME 2: SUPPORTING DOCUMENTATION

Prepared for the Federal Emergency Management Agency
Under Contract No. EMW 89-C-2991

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by

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FEMA Foreword

The Federal Emergency Management Agency (FEMA) is pleased to have sponsored the preparation of this publication on a cost/benefit methodology for the seismic rehabilitation of hazardous buildings. The publication is one of a series that FEMA is sponsoring to encourage local decisionmakers, the design professions, and other interested groups to undertake a program of mitigating the risks that would be posed by existing hazardous buildings in case of an earthquake. Publications in this series examine both engineering and architectural aspects as well as societal impacts of such an undertaking. They are prepared under the National Earthquake Hazards Reduction Program.

With respect to this particular publication, FEMA gratefully acknowledges the expertise and efforts of the management and staff of VSP Associates, Inc., its consultants, and the many individuals and organizations who provided valuable information and comments during the course of the effort.

The Federal Emergency Management Agency

FEMA Disclaimer

The report was prepared under Contract EMW 89-C-2991 between the Federal Emergency Management Agency and VSP Associates, Inc.

For further information regarding this document, additional copies, or the software to operate the model, contact the Federal Emergency Management Agency, Office of Earthquakes and Natural Hazards, Washington, D.C. 20472.

VSP Disclaimer

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INTRODUCTION

This is the second of two volumes prepared by VSP Associates, Inc. for the Federal Emergency Mangement Agency on a standard benefit/cost model that could be used throughout the United States to help practitioners and government officials evaluate the economic benefits and costs of seismic rehabilitation of existing buildings. This volume provides substantial additional background information so interested users can have a fuller understanding of the research and development activities that supported the preparation of this benefit-cost model. Volume 2 contains several appendices, as follows:

Appendix 1 contains the review of literature that was completed. This review confirmed that no existing model could be easily adapted to achieve FEMA's objectives, and it helped identify the necessary components of the model and the variables that had to be included;

Appendix 2 provides the background information used to develop the estimated costs for seismic rehabilitation. As noted in this appendix, this subject was one of the most difficult to address because of varying standards, little actual cost data outside of California, and the difficulty of separating the costs of seismic rehabilitation from other building rehabilitation costs;

Appendix 3 provides a series of 10 tables containing the details of the Seattle building inventory and the model's test calculations based on the Seattle data base gathered during the field data collection phase of the project; and

Appendix 4 summarizes the general context and strategies being pursued, if any, regarding seismic rehabilitation in the nine cities visited by the project team. These are intended to be insights only, and substantial additional information about most of these localities is contained in three recent FEMA reports, Financial Incentives for Seismic Rehabilitation of Hazardous Buildings - An Agenda for Action, Volumes 1, 2, and 3. (FEMA 198, 199, and 216).

It has been stressed throughout this report that because of wide variations, local data should be used whenever possible. The intent of Volume 1 is to provide the structure of the model, example results and guidance for its use. Volume 2 supports Volume 1 by providing additional technical information that might be helpful in adapting the model for use locally by those officials, practitioners, and others concerned about the safety of existing earthquake hazardous buildings.

Finally, readers are reminded that for further information regarding either Volume 1 or 2, additional copies, or the software to operate the model, they may contact the Federal Emergency Management Agency, Office of Earthquakes and Natural Hazards, Washington, D.C. 20472.

APPENDIX 1

REVIEW OF LITERATURE

The Federal Emergency Management Agency contracted with the Applied Technology Council (ATC) to develop earthquake damage evaluation data for California structures. The resulting report from that contract (ATC-13, 1985) classifies earthquake losses as being either direct physical damage, social loss, or economic loss. Direct physical damage is generally the monetary loss incurred as a result of damage to a structure and its contents. Social losses from earthquakes are deaths, injuries, and the social disruption of losing or experiencing damage to one's home or city. Economic losses include the monetary value of the direct physical damage loss incurred for facilities plus the industrial production and commercial loss in the affected region. Procedures defined in ATC-13 can be used to estimate these losses.

FEMA 174 (Building Systems Development, 1989) defines direct losses as the costs of facilities repair and replacement, and deaths and injuries. Indirect costs associated with building damage are grouped into four categories:

1. Loss to the housing stock and the need for temporary and new permanent housing;

2. Losses of revenue due to functional interruption;

3. Lost jobs due to business interruption and closure; and

4. Property taxes lost and payout for unemployment and welfare.

Procedures for estimating these losses are also presented in FEMA 174 and are mostly based on procedures defined in ATC-13.

Definition of Loss Variables

ATC-13 and FEMA 174 suggest six types of losses and damages that should be included in the benefit cost analysis of earthquake rehabilitation. While precise data is hard to obtain, it is clear that earthquakes cause economic redistributions. For example, retail store employees may become unemployed because of damage to buildings housing their employers, but the construction industry most likely will experience increased economic activity.

Damages to Structures and Facilities

Property damage losses includes the monetary value loss incurred as a result of damage to a given building or facility and damage to contents. This class of loss can be estimated directly for a benefit/cost analysis (BCA).

Life and Safety Issues

The loss of life and injuries due to an earthquake in the U.S. have not been substantial. Estimating injuries and loss of life is difficult; however assigning a monetary value to life, and the reduction of risk, is necessary for inclusion in the BCA.

Housing losses

FEMA 174 states that the loss of housing stock causes residents to seek alternative shelter until permanent housing is available. Depending on the capabilities of the housing industry and the extent of the damage, displaced persons may leave the region. In addition to the personal costs of stress, displacement, and relocation, the economic costs of lost purchasing power, economic contribution of the victims, labor, housing cost increases, and other social costs can be substantial.

FEMA 174 also identifies five indirect housing losses that must be borne by private or public funds. They include:

1. Cost of temporary shelters,

2. Cost of temporary portable housing,

3. Individual loss of personal possessions and furnishings,

4. Increased transportation costs of relocated persons,

5. Increased counseling and family assistance to deal with stress and dislocation.

Business and Industry Losses

Economic losses incurred by business and industry include loss of investment, salaries, profits, relocation cost, and business development and growth until facilities and equipment can be restored to pre-earthquake condition. These losses can be approximated by relating business activity to building damage estimates and recovery times.

Unemployment

Persons that become unemployed as a result of an earthquake can relocate to unaffected areas to seek employment or remain in the area until job opportunities are restored. FEMA 174 states that no accepted methodologies exist for estimating job losses after earthquakes.

Public Sector Fiscal Losses

Property damages cause reductions in property taxes. Sales and income tax collections decline due to lower personal incomes and business activity. Additional public assistance, unemployment benefits, and other public services increase as a result of a large earthquake. These fiscal impacts are usually unexpected, and it is difficult for government agencies to collect and retain contingency funds to offset these impacts.

Procedures For Estimating Losses

The purpose of ATC-13 is to develop useable data and procedures to estimate the economic impacts of earthquakes in California.

Damages to Structures and Facilities

Damage probability matrices were developed by ATC-13 that enables damage estimates to be made for about 40 types of structures. Damage probability matrices are based on an inventory of building structures, a loss rate by type of building, and a given earthquake intensity. Assessment of a dollar loss of buildings can be derived by taking losses from the damage probability matrices times the replacement costs of the structures. Data about replacement costs for structures can be obtained from many publications.

Life and Safety Issues

Death rates and injuries have been quantitatively related to building damage states in ATC-13. FEMA 174 recommends the following procedure for estimating deaths and injuries.

1. Select the Modified Mercalli Intensity (MMI) of the earthquake.

2. Determine occupancy type or type of building inventory.

3. Determine the Central Damage Factor (CDF) percentage within the selected MMI to determine the percentage of damage for each structural type.

4. Determine total building area of each structural type in the building inventory.

5. Determine occupants, day and night, by multiplying the building area of each occupancy type by the number of occupants per area by social function. This is provided by ATC-13.

6. Determine deaths and injuries by multiplying the number of occupants times the percent of buildings each CDF by the fraction dead and injured that would occur in each damage state (provided by ATC-13).

The value of a statistical life can be derived from past studies. The "consensus" estimate of the private value of a statistical life derived by Keech et al. (1989) draws on the work of many scientists specializing in the value of life. The studies were reviewed by Miller (1986), adjusted or revised when possible, and judged to be adequate as value of life estimates. It seems reasonable to use the estimates as derived and reported by Keech et al. (1989) for this model. As stated before, Keech et al, (1989) derived a "social" value of life based on the sum of the "private" value of life, foregone taxes and other direct costs of early death. This also seems appropriate for this model.

Foregone taxes are discounted present value of expected future earnings multiplied by the applicable state, local and federal tax rates. This value represents the lost tax revenues that the government will not collect as a result of early death. To estimate foregone taxes for this study, an age, sex, occupation, and income profile of potential death victims will need to be derived for the potential earthquake site.

A study by the National Highway Traffic Safety Administration (1986) included medical and emergency costs, legal and court costs (the cost of carrying out court proceedings, not the cost of settlements), and costs associated with the administration of public assistance insurance. The total direct costs using just these parameters was estimated to be $33,093 in 1987 dollars. Taxes foregone and other direct costs can be estimated for each individual test site.

Keech et al. (1989) suggests that the value of a statistical life be updated using the GNP Implicit Price Deflator for Total Personal Consumption Expenditures for the following reasons (page 122).

1. The private willingness-to-pay estimates are based upon individual assessments which in turn are based upon income, consumption of a wide variety of goods and services in the economy, and the consumption of other non-pecuniary activities. The resulting monetary values probably closely correspond with the typical mix of goods and services available in the economy.

2. The other elements of the valuation of a statistical life are expenses or income measures which should increase in approximate proportion to economy-wide inflation.

These procedures to estimate the value of life for the BCA model used in this study represent the least cost alternative which is defensible to the economics profession. The procedure is simple, the data needed for calculations are readily available, and the results are reasonable.

Housing losses

FEMA 174 suggests that a rough approximation of those made homeless by an earthquake can made from an estimation of the damage to the housing inventory. A specific quantitative relationship between housing inventory damage and the number of homeless can be found in Dunn and Sonnenfeld (1980).

Business and Industry Losses

Estimating indirect economic impacts can be made by first estimating the loss of function, which is related to the percentage damage factors, for the commercial and institutional facilities affected by the earthquake and the period of recovery. This procedure is described above.

Estimating dollar values from the disruption of economic activity is a difficult procedure. Milliman and Roberts (1985) have suggested an imposing set of conditions for measuring the regional economic effects of earthquakes.

1. Estimates should not be generalized from few case studies.

2. Baseline forecast of economic activity should be used to determine the impacts during the recovery period so that a proper "with and without" comparison can be made.

3. I-O models are not adequate because supply side constraints are not recognized in terms of damage to capital stocks and transportation systems.

4. Proper distinction needs to be made between the measurement of losses and the measurement of longer-run patterns of personal income, employment, and population growth.

5. Double counting economic impacts must be avoided by identifying losses as either capital (property/stocks) or incomes (flows).

6. All damages should be calculated in present value terms.

A number of regional economic models were reviewed and the "REMI" model offers the best opportunity of meeting the conditions established by Milliman and Roberts.

REMI is a regional economic and population forecasting model that uses econometric and input-output methods. The system was developed by George Treyz, Professor of Economics, Univ. of Mass. The system can be used for general forecasting, project and policy impact analysis, and market analysis.

The standard REMI model is called the Economic and Demographic Forecasting and Simulation Model with 53 industrial sectors and 202 age/sex cohorts (REMI EDFS-53). REMI FS-53 is the same model without the demographic detail. Similar types of models are also done with 14 industrial sectors. All of the models are available as a single region or inter-linked multi-area models. A 466 sector I-O model for industrial simulations and a 585 sector occupational forecast model can also be used in conjunction with the REMI models.

The REMI models are based on econometric models that specify economic growth as functions of the production process, product demand, the labor supply, and population. The "general equilibrium approach" is used in the labor and product markets. The model uses 1969 to current data to project economic variables to 2035. The impacts of policy and structural changes are traced through the regional economy by analyzing price and wage changes, technical substitutions by firms, and changes in exports and imports. The model has 10 general equations that are driven by a national model of the same structure and by

U.S. Bureau of Labor Statistics (BLS) forecasts.

The models have survived peer review (Treyz and Stevens) and they have performed well in the past (Lanzillo, 1985). REMI models have been used by state governments, planning agencies, universities, utilities and consulting firms to project the regional effects of economic development, transportation projects, environmental policies, changes in the pricing and supply of energy and natural resources, and changes in national and state fiscal policy and regulations.

Running the REMI model is a four step process:

1. Formulate the policy question and run the model to create a control forecast.

2. Estimate the direct effects of the policy and put them into the model by changing one or more of the policy variables.

3. Rerun the model, creating a complete, alternative forecast based on the policy variable changes you have specified.

4. Examine the computer output that shows the difference between the control and the alternative prediction for each variable in the model.

Unemployment

FEMA 174 suggests that a crude approximation of unemployment losses can be made from estimates of the loss of function time, the period of restoration for business and industry facilities, and the percentage of persons that will remain unemployed during the affected period. This procedure requires assumptions regarding the number of persons that will relocate and the degree to which businesses and industries can temporarily reestablish viable operations.

Public Sector Fiscal Losses

Property tax impacts can be derived using county assessor's guidelines on property damages and resulting tax rates (FEMA 174). Sales and income tax changes can be estimated directly from the REMI model results.

Theoretical Structure Of The Cost Benefit Analysis Model

Schulze et al. (1987) used an expected utility model to estimate "willingness to pay" for increased safety and reduced property losses. The methodology was used to determine the economic feasibility of requiring earthquake resistant buildings in Southern California. Simulation model results showed at that time (1985) and for a wide range of discount rates, the expected benefits of seismic building codes exceed costs in Los Angeles County.

Pate-Cornell (1985) determined the benefits and costs of reinforcing unreinforced masonry warehouses and reinforced concrete manufacturing buildings that are remodeled into apartment or office buildings. Benefits were defined as the number of lives saved and the value of avoided property damage. The study concluded that only the first levels of reinforcements were justified on economic criteria, and adopting higher standards should be left to the buildings' owners.

Milliman and Roberts (1985) warn that there can be too much mitigation as well as too little and that a "optimal" level needs to be estimated. This involves estimating expected losses and costs of various mitigation policies. They offer the concept of measuring the "wealth losses" that result in an earthquake while recognizing that death, trauma, and social dislocation losses are best handled outside of the economic analysis. This concept is defined as <u>either</u> the present value of the loss of regional income (both explicit and implicit flows) or the decline in the values of all capital (stocks). They state that adding regional income and property losses would be double counting and therefore overestimate the benefits of earthquake mitigation. Milliman and Roberts developed a regional economic model that measures wealth losses by estimating declines in earnings for some industries and declines in capital stock prices for other industries. They also cautioned that determining the damage to the economic base of the region is important. Damages to supporting industries will not seriously impair economic activity.

Milliman and Roberts suggest that a proper economic model be able to predict the level of economic activity with and without an earthquake event. The model must also be able to simulate changes in supply constraints in addition to demand changes.

Yezer and Ruben (1987) concluded that social welfare losses due to unanticipated natural disasters are reflected in land or house prices and wage-base measures are inappropriate. Two important differences from other studies are contained in this conclusion. First, the concept that anticipated disasters does not result in indirect economic effects comes from the economic theory of natural resources. If the disaster is expected, the damage has already been discounted at that frequency, and it is reflected in current land values, levels of employment and population.

Second, the concept that land value changes represent a proper change in social welfare comes from the opportunity cost concept that underlies neoclassical economic theory. The logic is as follows:

> "...the change in social welfare, as measured by value of output lost and changed real compensation required by workers, is fully reflected in the change in land rents and house prices. This change in social welfare is appropriate for use as a measure of benefits in economic benefit/cost analysis and has been used as such in the other literature on economic effects of natural disasters reviewed earlier. The intuitive reason for measuring social welfare changes through land and housing market effects is that capital and labor are mobile and may move away from areas where disaster expectations increase." [Page 67.]

This assumes that the rate of return to capital and real wage rates are equated spatially (perfect knowledge and markets) and that the change of location of resources is costless (zero transactions costs).

Obviously the theoretical model that one accepts as the "proper" evaluation of economic losses dictates the type of empirical model that must be used in the benefit cost analysis. Therefore, a diverse set of empirical models should be considered. A number of models have been developed to measure the economic effects of natural disasters.

Empirical Models

The model developed by Ellson, Milliman and Roberts (1984) is comprehensive, flexible and limited only by the lack of good regional data. An econometric model using 1965-80 annual data of Charleston SC SMSA was formulated to assess potential earthquake damages. Supply constraints of capital investment, housing starts, net migration, and transportation are explicitly modeled. The model is spatially disaggregated to indicate how consequences will vary across the region. The model is fully simultaneous both within an individual county in the region and between the three counties that comprise the SMSA.

The Multiple Equation Summarization of Process Analysis Models (MESPAM) technique was used for the areas where major structural changes were projected. MESPAM specifies alternative technologies for a particular economic and geographic sector. Input data for this process are engineered rather than observed. Transportation, resources, and housing sector's input coefficients were estimated using MESPAM. The remaining sectors were estimated using an economic base approach. MESPAM generates alternative input coefficients, and linear programming is used to determine optimal production technologies by simulating very high prices on damaged resources and allowing alternative processes to be substituted. These substitutions are then captured by econometric estimation.

The data series provided sufficient variation to simulate the 10 percent property damage that can result from an earthquake. The study concluded that the economy is resilient when compared to baseline projections, and that economic losses in terms of nonproperty income, and private and social capital are still significant even when expressed in present value terms. Although substantial employment and income are induced by the earthquake recovery, it does not offset the real income and wealth losses to the region caused by the event.

This approach would be very difficult to implement within the context of this project. First, the derivation of a general econometric model that could be used in all regions would be extremely difficult. This means that a separate model would need to be developed in each SMSA and in any other applications of the model. Second the incorporation of process models in regional models is difficult and requires trained personnel. Even though it offers the best performance, these considerations make it difficult to use in this project.

The expectation hypothesis was used as a theoretical basis to evaluate the potential economic effects of changes in the expected rate of natural disaster. An inter- and intra-city econometric model was developed to measure the actual rate of disaster activity from the expected rate of disaster activity.

The Yezer and Rubin (1987) model specifies the relation between recent experience and expectations based on past disaster rates as the basis for estimating the unanticipated component of disaster experience. Yezer and Rubin maintain it is not the direct measure of damage done but an indirect measure of damage on expectations for future economic productivity which should be used to measure local economic effects.

This model used FEMA's Disaster Management Information System (DMIS) Reports 1.2 and 2.4 which list federally recognized disasters. It also used the "Annual Housing Survey", conducted by the Bureau of Census for HUD (later called American Housing Survey). The analysis was conducted for 70 SMSAs.

This approach could be used to evaluate changes in housing values in the project SMSAs. If this proves to be too ambitious, results from this study could be adopted for the SMSAs included in this study as a number of SMSA were included in the study.

Cartwright, Beemiller, Trott, and Younder developed an industrial impact model to estimate the regional industry-specific impacts of disasters, both natural and manmade. Special attention is given to the impacts of possible nuclear reactor accidents. This model was applied to three areas that could experience nuclear reactor accidents. The impacts estimated in the case studies are based on (1) general information and reactor-specific data, supplied by the U.S. Nuclear Regulator Commission (NRC); and (2) regional economic models derived from BEA's Regional Input-Output Modeling System (RIMS II) developed especially for taking into account the unique characteristics of a nuclear reactor accident with respect to regional industrial activity.

Demand-driven and supply-constrained regional I-O models were derived for the affected and unaffected areas of the SMSA. This procedure captures the economic interdependence of the areas. A demand-driven model was used to determine the total effects on gross output, and earnings of final demand changes. A supply-constrained model determined the effects on gross output, and earnings of constraints on resources or imports. Both models assumed that the existing technology matrix will not be changed when demand changes or supply constraints are introduced into the economy. This is highly unlikely during a disaster. Locally supplied inputs could easily be imported and industry input patterns could change during emergency periods. These changes would be nearly impossible to predict with sufficient accuracy without an in-depth study of the regional economy. However, the modeling procedure does account for changes in production activity caused by excess productive capacity, and possible changes in export and import patterns. This procedure will provide an estimate of the potential total economic costs of a disaster.

Supply-constrained multipliers need to be derived from the transactions matrix just as the demand-driven multipliers are using a Location Quotient (LQ) procedure. To accomplish this a full regional transactions matrix needs to be derived from estimates of regional output and the 29 sector RIMS II table output multipliers.

The model requires the identification of the areas and industries that will be affected by the disaster. The direct production losses in the physically affected area are used to estimate demand-driven impacts and to indicate potential supply-constrained vulnerability in the unaffected part of the region.

Specific steps of this procedures are:

1. Estimate the proportion of total regional economic activity that occurs in the affected and unaffected areas.

2. Calculate LQs for both areas to determine export-import relationships with

the other area. To calculate LQs, total output by sector is required for the region, and proportioned between affected and unaffected areas. This can be approximated by industry employment estimates and industry output/ employment ratios.

3. Calculate purchase coefficients from the 39 sector RIMS II table of output multipliers and develop a full intrastudy-area I-O transactions table.

4. Estimate the direct damages in gross output by industry in the affected region.

5. Determine whether the affected and unaffected areas will experience demand changes or supply constraints based on damages to the affected region. This step is very important and requires judgment on the part of the planner.

   Factors that must be considered are:

   a. Will the economic activity in the unaffected area be disrupted because of curtailed imports from the affected area? Could these imports be supplied from outside the region?

   b. Can the unaffected area replace sales that were formerly made to the affected area by exporting outside of the region? Can lost demand be replaced by reduced imports?

   c. Will final demand be affected? (tourism, household evacuation, etc)

   d. Does excess capacity exist in the unaffected area industries that could replace those that were assumed to be damaged?

   e. Could manufacturing and services assumed to be damaged in the affected area be reallocated to similar industries located in the unaffected area? (Double counting the same loss as import loss to one region and an export loss to the other region will be avoided.)

Regional Economic Models, Inc. (REMI) is a regional economic and population forecasting model that uses econometric and input-output methods. The system was developed by George Treyz, Professor of Economics, Univ. of Mass (REMI, 306 Lincoln Avenue, Amherst MA 01002). The system can be used for general forecasting, project and policy impact analysis, and market analysis.

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Value of Life

Benefit-cost analysis (BCA) can be used to assess public-sector resource allocation decisions. However to identify and objectively measure all benefits of public projects can be very difficult if not impossible (Bentkover, 1986, p5). One of the principle benefits of seismic rehabilitation of hazardous buildings is reducing the expected number of fatalities resulting from an earthquake. Methods of measuring the value of reducing the risks to life and health in BCA are diverse and until recently, controversial (Broome, 1985, and Cochrane, et al. 1987).

Three principle methods have been used to derive the value of life in BCA. They are the human capital approach, the court awards approach, the risk-cost method, and the willingness-to-pay approach. These approaches will be briefly described and evaluated. Finally, a suggested procedure to measure the value of a statistical life for this project will outlined.

Human Capital Approach

Initially the value of health was estimated by measuring the lost wages, medical expenses and indirect costs resulting from the loss of life or injuries (Rice and Cooper, 1967, and Buehler, 1975). This approach is easy to conduct since only the deaths that can be prevented and the expected lifetime earnings need to be estimated. But Viscusi (1986a) concludes that this is a poor proxy for the value of reducing health risks. The benefit of a government program is the reduction of the probability of death or some other health aspect for a large number of individuals rather than the prevention of a certain number of deaths that might be identified after the fact.

This approach suffers from other deficiencies. Persons with low expected future income are under-represented (valued) under this approach. A very old person has a small amount of future earnings and a very young person's earnings are sufficiently distant that current discount rates reduce them to almost nothing in a BCA (Keech et al. 1989). This approach assumes that income determines individual utility and the value of life, and as a result, ignores all non-market goods consumed by individuals.

Court Awards Approach

Courts awarded damages for wrongful deaths are usually based on potential future earnings, which could serve as a proxy for the human capital approach, but they may include punitive damages and bereavement of the family or related consequences (Keech et al. 1989). Since it would be difficult to separate all of the influences that were included in the amount of the judgment, it probably cannot be used to evaluate the reduction.

Court awards are also based on specific historical cases but reducing earthquake hazards saves future lives which are statistical in nature and not individual specific. Therefore the use of court awards to evaluate risk reduction in public projects would not be a valid measure of the value of life.

Risk-Cost Approach

Another method used to value life is simply dividing the amount of project expenditures by the number of deaths that will be reduced by the project (Baecher et al. 1980). This approach transfers the responsibility of placing an explicit value on life from the analyst to the political level.

This approach does not value human life but provides decision makers with criteria for comparing programs dealing with safety and health related issues. The variation in the cost of lives saved for various public programs was found to be high which indicates that the procedure does not estimate the correct value of reducing risks to human safety (Broder and Morral, 1983).

Willingness-To-Pay Approach

Willingness-to-pay is a valid methodology for determining the value of risk reduction in BCA (Cochrane et al. 1987, Viscusi, 1986a, and Keech et al. 1989). The theoretical foundation for this method is that individuals will maximize their own utility by trading-off wealth or income for reducing the probability of death (Linnerooth, 1979). Cochrane et al. (1987) summarized why willingness-to-pay is the most correct method available of estimating the value of human life (page 21).

1. The value of life is embedded in the concept of willingness-to-pay for improved safety.

2. The concept provides a framework of establishing tradeoffs between wealth and greater safety.

3. The tradeoffs can be measured.

4. The concept is consistent with benefit-cost analysis because it poses the choice process that would enhance welfare.

5. It provides a pecuniary index of safety which is additive to other damages.

6. The willingness-to-pay for safety is a function of age, income and the perception of risk.

Willingness-to-pay assumes that individuals are rational (maximize utility), and correctly perceive the wealth-risk trade-off. These assumption may not be entirely met in all of the different empirical applications of the willingness-to-pay approach. Three basic procedures to measure willingness-to-pay have been developed and accepted as valid methods for valuing reductions in risk (Zeckhauser, 1975). These are: the survey approach; the labor market approach; and the consumer expenditure approach.

<u>The Survey Approach</u>--for deriving willingness-to-pay is also called the contingent valuation method (CVM). The survey simulates a "market" of the public or nonmarket goods. This analogy, or continent market, is presented to the

subject as providing public goods in return for his payment. Summing across all individuals provides an estimate of value of the public good. In initial CVM studies, individuals were simply asked to value the reduction of the risk in question (Acton, 1973, and Jones-Lee, 1976). Those studies were criticized because of flaws in the design procedure. Foremost was that the free rider issue was ignored and second, the individuals inability to perceive small differences in risk was not recognized (Cochrane, 1987). In addition, the individual subject to a CVM survey may perceive the environmental or social value rather than the individual's intended behavior (Bishop and Heberlein, 1979). Randall et al. (1983) have since offered a number of requirements to properly frame the situation to the subject to avoid these bias. This approach has also produced a wide variance of estimates (Blomquist, 1982).

The Labor Market Approach--is the willingness of workers to accept additional wages for riskier jobs. This approach has been offered as an indirect indication of the value of life (Keech et al. 1989). Econometric models are used to estimates the wage differential earned by workers in risky jobs. This approach assumes that labor is mobile and that labor markets are competitive and these conditions are rarely achieved which results in an under estimation of the risk differential in wages. In addition, most models use gross wages rather than after tax income which also produces bias results.

Labor market studies also produce high variations in estimates if voluntary vs involuntary risks are not specified. High risks jobs are voluntary and attract risk adverse labor that require small risk premiums. However, very small involuntary risks may produce high value estimates (Viscusi, 1986b). This method has the advantage of re-estimating existing econometric equations using different assumptions or new data to produce new estimates (Miller, 1986). The use of union or non-union workers (Gegax et al. 1985, Dillingham and Smith, 1985, Olson, 1981, and Viscusi, 1980), before vs after tax wages, and fatal vs non-fatal risks have been tested by changing and re-estimating existing models (Keech et al. 1989). Variations in these assumptions are responsible for the high variations in labor market study estimates (Blomquist, 1982).

The Consumer Analysis Approach--is observing the way consumers feel about risk. It is proposed that the value of relative risks of certain products can be measured by the willingness-to-pay for safer products. Econometric models are used to estimate the willingness-to-pay for products with better safety records. This approach assumes that consumers have perfect information on the relative safety of each product, and that estimates represent equilibrium demand-supply conditions that are seldom met (Keech et al. 1989). Using past societal decisions that imply health or life values also assumes that those decisions were optimal, which may not be true. As with previous approaches, most studies used very different assumptions and discount rates, and results are quite variable and incompatible without modification (Viscusi, 1986a).

Attempts have been made to combine the human capital approach and the consumer expenditure approach. Landefeld and Seskin (1982) studied the willingness-to-pay for life insurance and estimated the value of life at $873,000 in 1985 dollars. The authors claim this was the first empirical estimate of human capital values, reformulated using a willingness-to-pay criterion, to produce the only clear, consistent, and objective value for use in BCA of policies affecting risks to life.

The use of safety items such as seatbelts are also considered as indications of the value of life (Blomquist, 1979). The value of life has also been derived from automobile speeds (Ghosh et al. 1975, and Jondrow et al. 1983) and cigarette smoking (Ippolito and Ippolito, 1984).

Keech et al. (1989) derived the value of life for the Federal Aviation Agency using willingness-to-pay studies that had been done during the 1970's and 1980's. Miller (1986) had reviewed recently published willingness-to-pay studies and critically evaluated the analytical procedures used, risk variables, model specifications, and results. He found several studies that were judged appropriate and adopted those studies as a basis for determining the value of life.

Thirteen labor market studies were modified to assume after-tax wages, or to separate fatal from nonfatal risks. Nine consumer behavior studies were changed to reflect similar discount rates and other assumptions relating to value of time, and family size. Three survey studies done on cancer risks, highway safety, and labor markets were also declared valid. Values from all 25 studies were adjusted to reflect 1985 dollars.

Updated estimates from these 25 studies were summed and an average value calculated. The estimate was then adjusted to 1987 dollars which yielded a "consensus" value of life of $1,577,129. This estimate was defined as the "private value of a statistical life" which is just part of the "social value of a statistical life". Keech et al. (1989) defines the social value of early death as also including foregone taxes, and medical, emergency, legal, court, and public assistance administration costs. The total of these costs, which is the social value of a statistical life, was estimated at $1,740,000 in 1987 dollars.

A "consensus" procedure was also used by Schulze et al. (1987) to derive a value of life of $1 million. The studies used in this procedure were reported by Violette and Chestnut (1983).

The use of willingness-to-pay to estimate the value of life has been accepted by many Federal agencies. Viscusi (1986a) concludes:

> "Indeed as of 1984, the valuation of life has become a generally accepted component of the debate over risk regulation. The recent debate over an OSHA construction industry standard epitomizes this change. Rather than claiming that the value-of-life issue was too sensitive to be discussed, there was an open policy debate over the appropriate value of life. OSHA used a value of life of $3.5 million in its regulatory analysis based on results for the average blue-collar worker. OMB took a different approach, citing evidence regarding the heterogeneity in the value of life. After noting the high and well-known risks associated with construction jobs, OMB urged that OSHA use a lower value of life of $1 million. One Congressman viewed both of these estimates as too low, advocating a $7 million figure in line with results for the Panel Study of Income Dynamics. In each case, the willingness-to-pay approach was accepted, as was the importance of using labor market studies as a reference point." (page 207)

Cochrane et al. (1987) however, offers a more guarded endorsement.

> "Despite the significant gains that have occurred over the past decade in refining survey instruments and honing theoretical constructs, the essential ingredients for incorporating risk into BCA are still clearly lacking. It appears that although market data provide a useful glimpse of what society at large is willing to tolerate in terms of risks, it is still no more than a glimpse. The use of expected values in these analyses tends to obscure the losses that result when the less probable events materialize. Perhaps the primary criticism that has been leveled at risk-cost methods is the lack of appreciation for the process of valuation. It is clear from the work of Starr (1985) and others that risk wealth tradeoffs may be nonlinear. Hence, the social losses may not be a simple additive adjustment to project net benefits as Baecher et al. suggests. These concerns have led to the development of alternative technical means (multiobjective and partitioned risk) of deriving an optimum strategy for those situations involving more than economic efficiency." (page 27)

Value of a Statistical Life

The "consensus" estimate of the private value of a statistical life derived by Keech et al. (1989) draws on the work of many scientists specializing in the value of life. The studies were reviewed by Miller (1986), adjusted or revised when possible, and judged to be adequate as value of life estimates. It seems reasonable to use the estimates as derived and reported by Keech et al. (1989) in this study . As stated before, Keech et al, (1989) has derived a "social" value of life based on the sum of the "private" value of life, foregone taxes and other direct costs of early death. This also seems appropriate for this study.

Foregone taxes are discounted present value of expected future earnings multiplied by the applicable state, local and federal tax rates. This value represents the lost tax revenues that the government will not collect as a result of early death. To estimate foregone taxes for this study, an age, sex, occupation, and income profile of potential death victims will need to be derived for the earthquake site.

A study by the National Highway Traffic Safety Administration (1986) included medical and emergency costs, legal and court costs (the cost of carrying out court proceedings, not the cost of settlements), and costs associated with the administration of public assistance insurance. The total direct costs using just these parameters was estimated to be $33,093 in 1987 dollars. Taxes foregone and other direct costs can be estimated for each individual test site.

Updating the Value of a Statistical Life

Keech et al. (1989) suggests that the value of a statistical life be updated using the GNP Implicit Price Deflator for Total Personal Consumption Expenditures for the following reasons (page 122).

1. The private willingness-to-pay estimates are based upon individual assessments which in turn are based upon income, consumption of a wide variety of goods and services in the economy, and the consumption of other non-pecuniary activities. The resulting monetary values probably closely correspond with the typical mix of goods and services available in the economy.

2. The other elements of the valuation of a statistical life are expenses or income measures which should increase in approximate proportion to economy-wide inflation.

These procedures to estimate the value of life for the BCA model used in this study represent the least cost alternative which is defensible to the economics profession. The procedure is simple, the data needed for calculations are readily available, and the results are reasonable.

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APPENDIX 2

ESTIMATING SEISMIC REHABILITATION COSTS

The cost of seismic strengthening for existing buildings is difficult to estimate because work on existing buildings began relatively recently. It should be noted, there is a small data base on primarily California URM buildings. For these, there are numerous reports which provide examples of actual costs by building type and estimates of hypothetical examples. These include a specific study on costs by Englekirk and Hart, Typical Costs for Seismic Rehabilitation of Existing Buildings, FEMA #156 2/88, as well as several California reports (Comerio, Seismic Costs & Policy Implications 2/89; Comerio, Earthquake Hazards & Housing 3/87; Rutherford & Chekene, Seismic Retrofitting Alternatives for San Francisco's UMB's: Estimating Construction Costs & Seismic Damage 5/90; EQE Engineering, Identification of Potentially Hazardous Buildings in the City of Hayward 10/89).

In addition, examples of strengthening costs for various building types were collected from the nine cities that served as a sample for this study. In this report, we have provided tables of sample costs per square foot building type based on the best information currently available. These tables provide a range of estimates for hard construction costs (eg. the bid cost for labor and materials for the seismic portion of the work, including a component for restoring architectural finishes). These tables alone cannot provide a complete estimate of costs.

Clearly costs will vary by:

1. Building type (masonry, concrete frame, tilt-up steel frame, etc.)
2. Building characteristics (height, configuration, footprint size) and
3. Building conditions (original construction quality and maintenance).

These, in turn, will be influenced by:

1. The seismic improvements or level of safety required, and
2. Local labor costs.

In order to determine the cost of seismic strengthening for a particular building type for use in the cost-benefit model, we recommend the user go through the following exercise to determine the cost range to be used in the model.

1. Review your inventory and segregate these by Building type.
2. Review each type in terms of its characteristics and conditions and compare these with the example costs given in Table "X".
3. Note that the costs in Table "X" are for life-safety retrofits.* If your analysis involves protection of contents, another method of estimating costs must be used.
4. Adjust the sample costs with input from local engineers or cost estimators to match local conditions (if this assistance is not available, multiply by the locality factor in Table "Y" based on published national standards).

*Typically, strengthening costs are calculated either for life safety or for protection of contents/continuation of use. In this study Table 8.9 with costs on fire stations will be the only exception in that as essential facilities they are the only building type where the cost data includes the higher standards.

5. Multiply the hard cost number by two to determine total project costs (note this multiplier covers architecture and engineering fees, permit fees, legal fees, construction financing and other "soft costs" typically associated with renovation.

The factors for computing demolition and replacement costs are based on the criterion in ATC-13: a building suffers more than 60% damages.

The cost of <u>demolition</u> is best obtained by calling a local wrecking/salvage company which can provide an average dollar per cubic foot cost of demolition and rubble removal.

To this figure add the cost of replacement. <u>Replacement</u> assumes replacement of the function of the building with new construction. It also assumes that the local jurisdiction will allow replacement of existing uses "one for one" and will not require additional parking or other current planning/zoning requirements.

<u>Repair</u> costs are estimated as a percentage of replacement costs. This is defined by ATC 13. Repair costs are used in the "damage avoided" category if the damage is estimated to be less than 60 percent. Thus, to determine repair costs: find the replacement cost by using Dodge, Means, or other national square foot cost estimating guide and multiply by the appropriate central damage factor from ATC 13 listed in Table "Z".**

**Clearly, this method does not apply for historic buildings. It is virtually impossible to project average repair costs for historic buildings because of the unique requirements for repair and/or reconstruction.

TABLE 1

ESTIMATES OF TYPICAL COSTS FOR SEISMIC REHABILITATION OF EXISTING BUILDINGS[1]

All Costs in 1987 Dollars per Square Foot

Structural Type	Number of Buildings in Sample	Typical Cost Per Square Foot ($)[2]
Unreinforced Masonry Buildings	199	6.40
Reinforced Masonry Buildings	31	3.70
Reinforced Concrete Buildings	243	10.60
Precast Concrete Buildings	11	12.90
Wood Buildings	59	12.30
Steel Buildings	71	10.25
TOTAL	**614**	

Source: Englekirk & Hart Consulting Engineers, Typical Costs for Seismic Rehabilitation of Existing Buildings, FEMA #156, February 1988.

FOOTNOTES

1. Although a major portion of the sample of buildings were from California and Washington, costs were not adjusted for specific levels of seismic upgrade. Thus, typical costs are derived from a variety of estimates by structural type without segregation by design criteria.

2. Typical costs include only direct construction costs for seismic strengthening and associated architectural work. Indirect costs such as permits, fees, construction financing and owner and tenant impacts are not included.

TABLE 2

Actual Costs of Seismic Retrofit of Residential Buildings in Los Angeles[1]

All Costs in 1987 dollars

Case No.	Floor Area	No. of Units	No. of Stories	Seismic per Sq. Ft.[2]	Total per Sq. Ft.[3]	Seismic per Unit	Total per Unit
1	14,769	12	3	$9.75	$11.85	$11,994	$14,585
2	24,100	47	4	7.62	25.30	3,909	12,970
3	24,280	32	4	8.97	13.77	6,809	10,448
4	14,600	27	3	8.05	38.64	4,354	20,899
5	21,500	40	4	6.45	35.41	3,466	19,032
6	11,500	18	3	11.18	20.24	7,145	12,934
7	21,000	47	4	11.80	46.18	5,276	20,633
8	23,500	48	4	11.58	21.39	5,669	10,470
9	26,622	35	4	9.39	16.07	7,140	12,227
10	31,670	38	5	6.26	16.51	5,223	13,763
11	21,340	44	4	13.15	21.57	6,377	10,462
			average[4]	9.47	24.27	6,124	14,402
12	21,300	45	3	8.73	10.78	4,425	5,470
13	32,000	40	3	4.95	6.68	3,963	5,347
14	17,500	26	4	8.99	10.87	6,052	7,319
			average[5]	7.55	9.44	4,813	6,045
15	17,400	30	3	5.05[6]	5.05	2,932	2,932

Source: Comerio, Mary, Seismic Costs & Policy Implications, City of Los Angeles, February, 1989.

FOOTNOTES
TABLE 2

1. The Earthquake Hazards Reduction Ordinances (EHRO) was enacted in Los Angeles in 1981. It is commonly referred to as "Division 88," which is its location in the Los Angeles Code. In 1987, the City adopted the RGA method (Rules of General Application) which provides an alternative method of design for structural upgrading. Essentially, the method allows greater strengths for existing materials and requires less demolition of existing interior walls.

   The residential URM case study buildings are rectangular with their narrow face on the street (approx. 50' wide). Typically, they are set away from the property line such that they can have windows on all sides. They also tend to be prismatic, (without vertical steps) with double loaded corridors running longitudinally at the center. Concrete foundation walls are common under the masonry perimeter walls, as well as under interior load bearing walls which tend to be corridor walls. The floor diaphragms usually consist of 1" structural flooring and 3/4" finish flooring. Straight and diagonal structural floors are both common, whereas, roof diaphragms almost always consist of straight sheathing. Wall thicknesses are typically 13" with 18" at the lower floors.

   Typical earthquake upgrading includes the installation of anchors and shear bolts at all floors, usually done in combination. The most common method of increasing shear capacity is the addition of plywood sheathing over existing partition walls, although gunite on masonry walls is also used. Typical retrofits also include parapet strengthening and re-roofing to remove the excess weight of the accumulated roof layers. Strengthening usually does not necessitate out-of-plane braces. Also, diaphragm strengthening is normally necessary only when the plywood method is not used.

2. Seismic costs include all structural work plus architectural refinishing. For example, carpeting, vinyl floor tile and painting are considered 50 percent seismic. Electrical, plumbing and cabinetry are not attributed to seismic as these can be avoided with careful planning. The amount of general contractor requirements given to seismic is proportional to the ratio of seismic to the total construction cost. These values represent the necessary cost to refinish and restore a building after upgrade to its original level of finish.

3. Total project costs include seismic structural work, all architectural and refinish work, fees, permits, general requirements as well as contractor overhead and profit. Neither tenant relocation fees, nor income business interruption losses are included in the total costs.

4. The average cost of cases 1-11 are calculated by adding the cost of each building and dividing by 11. The averages are not weighted because the buildings are similar in size and configuration. The average for these case are calculated separately because these buildings were retrofitted under the original Division 88 rules with funding from the Community Development Department. This funding required contractors to install fire sprinklers and pay prevailing wages.

5. The average cost of cases 12-14 were calculated in the same manner as cases 1-11. These buildings received funding from the Community Redevelopment Agency which did require the fire sprinklers, but did not require contractors to pay prevailing wages.

6. Case 15 was done by a private owner with no city financing. This cost is somewhat lower because the owner did not have to comply with special funding requirements and the rehabilitation was designed using the RGA method.

TABLE 3

Estimates of Base Project Costs for Three Retrofit Alternatives for Unreinforced Masonry Buildings in San Francisco

All costs in December 1989 dollars per square foot

This table presents average costs/sq. ft. by building prototype for retrofitting and restoring a moderate level of finish to vacant UMBs. Actual costs will vary considerably from building to building.[1]

Prototype/Description	Alternative 1[2]	Alternative 2[3]	Alternative 3[4]
A - small, 1 story	$9.84	$10.71	$14.15
B - large, 1 story	5.59	7.87	9.30
C - irreg., Resid.	5.04	8.18	13.72
D - irreg., Non-Resid.	5.68	7.95	14.67
E - small, Indust.	9.21	10.90	15.26
F - large, Indust.	4.21	7.57	9.48
G - small, 2-3 story, Off/Comm.	12.31	13.66	18.44
H - large, 2-3 story, Off/Comm.	5.55	8.23	11.18
I - small, 4+ story, Off/Comm.	9.05	15.17	22.14
J - large, 4+ story, Off/Comm.	4.59	8.63	14.45
K - small, 2-3 story, Resid.	11.80	12.95	18.55
L - large, 2-3 story, Resid.	6.84	8.76	12.51
M - small, 4+ story, Resid.	6.55	15.83	18.81
N - large, 4+ story, Resid.	4.23	9.68	16.50
O - assembly	8.01	11.01	15.86
Overall weighted average	5.75	9.37	13.93

Cost premiums (to be added) to accommodate occupancy while retrofit work takes place are estimated as follows:

	Alternative 1	Alternative 2	Alternative 3
Industrial Group	15-25%	15-25%	15-25%
Commercial Group	30-40%	30-40%	30-40%
Residential Group	40-50%	30-40%	30-40%

FOOTNOTES
TABLE 3

1. It is important to understand what the estimated costs do and do not include. The base cost includes all material, equipment, and labor with the appropriate subcontractor's markup, general conditions (including field supervision, field engineering by the contractor, superintendent's costs, and any other known contractor expenses that are not specified in the contract), general contractor's overhead and profit, bond and insurance fees, contingencies, and escalation allowances necessary for a conceptual estimate of costs for rehabilitating and restoring a medium grade finish level to unreinforced masonry buildings.

   The base cost was estimated for vacant buildings and does not include cost premiums for work done with occupants in place. These premiums are separated from base costs to allow both cases to be considered. The need for cost premiums to accommodate retrofitting with as much occupation as possible would be caused by inefficient structural schemes and/or construction procedures determined by functional requirements; protection of areas adjacent to construction; off-hour work; and longer construction period creating increased general conditions costs.

   Other items excluded from the cost estimates are: engineering and architectural design fees; plan checking and permit fees; utilities needed to perform construction; owner's insurance and administration cost; construction management fees; cost of money; and lost revenues to owners and businesses. Indirect costs such as tenant relocation are also not included. Also excluded from these calculations are cost differentials attributable to retrofitting architecturally significant or historic buildings, and costs of any concurrent remodelling or renovation apart from seismic strengthening.

2. Alternative 1 strengthening activities are limited to anchoring unreinforced masonry walls to floors and roofs with shear and tension anchors (this includes parapet bracing) or those which are intended to prevent "out-of-plane" failure.

3. Alternative 2 is comparable to current practice in Los Angeles, that is, wall anchors and "out-of-plane" strengthening required in Alternative 1 would be supplemented by possible strengthening of other building elements including diaphragms (walls and roofs) and walls themselves. This is equivalent to the 1991 Uniform Code for Building Conservation requirements.

4. Alternative 3 requires a considerable number of strengthening activities. In most cases wall anchoring and out-of-plane strengthening required by Alternative 1 will almost always be supplemented by roof and floor diaphragm strengthening, as well as in-plane strengthening for walls with window and door openings. This is equivalent to the current San Francisco Building Code Section 104(f).

TABLE 3.1

The Cost Premium for Seismically Strengthening Architecturally or Historically Significant Buildings

Table 3.1 indicates the cost premium for each of the 15 prototypes for each Retrofit Alternative when the building under consideration is architecturally or historically significant. These figures consider the above-mentioned issues and are derived from judgment and engineering experience gained in implementing the retrofit ordinance in Los Angeles.

Cost Increase for Historic Buildings

Prototype	Retrofit Alternative 1	Retrofit Alternative 2	Retrofit Alternative 3
A	2%	2-5%	2-5%
B	2	2-5	2-5
C	2-6	3-8	3-8
D	2-6	3-8	3-10
E	2	2-5	2-8
F	2	2-5	2-10
G	2	3-10	3-10
H	2-3	4-10	5-15
I	2-3	5-12	5-15
J	2-8	5-20	10-30
K	2-3	3-8	3-10
L	2-3	3-8	3-10
M	2-3	3-8	3-10
N	2-5	3-10	3-15
O	2-10	15-25	15-30

Source: Rutherford & Chekene, Ibid.

TABLE 3.2

Replacement and Demolition Costs

Table 3.2 gives the cost to replace a prototypical building in dollars per square feet. These costs assume the land has been purchased. Since unreinforced masonry structures are not allowed by current building codes, the replacement building has been assumed to be constructed of cast-in-place concrete. Where applicable, tenant improvement costs, such as partitions, carpeting and painting, have been included. Table 3.2 also gives the cost to demolish a building in dollars per cubic foot of building volume, as it varies by prototype. Dollars per cubic foot is the standard estimating unit of measure.[1]

Replacement and Demolition Cost by Prototype

Prototype	Replacement Cost (Dollars/Square Foot)	Demolition Cost (Dollars/Cubic Foot)
A	$63/SF	$0.25/CF
B	59	.25
C	69	.31
D	87	.29
E	59	.25
F	62	.25
G	87	.29
H	90	.31
I	94	.23
J	98	.15
K	64	.24
L	67	.19
M	80	.17
N	82	.25
O	105	.25

Source: Rutherford & Chekene, Ibid.

FOOTNOTE

1. Replacement cost as used in this study is the cost of replacing a building that has been demolished due to damages sustained in an earthquake. It was further assumed that construction conditions were to be considered normal (non-emergency), and that land and demolition costs were not included.

   Square foot replacement costs have been provided for each of the 15 prototypes using Means Construction Cost Data Book (Means, 1989) for new construction for residential, commercial, industrial and institutional buildings. For each prototype, a geographical area adjustment factor was made based on the most common UMB study areas for the prototype. In addition, the Means San Francisco cost adjustment index has been applied, as has a labor overburden factor of 35 percent for union influences and unusual urban working conditions. Finally, a construction contingency allowance of 10-15 percent has been applied for the unknowns that might be encountered by the contractor.

TABLE 4

Estimates of Base Project Costs and Total Project Costs for Potentially Hazardous Buildings in Hayward

All costs in 1989 dollars per square foot

Building Type	Level of Retrofit[1]	Base Costs (rounded)[2]	Total Costs (rounded)[3]
URM	1	$15	$25
URM	1A	21	35
URM	2	40	65
T.U.	1A	6	10
T.U.	2	15	25
High Occupancy	1A	18	30
High Occupancy	2	42	70

Source: EQE Engineering, Identification of Potentially Hazardous Buildings in the City of Hayward Interim Report #2: Consequence Analysis, October 1989.

FOOTNOTES

1. For URM buildings, Level 1 is equivalent to the current City of Los Angeles requirements ("Division 88"). Level 1A requires somewhat more lateral force capacity and is equivalent to 1973 UBC seismic provisions. Level 2 is equivalent to the provisions of the 1985 UBC. For Tilt-up and high occupancy buildings, Level 1A is equivalent to the 1973 UBC provisions and Level 2 is equivalent to the 1985 UBC provisions for each building type.

2. Base construction costs include the basic cost for structural strengthening and a component for the cost of architectural work associated with the process of structural strengthening. Some figures from the Englekirk & Hart study (FEMA 156) were used in these estimates and these were adjusted to represent Bay Area costs in 1989 dollars.

3. The total project costs includes the base cost plus design fees, legal fees, permit and testing costs, as well as construction financing, business interruption and/or relocation cost factors and an adjustment for prevailing wage costs for union labor.

TABLE 4.1

Actual Construction Costs for Seismic Retrofit of Tilt-up Buildings in Hayward[1]

All Costs are in l990 Dollars per Square Foot

Case #	Size (sf)	Base Costs[2]	Foot-Notes
1	21,336	$2.00	
2	24,360	6.25	3
3-9	typical	1.00	4
10	17,760	.60	5

FOOTNOTES

1. There are 180 tilt-ups in Hayward all built prior to l973. The city is recommending to owners that upgrading be done to the l973 UBC for details and is focusing on out-of-plane anchorage of the tilt-up walls rather than the analysis of in-plane wall stresses and roof diaphragm capacity.

2. Base cost include structural strengthening, associated architectural work (if necessary), engineering fees and permits. Several contractors have suggested $2.50 (sf) as an appropriate average cost for estimating purposes.

3. The building had a high percentage of office space. The cost breaks down as follows: $2.75 seismic only; $2.50 new roof and diaphragm; $1.00 paint, air conditioning, permits, and fees.

4. No work on roof.

5. Work includes seismic upgrade and re-roofing/diaphragm nailing. However, the project was done by original owner/builder. The building was conservatively designed, and the result was a low retrofit cost.

TABLE 5

Repair vs. Mitigation Costs for Principal Hazards to Wood Frame Dwellings[1]

All Costs are in 1990 Dollars per Square Foot

Hazard	Repairs	Mitigation[2]	Benefit to Cost Ratio[3]
Dwelling off foundation:			
Typical	$23/sq.ft.	$1.00/sq.ft.	23
Representative range	$18-$25/sq.ft	$0.50-$2.00/sq. ft.	10 to 50
Chimney damage[4]:			
Typical	$7,500	$5,000	1.5
Representative range	$6,000 to >$15,000	$4,000 to >$8,000	1 to 2.5
Water heater overturning:			
Typical	$250[5]	$50	5
Representative range	$200 to >$400	$20 to >$150	2 to 20

Source: *R. P. Gallagher Associates, Inc., Consulting Engineers, Draft Report: Mitigation of Principal Earthquake Hazards to Wood Frame Dwellings and Mobile Homes, State of California, Department of Insurance, Los Angeles, CA, June 1990.*

FOOTNOTES

1. Can be considered representative 1990 costs in the San Francisco and Los Angeles areas. San Francisco area residential construction costs are about 8 percent higher than the Los Angeles area, but this is not considered to be a significant difference for purposes of this study.

2. Mitigation costs are for dwellings with an existing concrete foundation that is useable.

3. Ratio of cost of repairs divided by cost of mitigation.

4. Assumed major brick chimney damage with replacement in reinforced brick. Use of metal flue in wood or stucco enclosure of elimination of the chimney can substantially reduce repair costs.

5. Rough estimate, assumes unit has been replaced, but that no fire has been started.

TABLE 6

Actual Construction Costs for Seismic Retrofit of Various Building Types From BAREPP Case Studies of Hazardous Buildings

Building Type		Cost	Year Complete
(1)	URM	$39.64	1983
(2)	W	19.25	1979
(3)	C1	12.00	1989
(4)	C2	68.24	--
(5)	PC1	1.00	1986
(6)	PC1	1.00	1987

Source: BAREPP, Hazardous Buildings Case Studies, Reprinted 1989.

[1]**URM Configuration:** Rectangular Plan

Structure: Unreinforced masonry walls and foundation
Floors are wood joists with diagonal sheathing
Roof is straight sheathing over rafters supported by wood trusses

Problems: Inadequate system to resist lateral forces

Retrofit Approach: Reinforce walls with gunite
Add new shear elements in the transverse direction
Add plywood to the floor and roof diaphragms
Provide wall anchorage

[2]**W Configuration:** Rectangular plan

Structure: Balloon frame, one-piece wooden studs from foundation to rafter
A ledger or "ribbon strip" ties the studs and supports the joists
Wood beams and joists support the floor; straight wood sheathing covers exterior walls, floors, and roof

Problems: Inadequate resistance to lateral forces
House did not meet San Francisco building code structural requirements

Retrofit Approach: Replace existing foundations
Add shear strength
Replace termite damage

[3]C1 **Configuration:** Rectangular plan
Structure: Reinforced concrete frame throughout
Problems: Lack of ductility
Insufficient strength in columns
Retrofit Approach: Add four new brace towers with new pile footings
Tie existing diaphragm to brace towers

[4]C2 **Configuration:** Almost square plan
Structure: Concrete round columns with capitals
Two-way reinforced concrete flat slab
Reinforced concrete walls
Individual concrete spread footings
Problems: Addition of one more floor
Change of occupancy
Inadequate strength to resist lateral forces
Asymmetrical lateral system
Retrofit Approach: Add shear wall and steel "K"-braced frames to provide symmetry to structural system
Light wood post-and-beam system for additional top floor

[5]PC1 **Configuration:** Rectangular plan with extended wing
Structure: Concrete perimeter bearing walls
Interior steel columns
Glue laminated wood roof girders, beams, and purlins
Plywood diaphragm
Problems: Inadequate tension connections between wall panel and roof diaphragm
Retrofit Approach: Add additional perimeter girder and beam connectors
Reinforce diaphragm and tension members

[6]PC1 **Configuration:** Rectangular plan
Structure: Concrete perimeter bearing wall
Concrete interior bearing wall
Interior steel columns
Wooden trusses and purlins
Plywood diaphragm
Problems: Weak diaphragm
Inadequate connections between wall panels and roof diaphragm
Retrofit Approach: Add interior steel braces to reduce diaphragm stress
Add collectors and cross ties
Strengthen wall-roof connections

TABLE 7

Structural Type		Typical Costs per sf ($)
URM	Unreinforced Masonry Bearing Wall	10-25
RM	Reinforced Masonry	8-17
W	Wood	7-17
S1	Steel Moment Frame	8-20
S2	Steel Braced Frame	8-20
S4	Steel Frames & Shear Walls	5-12
S5	Steel Frames & URM Infill	5-12
C1	Cast in Place Reinforced Concrete Frame	10-12
C2	Cast in Place Reinforced Concrete Shear Walls	8-30
C3	Cast in Place Reinforced Concrete Frame with URM Infill	20-25
PC1	Precast Concrete Tilt-Up	3-12
PC2	Precast Concrete Frame	8-30

Based on Tables 1-8, these typical costs are a best estimate. There is very little actual cost data for some structural types. The user should adjust these figures for regional differences and should compare these to local construction experience whenever possible.

TABLE 8

Actual Cost of Seismic Rehabilitation by Structural Type

URM-Unreinforced Masonry Bearing Wall

City	Building	Code Level	Year Upgrade Complete	Seismic $/SF[1]	Total Rehab. $/SF[2]
Seattle	Mutual Life 56,700 sf		1981	$9.75	$78
Seattle	Union Station		1987	16.00 Estimate	Not Available
Provo	3 story 15,000 sf (approx.)		1987	N.A.	$33[3]
Provo	3 story 22,300 sf (approx.)		1988	N.A.	$43[3]
Charleston	Marden Paint Building 9,196 sf 4-story		1990	13.60[4]	$98
Salt Lake City	20 buildings			7.50[5] -18.90[6] Estimate	N.A.

S2-Steel Braced Frame

City	Building	Code Level	Year Upgrade Complete	Seismic $/SF[1]	Total Rehab. $/SF[2]
Memphis	Warehouse 200,000 sf	Zone 3 1988 Southern Building Code	1988	0.75	No Other Work

S5 Steel Frame with URM Infill

City	Building	Code Level	Year Upgrade Complete	Seismic $/SF[1]	Total Rehab. $/SF[2]
Kansas City	Boley Bldg. 65,000 sf 5-story		1986-1987	15.00	110.00
Salt Lake City	4 buildings			13.90-20.57 Estimate	N.A.
Seattle	Arctic Bldg. 101,700 sq		1981	7.25[10]	47.00 to 54.00

C-1-Cast in Place Reinforced Concrete Frame

City	Building	Code Level	Year Upgrade Complete	Seismic $/SF[1]	Total Rehab. $/SF[2]
Salt Lake City	School Building			2.70 Estimate	N.A.

C-2 Cast in Place Reinforced Concrete Shear Wall

City	Building	Code Level	Year Upgrade Complete	Seismic $/SF[1]	Total Rehab. $/SF[2]
Charleston	Mariott Hotel	Zone 3 1983 UBC	1990 (original built in 1983)	3.7 mil Total	23 mil Total
Salt Lake City	School Building			2.62 mil Estimate	

C-3 Cast in Place Reinforced Concrete with URM Infill

City	Building	Code Level	Year Upgrade Complete	Seismic $/SF[1]	Total Rehab. $/SF[2]
St. Louis	Union Electric 202,200 sf 4-story, plus basement	Zone 2 1985 UBC (except for detailing requirements)	1990	3.00[7]	38.00[8]
Seattle	Alaska Bldg. 135,000 sf		1981	8.50[9]	33.00 to 38.00
Salt Lake City	7 Buildings			5.30[11]- 14.70[11]	

PC1 Precast Concrete Tilt-Up

City	Building	Code Level	Year Upgrade Complete	Seismic $/SF[1]	Total Rehab. $/SF[2]
Hayward	Tilt-up 21,000 sf	1973 UBC		2.00	2.00
	Tilt-up 24,000 sf	1973 UBC		2.75	6.25
	Tilt-up	1973 UBC		1.00	1.00
	Tilt-up 17,700 sf	1973 UBC		0.60	0.60

PC2 Precast Concrete Frame

City	Building	Code Level	Year Upgrade Complete	Seismic $/SF[1]	Total Rehab. $/SF[2]
Memphis	Parking Garage with retail office on ground floor 378,000 sf 5 story		Estimates Only	Level II/III 1.16 Level IV 1.46 Level V 1.65	

Essential Buildings

City	Building	Code Level	Year Upgrade Complete	Seismic $/SF[1]	Total Rehab. $/SF[2]
St. Louis	Florissant Valley Firehouse 1	Original construction precast concrete roof beams and columns of reinforced concrete with block wall infill	1990 (estimate)	6.00 (approx.)	Seismic Total: 51,014
	Florissant Valley Firehouse 2			6.00 (approx.)	47,278
	Florissant Valley Firehouse 3			6.00 (approx.)	53,141
Salt Lake City	Fire Station 2 12,900 sf		1990	17.00	
	Fire Station 3 7,400 sf		1988	26.00	
	Fire Station 14 7,400 sf		1988	14.00	

FOOTNOTES

[1]These are hard costs only, that is contractor costs, and as such they do not include architectural and engineering fees, permits, insurance, construction financing and other typical soft costs. Multiply hard costs by a factor ranging from 1.3 to 2.0 (depending upon local conditions to determine total project costs.)

[2]Same as above.

[3]Plus or minus.

[4]Does not include the cost of reconstruction of the historic facade.

[5]Fair condition prior to retrofit.

[6]Very poor condition prior to retrofit.

[7]Does not include any demolition costs

[8]Includes interior remodeling for an additional 100,000 sf in an adjacent building

[9]Seismic upgrading on the Alaska Building was for parts and portions of the building (primarily for anchorage of ornamentation). No overall analysis or upgrading was done.

[10]Seismic upgrading on the Arctic Building amounted to parapets, facade stabilization, marquees, and ornamentation. No overall analysis or upgrading was done.

[11]Very poor condition prior to retrofit.

STRUCTURAL BUILDING TYPES
USED IN TYPICAL SEISMIC COST DATA
BASED ON ATC 14 & 22

Information for Tables X and Z

URM	Unreinforced Masonry Bearing Wall
RM	Reinforced Masonry
W	Wood
S1	Steel Moment Frame
S2	Steel Braced Frame
S4	Steel Frames & Shear Walls
S5	Steel Frames & URM Infill
C1	Cast in Place Reinforced Concrete Frame
C2	Cast in Place Reinforced Concrete Shear Walls
C3	Cast in Place Reinforced Concrete Frame with URM Infill
PC1	Precast Concrete Tilt-Up
PC2	Precast Concrete Frame

TABLE X

From ATC-13

Earthquake Engineering Facility Classification

	Facility Number
A. BUILDINGS	
* Wood Frame (Low Rise) W1	1
* Unreinforced Masonry (Bearing Wall)	
a. Low Rise (1-3 Stories) URMa	75
b. Medium Rise (4-7 Stories) URMb	76
* Unreinforced Masonry (with Load Bearing Frame)	
a. Low Rise C3/S5a	78
b. Medium Rise C3/S5b	79
c. High Rise (8+ Stories) C3/S5c	80
* Reinforced Concrete Shear Wall (with Moment-Resisting Frame)	
a. Low Rise C2a	3
b. Medium Rise C2b	4
c. High Rise C2c	5
* Reinforced Concrete Shear Wall (without Moment-Resisting Frame)	
a. Low Rise C2d	6
b. Medium Rise C2e	7
c. High Rise C2f	8
* Reinforced Masonry Shear Wall (without Moment-Resisting Frame)	
a. Low Rise RM1/RM2a	9
b. Medium Rise RM1/RM2b	10
c. High Rise RM1/RM2c	11

TABLE X (Cont.)

	Facility Number
* Reinforced Masonry Shear Wall (with Moment-Resisting Frame)	
a. Low Rise RM1/RM2d	84
b. Medium Rise RM1/RM2e	85
c. High Rise RM1/RM2f	86
* Braced Steel Frame	
a. Low Rise S2a	12
b. Medium Rise S2b	13
c. High Rise S2c	14
* Moment-Resisting Steel Frame (Perimeter Frame)	
a. Low Rise S1a	15
b. Medium Rise S1b	16
c. High Rise S1c	17
* Moment-Resisting Steel Frame (Distributed Frame)	
a. Low Rise S1d	72
b. Medium Rise S1e	73
c. High Rise S1f	74
* Moment-Resisting Ductile Concrete Frame (Distributed Frame)	
a. Low Rise C1a	18
b. Medium Rise C1b	19
c. High Rise C1c	20
* Moment Resisting Non-Ductile Concrete Frame (Distributed Frame)	
a. Low Rise C1d	87
b. Medium Rise C1e	88
c. High Rise C1f	89
* Precast Concrete (other than Tilt-up)	
a. Low Rise PC2a	81
b. Medium Rise PC2b	82
c. High Rise PC2c	83
* Tilt-up (Low Rise) PC1	21

Table Y

MAJOR CITIES COST RELATIONSHIP INDEX[1]

	INDEX NUMBER		INDEX NUMBER		INDEX NUMBER
THIS BOOK	100	Houston, Texas	83	Riverside, California	92
Akron, Ohio	84	Huntsville, Alabama	74	Rochester, New York	83
Albany, New York	79	Indianapolis, Indiana	82	Rock Island, Illinois	82
Albuquerque, New Mexico	77	Jackson, Mississippi	72	Rockford, Illinois	82
Anchorage, Alaska	136	Jacksonville, Florida	73	Sacramento, California	95
Atlanta, Georgia	77	Kansas City, Missouri	82	Salt Lake City, Utah	79
Baltimore, Maryland	77	Knoxville, Tennessee	72	San Antonio, Texas	75
Birmingham, Alabama	74	Lansing, Michigan	79	San Diego, California	92
Boise, Idaho	79	Las Vegas, Nevada	88	San Francisco, California	100
Boston, Massachusetts	85	Little Rock, Arkansas	74	San Jose, California	95
Buffalo, New York	84	Long Beach, California	93	Santa Ana, California	94
Burlington, Vermont	72	Los Angeles, California	93	Santa Fe, New Mexico	77
Butte, Montana	78	Louisville, Kentucky	79	Savannah, Georgia	71
Calgary, Canada	84	Lubbock, Texas	73	Schenectady, New York	79
Charleston, South Carolina	70	Madison, Wisconsin	78	Scranton, Pennsylvania	78
Charleston, West Virginia	80	Manchester, New Hampshire	75	Seattle, Washington	88
Charlotte, North Carolina	69	Memphis, Tennessee	78	Shreveport, Louisiana	75
Chattanooga, Tennessee	74	Miami, Florida	78	Sioux Falls, South Dakota	73
Cheyenne, Wyoming	81	Milwaukee, Wisconsin	82	South Bend, Indiana	81
Chicago, Illinois	83	Minneapolis, Minnesota	82	Spokane, Washington	87
Cincinnati, Ohio	83	Mobile, Alabama	77	Springfield, Massachusetts	81
Cleveland, Ohio	87	Montgomery, Alabama	72	Saint Louis, Missouri	83
Columbia, South Carolina	70	Montreal, Canada	81	Saint Petersburg, Florida	72
Columbus, Ohio	82	Nashville, Tennessee	72	Saint Paul, Minnesota	82
Corpus Christi, Texas	73	New Bedford, Massachusetts	81	Stamford, Conecticut	81
Dallas, Texas	81	New Haven, Connecticut	79	Syracuse, New York	79
Dayton, Ohio	81	New Orleans, Louisiana	77	Tampa, Florida	75
Denver, Colorado	82	New York, New York	87	Toledo, Ohio	86
Des Moines, Iowa	78	Newark, New Jersey	84	Topeka, Kansas	76
Detroit, Michigan	85	Norfolk, Virginia	72	Toronto, Canada	84
Duluth, Minnesota	81	Oakland, California	95	Trenton, New Jersey	82
El Paso, Texas	68	Oklahoma City, Oklahoma	78	Tulsa, Oklahoma	78
Erie, Pennsylvania	82	Omaha, Nebraska	79	Vancouver, Canada	80
Evansville, Illinois	80	Peoria, Illinois	83	Washington, D.C.	81
Fargo, North Dakota	75	Philadelphia, Pennsylvania	82	Wichita, Kansas	75
Flint, Michigan	81	Phoenix, Arizona	82	Wilmington, Delaware	82
Fort Worth, Texas	80	Pittsburgh, Pennsylvania	82	Winnipeg, Canada	80
Fremont, California	92	Portland, Maine	72	Worcester, Massachusetts	83
Fresno, California	90	Portland, Oregon	89	York, Pennsylvania	75
Grand Rapids, Michigan	76	Providence, Rhode Island	81	Youngstown, Ohio	83
Hammond, Indiana	84	Raleigh, North Carolina	69	Average, U.S. Cities	81
Hartford, Connecticut	81	Reading, Massachusetts	81		
Honolulu, Hawaii	104	Richmond, Virginia	74		

TABLE Y FOOTNOTE

[1]The authors have selected the Lee Saylor Cost Index because the predominant number of cases in this study are taken from California Experience. Users in other areas may wish to refer to other more detailed indexes to develop more precise local area factors. These sources include:

International Conference of Building Officials, "Regional Modifiers" Building Standards, March/April 1990, p.55

1990 National Construction Estimator "Area Modifiers," Craftsman Book Company, Carlsbad, CA p.8-9

Means 1990 Building Construction Cost Data, "City Cost Indexes," p.446-454

Table Z

Damage Probability Matrices Based on Expert Opinion for Earthquake Engineering Facility Classes

Central Damage Factor — Modified Mercalli Intensity

(W1) WOOD FRAME----------------------FACILITY CLASS=1------------------------------------LOW RISE--------

Central Damage Factor	VI	VII	VIII	IX	X	XI	XII
0.00	3.7	**	**	**	**	**	**
0.50	68.5	26.8	1.6	**	**	**	**
5.00	27.8	73.2	94.9	11.5	11.5	1.8	**
20.00	**	**	3.5	76.0	76.0	75.1	24.8
45.00	**	**	**	12.5	12.5	23.1	73.5
80.00	**	**	**	**	**	**	1.7
100.00	**	**	**	**	**	**	**

(C2a)R.C. SHEAR WALL----------------FACILITY CLASS=3---------------------------------LOW RISE 1-3 STORIES
WITH MOMENT FRAME

Central Damage Factor	VI	VII	VIII	IX	X	XI	XII
0.00	18.1	**	**	**	**	**	**
0.50	69.8	17.8	0.6	**	**	**	**
5.00	12.1	82.2	97.7	71.8	14.6	0.3	**
20.00	**	**	1.7	28.2	83.2	68.8	29.4
45.00	**	**	**	**	2.2	30.9	70.4
80.00	**	**	**	**	**	**	0.2
100.00	**	**	**	**	**	**	**

(C2b)R.C. SHEAR WALL---------------FACILITY CLASS=4---------------------------------MID RISE 4-7 STORIES
WITH MOMENT FRAME

Central Damage Factor	VI	VII	VIII	IX	X	XI	XII
0.00	20.4	**	**	**	**	**	**
0.50	70.3	15.5	**	**	**	**	**
5.00	9.3	84.5	88.4	28.9	1.4	**	**
20.00	**	**	11.6	71.1	81.6	38.7	3.8
45.00	**	**	**	**	17.0	61.3	88.7
80.00	**	**	**	**	**	**	7.5
100.00	**	**	**	**	**	**	**

(C2c)R.C. SHEAR WALL---------------FACILITY CLASS=5---------------------------------HIGH RISE 8+ STORIES
WITH MOMENT FRAME

Central Damage Factor	VI	VII	VIII	IX	X	XI	XII
0.00	19.1	**	**	**	**	**	**
0.50	62.9	7.2	0.2	**	**	**	**
5.00	18.0	92.2	83.4	17.6	0.6	**	**
20.00	**	0.6	16.4	81.9	70.1	6.2	0.7
45.00	**	**	**	0.5	29.3	86.5	59.2
80.00	**	**	**	**	**	7.34	0.1
100.00	**	**	**	**	**	**	**

(C2d)R.C. SHEAR WALL---------------FACILITY CLASS=6----------------------------------LOW RISE 1-3 STORIES
WITHOUT MOMENT FRAME

Central Damage Factor	VI	VII	VIII	IX	X	XI	XII
0.00	13.1	**	**	**	**	**	**
0.50	72.0	9.7	0.2	**	**	**	**
5.00	14.9	90.1	87.2	30.3	1.1	**	**
20.00	**	0.1	12.6	69.4	81.1	29.4	2.6
45.00	**	**	**	0.3	17.8	69.9	88.1
80.00	**	**	**	**	**	0.7	9.3
100.00	**	**	**	**	**	**	**

Central Damage Factor	Modified Mercalli Intensity						
	VI	VII	VIII	IX	X	XI	XII

(C2e)R.C. SHEAR WALL----------------FACILITY CLASS=7------------------------------------MID RISE 4-7 STORIES
WITHOUT MOMENT FRAME

Central Damage Factor	VI	VII	VIII	IX	X	XI	XII
0.00	2.5	**	**	**	**	**	**
0.50	59.0	8.6	**	**	**	**	**
5.00	38.5	89.2	66.4	11.7	0.4	**	**
20.00	**	2.2	33.6	83.9	56.9	19.7	3.7
45.00	**	**	**	4.4	42.7	77.0	77.6
80.00	**	**	**	**	**	3.3	18.7
100.00	**	**	**	**	**	**	**

(C2f)R.C. SHEAR WALL----------------FACILITY CLASS=8------------------------------------ HIGH RISE 8+ STORIES
WITHOUT MOMENT FRAME

Central Damage Factor	VI	VII	VIII	IX	X	XI	XII
0.00	2.8	**	**	**	**	**	**
0.50	49.9	2.5	**	**	**	**	**
5.00	47.3	86.8	42.3	2.8	**	**	**
20.00	**	10.7	57.3	70.8	19.3	1.8	0.3
45.00	**	**	0.4	26.4	80.0	67.2	27.3
80.00	**	**	**	**	0.7	31.0	72.4
100.00	**	**	**	**	**	**	**

(RM1a)R. MASONRY SHEAR WALL---------FACILITY CLASS=9---------- LOW RISE
(RM2a) WITHOUT MOMENT FRAME

Central Damage Factor	VI	VII	VIII	IX	X	XI	XII
0.00	2.7	**	**	**	**	**	**
0.50	65.8	10.0	1.0	**	**	**	**
5.00	31.5	89.7	88.0	34.5	3.5	**	**
20.00	**	0.3	11.0	63.4	76.2	17.5	3.7
45.00	**	**	**	2.1	20.3	74.5	68.3
80.00	**	**	**	**	**	8.0	28.0
100.00	**	**	**	**	**	**	**

(RM1b)R. MASONRY SHEAR WALL---------FACILITY CLASS=10---------- MID RISE
(RM2b) WITHOUT MOMENT FRAME

Central Damage Factor	VI	VII	VIII	IX	X	XI	XII
0.00	1.2	**	**	**	**	**	**
0.50	47.0	3.1	0.3	**	**	**	**
5.00	51.8	96.6	57.2	16.2	1.0	**	**
20.00	**	0.3	42.2	75.6	49.9	12.2	2.8
45.00	**	**	0.3	8.2	48.6	71.6	46.3
80.00	**	**	**	**	0.5	16.2	50.9
100.00	**	**	**	**	**	**	**

(RM1c)R. MASONRY SHEAR WALL --------FACILITY CLASS=11--------- HIGH RISE
(RM2c) WITHOUT MOMENT FRAME

Central Damage Factor	VI	VII	VIII	IX	X	XI	XII
0.00	1.5	**	**	**	**	**	**
0.50	48.6	2.8	0.2	**	**	**	**
5.00	49.9	89.8	37.6	5.9	0.7	**	**
20.00	**	7.4	59.6	74.7	31.6	5.9	1.9
45.00	**	**	2.6	19.4	63.3	54.9	24.3
80.00	**	**	**	**	4.4	39.2	69.6
100.00	**	**	**	**	**	**	4.2

(S2a) STEEL BRACED FRAME ---------- FACILITY CLASS=12--------- LOW RISE

Central Damage Factor	VI	VII	VIII	IX	X	XI	XII
0.00	18.9	0.6	**	**	**	**	**
0.50	60.4	29.2	2.6	**	**	**	**
5.00	20.7	70.2	90.3	54.4	15.5	1.2	**
20.00	**	**	7.1	45.6	82.9	64.1	20.4
45.00	**	**	**	**	1.6	34.7	77.3
80.00	**	**	**	**	**	**	2.3
100.00	**	**	**	**	**	**	**

Central Damage Factor	Modified Mercalli Intensity VI	VII	VIII	IX	X	XI	XII

(S2b) STEEL BRACED FRAME-----------FACILITY CLASS=13--MID RISE---------

Central Damage Factor	VI	VII	VIII	IX	X	XI	XII
0.00	14.2	**	**	**	**	**	**
0.50	56.5	**	**	**	**	**	**
5.00	29.3	100.0	81.0	36.8	4.2	0.5	**
20.00	**	**	19.0	63.2	86.9	51.6	16.8
45.00	**	**	**	**	8.9	47.7	76.2
80.00	**	**	**	**	**	0.2	7.0
100.00	**	**	**	**	**	**	**

(S2c) STEEL BRACED FRAME---------FACILITY CLASS=14---------- HIGH RISE

Central Damage Factor	VI	VII	VIII	IX	X	XI	XII
0.00	21.5	**	**	**	**	**	**
0.50	49.0	2.8	0.1	**	**	**	**
5.00	29.5	88.0	54.6	8.4	1.2	0.2	**
20.00	**	9.2	45.1	90.5	84.8	27.2	9.1
45.00	**	**	0.2	1.1	14.0	68.8	63.3
80.00	**	**	**	**	**	3.8	27.6
100.00	**	**	**	**	**	**	**

(S1a) STEEL MOMENT FRAME --------FACILITY CLASS=15--------- LOW RISE
(Perimeter)

Central Damage Factor	VI	VII	VIII	IX	X	XI	XII
0.00	13.7	0.2	**	**	**	**	**
0.50	62.0	27.5	0.4	**	**	**	**
5.00	24.3	72.3	99.5	87.4	19.3	1.9	**
20.00	**	**	0.1	12.6	80.6	85.1	45.3
45.00	**	**	**	**	0.1	13.0	54.7
80.00	**	**	**	**	**	**	**
100.00	**	**	**	**	**	**	**

(S1b) STEEL MOMENT FRAME --------FACILITY CLASS=16--------- MID RISE
(Perimeter)

Central Damage Factor	VI	VII	VIII	IX	X	XI	XII
0.00	21.2	**	**	**	**	**	**
0.50	56.1	17.5	1.9	**	**	**	**
5.00	22.7	82.5	95.9	66.5	12.6	0.5	**
20.00	**	**	2.2	33.5	86.6	60.2	27.8
45.00	**	**	**	**	0.8	39.3	70.8
80.00	**	**	**	**	**	**	1.4
100.00	**	**	**	**	**	**	**

(S1c) STEEL MOMENT FRAME---------FACILITY CLASS=17---------- HIGH RISE
(Perimeter)

Central Damage Factor	VI	VII	VIII	IX	X	XI	XII
0.00	26.8	**	**	**	**	**	**
0.50	50.4	12.9	0.8	**	**	**	**
5.00	22.8	87.1	86.8	24.8	5.4	**	**
20.00	**	**	12.4	73.7	86.8	25.8	8.0
45.00	**	**	**	1.5	7.8	73.0	84.9
80.00	**	**	**	**	**	1.2	7.1
100.00	**	**	**	**	**	**	**

(C1a)CONC. DUCTILE MOMENT--------FACILITY CLASS=18---------- LOW RISE
FRAME (Distributed)

Central Damage Factor	VI	VII	VIII	IX	X	XI	XII
0.00	2.5	**	**	**	**	**	**
0.50	95.8	23.7	0.6	**	**	**	**
5.00	1.7	76.3	99.0	63.2	7.3	0.1	**
20.00	**	**	0.4	36.8	90.4	74.3	3.8
45.00	**	**	**	**	2.3	25.6	95.7
80.00	**	**	**	**	**	**	0.5
100.00	**	**	**	**	**	**	**

Central Damage Factor — Modified Mercalli Intensity

(C1b)CONC. DUCTILE MOMENT--------FACILITY CLASS=19--------- MID RISE
FRAME (Distributed)

Central Damage Factor	VI	VII	VIII	IX	X	XI	XII
0.00	0.3	**	**	**	**	**	**
0.50	41.0	2.8	0.6	**	**	**	**
5.00	58.7	97.0	91.2	46.7	9.0	**	**
20.00	**	0.2	8.2	53.3	89.3	60.6	20.3
45.00	**	**	**	**	1.7	39.4	79.3
80.00	**	**	**	**	**	**	0.4
100.00	**	**	**	**	**	**	**

(C1c)CONC. DUCTILE MOMENT -------FACILITY CLASS=20--------- HIGH RISE
FRAME (Distributed)

Central Damage Factor	VI	VII	VIII	IX	X	XI	XII
0.00	**	**	**	**	**	**	**
0.50	22.5	2.3	0.2	**	**	**	**
5.00	77.5	97.7	83.4	27.6	3.1	0.4	0.1
20.00	**	**	16.4	71.6	85.0	44.8	23.7
45.00	**	**	**	0.8	11.9	54.4	72.7
80.00	**	**	**	**	**	0.4	3.5
100.00	**	**	**	**	**	**	**

(PC1) CONCRETE TILT-UP---------FACILITY CLASS=21---------- LOW RISE

Central Damage Factor	VI	VII	VIII	IX	X	XI	XII
0.00	0.3	**	**	**	**	**	**
0.50	35.2	1.2	**	**	**	**	**
5.00	64.5	97.7	49.7	8.7	1.2	**	**
20.00	**	1.1	50.3	85.7	56.6	13.0	0.7
45.00	**	**	**	5.6	42.0	73.6	40.1
80.00	**	**	**	**	0.2	13.4	59.2
100.00	**	**	**	**	**	**	**

(S1d)STEEL MOMENT FRAME--------- FACILITY CLASS=72-------------- LOW RISE (Distributed)

Central Damage Factor	VI	VII	VIII	IX	X	XI	XII
0.00	34.2	6.3	**	**	**	**	**
0.50	55.6	43.6	6.8	0.1	**	**	**
5.00	10.2	50.1	93.1	94.1	47.8	8.1	**
20.00	**	**	0.1	5.8	52.2	82.4	39.2
45.00	**	**	**	**	**	9.5	60.8
80.00	**	**	**	**	**	**	**
100.00	**	**	**	**	**	**	**

(S1e)STEEL MOMENT FRAME--------- FACILITY CLASS=73---------- MID RISE
(Distributed)

Central Damage Factor	VI	VII	VIII	IX	X	XI	XII
0.00	22.4	1.1	**	**	**	**	**
0.50	51.3	34.0	2.5	**	**	**	**
5.00	26.3	64.9	95.4	83.1	29.5	9.2	0.2
20.00	**	**	2.1	16.9	70.5	80.7	50.6
45.00	**	**	**	**	**	10.1	49.2
80.00	**	**	**	**	**	**	**
100.00	**	**	**	**	**	**	**

Central Damage Factor	Modified Mercalli Intensity VI	VII	VIII	IX	X	XI	XII
(S1f)STEEL MOMENT FRAME--------- FACILITY CLASS=74---------- HIGH RISE (Distributed)							
0.00	26.8	0.5					
0.50	60.0	22.2	2.7				
5.00	13.2	77.1	92.3	58.8	14.7	5.9	0.8
20.00		0.2	5.0	41.2	83.0	67.1	42.3
45.00					2.3	26.9	55.7
80.00						0.1	1.2
100.00							
URM BEARING WALL---------------- FACILITY CLASS=75---------- LOW RISE 1-3 STORIES							
0.00							
0.50	9.1	0.6					
5.00	90.5	55.5	10.9	0.5			
20.00	0.4	43.4	66.0	22.4	2.0	0.1	0.1
45.00		0.5	22.9	65.9	35.0	10.1	3.4
80.00			0.2	11.2	62.5	83.1	50.4
100.00					0.5	6.7	46.1
URM BEARING WALL---------------- FACILITY CLASS=76---------- MEDIUM RISE 4-7 STORIES							
0.00							
0.50	4.7	1.5					
5.00	89.9	49.5	3.7				
20.00	5.4	46.4	53.3	7.6	0.9		
45.00		2.6	42.0	63.4	21.4	5.3	3.1
80.00			1.0	29.0	74.7	80.0	43.0
100.00					3.0	14.7	53.9
(C3/S5a)URM INFILL OF FRAME--------- FACILITY CLASS=78---------- LOW RISE 1 - 3 STORIES							
0.00	5.2						
0.50	38.8	3.2	0.7				
5.00	55.9	84.1	37.9	5.5	0.8	0.2	0.1
20.00	0.1	12.7	55.4	52.6	20.6	6.9	2.5
45.00			6.0	40.4	60.8	40.2	17.7
80.00				1.5	17.8	51.7	62.8
100.00						1.0	16.9
(C3/S5b)URM INFILL OF FRAME--------- FACILITY CLASS=79---------- MID RISE 4 - 7 STORIES							
0.00	0.5						
0.50	15.3	2.9					
5.00	81.2	66.6	13.5	1.9	0.3		
20.00	3.0	30.1	69.3	40.6	14.1	2.0	0.2
45.00		0.4	17.2	54.4	63.4	28.4	8.5
80.00				3.1	22.2	67.5	78.8
100.00						2.1	12.5
(C3/S5c)URM INFILL OF FRAME--------- FACILITY CLASS=80---------- HIGH RISE 8+ STORIES							
0.00							
0.50	5.8	1.7					
5.00	87.0	51.2	10.2	0.3			
20.00	7.2	44.9	63.3	18.4	6.0	2.1	
45.00		2.2	26.2	66.5	51.5	26.9	9.6
80.00			0.3	14.8	42.5	68.2	87.6
100.00						2.8	2.8

Central Damage Factor — Modified Mercalli Intensity

(PC2a)PRECAST CONCRETE-------- FACILITY CLASS=81---------- LOW RISE
OTHER THAN TILT-UP

Central Damage Factor	VI	VII	VIII	IX	X	XI	XII
0.00	9.8						
0.50	49.6	12.8	0.3				
5.00	40.6	86.8	72.4	1.8	0.2		
20.00		0.4	27.3	80.7	27.0	8.2	3.3
45.00				17.5	69.6	71.1	44.9
80.00					3.2	20.7	51.6
100.00							0.2

(PC2b)PRECAST CONC.----------- FACILITY CLASS=82------------ MID RISE
OTHER THAN TILT-UP

Central Damage Factor	VI	VII	VIII	IX	X	XI	XII
0.00	15.3						
0.50	47.4	7.1	0.3				
5.00	37.3	92.1	68.8				
20.00		0.8	30.9	70.5	13.6	6.0	2.6
45.00				29.5	78.2	59.0	27.3
80.00					8.1	35.0	66.7
100.00							3.4

(PC2c)PRECAST CONC.----------- FACILITY CLASS=83------------ HIGH RISE
OTHER THAN TILT-UP

Central Damage Factor	VI	VII	VIII	IX	X	XI	XII
0.00	14.3						
0.50	47.7	6.2	0.5				
5.00	38.0	90.7	55.7				
20.00		3.1	43.3	54.1	11.9	6.1	5.8
45.00			0.5	45.9	78.1	56.7	25.1
80.00					10.0	37.2	58.1
100.00							11.0

(RM1d)R.MASONRY SHEAR--------- FACILITY CLASS=84------------ LOW RISE
(RM2d) WALL W/MOMENT FRAME

Central Damage Factor	VI	VII	VIII	IX	X	XI	XII
0.00	9.1	0.6					
0.50	71.9	23.2	0.3				
5.00	19.0	76.1	97.7	63.0	12.5	1.6	0.3
20.00		0.2	2.0	37.0	77.3	66.0	22.0
45.00					10.2	32.4	70.7
80.00							7.0
100.00							

(RM1e)R.MASONRY SHEAR--------- FACILITY CLASS=85------------ MID RISE
(RM2e) WALL W/MOMENT FRAME

Central Damage Factor	VI	VII	VIII	IX	X	XI	XII
0.00	0.2						
0.50	57.2	5.2	0.2				
5.00	42.6	94.4	83.2	42.3	8.9	0.7	
20.00		0.4	16.6	57.7	70.8	35.3	10.4
45.00					20.3	61.0	71.0
80.00						2.9	18.6
100.00							

Central Damage Factor	VI	VII	VIII	IX	X	XI	XII
			Modified Mercalli Intensity				
(RM1f)R.MASONRY SHEAR------------ FACILITY CLASS=86------------ HIGH RISE (RM2f) WALL W/MOMENT FRAME							
0.00							
0.50	47.1	1.3					
5.00	52.9	97.5	62.5	12.3	2.2		
20.00		1.2	37.5	87.4	69.0	14.5	1.4
45.00				0.3	28.8	72.3	41.5
80.00						13.2	57.1
100.00							
(C1d)CONC. NON-DUCTILE---------- FACILITY CLASS=87------------ LOW RISE MOMENT FRAME (Distributed)							
0.00	2.9						
0.50	45.7	1.1					
5.00	51.4	97.9	37.5	2.5	0.4		
20.00		1.0	62.3	88.0	44.6	6.6	0.5
45.00			0.2	9.5	54.6	78.8	41.6
80.00					0.4	14.6	57.9
100.00							
(C1e)CONC. NON-DUCTILE---------- FACILITY CLASS=88------------ MID RISE MOMENT FRAME (Distributed)							
0.00	0.3						
0.50	30.9	0.3					
5.00	68.8	96.9	33.6	1.9	0.2		
20.00		2.8	65.7	65.1	30.8	3.60.5	
45.00			0.7	33.0	67.7	70.0	27.9
80.00					1.3	26.4	71.2
100.00							0.4
(C1f)CONC. NON-DUCTILE---------- FACILITY CLASS=89------------ HIGH RISE MOMENT FRAME (Distributed)							
0.00	0.1						
0.50	27.0	2.2					
5.00	72.9	89.3	32.2	3.0			
20.00		8.5	66.9	68.1	19.9	3.9	0.1
45.00			0.9	28.9	74.2	57.8	12.4
80.00					5.9	38.3	84.3
100.00							3.2

** Very small probability.

APPENDIX 3

TABLES FOR THE SEATTLE BUILDING INVENTORY

Table E-1. Seattle Building Inventory, Blocks 81 and 92.

DATE	CENSUS TRACT	BLOCK	NUMBER	YEAR OF CONST.	STORIES	TOTAL AREA	SSC	UC	SOIL TYPE
3/03/88	81	207	1	1963	6	200760	37	10	S-1
3/03/88	81	207	2	1910	7	12000	12	10	S-1
3/03/88	81	207	3	1900	2	36000	7	2	S-1
3/03/88	81	207	4	1910	6	8640	30	7	S-1
3/03/88	81	207	5	1900	2	6480	1	2	S-1
3/04/88	81	212	1	1950	13	24163	14	7	S-1
3/03/88	81	213	1	1962	1	14400	36	10	S-1
3/03/88	81	213	2	1924	4	59520	31	10	S-1
3/03/88	81	213	3	1972	22	218772	29	7	S-1
3/04/88	81	213	3	1916	9	86415	32	7	S-1
3/03/88	81	220	1	1920	15	128600	14	7	S-1
3/03/88	81	220	2	1924	4	52856	10	7	S-1
3/03/88	81	220	3	1920	3	35700	3	7	S-1
3/03/88	81	221	1	1925	13	168480	26	7	S-1
3/03/88	81	221	2	1925	6	63200	22	7	S-1
3/03/88	81	221	3	1900	6	25920	7	2	S-1
3/03/88	81	221	4	1900	6	38880	4	99	S-1
3/03/88	81	221	5	1900	3	12960	12	4	S-1
3/03/88	81	221	6	1900	5	66600	6	10	S-1
3/03/88	81	222	1	1900	2	8640	3	9	S-1
3/03/88	81	222	2	1900	7	126160	7	2	S-1
3/03/88	81	222	3	1914	42	695200	26	7	S-1
3/03/88	81	222	4	1890	3	20860	3	99	S-1
3/03/88	81	222	5	1900	5	43200	4	99	S-1
3/03/88	81	302	1	1900	10	55500	17	7	S-3
3/03/88	81	302	2	1840	3	24624	3	4	S-3
3/03/88	81	302	3	1900	7	75600	7	7	S-3
3/03/88	81	302	4	1900	6	19980	7	7	S-3
3/03/88	81	302	5	1900	3	14000	6	7	S-3
3/03/88	81	302	6	1900	6	66600	7	7	S-3
3/03/88	81	304	1	1910	19	122220	23	7	S-3
3/03/88	81	304	2	1900	3	19980	6	7	S-3
3/03/88	81	304	3	1962	2	39960	30	10	S-3
3/03/88	81	304	4	1920	5	64800	31	7	S-1
3/03/88	81	304	5	1900	3	19440	3	7	S-1
3/03/88	81	305	1	1970	10	236550	38	10	S-3
3/03/88	81	305	2	1890	3	9990	3	7	S-3
3/03/88	81	305	3	1890	3	10800	6	7	S-3
3/03/88	81	305	4	1890	5	14850	7	1	S-3
3/03/88	81	305	5	1897	6	48118	7	7	S-3
3/02/88	81	306	1	1900	3	28200	6	7	S-3
3/02/88	81	306	2	1900	1	9230	3	12	S-3
3/02/88	81	306	3	1900	3	30240	3	30	S-3
2/02/88	91	306	4	1898	4	40320	4	7	S-3
2/25/88	92	304	1	1890	4	68400	7	7	S-3
2/25/88	92	304	2	1890	5	17100	7	4	S-3
2/25/88	92	304	3	1890	3	20520	6	4	S-3
2/24/88	92	306	1	1900	3	4700	6	7	S-3
2/24/88	92	306	2	1900	4	43560	4	2	S-3
2/24/88	92	306	3	1900	3	15840	3	4	S-3
2/24/88	92	306	4	1900	5	33852	7	7	S-3
2/24/88	92	306	5	1900	3	44550	6	4	S-3
2/24/88	92	306	6	1900	5	32400	7	7	S-3
2/24/88	92	306	7	1900	4	15120	4	99	S-3
2/24/88	92	306	7	1900	5	54000	4	99	S-3
2/24/88	92	306	8	1900	3	4500	3	7	S-3
2/25/88	92	365	1	1983	8	52800	29	7	S-3
2/25/88	92	365	2	1890	4	19200	7	7	S-3
2/25/88	92	365	3	1890	3	11700	6	7	S-3
2/25/88	92	365	4	1890	4	31620	7	7	S-3

2/25/88	92	365	5	1890	2	2400	6	7	S-3
2/25/88	92	365	6	1890	1	3060	6	7	S-3
2/25/88	92	365	7	1890	1	3000	3	9	S-3
2/25/88	92	365	8	1890	1	9900	3	4	S-3
2/25/88	92	365	9	1890	3	10800	3	4	S-3
2/25/88	92	365	10	1890	3	3600	3	99	S-3
2/25/88	92	365	11	1890	3	5400	3	4	S-3

Table E-2. Seattle Building Inventory Aggregated by Social Function and Function Class.

Soil Type: S-1, Normal Soils.

Buildings Included in Social Function Class: 2, Temporary Dwelling

Facilities Class: 1, Wood Frame

CENSUS TRACT	BLOCK	NUMBER	YEAR OF CONST.	STORIES	TOTAL AREA
81	207	5	1900	2	6480

Total Number of Buildings: 1 Total Floor Area: 6480

Summary: Social Function Class 2, Facilities Class 1.
Total Number of Buildings: 1
Average Floor Space: 6480
Average Replacement Cost: 52.80
Average Rental Rate: .44

Facilities Class: 76, URM:Strengthened 4-7 Stories

CENSUS TRACT	BLOCK	NUMBER	YEAR OF CONST.	STORIES	TOTAL AREA
81	207	3	1900	2	36000
81	221	3	1900	6	25920
81	222	2	1900	7	126160

Total Number of Buildings: 3 Total Floor Area: 188080

Summary: Social Function Class 2, Facilities Class 76.
Total Number of Buildings: 3
Average Floor Space: 62693
Average Replacement Cost: 60.63
Average Rental Rate: .50

Summary: Social Function Class 2.
Total Number of Buildings: 4
Average Floor Space: 48640
Average Replacement Cost: 58.67
Average Rental Rate: .49

Buildings Included in Social Function Class: 4, Retail Trade

Facilities Class: 6, R Concrete Shear Wall(with moment res. frame) 1-3 Stories

CENSUS TRACT	BLOCK	NUMBER	YEAR OF CONST.	STORIES	TOTAL AREA
81	221	5	1900	3	12960

Total Number of Buildings: 1 Total Floor Area: 12960

Summary: Social Function Class 4, Facilities Class 6.
Total Number of Buildings: 1
Average Floor Space: 12960
Average Replacement Cost: 41.98
Average Rental Rate: .35

Summary: Social Function Class 4.
Total Number of Buildings: 1
Average Floor Space: 12960
Average Replacement Cost: 41.98
Average Rental Rate: .35

Buildings Included in Social Function Class: 7, Professional, Technical & Business

Facilities Class: 75, URM 1-3 Stories

CENSUS TRACT	BLOCK	NUMBER	YEAR OF CONST.	STORIES	TOTAL AREA

81	220	3	1920	3	35700
81	304	5	1900	3	19440

Total Number of Buildings: 2 Total Floor Area: 55140

Summary: Social Function Class 7, Facilities Class 75.
Total Number of Buildings: 2
Average Floor Space: 27570
Average Replacement Cost: 46.29
Average Rental Rate: .38

Facilities Class: 4, R Concrete Shear Wall(moment res. frame) 4-7 Stories

CENSUS TRACT	BLOCK	NUMBER	YEAR OF CONST.	STORIES	TOTAL AREA
81	220	2	1924	4	52856

Total Number of Buildings: 1 Total Floor Area: 52856

Summary: Social Function Class 7, Facilities Class 4.
Total Number of Buildings: 1
Average Floor Space: 52856
Average Replacement Cost: 52.45
Average Rental Rate: .44

Facilities Class: 8, R Concrete Shear Wall(with moment res. frame) 8+ Stories

CENSUS TRACT	BLOCK	NUMBER	YEAR OF CONST.	STORIES	TOTAL AREA
81	220	1	1920	15	128600
81	212	1	1950	13	24163

Total Number of Buildings: 2 Total Floor Area: 152763

Summary: Social Function Class 7, Facilities Class 8.
Total Number of Buildings: 2
Average Floor Space: 76382
Average Replacement Cost: 73.57
Average Rental Rate: .61

Facilities Class: 13, Braced Steel Frame 4-7 Stories

CENSUS TRACT	BLOCK	NUMBER	YEAR OF CONST.	STORIES	TOTAL AREA
81	221	2	1925	6	63200

Total Number of Buildings: 1 Total Floor Area: 63200

Summary: Social Function Class 7, Facilities Class 13.
Total Number of Buildings: 1
Average Floor Space: 63200
Average Replacement Cost: 52.45
Average Rental Rate: .44

Facilities Class: 17, Ordinary Moment Resisting Steel Frame 8+ Stories

CENSUS TRACT	BLOCK	NUMBER	YEAR OF CONST.	STORIES	TOTAL AREA
81	221	1	1925	13	168480
81	222	3	1914	42	695200

Total Number of Buildings: 2 Total Floor Area: 863680

Summary: Social Function Class 7, Facilities Class 17.
Total Number of Buildings: 2
Average Floor Space: 431840
Average Replacement Cost: 73.57
Average Rental Rate: .61

Facilities Class: 74, Dectile Moment Resisting Steel Frame 8+ Stories

CENSUS TRACT	BLOCK	NUMBER	YEAR OF CONST.	STORIES	TOTAL AREA
81	213	3	1972	22	218772

Total Number of Buildings: 1 Total Floor Area: 218772

Summary: Social Function Class 7, Facilities Class 74.

Total Number of Buildings:	1
Average Floor Space:	218772
Average Replacement Cost:	73.57
Average Rental Rate:	.61

Facilities Class: 87, Ordinary Moment Resisting Concrete Frame 1-3 Stories

CENSUS TRACT	BLOCK	NUMBER	YEAR OF CONST.	STORIES	TOTAL AREA
81	207	4	1910	6	8640

Total Number of Buildings: 1 Total Floor Area: 8640

Summary: Social Function Class 7, Facilities Class 87.

Total Number of Buildings:	1
Average Floor Space:	8640
Average Replacement Cost:	52.45
Average Rental Rate:	.44

Facilities Class: 88, Ordinary Moment Resisting Concrete Frame 4-7 Stories

CENSUS TRACT	BLOCK	NUMBER	YEAR OF CONST.	STORIES	TOTAL AREA
81	304	4	1920	5	64800

Total Number of Buildings: 1 Total Floor Area: 64800

Summary: Social Function Class 7, Facilities Class 88.
Total Number of Buildings: 1
Average Floor Space: 64800
Average Replacement Cost: 52.45
Average Rental Rate: .44

Facilities Class: 89, Ordinary Moment Resisting Concrete Frame 8+ Stories

CENSUS TRACT	BLOCK	NUMBER	YEAR OF CONST.	STORIES	TOTAL AREA
81	213	3	1916	9	86415

Total Number of Buildings: 1 Total Floor Area: 86415

Summary: Social Function Class 7, Facilities Class 89.
Total Number of Buildings: 1
Average Floor Space: 86415
Average Replacement Cost: 73.57
Average Rental Rate: .61

Summary: Social Function Class 7.
Total Number of Buildings: 12
Average Floor Space: 130522
Average Replacement Cost: 61.98
Average Rental Rate: .51

Buildings Included in Social Function Class: 9, Entertainment and Recreation
Facilities Class: 75, URM 1-3 Stories

CENSUS TRACT	BLOCK	NUMBER	YEAR OF CONST.	STORIES	TOTAL AREA
81	222	1	1900	2	8640

Total Number of Buildings: 1 Total Floor Area: 8640

Summary: Social Function Class 9, Facilities Class 75.
Total Number of Buildings: 1
Average Floor Space: 8640
Average Replacement Cost: 47.43
Average Rental Rate: .39

Summary: Social Function Class 9.
Total Number of Buildings: 1
Average Floor Space: 8640
Average Replacement Cost: 47.43
Average Rental Rate: .39

Buildings Included in Social Function Class: 10, Parking
Facilities Class: 75, URM:Strengthened 1-3 Stories

CENSUS TRACT	BLOCK	NUMBER	YEAR OF CONST.	STORIES	TOTAL AREA
81	221	6	1900	5	66600

Total Number of Buildings: 1 Total Floor Area: 66600

Summary: Social Function Class 10, Facilities Class 75.
Total Number of Buildings: 1
Average Floor Space: 66600
Average Replacement Cost: 23.85

Average Rental Rate: .20

Facilities Class: 6, R Concrete Shear Wall(with moment res. frame) 1-3 Stories

CENSUS TRACT	BLOCK	NUMBER	YEAR OF CONST.	STORIES	TOTAL AREA
81	207	2	1910	7	12000

Total Number of Buildings: 1 Total Floor Area: 12000

Summary: Social Function Class 10, Facilities Class 6.
Total Number of Buildings: 1
Average Floor Space: 12000
Average Replacement Cost: 41.98
Average Rental Rate: .35

Facilities Class: 88, Ordinary Moment Resisting Concrete Frame 4-7 Stories

CENSUS TRACT	BLOCK	NUMBER	YEAR OF CONST.	STORIES	TOTAL AREA
81	213	2	1924	4	59520

Total Number of Buildings: 1 Total Floor Area: 59520

Summary: Social Function Class 10, Facilities Class 88.
Total Number of Buildings: 1
Average Floor Space: 59520
Average Replacement Cost: 23.85
Average Rental Rate: .20

Facilities Class: 81, Precast Concrete Lateral Force Resisting System 1-3 Stories

CENSUS TRACT	BLOCK	NUMBER	YEAR OF CONST.	STORIES	TOTAL AREA
81	213	1	1962	1	14400

Total Number of Buildings: 1 Total Floor Area: 14400

Summary: Social Function Class 10, Facilities Class 81.
Total Number of Buildings: 1
Average Floor Space: 14400
Average Replacement Cost: 19.80
Average Rental Rate: .16

Facilities Class: 82, Precast Concrete Lateral Force Resisting System 4-7 Stories

CENSUS TRACT	BLOCK	NUMBER	YEAR OF CONST.	STORIES	TOTAL AREA
81	207	1	1963	6	200760

Total Number of Buildings: 1 Total Floor Area: 200760

Summary: Social Function Class 10, Facilities Class 82.
Total Number of Buildings: 1
Average Floor Space: 200760
Average Replacement Cost: 23.85
Average Rental Rate: .20

Summary: Social Function Class 10.
Total Number of Buildings: 5
Average Floor Space: 70656
Average Replacement Cost: 26.66
Average Rental Rate: .22

Buildings Included in Social Function Class: 99, Vacant

Facilities Class: 75, URM 1-3 Stories

CENSUS TRACT	BLOCK	NUMBER	YEAR OF CONST.	STORIES	TOTAL AREA
81	222	4	1890	3	20860

Total Number of Buildings: 1 Total Floor Area: 20860

Summary: Social Function Class 99, Facilities Class 75.
Total Number of Buildings: 1
Average Floor Space: 20860
Average Replacement Cost: 22.09
Average Rental Rate: .18

Facilities Class: 76, URM 4-7 Stories

CENSUS TRACT	BLOCK	NUMBER	YEAR OF CONST.	STORIES	TOTAL AREA
81	221	4	1900	6	38880
81	222	5	1900	5	43200

Total Number of Buildings:	2	Total Floor Area:	82080

Summary: Social Function Class 99, Facilities Class 76.

Total Number of Buildings:	2
Average Floor Space:	41040
Average Replacement Cost:	23.14
Average Rental Rate:	.19

Summary: Social Function Class 99.

Total Number of Buildings:	3
Average Floor Space:	34313
Average Replacement Cost:	22.79
Average Rental Rate:	.19

Summary: Soil Type S-1.
Total Number of Buildings: 26
Average Floor Space: 86102
Average Replacement Cost: 48.83
Average Rental Rate: .41

Soil Type: S-3, Poor Soils.

Buildings Included in Social Function Class: 1, Permanent Dwelling
Facilities Class: 76, URM:Strengthened 4-7 Stories

CENSUS TRACT	BLOCK	NUMBER	YEAR OF CONST.	STORIES	TOTAL AREA
81	305	4	1890	5	14850

Total Number of Buildings: 1 Total Floor Area: 14850

Summary: Social Function Class 1, Facilities Class 76.
Total Number of Buildings: 1
Average Floor Space: 14850
Average Replacement Cost: 59.84
Average Rental Rate: .50

Summary: Social Function Class 1.
Total Number of Buildings: 1
Average Floor Space: 14850
Average Replacement Cost: 59.84
Average Rental Rate: .50

Buildings Included in Social Function Class: 2, Temporary Dwelling
Facilities Class: 76, URM 4-7 Stories

CENSUS TRACT	BLOCK	NUMBER	YEAR OF CONST.	STORIES	TOTAL AREA
92	306	2	1900	4	43560

Total Number of Buildings: 1 Total Floor Area: 43560

Summary: Social Function Class 2, Facilities Class 76.
Total Number of Buildings: 1
Average Floor Space: 43560
Average Replacement Cost: 60.63
Average Rental Rate: .50

Summary: Social Function Class 2.
Total Number of Buildings: 1
Average Floor Space: 43560
Average Replacement Cost: 60.63
Average Rental Rate: .50

Buildings Included in Social Function Class: 4, Retail Trade
Facilities Class: 75, URM 1-3 Stories

CENSUS TRACT	BLOCK	NUMBER	YEAR OF CONST.	STORIES	TOTAL AREA
92	306	3	1900	3	15840
92	365	8	1890	1	9900
92	365	9	1890	3	10800
92	365	11	1890	3	5400
81	302	2	1840	3	24624

Total Number of Buildings: 5 Total Floor Area: 66564

Summary: Social Function Class 4, Facilities Class 75.
Total Number of Buildings: 5

Average Floor Space:	13313
Average Replacement Cost:	31.68
Average Rental Rate:	.26

Facilities Class: 75, URM:Strengthened 1-3 Stories

CENSUS TRACT	BLOCK	NUMBER	YEAR OF CONST.	STORIES	TOTAL AREA
92	306	5	1900	3	44550
92	304	3	1890	3	20520

Total Number of Buildings: 2 Total Floor Area: 65070

Summary: Social Function Class 4, Facilities Class 75.

Total Number of Buildings:	2
Average Floor Space:	32535
Average Replacement Cost:	31.68
Average Rental Rate:	.26

Facilities Class: 76, URM:Strengthened 4-7 Stories

CENSUS TRACT	BLOCK	NUMBER	YEAR OF CONST.	STORIES	TOTAL AREA
92	304	2	1890	5	17100

Total Number of Buildings: 1 Total Floor Area: 17100

Summary: Social Function Class 4, Facilities Class 76.
Total Number of Buildings: 1
Average Floor Space: 17100
Average Replacement Cost: 41.98
Average Rental Rate: .35

Summary: Social Function Class 4.
Total Number of Buildings: 8
Average Floor Space: 18592
Average Replacement Cost: 32.97
Average Rental Rate: .27

Buildings Included in Social Function Class: 7, Professional, Technical & Business

Facilities Class: 75, URM 1-3 Stories

CENSUS TRACT	BLOCK	NUMBER	YEAR OF CONST.	STORIES	TOTAL AREA
92	306	8	1900	3	4500
81	305	2	1890	3	9990

Total Number of Buildings: 2 Total Floor Area: 14490

Summary: Social Function Class 7, Facilities Class 75.
Total Number of Buildings: 2
Average Floor Space: 7245
Average Replacement Cost: 46.29
Average Rental Rate: .38

Facilities Class: 76, URM 4-7 Stories

CENSUS TRACT	BLOCK	NUMBER	YEAR OF CONST.	STORIES	TOTAL AREA
91	306	4	1898	4	40320

Total Number of Buildings: 1 Total Floor Area: 40320

Summary: Social Function Class 7, Facilities Class 76.
Total Number of Buildings: 1
Average Floor Space: 40320
Average Replacement Cost: 52.45
Average Rental Rate: .44

Facilities Class: 75, URM:Strengthened 1-3 Stories

CENSUS TRACT	BLOCK	NUMBER	YEAR OF CONST.	STORIES	TOTAL AREA
92	306	1	1900	3	4700
92	365	3	1890	3	11700
92	365	5	1890	2	2400
92	365	6	1890	1	3060
81	306	1	1900	3	28200
81	302	5	1900	3	14000
81	304	2	1900	3	19980
81	305	3	1890	3	10800

Total Number of Buildings: 8 Total Floor Area: 94840

Summary: Social Function Class 7, Facilities Class 75.
Total Number of Buildings: 8
Average Floor Space: 11855

Average Replacement Cost:	46.29
Average Rental Rate:	.38

Facilities Class: 76, URM:Strengthened 4-7 Stories

CENSUS TRACT	BLOCK	NUMBER	YEAR OF CONST.	STORIES	TOTAL AREA
92	306	4	1900	5	33852
92	306	6	1900	5	32400
92	304	1	1890	4	68400
92	365	2	1890	4	19200
92	365	4	1890	4	31620
81	302	3	1900	7	75600
81	302	4	1900	6	19980
81	302	6	1900	6	66600
81	305	5	1897	6	48118

Total Number of Buildings: 9 Total Floor Area: 395770

Summary: Social Function Class 7, Facilities Class 76.
Total Number of Buildings: 9
Average Floor Space: 43974
Average Replacement Cost: 52.45
Average Rental Rate: .44

Facilities Class: 86, R Masonry Shear Wall(with moment res. frame) 8+ Stories

CENSUS TRACT	BLOCK	NUMBER	YEAR OF CONST.	STORIES	TOTAL AREA
81	302	1	1900	10	55500

Total Number of Buildings: 1 Total Floor Area: 55500

Summary: Social Function Class 7, Facilities Class 86.
Total Number of Buildings: 1
Average Floor Space: 55500
Average Replacement Cost: 73.57
Average Rental Rate: .61

Facilities Class: 14, Braced Steel Frame 8+ Stories

CENSUS TRACT	BLOCK	NUMBER	YEAR OF CONST.	STORIES	TOTAL AREA
81	304	1	1910	19	122220

Total Number of Buildings: 1 Total Floor Area: 122220

Summary: Social Function Class 7, Facilities Class 14.
Total Number of Buildings: 1
Average Floor Space: 122220
Average Replacement Cost: 73.57
Average Rental Rate: .61

Facilities Class: 74, Dectile Moment Resisting Steel Frame 8+ Stories

CENSUS TRACT	BLOCK	NUMBER	YEAR OF CONST.	STORIES	TOTAL AREA
92	365	1	1983	8	52800

Total Number of Buildings: 1 Total Floor Area: 52800

Summary: Social Function Class 7, Facilities Class 74.
Total Number of Buildings: 1
Average Floor Space: 52800
Average Replacement Cost: 73.57
Average Rental Rate: .61

Summary: Social Function Class 7.
Total Number of Buildings: 23
Average Floor Space: 33737
Average Replacement Cost: 52.52
Average Rental Rate: .44

Buildings Included in Social Function Class: 9, Entertainment and Recreation
Facilities Class: 75, URM 1-3 Stories

CENSUS TRACT	BLOCK	NUMBER	YEAR OF CONST.	STORIES	TOTAL AREA
92	365	7	1890	1	3000

Total Number of Buildings: 1 Total Floor Area: 3000

Summary: Social Function Class 9, Facilities Class 75.

Total Number of Buildings:	1
Average Floor Space:	3000
Average Replacement Cost:	47.43
Average Rental Rate:	.39

Summary: Social Function Class 9.
Total Number of Buildings: 1
Average Floor Space: 3000
Average Replacement Cost: 47.43
Average Rental Rate: .39

Buildings Included in Social Function Class: 10, Parking
Facilities Class: 87, Ordinary Moment Resisting Concrete Frame 1-3 Stories

CENSUS TRACT	BLOCK	NUMBER	YEAR OF CONST.	STORIES	TOTAL AREA
81	304	3	1962	2	39960

Total Number of Buildings: 1 Total Floor Area: 39960

Summary: Social Function Class 10, Facilities Class 87.
Total Number of Buildings: 1
Average Floor Space: 39960
Average Replacement Cost: 23.85
Average Rental Rate: .20

Facilities Class: 83, Precast Concrete Lateral Force Resisting System 8+ Stories

CENSUS TRACT	BLOCK	NUMBER	YEAR OF CONST.	STORIES	TOTAL AREA
81	305	1	1970	10	236550

Total Number of Buildings: 1 Total Floor Area: 236550

Summary: Social Function Class 10, Facilities Class 83.
Total Number of Buildings: 1
Average Floor Space: 236550
Average Replacement Cost: 33.79
Average Rental Rate: .28

Summary: Social Function Class 10.
Total Number of Buildings: 2
Average Floor Space: 138255
Average Replacement Cost: 28.82
Average Rental Rate: .24

Buildings Included in Social Function Class: 12, Light Fabrication, Assembly & Rep
Facilities Class: 75, URM 1-3 Stories

CENSUS TRACT	BLOCK	NUMBER	YEAR OF CONST.	STORIES	TOTAL AREA
81	306	2	1900	1	9230

Total Number of Buildings: 1 Total Floor Area: 9230

Summary: Social Function Class 12, Facilities Class 75.
Total Number of Buildings: 1
Average Floor Space: 9230
Average Replacement Cost: 24.99
Average Rental Rate: .21

Summary: Social Function Class 12.
Total Number of Buildings: 1
Average Floor Space: 9230
Average Replacement Cost: 24.99
Average Rental Rate: .21

Buildings Included in Social Function Class: 30, Utilities: Water
Facilities Class: 75, URM 1-3 Stories

CENSUS TRACT	BLOCK	NUMBER	YEAR OF CONST.	STORIES	TOTAL AREA

81	306	3	1900	3	30240

Total Number of Buildings: 1 Total Floor Area: 30240

Summary: Social Function Class 30, Facilities Class 75.

Total Number of Buildings:	1
Average Floor Space:	30240
Average Replacement Cost:	24.99
Average Rental Rate:	.21

Summary: Social Function Class 30.

Total Number of Buildings:	1
Average Floor Space:	30240
Average Replacement Cost:	24.99
Average Rental Rate:	.21

Buildings Included in Social Function Class: 99, Vacant

Facilities Class: 75, URM 1-3 Stories

CENSUS TRACT	BLOCK	NUMBER	YEAR OF CONST.	STORIES	TOTAL AREA
92	365	10	1890	3	3600

Total Number of Buildings: 1 Total Floor Area: 3600

Summary: Social Function Class 99, Facilities Class 75.

Total Number of Buildings:	1
Average Floor Space:	3600
Average Replacement Cost:	22.09
Average Rental Rate:	.18

Facilities Class: 76, URM 4-7 Stories

CENSUS TRACT	BLOCK	NUMBER	YEAR OF CONST.	STORIES	TOTAL AREA
92	306	7	1900	4	15120
92	306	7	1900	5	54000

Total Number of Buildings: 2 Total Floor Area: 69120

Summary: Social Function Class 99, Facilities Class 76.

Total Number of Buildings:	2
Average Floor Space:	34560
Average Replacement Cost:	23.14
Average Rental Rate:	.19

Summary: Social Function Class 99.

Total Number of Buildings:	3
Average Floor Space:	24240
Average Replacement Cost:	22.79
Average Rental Rate:	.19

Summary: Soil Type S-3.

Total Number of Buildings:	41
Average Floor Space:	33531
Average Replacement Cost:	44.29
Average Rental Rate:	.37

Summary: Seattle Inventory.

Total Number of Buildings:	67
Average Floor Space:	53932
Average Replacement Cost:	46.05
Average Rental Rate:	.38

Table E-3. Facility Function Class Assumptions.

	Relocation Costs ($/sq.ft /month)	Income ($/sq.ft. /year)	Business Inventory ($/sq.ft. /year)	Personal Property (% Rep. value)	Number of Occupants Day (#/1000 sq.ft.)	Night
RESIDENTIAL						
1 Permanent	$1.50			49%	1.20	3.10
2 Temporary	$1.50			21%	0.60	2.50
3 Inst.	$1.50			21%	2.00	3.00
COMMERCIAL						
4 Retail	$1.50	$80	$20	9%	10.00	
5 Wholesale	$1.50	$35	$100	12%	1.00	
6 Pers&Repair	$1.50	$50		25%	4.00	0.10
7 Prof.	$1.50	$100	$0	34%	4.00	
8 Health Care	$1.50	$100		185%	5.00	2.00
9 Entert.	$1.50	$15		20%	6.00	
10 Parking	$1.50	$15		40%	0.20	
INDUSTRIAL						
11 Heavy	$1.50	$50	$30	70%	3.00	0.30
12 Light	$1.50	$75	$25	60%	5.00	0.30
13 Food&Drug	$1.50	$35	$25	60%	2.50	0.30
14 Chemicals	$1.50	$50	$25	60%	2.50	0.30
15 Metal	$1.50	$60	$15	85%	1.20	0.10
16 High Tech.	$1.50	$75	$45	90%	3.00	0.30
17 Const.	$1.50		$5	58%	4.00	0.10
RELIGION & NONPROFIT						
21	$1.50			34%	65.00	
GOVERNMENT						
22 General	$1.50			34%	4.00	
23 Emergency	$1.50			80%	3.00	0.40
EDUCATION						
24	$1.50			45%	20.00	
COMMUNICATION (Radio and TV)						
34	$1.50			95%	4.00	1.00

Table E-4. SCENARIO DAMAGES & ECONOMIC LOSSES, Seattle Normal Soils.

INDEX 1 = TEMPRES2 INDEX 2 = WOOD1

	BLDG_DAM	RENT_LOSS	RELOC_EXP	PERS_PROP	TOTAL
VI	5928	42	143	1245	7357
VII	12981	177	603	2726	16486
VIII	18058	607	2070	3792	24528
IX	29972	4036	13760	6294	54063
X	60217	9878	33677	12646	116418
XI	74416	15400	52501	15627	157945
XII	130545	15400	52501	27414	225861

INDEX 1 = TEMPRES2 INDEX 2 = URM76

	BLDG_DAM	RENT_LOSS	RELOC_EXP	PERS_PROP	TOTAL
VI	607621	1462	4138	127600	740821
VII	1210168	6180	17491	254135	1487975
VIII	3179220	21232	60091	667636	3928180
IX	6028888	141116	399386	1266066	7835456
X	8270192	345364	977447	1736740	11329744
XI	9246309	538415	1523816	1941725	13250265
XII	10228127	538415	1523816	2147907	14438265

INDEX 1 = TEMPRES2 INDEX 2 = TOTAL

	BLDG_DAM	RENT_LOSS	RELOC_EXP	PERS_PROP	TOTAL
VI	613549	1504	4280	128845	748178
VII	1223149	6357	18094	256861	1504461
VIII	3197279	21840	62162	671429	3952709
IX	6058859	145153	413146	1272360	7889519
X	8330410	355243	1011123	1749386	11446162
XI	9320725	553815	1576317	1957352	13408210
XII	10358672	553815	1576317	2175321	14664125

INDEX 1 = RETAIL4 INDEX 2 = RIC6

	BLDG_DAM	RENT_LOSS	RELOC_EXP	INC_LOSS	BUS_INV	PERS_PROP	TOTAL
VI	6012	514	2203	9658	2864	541	21792
VII	24855	1826	7828	34314	11842	2237	82902
VIII	34009	6762	28979	127029	16203	3061	216042
IX	65614	19000	81428	356943	31260	5905	560149
X	110063	35647	152772	669688	52436	9906	1030512
XI	198174	52456	224811	985471	94414	17836	1573161
XII	258293	52456	224811	985471	123055	23246	1667332

INDEX 1 = RETAIL4 INDEX 2 = TOTAL

	BLDG_DAM	RENT_LOSS	RELOC_EXP	INC_LOSS	BUS_INV	PERS_PROP	TOTAL
VI	6012	514	2203	9658	2864	541	21792
VII	24855	1826	7828	34314	11842	2237	82902
VIII	34009	6762	28979	127029	16203	3061	216042
IX	65614	19000	81428	356943	31260	5905	560149
X	110063	35647	152772	669688	52436	9906	1030512
XI	198174	52456	224811	985471	94414	17836	1573161
XII	258293	52456	224811	985471	123055	23246	1667332

INDEX 1 = PROFES7 INDEX 2 = URM75

	BLDG_DAM	RENT_LOSS	RELOC_EXP	INC_LOSS	PERS_PROP	TOTAL

VI	162901	3273	12920	70794	55386	305273
VII	334667	11629	45903	251525	113787	757511
VIII	735612	43050	169934	931144	250108	2129848
IX	1477557	120967	477502	2616448	502370	5194843
X	2341225	226955	895876	4908911	796016	9168984
XI	2734888	333974	1318317	7223653	929862	12540693
XII	3094603	333974	1318317	7223653	1052165	13022711

INDEX 1 = PROFES7 INDEX 2 = URM76

	BLDG_DAM	RENT_LOSS	RELOC_EXP	INC_LOSS	PERS_PROP	TOTAL
VI	101206	1767	13954	76458	34410	227795
VII	201567	6280	49576	271651	68533	597606
VIII	529534	23247	183531	1005649	180041	1922002
IX	1004176	65323	515709	2825801	341420	4752429
X	1377490	122557	967559	5301693	468347	8237646
XI	1540073	180348	1423801	7801648	523625	11469494
XII	1703605	180348	1423801	7801648	579226	11688627

INDEX 1 = PROFES7 INDEX 2 = RIC4

	BLDG_DAM	RENT_LOSS	RELOC_EXP	INC_LOSS	PERS_PROP	TOTAL
VI	22636	2636	8986	49236	7696	91189
VII	119278	9365	31925	174932	40555	376054
VIII	170774	34668	118186	647595	58063	1029285
IX	335725	97414	332094	1819695	114147	2699075
X	553351	182766	623067	3414063	188139	4961386
XI	925670	268948	916867	5023927	314728	7450139
XII	1288702	268948	916867	5023927	438159	7936602

INDEX 1 = PROFES7 INDEX 2 = RIC8

	BLDG_DAM	RENT_LOSS	RELOC_EXP	INC_LOSS	PERS_PROP	TOTAL
VI	293840	10561	25970	142301	99905	572577
VII	669554	37523	92269	505586	227648	1532581
VIII	1223910	138909	341580	1871673	416130	3992203
IX	2544475	390325	959816	5259267	865122	10019005
X	4434287	732318	1800782	9867299	1507658	18342344
XI	6216207	1077634	2649921	14520114	2113510	26577385
XII	7895290	1077634	2649921	14520114	2684399	28827358

INDEX 1 = PROFES7 INDEX 2 = BSF13

	BLDG_DAM	RENT_LOSS	RELOC_EXP	INC_LOSS	PERS_PROP	TOTAL
VI	57927	3152	10744	58871	19695	150389
VII	165742	11197	38173	209166	56352	480630
VIII	228724	41452	141315	774330	77766	1263588
IX	375240	116478	397086	2175812	127582	3192197
X	571810	218534	745002	4082201	194415	5811961
XI	974231	321581	1096299	6007117	331239	8730467
XII	1405824	321581	1096299	6007117	477980	9308800

INDEX 1 = PROFES7 INDEX 2 = MRSPF17

	BLDG_DAM	RENT_LOSS	RELOC_EXP	INC_LOSS	PERS_PROP	TOTAL
VI	884490	59709	146826	804524	300727	2196275
VII	2808192	212143	521663	2858426	954785	7355208
VIII	3942080	785350	1931188	10581855	1340307	18580780
IX	8241260	2206777	5426501	29734254	2802028	48410821
X	10674878	4140298	10181060	55786629	3629458	84412323
XI	23942225	6092609	14981825	82092192	8140357	135249208
XII	28647432	6092609	14981825	82092192	9740127	141554185

INDEX 1 = PROFES7 INDEX 2 = MRSDF74

	BLDG_DAM	RENT_LOSS	RELOC_EXP	INC_LOSS	PERS_PROP	TOTAL
VI	154513	15124	37191	203788	52534	463150

VII	643158	53736	132138	724045	218674	1771752
VIII	865673	198931	489174	2680407	294329	4528513
IX	1467869	558981	1374544	7531751	499075	11432221
X	2288717	1048746	2578884	14130873	778164	20825384
XI	3628630	1543271	3794928	20794129	1233734	30994693
XII	5216408	1543271	3794928	20794129	1773579	33122314

INDEX 1 = PROFES7 INDEX 2 = MRNDC87

	BLDG_DAM	RENT_LOSS	RELOC_EXP	INC_LOSS	PERS_PROP	TOTAL
VI	12682	431	1469	8048	4312	26942
VII	22887	1531	5219	28595	7782	66013
VIII	51253	5667	19319	105858	17426	199523
IX	79758	15924	54285	297453	27118	474537
X	143201	29876	101848	558073	48688	881686
XI	218110	43963	149874	821226	74157	1307330
XII	295080	43963	149874	821226	100327	1410470

INDEX 1 = PROFES7 INDEX 2 = MRNDC88

	BLDG_DAM	RENT_LOSS	RELOC_EXP	INC_LOSS	PERS_PROP	TOTAL
VI	122168	3231	11016	60362	41537	238315
VII	178996	11481	39139	214461	60859	504936
VIII	402753	42502	144893	793933	136936	1521017
IX	839834	119427	407138	2230895	285543	3882838
X	1228142	224066	763862	4185547	417568	6819186
XI	1806781	329722	1124053	6159196	614305	10034057
XII	2378792	329722	1124053	6159196	808789	10800553

INDEX 1 = PROFES7 INDEX 2 = MRNDC89

	BLDG_DAM	RENT_LOSS	RELOC_EXP	INC_LOSS	PERS_PROP	TOTAL
VI	240315	5974	14691	80496	81707	423184
VII	365623	21226	52195	285998	124312	849353
VIII	766085	78578	193224	1058761	260469	2357117
IX	1485760	220798	542945	2975044	505158	5729705
X	2612636	414255	1018660	5581699	888296	10515546
XI	3638745	609592	1498998	8213687	1237173	15198195
XII	4846679	609592	1498998	8213687	1647871	16816827

INDEX 1 = PROFES7 INDEX 2 = TOTAL

	BLDG_DAM	RENT_LOSS	RELOC_EXP	INC_LOSS	PERS_PROP	TOTAL
VI	2052677	105859	283765	1554877	697910	4695088
VII	5509664	376110	1008200	5524386	1873286	14291646
VIII	8916398	1392354	3732345	20451203	3031575	37523875
IX	17851654	3912416	10487621	57466418	6069562	95787671
X	26225736	7340372	19676600	107816988	8916750	169976446
XI	45625560	10801642	28954882	158656887	15512690	259551661
XII	56772416	10801642	28954882	158656887	19302621	274488448

INDEX 1 = ENTERT9 INDEX 2 = URM75

	BLDG_DAM	RENT_LOSS	RELOC_EXP	INC_LOSS	PERS_PROP	TOTAL
VI	18976	382	1469	1207	3795	25829
VII	38984	1357	5219	4289	7797	57645
VIII	85688	5023	19319	15879	17138	143046
IX	172114	14114	54285	44618	34423	319554
X	272719	26457	101758	83636	54544	539113
XI	318575	38967	149874	123184	63715	694315

XII	360476	38967	149874	123184	72095	744596

INDEX 1 = ENTERT9 INDEX 2 = TOTAL

	BLDG_DAM	RENT_LOSS	RELOC_EXP	INC_LOSS	PERS_PROP	TOTAL
VI	18976	382	1469	1207	3795	25829
VII	38984	1357	5219	4289	7797	57645
VIII	85688	5023	19319	15879	17138	143046
IX	172114	14114	54285	44618	34423	319554
X	272719	26457	101758	83636	54544	539113
XI	318575	38967	149874	123184	63715	694315
XII	360476	38967	149874	123184	72095	744596

INDEX 1 = PARK10 INDEX 2 = URM75

	BLDG_DAM	RENT_LOSS	RELOC_EXP	INC_LOSS	PERS_PROP	TOTAL
VI	73551	98	733	602	29421	104404
VII	151105	1461	10956	9005	60442	232969
VIII	332137	6997	52481	43135	132855	567604
IX	667132	23585	176890	145389	266853	1279849
X	1057087	57183	428871	352496	422835	2318472
XI	1234830	113753	853146	701216	493932	3396877
XII	1397245	113753	853146	701216	558898	3624257

INDEX 1 = PARK10 INDEX 2 = RIC6

	BLDG_DAM	RENT_LOSS	RELOC_EXP	INC_LOSS	PERS_PROP	TOTAL
VI	5567	31	132	108	2227	8064
VII	23014	461	1974	1622	9206	36277
VIII	31490	2206	9456	7772	12596	63521
IX	60753	7437	31872	26196	24301	150560
X	101911	18031	77274	63513	40764	301492
XI	183495	35868	153720	126345	73398	572826
XII	239160	35868	153720	126345	95664	650757

INDEX 1 = PARK10 INDEX 2 = MRNDC88

	BLDG_DAM	RENT_LOSS	RELOC_EXP	INC_LOSS	PERS_PROP	TOTAL
VI	51026	87	655	538	20410	72716
VII	74761	1305	9791	8047	29904	123809
VIII	168217	6254	46902	38549	67287	327208
IX	350771	21078	158085	129933	140309	800176
X	512955	51104	383279	315024	205182	1467544
XI	754634	101660	762451	626672	301854	2547271
XII	993544	101660	762451	626672	397418	2881746

INDEX 1 = PARK10 INDEX 2 = PCC81

	BLDG_DAM	RENT_LOSS	RELOC_EXP	INC_LOSS	PERS_PROP	TOTAL
VI	6495	17	158	130	2598	9399
VII	12728	253	2369	1947	5091	22387
VIII	22001	1210	11347	9326	8801	52686
IX	57224	4080	38246	31435	22889	153874
X	108175	9891	92729	76215	43270	330280
XI	141947	19676	184464	151614	56779	554480
XII	177288	19676	184464	151614	70915	603957

INDEX 1 = PARK10 INDEX 2 = PCC82

	BLDG_DAM	RENT_LOSS	RELOC_EXP	INC_LOSS	PERS_PROP	TOTAL
VI	100646	294	2208	1815	40259	145223

VII	227939	4403	33025	27144	91175	383686
VIII	401796	21093	158199	130026	160718	871832
IX	1141968	71096	533219	438262	456787	2641331
X	2092890	172373	1292794	1062570	837156	5457783
XI	2655016	342898	2571736	2113755	1062006	8745411
XII	3324635	342898	2571736	2113755	1329854	9682878

INDEX 1 = PARK10 INDEX 2 = TOTAL

	BLDG_DAM	RENT_LOSS	RELOC_EXP	INC_LOSS	PERS_PROP	TOTAL
VI	237285	527	3886	3194	94914	339806
VII	489547	7883	58115	47765	195819	799128
VIII	955640	37761	278385	228809	382256	1882851
IX	2277849	127276	938312	771215	911139	5025790
X	3873017	308581	2274947	1869819	1549207	9875570
XI	4969921	613855	4525517	3719603	1987968	15816865
XII	6131872	613855	4525517	3719603	2452749	17443596

INDEX 1 = TOTAL INDEX 2 = WOOD1

	BLDG_DAM	RENT_LOSS	RELOC_EXP	PERS_PROP	TOTAL
VI	5928	42	143	1245	7357
VII	12981	177	603	2726	16486
VIII	18058	607	2070	3792	24528
IX	29972	4036	13760	6294	54063
X	60217	9878	33677	12646	116418
XI	74416	15400	52501	15627	157945
XII	130545	15400	52501	27414	225861

INDEX 1 = TOTAL INDEX 2 = URM75

	BLDG_DAM	RENT_LOSS	RELOC_EXP	INC_LOSS	PERS_PROP	TOTAL
VI	255428	3753	15121	72603	88602	435506
VII	524756	14446	62078	264819	182026	1048125
VIII	1153437	55070	241734	990157	400100	2840499
IX	2316804	158667	708676	2806454	803645	6794246
X	3671030	310595	1426505	5345044	1273395	12026568
XI	4288293	486694	2321336	8048053	1487509	16631885
XII	4852324	486694	2321336	8048053	1683158	17391565

INDEX 1 = TOTAL INDEX 2 = URM76

	BLDG_DAM	RENT_LOSS	RELOC_EXP	INC_LOSS	PERS_PROP	TOTAL
VI	708827	3229	18091	76458	162010	968616
VII	1411734	12460	67068	271651	322668	2085581
VIII	3708754	44479	243622	1005649	847678	5850182
IX	7033064	206439	915094	2825801	1607486	12587885
X	9647682	467922	1945006	5301693	2205087	19567390
XI	10786382	718763	2947617	7801648	2465350	24719759
XII	11931732	718763	2947617	7801648	2727132	26126892

INDEX 1 = TOTAL INDEX 2 = RIC4

	BLDG_DAM	RENT_LOSS	RELOC_EXP	INC_LOSS	PERS_PROP	TOTAL
VI	22636	2636	8986	49236	7696	91189
VII	119278	9365	31925	174932	40555	376054
VIII	170774	34668	118186	647595	58063	1029285
IX	335725	97414	332094	1819695	114147	2699075
X	553351	182766	623067	3414063	188139	4961386
XI	925670	268948	916867	5023927	314728	7450139

XII	1288702	268948	916867	5023927	438159	7936602

INDEX 1 = TOTAL INDEX 2 = RIC6

	BLDG_DAM	RENT_LOSS	RELOC_EXP	INC_LOSS	BUS_INV	PERS_PROP	TOTAL
VI	11578	545	2335	9766	2864	2768	29857
VII	47870	2287	9802	35936	11842	11443	119179
VIII	65499	8968	38435	134801	16203	15657	279563
IX	126367	26437	113300	383139	31260	30207	710709
X	211974	53678	230046	733200	52436	50670	1332005
XI	381669	88324	378531	1111817	94414	91234	2145987
XII	497453	88324	378531	1111817	123055	118910	2318089

INDEX 1 = TOTAL INDEX 2 = RIC8

	BLDG_DAM	RENT_LOSS	RELOC_EXP	INC_LOSS	PERS_PROP	TOTAL
VI	293840	10561	25970	142301	99905	572577
VII	669554	37523	92269	505586	227648	1532581
VIII	1223910	138909	341580	1871673	416130	3992203
IX	2544475	390325	959816	5259267	865122	10019005
X	4434287	732318	1800782	9867299	1507658	18342344
XI	6216207	1077634	2649921	14520114	2113510	26577385
XII	7895290	1077634	2649921	14520114	2684399	28827358

INDEX 1 = TOTAL INDEX 2 = BSF13

	BLDG_DAM	RENT_LOSS	RELOC_EXP	INC_LOSS	PERS_PROP	TOTAL
VI	57927	3152	10744	58871	19695	150389
VII	165742	11197	38173	209166	56352	480630
VIII	228724	41452	141315	774330	77766	1263588
IX	375240	116478	397086	2175812	127582	3192197
X	571810	218534	745002	4082201	194415	5811961
XI	974231	321581	1096299	6007117	331239	8730467
XII	1405824	321581	1096299	6007117	477980	9308800

INDEX 1 = TOTAL INDEX 2 = MRSPF17

	BLDG_DAM	RENT_LOSS	RELOC_EXP	INC_LOSS	PERS_PROP	TOTAL
VI	884490	59709	146826	804524	300727	2196275
VII	2808192	212143	521663	2858426	954785	7355208
VIII	3942080	785350	1931188	10581855	1340307	18580780
IX	8241260	2206777	5426501	29734254	2802028	48410821
X	10674878	4140298	10181060	55786629	3629458	84412323
XI	23942225	6092609	14981825	82092192	8140357	135249208
XII	28647432	6092609	14981825	82092192	9740127	141554185

INDEX 1 = TOTAL INDEX 2 = MRSDF74

	BLDG_DAM	RENT_LOSS	RELOC_EXP	INC_LOSS	PERS_PROP	TOTAL
VI	154513	15124	37191	203788	52534	463150
VII	643158	53736	132138	724045	218674	1771752
VIII	865673	198931	489174	2680407	294329	4528513
IX	1467869	558981	1374544	7531751	499075	11432221
X	2288717	1048746	2578884	14130873	778164	20825384
XI	3628630	1543271	3794928	20794129	1233734	30994693
XII	5216408	1543271	3794928	20794129	1773579	33122314

INDEX 1 = TOTAL INDEX 2 = MRNDC87

	BLDG_DAM	RENT_LOSS	RELOC_EXP	INC_LOSS	PERS_PROP	TOTAL

VI	12682	431	1469	8048	4312	26942
VII	22887	1531	5219	28595	7782	66013
VIII	51253	5667	19319	105858	17426	199523
IX	79758	15924	54285	297453	27118	474537
X	143201	29876	101848	558073	48688	881686
XI	218110	43963	149874	821226	74157	1307330
XII	295080	43963	149874	821226	100327	1410470

INDEX 1 = TOTAL INDEX 2 = MRNDC88

	BLDG_DAM	RENT_LOSS	RELOC_EXP	INC_LOSS	PERS_PROP	TOTAL
VI	173194	3319	11671	60900	61948	311031
VII	253756	12786	48930	222509	90763	628745
VIII	570970	48755	191795	832483	204223	1848225
IX	1190605	140505	565224	2360828	425852	4683014
X	1741097	275170	1147141	4500571	622750	8286730
XI	2561415	431382	1886504	6785868	916159	12581328
XII	3372337	431382	1886504	6785868	1206207	13682298

INDEX 1 = TOTAL INDEX 2 = MRNDC89

	BLDG_DAM	RENT_LOSS	RELOC_EXP	INC_LOSS	PERS_PROP	TOTAL
VI	240315	5974	14691	80496	81707	423184
VII	365623	21226	52195	285998	124312	849353
VIII	766085	78578	193224	1058761	260469	2357117
IX	1485760	220798	542945	2975044	505158	5729705
X	2612636	414255	1018660	5581699	888296	10515546
XI	3638745	609592	1498998	8213687	1237173	15198195
XII	4846679	609592	1498998	8213687	1647871	16816827

INDEX 1 = TOTAL INDEX 2 = PCC81

	BLDG_DAM	RENT_LOSS	RELOC_EXP	INC_LOSS	PERS_PROP	TOTAL
VI	6495	17	158	130	2598	9399
VII	12728	253	2369	1947	5091	22387
VIII	22001	1210	11347	9326	8801	52686
IX	57224	4080	38246	31435	22889	153874
X	108175	9891	92729	76215	43270	330280
XI	141947	19676	184464	151614	56779	554480
XII	177288	19676	184464	151614	70915	603957

INDEX 1 = TOTAL INDEX 2 = PCC82

	BLDG_DAM	RENT_LOSS	RELOC_EXP	INC_LOSS	PERS_PROP	TOTAL
VI	100646	294	2208	1815	40259	145223
VII	227939	4403	33025	27144	91175	383686
VIII	401796	21093	158199	130026	160718	871832
IX	1141968	71096	533219	438262	456787	2641331
X	2092890	172373	1292794	1062570	837156	5457783
XI	2655016	342898	2571736	2113755	1062006	8745411
XII	3324635	342898	2571736	2113755	1329854	9682878

INDEX 1 = TOTAL INDEX 2 = TOTAL

	BLDG_DAM	RENT_LOSS	RELOC_EXP	INC_LOSS	BUS_INV	PERS_PROP	TOTAL
VI	2928498	108786	295603	1568936	2864	926006	5830693
VII	7286198	393533	1097455	5610754	11842	2335999	16735782
VIII	13189014	1463739	4121188	20822921	16203	4105458	43718524
IX	26426089	4217958	11974792	58639194	31260	8293390	109582683

X	38811945	8066299	23217200	110440131	52436	12279792	192867804
XI	60432955	12060736	35431400	163485145	94414	19539562	291044211
XII	73881729	12060736	35431400	163485145	123055	24026033	309008098

Table E-5. EXPECTED DAMAGES AND ECONOMIC LOSSES AVOIDED, Seattle Normal Soils.

INDEX 1 = TEMPRES2 INDEX 2 = WOOD1

	BLDG_DAM	RENT_LOSS	RELOC_EXP	PERS_PROP	TOTAL
VI	412	3	10	86	511
VII	359	5	17	75	456
VIII	169	6	19	35	229
IX	92	12	42	19	166
X	58	9	32	12	112
XI	21	4	15	4	44
XII	9	1	4	2	15
TOTAL	1119	41	139	235	1533

INDEX 1 = TEMPRES2 INDEX 2 = URM76

	BLDG_DAM	RENT_LOSS	RELOC_EXP	PERS_PROP	TOTAL
VI	42187	102	287	8859	51435
VII	33449	171	483	7024	41128
VIII	31489	210	595	6613	38907
IX	21125	494	1399	4436	27455
X	10102	422	1194	2121	13839
XI	3856	225	635	810	5525
XII	1043	55	155	219	1473
TOTAL	143251	1678	4750	30083	179762

INDEX 1 = TEMPRES2 INDEX 2 = TOTAL

	BLDG_DAM	RENT_LOSS	RELOC_EXP	PERS_PROP	TOTAL
VI	42599	104	297	8946	51946
VII	33808	176	500	7100	41583
VIII	31658	216	615	6648	39136
IX	21217	507	1442	4456	27621
X	10160	431	1226	2134	13951
XI	3876	229	650	814	5569
XII	1052	56	159	221	1488
TOTAL	144370	1719	4889	30318	181295

INDEX 1 = RETAIL4 INDEX 2 = RIC6

	BLDG_DAM	RENT_LOSS	RELOC_EXP	INC_LOSS	BUS_INV	PERS_PROP	TOTAL
VI	417	36	153	671	199	38	1513
VII	687	50	216	948	327	62	2291
VIII	337	67	287	1258	160	30	2140
IX	230	67	285	1251	110	21	1963
X	134	44	187	818	64	12	1259
XI	83	22	94	411	39	7	656
XII	26	5	23	101	13	2	170
TOTAL	1915	290	1245	5457	912	172	9992

INDEX 1 = RETAIL4 INDEX 2 = TOTAL

	BLDG_DAM	RENT_LOSS	RELOC_EXP	INC_LOSS	BUS_INV	PERS_PROP	TOTAL
VI	417	36	153	671	199	38	1513
VII	687	50	216	948	327	62	2291
VIII	337	67	287	1258	160	30	2140
IX	230	67	285	1251	110	21	1963
X	134	44	187	818	64	12	1259
XI	83	22	94	411	39	7	656
XII	26	5	23	101	13	2	170

TOTAL	1915	290	1245	5457	912	172	9992

INDEX 1 = PROFES7 INDEX 2 = URM75

	BLDG_DAM	RENT_LOSS	RELOC_EXP	INC_LOSS	PERS_PROP	TOTAL
VI	11310	227	897	4915	3845	21195
VII	9250	321	1269	6952	3145	20938
VIII	7286	426	1683	9223	2477	21095
IX	5177	424	1673	9168	1760	18203
X	2860	277	1094	5996	972	11200
XI	1140	139	550	3012	388	5229
XII	316	34	134	737	107	1328
TOTAL	37340	1849	7301	40003	12695	99188

INDEX 1 = PROFES7 INDEX 2 = URM76

	BLDG_DAM	RENT_LOSS	RELOC_EXP	INC_LOSS	PERS_PROP	TOTAL
VI	7027	123	969	5308	2389	15816
VII	5571	174	1370	7508	1894	16518
VIII	5245	230	1818	9960	1783	19036
IX	3519	229	1807	9902	1196	16653
X	1683	150	1182	6476	572	10062
XI	642	75	594	3253	218	4783
XII	174	18	145	796	59	1192
TOTAL	23860	999	7885	43204	8112	84060

INDEX 1 = PROFES7 INDEX 2 = RIC4

	BLDG_DAM	RENT_LOSS	RELOC_EXP	INC_LOSS	PERS_PROP	TOTAL
VI	629	73	250	1367	214	2533
VII	1319	104	353	1934	448	4158
VIII	705	143	488	2673	240	4248
IX	515	149	509	2790	175	4138
X	314	104	353	1936	107	2814
XI	193	56	191	1047	66	1553
XII	66	14	47	256	22	405
TOTAL	3739	643	2191	12003	1271	19847

INDEX 1 = PROFES7 INDEX 2 = RIC8

	BLDG_DAM	RENT_LOSS	RELOC_EXP	INC_LOSS	PERS_PROP	TOTAL
VI	12241	440	1082	5928	4162	23852
VII	11104	622	1530	8385	3775	25416
VIII	7071	803	1974	10814	2404	23065
IX	5015	769	1892	10366	1705	19747
X	2902	479	1178	6457	987	12003
XI	1296	225	553	3027	441	5541
XII	403	55	135	741	137	1470
TOTAL	40032	3393	8343	45717	13611	111096

INDEX 1 = PROFES7 INDEX 2 = BSF13

	BLDG_DAM	RENT_LOSS	RELOC_EXP	INC_LOSS	PERS_PROP	TOTAL
VI	2815	153	522	2861	957	7309
VII	3207	217	739	4047	1090	9299
VIII	1573	285	972	5326	535	8691
IX	904	281	957	5242	307	7690
X	474	181	618	3384	161	4817
XI	271	89	305	1670	92	2427
XII	96	22	75	408	33	633
TOTAL	9340	1228	4186	22938	3175	40867

INDEX 1 = PROFES7 INDEX 2 = MRSPF17

	BLDG_DAM	RENT_LOSS	RELOC_EXP	INC_LOSS	PERS_PROP	TOTAL
VI	42987	2902	7136	39101	14616	106741
VII	54333	4105	10093	55305	18473	142309
VIII	27114	5402	13283	72783	9219	127801
IX	19853	5316	13072	71630	6750	116622
X	8848	3432	8439	46240	3008	69967
XI	6656	1694	4165	22822	2263	37599
XII	1948	414	1019	5582	662	9626
TOTAL	161739	23264	57207	313463	54991	610665

INDEX 1 = PROFES7 INDEX 2 = MRSDF74

	BLDG_DAM	RENT_LOSS	RELOC_EXP	INC_LOSS	PERS_PROP	TOTAL
VI	7509	735	1808	9904	2553	22510
VII	12444	1040	2557	14009	4231	34280
VIII	5954	1368	3365	18436	2024	31148
IX	3536	1347	3311	18144	1202	27540
X	1897	869	2138	11713	645	17262
XI	1009	429	1055	5781	343	8617
XII	355	105	258	1414	121	2252
TOTAL	32704	5893	14491	79401	11119	143608

INDEX 1 = PROFES7 INDEX 2 = MRNDC87

	BLDG_DAM	RENT_LOSS	RELOC_EXP	INC_LOSS	PERS_PROP	TOTAL
VI	616	21	71	391	210	1309
VII	443	30	101	553	151	1277
VIII	353	39	133	728	120	1372
IX	192	38	131	717	65	1143
X	119	25	84	463	40	731
XI	61	12	42	228	21	363
XII	20	3	10	56	7	96
TOTAL	1803	168	572	3136	613	6292

INDEX 1 = PROFES7 INDEX 2 = MRNDC88

	BLDG_DAM	RENT_LOSS	RELOC_EXP	INC_LOSS	PERS_PROP	TOTAL
VI	5938	157	535	2934	2019	11582
VII	3463	222	757	4149	1177	9769
VIII	2770	292	997	5461	942	10462
IX	2023	288	981	5374	688	9354
X	1018	186	633	3469	346	5652
XI	502	92	312	1712	171	2789
XII	162	22	76	419	55	734
TOTAL	15876	1259	4292	23518	5398	50343

INDEX 1 = PROFES7 INDEX 2 = MRNDC89

	BLDG_DAM	RENT_LOSS	RELOC_EXP	INC_LOSS	PERS_PROP	TOTAL
VI	11680	290	714	3912	3971	20567
VII	7074	411	1010	5533	2405	16433
VIII	5269	540	1329	7282	1792	16213
IX	3579	532	1308	7167	1217	13803
X	2166	343	844	4627	736	8716
XI	1012	169	417	2283	344	4225
XII	330	41	102	559	112	1144
TOTAL	31109	2328	5724	31363	10577	81101

INDEX 1 = PROFES7 INDEX 2 = TOTAL

	BLDG_DAM	RENT_LOSS	RELOC_EXP	INC_LOSS	PERS_PROP	TOTAL
VI	102752	5122	13984	76622	34936	233414
VII	108208	7244	19779	108376	36791	280397
VIII	63340	9529	26040	142686	21536	263131
IX	44314	9373	25641	140498	15067	234892
X	22279	6046	16564	90760	7575	143224
XI	12782	2981	8183	44837	4346	73128
XII	3868	729	2002	10967	1315	18880
TOTAL	357542	41023	112191	614747	121564	1247067

INDEX 1 = ENTERT9 INDEX 2 = URM75

	BLDG_DAM	RENT_LOSS	RELOC_EXP	INC_LOSS	PERS_PROP	TOTAL
VI	1317	27	102	84	263	1793
VII	1078	38	144	119	216	1593
VIII	849	50	191	157	170	1417
IX	603	49	190	156	121	1120
X	333	32	124	102	67	659
XI	133	16	62	51	27	290
XII	37	4	15	13	7	76
TOTAL	4350	216	830	682	870	6947

Table E-6. BENEFITS AND COSTS OF REHABILITATION WITHOUT VALUE OF LIFE, Seattle Normal Soils.

INDEX 1 = TEMPRES2

	WOOD1	URM76	TOTAL
PV LOSSES	20829.43	2443028.10	2463857.53
RETRO COST	77760.00	3291382.50	3369142.50
SALVAGE V	3548.86	150214.40	153763.27
B-C	-53381.70	-698140.00	-751521.70
B/C	0.28	0.78	0.77

INDEX 1 = RETAIL4

	RIC6	TOTAL
PV LOSSES	135792.50	135792.50
RETRO COST	246240.00	246240.00
SALVAGE V	11238.07	11238.07
B-C	-99209.43	-99209.43
B/C	0.58	0.58

INDEX 1 = PROFES7

	URM75	URM76	RIC4	RIC8	BSF13	MRSPF17	MRSDF74	MRNDC87
PV LOSSES	1348000.71	1142401.78	269732.80	1509830.79	555393.91	8299130.55	1951676.88	85514.04
RETRO COST	1329982.50	1436400.00	449276.00	2902516.00	884800.00	12091520.00	3062808.00	151200.00
SALVAGE V	60698.67	65555.42	20504.37	132467.04	40381.12	551841.19	139782.56	6900.57
B-C	78716.88	-228442.80	-159038.83	-1260218.16	-289024.97	-3240548.26	-971348.56	-58785.39
B/C	1.06	0.83	0.63	0.55	0.66	0.72	0.67	0.59

+	MRNDC88	MRNDC89	TOTAL
PV LOSSES	684184.42	1102182.92	16948048.81
RETRO COST	1134000.00	1512262.50	24954765.00
SALVAGE V	51754.28	69017.69	1138902.90
B-C	-398061.30	-341061.89	-6867813.29
B/C	0.63	0.76	0.71

INDEX 1 = ENTERT9

	URM75	TOTAL
PV LOSSES	94413.61	94413.61
RETRO COST	151200.00	151200.00
SALVAGE V	6900.57	6900.57
B-C	-49885.82	-49885.82
B/C	0.65	0.65

INDEX 1 = PARK10

	URM75	RIC6	MRNDC88	PCC81	PCC82	TOTAL
PV LOSSES	386137.27	46109.70	166185.94	33308.72	548566.81	1180308.43
RETRO COST	1165500.00	228000.00	1041600.00	273600.00	3814440.00	6523140.00
SALVAGE V	53191.90	10405.62	47537.26	12486.75	174086.06	297707.59
B-C	-726170.83	-171484.68	-827876.79	-227804.54	-3091787.13	-5045123.97
B/C	0.35	0.21	0.17	0.13	0.15	0.19

INDEX 1 = TOTAL

	WOOD1	URM75	URM76	RIC4	RIC6	RIC8	BSF13	MRSPF17
PV LOSSES	20829.43	1828551.59	3585429.88	269732.80	181902.19	1509830.79	555393.91	8299130.55
RETRO COST	77760.00	2646682.50	4727782.50	449276.00	474240.00	2902516.00	884800.00	12091520.00
SALVAGE V	3548.86	120791.13	215769.82	20504.37	21643.69	132467.04	40381.12	551841.19
B-C	-53381.70	-697339.77	-926582.80	-159038.83	-270694.11	-1260218.16	-289024.97	-3240548.26
B/C	0.28	0.72	0.79	0.63	0.40	0.55	0.66	0.72

+	MRSDF74	MRNDC87	MRNDC88	MRNDC89	PCC81	PCC82	TOTAL
PV LOSSES	1951676.88	85514.04	850370.36	1102182.92	33308.72	548566.81	20822420.88
RETRO COST	3062808.00	151200.00	2175600.00	1512262.50	273600.00	3814440.00	35244487.50
SALVAGE V	139782.56	6900.57	99291.54	69017.69	12486.75	174086.06	1608512.40
B-C	-971348.56	-58785.39	-1225938.09	-341061.89	-227804.54	-3091787.13	-1.28136E+7
B/C	0.67	0.59	0.41	0.76	0.13	0.15	0.62

Table E-7. SCENARIO DEATH LOSS, Seattle Normal Soils.

INDEX 1 = TEMPRES2

	WOOD1	URM76	TOTAL
CDFHALF	0.000001	0.000292	0.000293
CDF5	0.000010	0.002915	0.002925
CDF15	0.000100	0.029152	0.029253
CDF45	0.001004	0.291522	0.292527
CDF80	0.010044	2.915224	2.925268
CDF100	0.200880	58.304490	58.505370

INDEX 1 = RETAIL4

	RIC6	TOTAL
CDFHALF	0.000065	0.000065
CDF5	0.000648	0.000648
CDF15	0.006480	0.006480
CDF45	0.064800	0.064800
CDF80	0.648000	0.648000
CDF100	12.960000	12.960000

INDEX 1 = PROFES7

	URM75	URM76	RIC4	RIC8	BSF13	MRSPF17	MRSDF74	MRNDC87
CDFHALF	0.000152	0.000164	0.000106	0.000306	0.000126	0.001727	0.000438	0.000017
CDF5	0.001520	0.001642	0.001057	0.003055	0.001264	0.017274	0.004375	0.000173
CDF15	0.015200	0.016416	0.010571	0.030553	0.012640	0.172736	0.043754	0.001728
CDF45	0.151998	0.164160	0.105712	0.305528	0.126400	1.727360	0.437544	0.017280
CDF80	1.519980	1.641600	1.057120	3.055280	1.264000	17.273600	4.375440	0.172800
CDF100	30.399600	32.832000	21.142400	61.105600	25.280000	345.472000	87.508800	3.456000

+	MRNDC88	MRNDC89	TOTAL
CDFHALF	0.000130	0.000173	0.003338
CDF5	0.001296	0.001728	0.033384
CDF15	0.012960	0.017283	0.333841
CDF45	0.129600	0.172830	3.338412
CDF80	1.296000	1.728300	33.384120
CDF100	25.920000	34.566000	667.682400

INDEX 1 = ENTERT9

	URM75	TOTAL
CDFHALF	0.000026	0.000026
CDF5	0.000259	0.000259
CDF15	0.002592	0.002592
CDF45	0.025920	0.025920
CDF80	0.259200	0.259200
CDF100	5.184000	5.184000

INDEX 1 = PARK10

	URM75	RIC6	MRNDC88	PCC81	PCC82	TOTAL
CDFHALF	0.000007	0.000001	0.000006	0.000001	0.000020	0.000035
CDF5	0.000067	0.000012	0.000060	0.000014	0.000201	0.000353
CDF15	0.000666	0.000120	0.000595	0.000144	0.002008	0.003533
CDF45	0.006660	0.001200	0.005952	0.001440	0.020076	0.035328
CDF80	0.066600	0.012000	0.059520	0.014400	0.200760	0.353280
CDF100	1.332000	0.240000	1.190400	0.288000	4.015200	7.065600

INDEX 1 = TOTAL

	WOOD1	URM75	URM76	RIC4	RIC6	RIC8	BSF13	MRSPF17
CDFHALF	0.000001	0.000185	0.000456	0.000106	0.000066	0.000306	0.000126	0.001727
CDF5	0.000010	0.001846	0.004557	0.001057	0.000660	0.003055	0.001264	0.017274
CDF15	0.000100	0.018458	0.045568	0.010571	0.006600	0.030553	0.012640	0.172736
CDF45	0.001004	0.184578	0.455682	0.105712	0.066000	0.305528	0.126400	1.727360
CDF80	0.010044	1.845780	4.556824	1.057120	0.660000	3.055280	1.264000	17.273600
CDF100	0.200880	36.915600	91.136490	21.142400	13.200000	61.105600	25.280000	345.472000

+	MRSDF74	MRNDC87	MRNDC88	MRNDC89	PCC81	PCC82	TOTAL
CDFHALF	0.000438	0.000017	0.000136	0.000173	0.000001	0.000020	0.003757
CDF5	0.004375	0.000173	0.001356	0.001728	0.000014	0.000201	0.037570
CDF15	0.043754	0.001728	0.013555	0.017283	0.000144	0.002008	0.375699
CDF45	0.437544	0.017280	0.135552	0.172830	0.001440	0.020076	3.756987
CDF80	4.375440	0.172800	1.355520	1.728300	0.014400	0.200760	37.569868
CDF100	87.508800	3.456000	27.110400	34.566000	0.288000	4.015200	751.397370

Table E-8. EXPECTED ANNUAL DEATH LOSS AVOIDED, Seattle Normal Soils.

INDEX 1 = TEMPRES2

	WOOD1	URM76	TOTAL
VI	1.394710E-7	0.000040	0.000041
VII	5.552323E-7	0.000161	0.000162
VIII	0.000002	0.000642	0.000644
IX	0.000009	0.002551	0.002560
X	0.000035	0.010164	0.010199
XI	0.000279	0.081003	0.081282
XII	0.000068	0.019814	0.019882
TOTAL	0.000394	0.114375	0.114769

INDEX 1 = RETAIL4

	RIC6	TOTAL
VI	0.000009	0.000009
VII	0.000036	0.000036
VIII	0.000143	0.000143
IX	0.000567	0.000567
X	0.002259	0.002259
XI	0.018005	0.018005
XII	0.004404	0.004404
TOTAL	0.025423	0.025423

INDEX 1 = PROFES7

	URM75	URM76	RIC4	RIC8	BSF13	MRSPF17	MRSDF74	MRNDC87
VI	0.000021	0.000023	0.000015	0.000042	0.000018	0.000240	0.000061	0.000002
VII	0.000084	0.000091	0.000058	0.000169	0.000070	0.000955	0.000242	0.000010
VIII	0.000335	0.000361	0.000233	0.000672	0.000278	0.003802	0.000963	0.000038
IX	0.001330	0.001437	0.000925	0.002674	0.001106	0.015117	0.003829	0.000151
X	0.005299	0.005723	0.003686	0.010652	0.004407	0.060225	0.015255	0.000602
XI	0.042234	0.045614	0.029373	0.084894	0.035122	0.479966	0.121576	0.004801
XII	0.010331	0.011157	0.007185	0.020766	0.008591	0.117402	0.029738	0.001174
TOTAL	0.059634	0.064406	0.041475	0.119870	0.049591	0.677706	0.171664	0.006780

+	MRNDC88	MRNDC89	TOTAL
VI	0.000018	0.000024	0.000464
VII	0.000072	0.000096	0.001845
VIII	0.000285	0.000380	0.007348
IX	0.001134	0.001512	0.029215
X	0.004519	0.006026	0.116394
XI	0.036011	0.048023	0.927614
XII	0.008808	0.011747	0.226899
TOTAL	0.050847	0.067807	1.309779

INDEX 1 = ENTERT9

	URM75	TOTAL
VI	0.000004	0.000004
VII	0.000014	0.000014
VIII	0.000057	0.000057
IX	0.000227	0.000227
X	0.000904	0.000904
XI	0.007202	0.007202
XII	0.001762	0.001762
TOTAL	0.010169	0.010169

INDEX 1 = PARK10

	URM75	RIC6	MRNDC88	PCC81	PCC82	TOTAL
VI	9.248076E-7	1.666320E-7	8.264947E-7	1.999584E-7	0.000003	0.000005
VII	0.000004	6.633600E-7	0.000003	7.960320E-7	0.000011	0.000020
VIII	0.000015	0.000003	0.000013	0.000003	0.000044	0.000078
IX	0.000058	0.000011	0.000052	0.000013	0.000176	0.000309
X	0.000232	0.000042	0.000208	0.000050	0.000700	0.001232
XI	0.001851	0.000333	0.001654	0.000400	0.005578	0.009816
XII	0.000453	0.000082	0.000405	0.000098	0.001364	0.002401
TOTAL	0.002613	0.000471	0.002335	0.000565	0.007877	0.013860

INDEX 1 = TOTAL

	WOOD1	URM75	URM76	RIC4	RIC6	RIC8	BSF13	MRSPF17
VI	1.394710E-7	0.000026	0.000063	0.000015	0.000009	0.000042	0.000018	0.000240
VII	5.552323E-7	0.000102	0.000252	0.000058	0.000036	0.000169	0.000070	0.000955
VIII	0.000002	0.000406	0.001003	0.000233	0.000145	0.000672	0.000278	0.003802
IX	0.000009	0.001615	0.003988	0.000925	0.000578	0.002674	0.001106	0.015117
X	0.000035	0.006435	0.015887	0.003686	0.002301	0.010652	0.004407	0.060225
XI	0.000279	0.051287	0.126616	0.029373	0.018339	0.084894	0.035122	0.479966
XII	0.000068	0.012545	0.030971	0.007185	0.004486	0.020766	0.008591	0.117402
TOTAL	0.000394	0.072417	0.178781	0.041475	0.025894	0.119870	0.049591	0.677706

+	MRSDF74	MRNDC87	MRNDC88	MRNDC89	PCC81	PCC82	TOTAL
VI	0.000061	0.000002	0.000019	0.000024	1.999584E-7	0.000003	0.000522
VII	0.000242	0.000010	0.000075	0.000096	7.960320E-7	0.000011	0.002077
VIII	0.000963	0.000038	0.000298	0.000380	0.000003	0.000044	0.008269
IX	0.003829	0.000151	0.001186	0.001512	0.000013	0.000176	0.032878
X	0.015255	0.000602	0.004726	0.006026	0.000050	0.000700	0.130988
XI	0.121576	0.004801	0.037665	0.048023	0.000400	0.005578	1.043920
XII	0.029738	0.001174	0.009213	0.011747	0.000098	0.001364	0.255347
TOTAL	0.171664	0.006780	0.053182	0.067807	0.000565	0.007877	1.474001

Table E-9. BENEFITS AND COSTS OF REHABILITATION WITH VALUE OF LIFE, Seattle Normal Soils.

INDEX 1 = TEMPRES2

	WOOD1	URM76	TOTAL
PV LOSSES	20829.43	2443028.10	2463857.53
PV DEATHS	9318.46	2704638.96	2713957.41
PV TOTAL	30147.89	5147667.05	5177814.94
RETRO COST	77760.00	3291382.50	3369142.50
SALVAGE V	3548.86	150214.40	153763.27
B-C	-44063.24	2006498.95	1962435.71
B/C	0.41	1.64	1.61

INDEX 1 = RETAIL4

	RIC6	TOTAL
PV LOSSES	135792.50	135792.50
PV DEATHS	601190.76	601190.76
PV TOTAL	736983.26	736983.26
RETRO COST	246240.00	246240.00
SALVAGE V	11238.07	11238.07
B-C	501981.33	501981.33
B/C	3.14	3.14

INDEX 1 = PROFES7

	URM75	URM76	RIC4	RIC8	BSF13	MRSPF17	MRSDF74	MRNDC87
PV LOSSES	1348000.71	1142401.78	269732.80	1509830.79	555393.91	8299130.55	1951676.88	85514.04
PV DEATHS	1410182.00	1523016.60	980757.38	2834577.34	1172693.09	16025816.01	4059373.63	160317.54
PV TOTAL	2758182.71	2665418.38	1250490.18	4344408.13	1728087.00	24324946.56	6011050.51	245831.57
RETRO COST	1329982.50	1436400.00	449276.00	2902516.00	884800.00	12091520.00	3062808.00	151200.00
SALVAGE V	60698.67	65555.42	20504.37	132467.04	40381.12	551841.19	139782.56	6900.57
B-C	1488898.88	1294573.81	821718.55	1574359.18	883668.12	12785267.75	3088025.07	101532.14
B/C	2.17	1.94	2.92	1.57	2.05	2.11	2.06	1.70

+	MRNDC88	MRNDC89	TOTAL
PV LOSSES	684184.42	1102182.92	16948048.81
PV DEATHS	1202381.53	1603453.70	30972568.82
PV TOTAL	1886565.95	2705636.62	47920617.63
RETRO COST	1134000.00	1512262.50	24954765.00
SALVAGE V	51754.28	69017.69	1138902.90
B-C	804320.23	1262391.81	24104755.53
B/C	1.74	1.87	2.01

INDEX 1 = ENTERT9

	URM75	TOTAL
PV LOSSES	94413.61	94413.61
PV DEATHS	240476.31	240476.31
PV TOTAL	334889.92	334889.92
RETRO COST	151200.00	151200.00
SALVAGE V	6900.57	6900.57
B-C	190590.49	190590.49
B/C	2.32	2.32

INDEX 1 = PARK10

	URM75	RIC6	MRNDC88	PCC81	PCC82	TOTAL
PV LOSSES	386137.27	46109.70	166185.94	33308.72	548566.81	1180308.43
PV DEATHS	61789.05	11133.16	55220.48	13359.79	186257.81	327760.30
PV TOTAL	447926.32	57242.86	221406.43	46668.51	734824.61	1508068.73
RETRO COST	1165500.00	228000.00	1041600.00	273600.00	3814440.00	6523140.00
SALVAGE V	53191.90	10405.62	47537.26	12486.75	174086.06	297707.59
B-C	-664381.78	-160351.52	-772656.31	-214444.74	-2905529.33	-4717363.67
B/C	0.40	0.26	0.22	0.18	0.20	0.24

INDEX 1 = TOTAL

	WOOD1	URM75	URM76	RIC4	RIC6	RIC8	BSF13	MRSPF17
PV LOSSES	20829.43	1828551.59	3585429.88	269732.80	181902.19	1509830.79	555393.91	8299130.55
PV DEATHS	9318.46	1712447.36	4227655.56	980757.38	612323.93	2834577.34	1172693.09	16025816.01
PV TOTAL	30147.89	3540998.95	7813085.44	1250490.18	794226.12	4344408.13	1728087.00	24324946.56
RETRO COST	77760.00	2646682.50	4727782.50	449276.00	474240.00	2902516.00	884800.00	12091520.00
SALVAGE V	3548.86	120791.13	215769.82	20504.37	21643.69	132467.04	40381.12	551841.19
B-C	-44063.24	1015107.59	3301072.76	821718.55	341629.81	1574359.18	883668.12	12785267.75
B/C	0.41	1.40	1.73	2.92	1.75	1.57	2.05	2.11

+	MRSDF74	MRNDC87	MRNDC88	MRNDC89	PCC81	PCC82	TOTAL
PV LOSSES	1951676.88	85514.04	850370.36	1102182.92	33308.72	548566.81	20822420.88
PV DEATHS	4059373.63	160317.54	1257602.01	1603453.70	13359.79	186257.81	34855953.60
PV TOTAL	6011050.51	245831.57	2107972.38	2705636.62	46668.51	734824.61	55678374.48
RETRO COST	3062808.00	151200.00	2175600.00	1512262.50	273600.00	3814440.00	35244487.50
SALVAGE V	139782.56	6900.57	99291.54	69017.69	12486.75	174086.06	1608512.40
B-C	3088025.07	101532.14	31663.92	1262391.81	-214444.74	-2905529.33	22042399.38
B/C	2.06	1.70	1.02	1.87	0.18	0.20	1.66

Table E-10. BENEFITS AND COSTS OF REHABILITATION WITH VALUE OF LIFE, Seattle, Poor Soils.

INDEX 1 = PERMRES1

	URM76	TOTAL
PV LOSSES	455873.58	455873.58
PV DEATHS	875714.86	875714.86
PV TOTAL	1331588.45	1331588.45
RETRO COST	259875.00	259875.00
SALVAGE V	11860.36	11860.36
B-C	1083573.80	1083573.80
B/C	5.37	5.37

INDEX 1 = TEMPRES2

	URM76	TOTAL
PV LOSSES	1109873.58	1109873.58
PV DEATHS	1851899.33	1851899.33
PV TOTAL	2961772.92	2961772.92
RETRO COST	762300.00	762300.00
SALVAGE V	34790.38	34790.38
B-C	2234263.29	2234263.29
B/C	4.07	4.07

INDEX 1 = RETAIL4

	URM75	URM76	TOTAL
PV LOSSES	4339291.07	681444.11	5020735.18
PV DEATHS	18052576.27	2345113.79	20397690.06
PV TOTAL	22391867.34	3026557.91	25418425.25
RETRO COST	2303612.50	299250.00	2602862.50
SALVAGE V	105133.87	13657.38	118791.25
B-C	20193388.71	2740965.29	22934353.99
B/C	10.19	10.60	10.23

INDEX 1 = PROFES7

	URM75	URM76	RIM86	BSF14	MRSDF74	TOTAL
PV LOSSES	4384470.71	22772758.23	1321125.52	2963043.55	1114140.08	32555538.09
PV DEATHS	6194720.94	27714143.39	3044533.70	6704556.91	2896421.25	46554376.19
PV TOTAL	10579191.66	50486901.62	4365659.22	9667600.46	4010561.33	79109914.28
RETRO COST	1976205.00	8841210.00	471750.00	1711080.00	739200.00	13739445.00
SALVAGE V	90191.42	403501.28	21530.05	78091.46	33736.12	627050.33
B-C	8693178.07	42049192.90	3915439.27	8034611.92	3305097.45	65997519.61
B/C	5.61	5.98	9.70	5.92	5.68	6.03

INDEX 1 = ENTERT9

	URM75	TOTAL
PV LOSSES	67218.96	67218.96
PV DEATHS	246854.08	246854.08
PV TOTAL	314073.05	314073.05
RETRO COST	52500.00	52500.00
SALVAGE V	2396.03	2396.03
B-C	263969.08	263969.08
B/C	6.27	6.27

INDEX 1 = PARK10

	MRNDC87	PCC83	TOTAL
PV LOSSES	207792.32	1965358.01	2173150.33
PV DEATHS	109603.21	648814.82	758418.03
PV TOTAL	317395.53	2614172.82	2931568.36
RETRO COST	699300.00	4494450.00	5193750.00
SALVAGE V	31915.14	205120.83	237035.97
B-C	-349989.33	-1675156.35	-2025145.67
B/C	0.48	0.61	0.59

INDEX 1 = HVYIND11

	URM75	TOTAL
PV LOSSES	1104014.65	1104014.65
PV DEATHS	1368559.04	1368559.04
PV TOTAL	2472573.69	2472573.69
RETRO COST	529200.00	529200.00
SALVAGE V	24152.00	24152.00
B-C	1967525.68	1967525.68
B/C	4.90	4.90

INDEX 1 = LHTIND12

	URM75	TOTAL
PV LOSSES	371760.88	371760.88
PV DEATHS	670880.83	670880.83
PV TOTAL	1042641.70	1042641.70
RETRO COST	161525.00	161525.00
SALVAGE V	7371.79	7371.79
B-C	888488.50	888488.50
B/C	6.76	6.76

INDEX 1 = TOTAL

	URM75	URM76	RIM86	BSF14	MRSDF74	MRNDC87	PCC83	TOTAL
PV LOSSES	10266756.27	25019949.51	1321125.52	2963043.55	1114140.08	207792.32	1965358.01	42858165.25
PV DEATHS	26533591.16	32786871.38	3044533.70	6704556.91	2896421.25	109603.21	648814.82	72724392.43
PV TOTAL	36800347.43	57806820.89	4365659.22	9667600.46	4010561.33	317395.53	2614172.82	1.155826E+8
RETRO COST	5023042.50	10162635.00	471750.00	1711080.00	739200.00	699300.00	4494450.00	23301457.50
SALVAGE V	229245.10	463809.40	21530.05	78091.46	33736.12	31915.14	205120.83	1063448.10
B-C	32006550.04	48107995.28	3915439.27	8034611.92	3305097.45	-349989.33	-1675156.35	93344548.28
B/C	7.68	5.96	9.70	5.92	5.68	0.48	0.61	5.20

APPENDIX 4

LOCAL CONTEXTS IN THE NINE STUDY CITIES

The project team visited nine U.S. cities to find example retrofit projects and to understand how local conditions, such as code history and enforcement practices, general economic conditions, and the development climate affected the city's attitude toward seismic safety, as well as how each city might use the cost-benefit model. What follows is a summary of the key issues that emerged in discussions with building officials and a variety of redevelopment, community development, planning and school district officials, local engineers, and representatives of civic and business organizations. These are limited insights only, and are not intended to be definitive analyses. Nevertheless, they should add to the growing base of information about the nature of various localities with various degrees of seismic risk.

SEATTLE

Code History

Seattle uses the 1988 Uniform Building Code (UBC) for new construction. Seismic retrofit requirements for existing buildings are triggered by a "substantial rehab" amendment to Section 104 of the code. Typically this includes extensive structural repair, extension of the building's economic life, change in occupancy, or the reoccupation of a vacant building after 12 months or more. The extent of seismic rehabilitation required by the city is subject to negotiation on a case by case basis. The city often looks at the other work proposed in determining the seismic requirements to be applied to a given building. Moving walls and the upgrading of mechanical systems are used as indicators of substantial rehabilitation. In the 1970's the push for historic preservation changed public policy. Preservation meant "use and occupy" existing buildings. Politically, the desire to renovate and redevelop declining downtown neighborhoods encouraged flexibility on code requirements. The building department's charge was to push for maximum safety, but not to stand in the way of potential development.

Building Stock

Seattle has a concentration of Unreinforced Masonry (URM) buildings in Pioneer Square, Seattle's oldest neighborhood. The brick and stone Romanesque revival buildings were built after the 1889 great fire that destroyed 25 blocks of mostly wood commercial buildings. Although the city of Seattle has documented the renovation of some 25 buildings in the Pioneer Square area between 1982 and 1985, only a few have had any seismic improvement. Of these, the Mutual Life

Building is the best example. It is a 56,700 square foot (sf) mixed use (commercial and office) building renovated in 1984. At that time, the seismic structural work included both horizontal and vertical elements as well as foundation work. Structural costs were $16/sf and the total rehab cost was $78/sf.

Economic/Development Conditions

The Pioneer Square area began a decline after World War I that continued into the 1960's. A business district plan called for the area to be razed, but a small number of developers and architects began to renovate the historic buildings. The area's resurgence can be attributed to the protection and predictability ensured by the establishment of the Historic District in 1970. Still, the area has not gentrified completely, and more than 90% of the area's residential units are in "single room occupancy" (SRO) hotels, missions and shelters. For commercial buildings, the average renovation cost is $35/sf, and typical rents range from $9-30/sf. Developers in the area were hurt by changes made in the 1986 Federal Tax Act, and business owners in the area are typically underfinanced. Thus, while Seattle has generally enjoyed a development surge in recent years, Pioneer Square remains on the fringe of downtown development. Business owners generally feel that the seismic laws are acceptable and the building department is reasonable, but most will draw a line between wall anchoring (as acceptable) and shear wall requirements (as expensive and difficult).

HAYWARD

Code History

As the only California city in the study, Hayward presents a leading example of applying building retrofit requirements. It is in the process of adopting the 1991 Uniform Code for Building Conservation (UCBC) for the retrofit of all URM buildings and the 1973 UBC for all tilt-up concrete and high occupancy buildings. These less than current code requirements were selected in part because the City felt the associated renovation costs, particularly for the URM stock, were the maximum business owners could manage. They feared higher standards would force owners to abandon buildings rather than renovate them.

Building Stock

A 1990 survey by EQE Engineering identified three types of hazardous buildings in Hayward. The City has 70-80 URM buildings located in the old downtown on or adjacent to the Hayward Fault. In addition, there are 190 tilt-up buildings all built prior to 1973. All of these are lacking adequate ties between walls and roof. There are 22 high occupancy buildings (such as offices and church halls) built in the late 1960's of non-ductile concrete. The city is particularly concerned about portions of the old downtown straddling the fault, and many officials wondered privately whether these buildings should be condemned and removed rather than retrofitted. In this case they wondered if any retrofit technique could provide sufficient safety. By comparison, the tilt-up buildings are part of a viable industrial area, and some building owners have begun retrofitting them on a volunteer basis. There are numerous examples of tilt-up retrofits for costs that range from $1 to $5/sf depending on the original building condition, and whether the owner decided to reroof and add a roof diaphragm. It is significant to note that after an analysis of City Hall, a 10 story concrete frame building, the city has decided to close the building rather than renovate it.

Economic/Development Conditions

Hayward sees itself as the "heart" of the East Bay with a strong industrial and commercial base away from the downtown. In this area the tilt-up owners see the earthquake issue as a vehicle for improving the industrial area. The old downtown is very different. Business owners see seismic upgrading requirements as taking away their livelihood. Council members' top priority is downtown revitalization, but they are torn between the potential loss of historic value and a desire to redevelop. With downtown property values very depressed, there seems to be no easy solution to the URM problem. The high occupancy buildings present a different problem. Many are owned by institutions and churches, and the City does not want to force these owners to renovate until they set an example with the City Hall and other public safety buildings.

BOSTON

Code History

The State of Massachusetts has had a code requirement for seismic design for new construction since 1975, and for rehabilitation requirements since 1980. However, this code has an "economic hardship" loophole, and as a result there has not been a single example of voluntary or code enforced seismic retrofit since the enactment of these standards. Owners initially protested and claimed they would have to abandon their buildings, yet there have been millions of dollars of rehabilitation done in the intervening years. Despite a general disinterest in seismic issues, a committee of structural engineers has been working for 10 years to improve the seismic requirements in Article 22 of the state code that addresses the renovation of existing buildings.

Building Stock

Large portions of Boston have 3-4 story URM buildings built on fill with wood pile foundations. The Boston building department's major concern is not earthquake damage but foundation failure. The Back Bay area has 19th century townhouses built on a huge tidal flat. Piles were used to stabilize the heavy marine clay soils, and a high water table saturated the wooden piles and prevented rot. In recent years however, subway construction and expanding sewer lines have drained groundwater away. The pilings have begun to rot, and numerous townhouses have collapsed. The cost of foundation repair has been reported to run $250,000 per building, and it is dangerous and difficult work.

Economic/Development Conditions

Boston has endured both periods of recession and periods of major economic growth in the last two decades. In good and bad times, the seismic requirements have largely been ignored. The building department seems focused on the wood pile/water table issues, and the Redevelopment Agency states that its focus has been affordable housing rehabilitation for the past 20 years. In fact, both have simply ignored the state code and sanctioned the "economic hardship" exemption for a myriad of commercial area redevelopments, harbor and waterfront area plans, and hundreds of building renovations.

CHARLESTON, SOUTH CAROLINA

Code History

The City of Charleston has adopted the 1988 Standard Building Code, but not all areas of the state have adopted a building code. A committee known as the Citizens and Organizations for Minimum Building Standards has been lobbying state government for minimum standards that address not only seismic issues but also threats from wind and water damage. Such provisions, if adopted, will correct the absence of code standards for new construction in areas currently without a code, but would not provide for the strengthening of existing buildings. The City of Charleston has adopted a measure that would apply some seismic design requirements to existing buildings, but historic buildings are exempt unless the change in use significantly increases the number of occupants. The major part of Charleston is a Historic District.

Building Stock

Eighty percent of the URM buildings in Charleston are historic, and many existing schools are both historic and unreinforced masonry. Similarly, half of the

16 existing fire stations are in URM structures, and there is not program for making seismic improvements to critical facilities, schools, or its historic district. Despite this dilemma, the team found two examples of voluntary seismic strengthening of privately owned buildings. One is an 1850's era, 4 story, brick bearing wall commercial building, and the second is a modern concrete frame and shear wall hotel building.

Economic/Development Conditions

Historic preservation in the Old Town portions of the city is a paramount concern since a great deal of the tourist attractiveness and hence commerce is based on the city's historic heritage. The City estimates that the tourist industry generated over $550 million in 1987 by attracting 2.7 million visitors that year. Charleston was the first city in the U.S. to enact a historic zoning district in 1931. Currently, 59 structures are listed on the National Register of Historic Places. Similarly, the City has programs aimed at the revitalization and rehabilitation of residential structures. Maintaining the built heritage is clearly critical to continued economic development, not only in terms of tourism, but in terms of attracting business and development to the area.

MEMPHIS

Code History

The City of Memphis adopted the 1988 Standard Building Code, but it did not include its seismic provisions until early 1990. Local jurisdictions had the option of accepting or declining the seismic provisions but with a lower "Z" factor than suggested in the code maps. It should be noted that the line between seismic zone 2 and 3 bisects Memphis. This fact, plus mixed signals from the State regarding seismic compliance coupled with acrimonious debates between engineers on the cost impacts of the code produced a lengthy political debate ending in the Memphis City Council voting for a code with $Z=0.375$, about halfway between the values for zones 2 and 3, a solution which did not seem to please either side. Still, this begins a precedent for new buildings, although there are no requirements for strengthening existing buildings.

Building Stock

Memphis is located on a flood basin which places large commercial developments on old tributaries. Despite its proximity to the New Madrid fault, the city did not exist during 1811-12 earthquakes. The city began in the 1820's but was destroyed by a yellow fever epidemic so most historic buildings date from the 1840's. Early buildings (1900-1930) were primarily masonry bearing walls; in the

1940's and 1950's a number of concrete block/brick facade buildings were built; in the 1960's concrete and masonry structures with brick facades were again common. The city does not have a significant historic core. Many buildings were razed during the period of urban renewal. In the small Beale St. area which remains, historic facades were stabilized and saved, but the buildings behind are essentially new. Overall, there is some recognition that the existing building stock poses a hazard, but there is very little sense of what can be done.

Some professionals have taken an active interest in promoting seismic safety and have concrete evidence that the change from no seismic requirements had added only 2-3% to the cost of new schools and post offices. This data will certainly begin to influence the design professions On rehabilitation however, cost concerns and development competition dominate. The majority of downtown buildings which have been renovated had no structural work unless parapet bracing was needed for wind loads. Only one or two major corporations and the Veterans Hospital have considered seismic renovation. In the one example the team found of a completed project, an industrial concern completed the upgrading on a 3 year old, 200,000 sf warehouse located outside the city for $0.75/sf.

Economic/Development Conditions

Memphis is primarily a distribution center with no major industry. The economy is described as holding its own, but appears very fragile. The driving concern of developers is that code changes will discourage outside interests from coming to the city. There is some truth to these fears. Memphis is surrounded by unincorporated rural areas in two other states which have no building codes. These areas compete with the City of Memphis for development and promise lower costs to potential industries. Given the weak development conditions, many officials felt that a cost-benefit model would be more useful to institutional users such as hospitals, universities, and school systems, than to the city.

ST. LOUIS

Code History

The City and County of St. Louis use the 1990 Basic Building Code (BOCA) Zone 2 for new construction. The 1987 provisions had requirements for existing buildings to meet current code if the alteration exceeds 50% of the market value of the building prior to alteration. This is an unlikely trigger that was removed from the code in the 1990 edition. In 1990 the Missouri legislature passed a bill requiring any county expected to experience a shaking intensity of MMI VII from an earthquake on the New Madrid Fault to adopt a not more than 3 year old version of the UBC or BOCA by January 1991. The requirements are somewhat loose, because the bill does not require counties which have no building departments to establish them. As such, the effectiveness of the bill is unclear. Seismic design has not been a concern among design professionals, and the State Office of Emergency Planning has undertaken an active education program to clear up misconceptions regarding structural design.

Building Stock

St. Louis is a brick city. Historically, no other building material was allowed, and the result is a city with 90% of its building stock composed of unreinforced masonry. Between 1930 and 1960, St. Louis went without any new buildings, and although there was a small resurgence in the 1970's and 1980's, there is little new building and little demand. The City does boast of a strong rehabilitation tradition, and claims to have led the nation in the late 1970's with the rehabilitation of 10,000-20,000 housing units. Although this is approximately 5% of the total residential stock, the work has concentrated in three neighborhoods: the Central West End, the Southland District, and Lafayette Square.

Major industries in St. Louis and St. Louis County, such as Anheiser Busch, McDonald Douglas, Monsanto, and others, have a reputation for careful maintenance and upgrading of their building stock, but most owners and businesses simply cannot afford structural improvements. One notable exception is the utility, Union Electric, which is undertaking a major addition and upgrade of its corporate offices. Union Electric has seismically upgraded a 200,000 sf office building to meet current BOCA Zone 2 requirements. Because this work was part of a larger remodeling and addition project, it is difficult to precisely separate costs, but the structural work was approximately $3/sf while the total rehabilitation was $38/sf. The team also found a county fire district making plans to upgrade three fire stations built in the early 1950's of reinforced concrete and block infill with precast concrete roofs. Preliminary cost estimates for the structural work averaged $6/sf.

Economic/Development Conditions

The population of St. Louis declined from 800,000 in 1950 to 400,000 in 1990. This dramatic loss is clearly one factor in the City's weak economic position. In the 1970's and 1980's the city experienced oil money investments. In this period, the St. Louis Center (a downtown mall) and the renovated Union Station (a festival marketplace) both opened. The 1986 Tax Act changed the development climate, and the city has a list of 60-70 troubled commercial projects as well as 6,000-7,000 housing units requiring public assistance to stay operable. Thus, the economy and development prospectus is very fragile. Although there is considerable interest in renovation, and an active Heritage and Urban Design Commission which sets minimum exterior standards, the primary concern is to promote investment of any kind.

KANSAS CITY, MISSOURI

Code History

Kansas City adopted the UBC in 1984, and it was only at that point that the City had any seismic code. To date, no rehabilitation has triggered seismic requirements. However, the UBC would require existing buildings to meet the current code if a change in use occurs. There seems to be some debate within the City as to whether they will remain in Zone 1 or change to Zone 2 as a result of adopting the 1988 UBC. As of this writing, the City had not adopted the 1988 edition of this code. In general, there is very little interest in or awareness of seismic design for either new construction or renovation, despite the fact that Kansas City officials would describe themselves as sensitive to building collapse after the tragedies involved in the collapse of a hotel walkway and the collapse of an arena roof in the past decade.

Building Stock

Kansas City is unique in that it covers a large land area, so that suburbanization has taken place within the city limits. The core of the City was developed before 1940 and has significant public facilities, a parkway system and numerous parks. Most of this public investment was done as part of the City Beautiful Movement at the turn of the century. There has been little public investment or improvement since. Kansas City has a mix of highly gentrified areas, such as the Country Club Plaza, and vast tracts of rundown housing. The downtown is very small, and new office development has been concentrated in the far southern areas of the city. There are two small areas known as Old River Market and River Key which were the original city. These are being renovated into a festival marketplace and commercial/residential district, but no structural improvements have been part of either project. Another key element of the building stock is the school district which at present is under court order to bring the old Kansas City Missouri District up to the standards of the newer districts. This $135 million renovation/rebuilding is also part of a desegregation order, and is clearly the largest building project in the City. In all of this work, there is no test loading, redesign or analysis of building frames.

Two examples of voluntary seismic upgrading were found. The first is a nine story medical office building completed in 1982. The original building appears to be a reinforced concrete frame structure. Costs of this project were not available. The second was a five story mixed use building originally constructed in 1928-1930 in the old downtown. It is an early example of a steel frame building using a curtainwall enclosure. It was brought up to Zone 1 requirements in 1986 and included complex structural modifications to include a two story atrium. The structural work was completed for approximately $16/sf.

Economic/Development Conditions

The economy in Kansas City is generally slow. It also had the influx and loss of oil investments in the 1970's and 1980's. Certain key industries, such as Hallmark Cards, provide a backbone to the city's stability, but new development has been consistent in the corridor from downtown to County Club Plaza. Housing is very inexpensive in Kansas City, and this, along with the historic public infrastructure, is part of its attractiveness. The pace of development is slow, however, and there does not appear to be an overarching interest in historic preservation except in the Country Club Plaza area, and there it is driven primarily by retail interests.

SALT LAKE CITY

Code History

Salt Lake City, the capital and the largest city in the state, has regularly adopted the latest edition of the Uniform Building Code. About three years ago a new "Building Standards Act" was passed. It created a new state level commission which adopted the 1988 UBC for statewide application to new construction. It also required that all building inspectors be licensed and certified by the state by 1993. There are no requirements governing the seismic rehabilitation of existing buildings, but in April 1990 the City of Salt Lake adopted the Uniform Code for Building Conservation (UCBC). Administratively, the Building and Housing Services Department's policy is to require as a condition of a permit that major rehabilitation projects must meet 75% of the UBC's Zone 3 requirements. This is interpreted by the Department on a case by case basis, but has resulted in decisions by owners and developers to do nothing or to make only minor modifications to their buildings. Thus, seismic improvements rest primarily on persuading the owners to improve their buildings.

Building Stock

Mormon pioneers settled on the land between the Great Salt Lake and the Wasatch Mountain Range beginning in the mid-1840s. The vast majority of the state's population resides in several cities running north to south along the mountain front, which also is generally the boundary of the Wasatch Fault. Historically, the building stock has been characterized by several phases. Residential construction has been dominated by wood, unreinforced masonry, and later reinforced masonry structures. Earlier commercial, institutional, and industrial buildings consisted primarily of unreinforced masonry buildings or URMs with some combination of wood, concrete, or steel and concrete frame and steel frame structures. About 1960 reinforced masonry, precast concrete frame, and concrete tilt-up buildings began to be used, and URMs still were being built throughout the 1970s. Since then, concrete frame, steel frame, reinforced masonry, precast concrete frame, and tilt-up buildings have dominated construction.

Overall, there is recognition that the existing building stock represents an earthquake hazard, and partly on their own initiative and partly from community pressure some critical and high occupancy structures are, or likely will be, replaced or strengthened. Two replacement fire stations have been constructed, and a third is under construction. The city invested substantial funds in strengthening the City/County Administration Building, the first structure in the U.S. retrofitted with a base isolation system. The Salt Lake City School District has evaluated all of its buildings, and with the involvement of a District "seismic review committee", has prepared a 20 year plan to upgrade or replace the most vulnerable buildings. Some privately owned buildings have been retrofitted, and the standards and techniques have been worked out on a case-by-case basis. The Building Official is trying to find ways to get the owners of apartment buildings to do analyses of their structures.

Local professionals on their own, and building on the work done by the earlier state level Seismic Safety Advisory Council, the Applied Technology Council, and the FEMA NEHRP documents have helped raise awareness of the earthquake threat and the problem of existing buildings. One Salt Lake City private engineer identified 11 reasons for seismically inadequate buildings in Utah. They are a lack of knowledge about the earthquake problem and infrequent large seismic events; inadequate building codes; inadequate training of architects, engineers, and building officials; initial seismic zoning that underestimated the real hazard; public apathy; perceived economic hardship; not recognizing the liability of the failure to act; resistance to governmental directives; resistance to change; inadequate plan review and construction inspection; and greed and laziness. (Reference: Larry D. Reaveley, "The Process of Dealing with Existing Hazardous Buildings in Utah," undated.)

Economic/Development Conditions

Salt Lake City is the industrial, financial, governmental, and services center of Utah. Although the economy is diversified, it has not experienced significant growth in recent years. Recovery from a recession throughout most of the 1980's has been slow. Tourist facilities have been added, and tourism is being strongly promoted, but general conditions remain somewhat depressed. The reasons vary, but concern about the economic health of the area has led to priorities being given to promoting development.

PROVO

Code History

Home to Brigham Young University (BYU) and serving the nearby largely agricultural area, Provo also sits along the Wasatch Front and in close proximity to the Wasatch Fault. The Building Inspection Division of the Department of Community Development is aware of the earthquake threat and enforces the latest edition of the Uniform Building Code for new construction. The major concern are the URMs in the old downtown area of Provo, some of which date from the late 1800s. Based on his review of some studies of Los Angeles's URM buildings, the Building Official developed an internal but published policy that allows the city and the owners/developers/contractors to negotiate seismic improvements as part of major renovations. However, the great majority of the URM buildings are in an "as is" condition. Some see the Building Department's seismic rehabilitation policy as greatly inhibiting the redevelopment of the older downtown. The City Council has avoided becoming involved in this issue, preferring to treat it as a "technical" one.

Building Stock

Provo is a small town. The older residential and commercial areas are dominated by unreinforced masonry and wood structures. Newer commercial areas to the north and south of town consist of a small masonry, wood, and mixed types of construction. A few tilt-ups and long span structures common to shopping centers have been built recently. The BYU campus dominates the city, and it has its own facilities and engineering staff. No seismic rehabilitation has been done to any of its buildings, which date from about the late 1800s to the present. There is a wide mix of construction types on the campus.

Economic/Development Conditions

Overall, the city's situation is stable. BYU plays a major role in the local economy, and Provo provides financial, commercial, and governmental services for the nearby areas. The older downtown area is becoming a professional office and "civic center" as it contains a relatively new city hall and several county and state buildings. A new 10 story office building will be constructed in the area. Newer growth, symbolized by a "business park" on the south and a shopping center on the north are reported to be doing well, and Provo's city limits are relatively large so no annexations are necessary to accommodate the new growth.

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