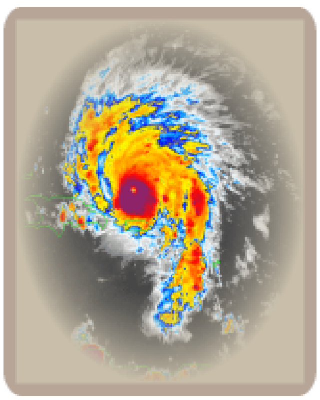
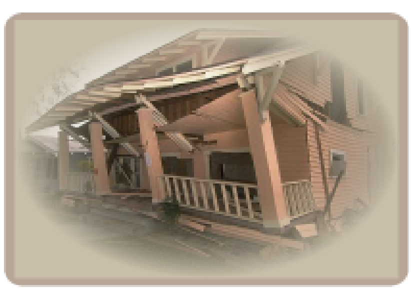
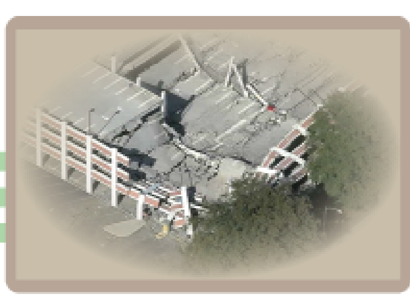
prepared by • **Federal Emergency Management Agency**



Report on Costs and Benefits of Natural Hazard Mitigation





Acknowledgements

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A special work group was held on December 12, 1996 to identify potential cases for the report and to discuss issues related with identifying the costs and benefits of natural hazard mitigation. The work group included:

Daniel J. Alesch, Ph.D., University of Wisconsin, Green Bay

David Bush, Ph.D., University of West Georgia

Hal Cochrane, Ph.D., Colorado State University

Brian Cowan, Federal Emergency Management Agency

Michael A. Cassaro, Ph.D., P.E., University of Louisville

Mary C. Comerio, Ph.D., University of California, Berkley

Donna Erat, Federal Emergency Management Agency

Robert Hanson, Ph.D., University of Michigan

P. Michael Laub, Ph.D.

Margaret Lawless, Federal Emergency Management Agency

Orrin H. Pilkey, Ph.D., Duke University

Robert Reitherman, CUREe

Michael F. Robinson, Federal Emergency Management Agency

Paul Tertell, P.E., Federal Emergency Management Agency

Kathleen Tierney, Ph.D., University of Delaware

L. Thomas Tobin, Ph.D., Tobin & Associates

Ted VanKirk, P.E., Dewberry & Davis

In additional to the assistance provided by the members of the work group, FEMA received valuable assistance in obtaining information and in reviewing cases from the following individuals: Bud Andress, FEMA Mitigation Directorate; Susan Boldt, FEMA Region V; Phil Cathey, City of Memphis, Tennessee, Memphis Light, Gas and Water Division; Ralph Clark, State of Florida, Department of Environmental Protection;

Jerry Coop, State of California, Office of Emergency Services; Claire Drury, FEMA, Mitigation Directorate; J. David Duffer, FEMA, Response and Recovery Directorate; Lawrence Frank, FEMA, Region IV; Jack Hurst, FEMA, Response & Recovery Directorate; Siavesh "Jay" Jazayeri, FEMA, Mitigation Directorate; Tamera Mason, City of Des Moines, Iowa, Des Moines Water Works; Stanley Mendes, Mendes & Associates; William J. Moriarty, Metro-Dade, Office of Community Services; Vern Persson, State of Califomia, Department of Natural Resources; Andrew Sachs, FEMA, Mitigation Directorate; Mike Raeburn, Anheuser-Busch, Inc.; Laverne Taylor, Metro Dade, Office of Community Services; and Mark Yashinsky, California Department of Transportation.

Executive Summary

Natural hazard mitigation is defined as a sustained action taken to reduce or eliminate the long-term risk to people and property from natural hazards and their effects. This report reviews the types of benefits that can accrue to different segments of society from mitigative measures, the types of costs that can be incurred by undertaking the actions, and the types of analyses needed to evaluate the cost-effectiveness associated with the mitigation measure. In addition, the report provides a review of the tools of hazard mitigation, to give the reader an understanding of how mitigation measures are implemented.

At the core of this report are 16 case studies of mitigation measures that were implemented in various locations across the nation. These cases demonstrate that mitigation is effective against several types of natural hazards and can be accomplished through the use of many different mitigation tools. The cases also illustrate that the various tools can be implemented in all major regions of the country. Further, since disasters impact the entire community, hazard mitigation relies on an investment from all sectors of the community, not just Federal, State, and local governments. An important theme that emerges from several of the cases is that mitigation is more effective when undertaken before the advent of a natural hazard. The cases demonstrate representative solutions for cost-effective hazard mitigation.

Each case study also uses photographs, graphic illustrations, and information boxes to highlight important findings. Although these tools assist in clearly conveying important points and add interest to each study, it is best to read the entire case study to get a thorough understanding of the tools and concepts of hazard mitigation, approaches to mitigation, and their applications.

Table of Contents

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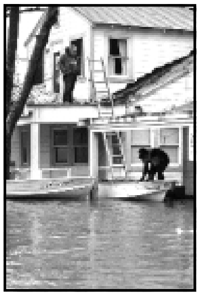
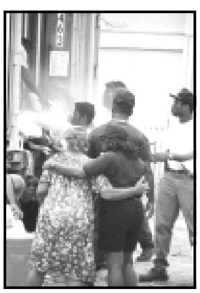
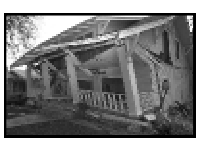
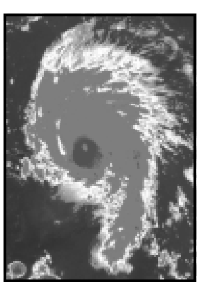
I. Introduction



Over the last decade, the overall cost of disasters to the United States has grown significantly. From 1989 to 1993, the average annual losses from disasters were $3.3 billion. Over the last 4 years, the average annual losses have increased to $13 billion. On the Federal side alone, disasters have cost over $20 billion over the last four years. The disaster losses are equally as staggering for the American public. Since 1993, over 1.4 million Americans have been impacted by Presidentially declared disasters, resulting in the loss of their homes, property, communities, jobs, and in some cases their lives. This figure does not include the hundreds of thousands of people impacted by natural hazard events that were managed entirely at the State and local levels, and involved the personal savings and private resources of property owners. Indeed, the impacts of major disasters on Americans go well beyond those damages that are directly sustained. Recovery from disasters requires resources to be diverted from other important public and private programs, and adversely impacts the productivity of economic systems.

To many, the rising costs associated with natural disasters have become unacceptable. To address this growing problem, the Federal Emergency Management Agency (FEMA), under Director James L. Witt, has encouraged the emergency management community to become more proactive in reducing the potential for losses before an event occurs. This proactive strategy is commonly known as "mitigation." Hazard mitigation is defined as *sustained action taken to reduce or eliminate the long-term risk to people and property from hazards and their effects*. This distinguishes mitigation from other major emergency management functions such as preparedness and training, response, and short-term recovery.

This emphasis on mitigation led FEMA to introduce a National Mitigation Strategy in December of 1995 to encourage a national focus on hazard mitigation.[1] The strategy is based on the objective of strengthening the partnership among all levels of government and the private sector and to empower all Americans to fulfill their responsibilities for ensuring safer communities. The strategy was developed with input from State and local officials, as well as individuals and organizations with expertise in hazard mitigation. The strategy has two goals:

- To substantially increase the public awareness of natural hazard risk so that the public demands safer communities in which to live and work; and

[1] Federal Emergency Management Agency, "National Mitigation Strategy: Partnerships for Building Safer Communities," (Washington, DC: Government Printing Office, 1995).

- To significantly reduce the risk of loss of life, injury, economic costs, and destruction of natural and cultural resources that result from natural hazards.

The reason for the emphasis on mitigation is clear. Experience at the Federal, State, and local levels during natural disasters, and a growing body of associated research, have demonstrated that the losses from such events (in terms of life, property, and community resources) can be substantially reduced when mitigation techniques and technologies are applied.

This paper was prepared to illustrate the comparative benefits and costs associated with the implementation of a variety of mitigation measures by Federal, State, and local governments, and private sector entities. To accomplish this, this paper will identify, through a series of case studies, the mitigation tools used to achieve cost-effective hazard mitigation benefits. The case studies used are representative of the types of mitigation measures that are, or could be, performed elsewhere in the nation under similar conditions.

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II. Evaluating Costs and Benefits

Before beginning the case study analyses, it is important to understand the methodologies that were utilized to determine the relative costs and benefits of each mitigation measure. Evaluating natural hazard mitigation is a complex and difficult undertaking which is influenced by several variables. First, natural disasters affect all segments of the communities they strike, including individuals, businesses, and public services such as fire, police, utilities, and schools. Second, while some of the direct and indirect costs of disaster damages are measurable, some of the costs are non-financial and difficult to quantify in dollars. Third, many of the impacts of such events produce "ripple-effects" throughout the community, thus increasing the variables to be considered. While not easily accomplished, there is value, from a public policy perspective, in assessing such impacts and obtaining an instructive cost/benefit comparison. Otherwise, the decision to pursue or not pursue various mitigation options would not be based on an objective understanding of the net benefit or loss associated with these actions.

Because of the inherent difficulties in empirically measuring all the disaster impacts and the corresponding value of mitigation measures, this paper utilized two different methodologies to identify the costs and benefits associated with natural hazard mitigation measures: *benefit/cost analysis* and *cost-effectiveness analysis*. The distinction between the two methods is the way in which the relative costs and benefits are measured. Through the first method, benefit/cost analysis, all costs and benefits are evaluated in terms of dollars and a net benefit/cost ratio is computed to determine whether a project should be undertaken (i.e., if net benefits exceed net costs, the project is worth pursuing). By contrast, the second method, cost-effectiveness analysis, evaluates how best to spend a given amount of money to achieve a specific goal; this type of analysis does not necessarily measure costs and benefits in terms of dollars, or any other common unit of measurement.[2] This paper uses both methods as necessary to obtain a true picture of the value of mitigation in the case studies. Wherever possible however, associated costs and benefits of mitigation measures are measured in terms of dollars.

In completing each case study, many types of cost data were considered in order to define both the direct and indirect costs of natural hazard events. First, the actual cost outlays by Federal, State, and local governments and the private sector are identified in the analysis of each case study. To this end, damages are accounted for to appropriately quantify the costs and benefits of mitigation.[3] In cases where damages could not be taken into account, this paper discusses the reasons why, and any resulting biases. Indirect costs (i.e., costs incurred as a result of the "ripple-effect" of actual damages to other parts of the society or economy) are also identified and discussed, whenever possible. Although it cannot be accurately measured, the reduction of a community's image as a dependable and viable entity, and a reduction in its ability to provide basic services, is recognized as an additional cost.

Throughout the case study analyses, care was taken not to count costs twice in instances where they could be measured in multiple ways. For example, the costs incurred by insurance companies are, in part, a reflection of the value of the damage a building has incurred. The depreciation costs for the usage of capital should also be taken into account in order to account for the actual loss attributable to a natural hazard event. To further clarify, suppose a 10-year old building

[2] Edith Stokey and Richard Zeckhauser, *A Primer for Policy Analysis* (New York: W.W. Norton & Company, 1978), pp. 136-37, and 153.

[3] A set of guidelines for addressing these problems has been developed by Harold C. Cochrane and Charles W. Howe, "Guidelines for the Uniform Definition, Identification, and Measurement of Damages from Natural Hazard Events," *Program on Environment and Behavior, Special Publication No. 28,* Institute of Behavioral Science (Boulder: University of Colorado, 1993).

with a normal life span of 20 years is destroyed; the cost of replacing the building, which is attributable to the disaster, is the capitalized cost of the 10 years of lost usage of the building, not 20.

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III. The Tools of Hazard Mitigation

Mitigation implementation is accomplished using a variety of tools, activities, projects, and programs. Some tools can be utilized only by public sector entities, while some can be used by both the public and the private sector. Mitigation is typically less expensive to implement when included in the planning and construction stage rather than after a building has been constructed. Mitigating the potential for natural hazard damages in existing structures is generally more costly, but when carried out effectively before a disaster, prevents loss of life or reduces damages, and also avoids the outlay of associated costs for response and recovery operations. The following is an illustrative list of some of the most utilized hazard mitigation tools.

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Design and Construction

The design and construction of hazard-resistant structures are perhaps the most cost-effective mitigation measure. The adoption and enforcement of natural hazards building codes, for example, will ensure that structures are resistant to the effects of natural disasters. However, it is important to note that such codes generally apply only to new or substantially improved structures, and this does not guarantee the rehabilitation of most existing hazardous structures.

Where appropriate, the establishment of financial incentives or the adoption of passive or active code triggers (e.g., change of building's use) by State and local governments, the Federal government, and private entities, can reduce existing natural hazard risks. One of the highlighted case studies (the unreinforced masonry regulations in Los Angeles, California) involves the use of local regulatory authority for the adoption of an active trigger to assure that existing hazardous structures are rehabilitated. Another example of a code trigger is to require a building being renovated, after a certain level of disaster damage, to be renovated to a higher level of natural hazards resistance.

The development and application of consensus building codes, and standards of construction for utilities and transportations systems, is a complex process that relies on both the private and public sectors. Building professionals, engineers, land use planners, and others play vital leadership roles in the promulgation and regular updating of building codes and standards. Through grant programs which support a wide range of research and application, technical studies on the usage of building research results in codes and standards, and educational efforts, FEMA and other Federal agencies have played an important role in assuring that such codes and standards are developed and used. State and local governments have a responsibility to adopt building codes that, through local enforcement, assist in creating communities that are built to resist natural hazard damages. And finally, building professionals implement mitigation through compliance with code requirements.

Beyond these building performance tools which are used to assure structural integrity, there are also important mitigation tools for the non-structural elements of buildings, utility systems, and transportation systems. The securing of light fixtures to ceilings, installation of wind shutters, strapping or bolting generators to walls, and numerous other techniques prevent injuries and also allow for the continued operation of businesses and facilities.

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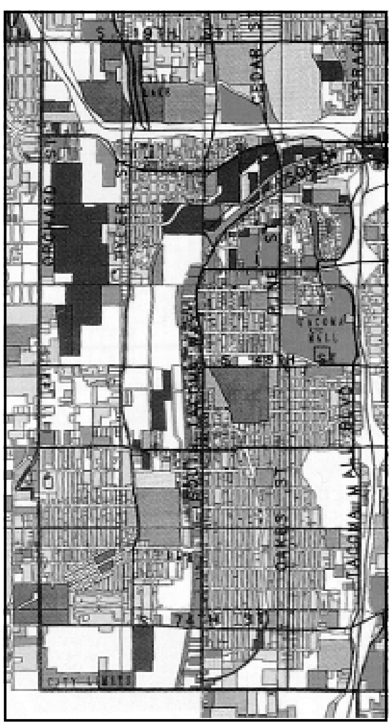
Land Use Planning



The process of establishing and implementing State and community comprehensive development and land use plans provides significant opportunities to mitigate damages caused by natural hazards. Land use planning is generally most effective in areas that have not been developed, or where there has been minimal investment in capital improvements. Since location is a key factor in determining the risks associated with natural hazards, land use plans are a valuable tool in that they can designate low-risk uses for areas that are most vulnerable to natural hazards impacts.

Comprehensive development and land use plans are implemented through ordinances and policies; subdivision, zoning, and sanitary ordinances; police power; and through a jurisdiction's capital improvement program. Tools such as density transfers, transfer of development rights, planned unit developments, cluster development, and similar innovative approaches can ensure that the property owners receive an adequate return on their investments while still providing community protection against natural hazards. For example, floodplains, steep slopes, areas subject to liquefaction, and areas susceptible to wildfires, can be designated for open space uses while the property owner is allowed to develop the remaining areas of the property at a higher density. This method not only reduces the potential for damages, but open space uses will also enhance the marketability and attractiveness of the development, and may even reduce the developer's costs.

A community also can influence the location and density of development through its capital improvement plans which determine where the community places critical infrastructure needed for development, such as roads, water supply, and wastewater treatment. For example, eliminating sewer service extensions onto a barrier island will often result in low density development. Low density development will sustain far less monetary damages than a densely developed area which would likely occur if full infrastructure had been provided. Planning for low density development therefore reduces the opportunity for sustained damages.

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Organizational Plans

Organizations need to integrate mitigation into their operating and strategic plans; governments can play a leading role in this integration. An important example of mitigation integration is planning for protection of basic lifelines and the provision of services to preserve public health and safety. State and local governments and private organizations of any size have capital improvements plans for building new facilities and the replacement of inadequate facilities. These plans should include provisions for upgrading replacement facilities using the latest mitigation techniques, and assuring that new facilities are built to the most current codes, standards, and specifications. Corporate and government response plans for natural disasters can also have important mitigation components.

An important concept in mitigation planning is that of redundancies. As an example in the banking industry, every bank over a certain size must have back-up computer facilities at an alternate location, to allow the bank to continue its basic functions should a disaster strike its main facility. Many smaller banks in disaster prone areas already make arrangements to outsource their computer operations to a service provider located outside of the bank's area in the event of a disaster. As this example illustrates, an important prerequisite to the success of mitigation is the view that mitigation is a priority with organizations whose constituencies are subject to increased potential for losses due to disasters.

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Hazard Control

Mitigation tools that seek to control a hazard, and thus reduce risks and losses are also available. Generally, these tools are used to protect existing at-risk developments and structures. These tools are often not the best to use since they require some maintenance and also tend to constitute a delay of the inevitable forces of nature rather than a permanent solution. Two examples may help to define the category and illustrate the limitations of such tools.

One commonly used and recognized hazard control structure is the levee. The levee has been utilized very effectively to protect flood hazard areas. Yet, the experience of the Midwest Floods of 1993, and other flood events, have clearly demonstrated some of the limitations of these structures—they can be overtopped or breached by floods that exceed their design; they can encourage further at-risk development behind them attributable in part to, an increase in the sense of safety; they can worsen the hazard in other locations; and they can deprive the natural environment of crucial processes, such as wetlands.

The North Carolina Outer Banks, which is a barrier island, also offers a compelling example. The barrier island had sustained major, and in the view of some, fatal, damage to its natural dune structure from a combination of natural and man-made impacts. In the 1930's and early 1940's, the entire barrier island from Cape Hatteras to the Virginia border was successfully rehabilitated with sand dunes and replanted with vegetation. The Outer Banks of post-World War II has seen enormous growth and prosperity as a result of the stabilization of the sand dunes. Some 50 years later however, the dunes are beginning to erode through the natural geologic process, and the beaches, which attract tourists so readily, are diminishing in size. In order to sustain the island's viability, many experts suggest that a landward retreat of the dune and its maintenance will be needed. In the absence of such actions, disaster costs are predicted to grow.

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IV. FEMA Mitigation Programs

FEMA contributed funding towards almost all of the mitigation projects included in the case studies.

FEMA funding for implementing mitigation measures is appropriated for two post-disaster mitigation programs. These are authorized by Sections 404 and 406 of the Robert T. Stafford Disaster Relief and Emergency Assistance Act, and provide mitigation assistance after a Presidentially declared Major Disaster Declaration.[4]

Section 404 of the Stafford Act established the Hazard Mitigation Grant Program (HMGP) in 1988. The 1993 Volkmer amendment enhanced the incentive for mitigation implementation by revising the cost sharing requirements, and increased significantly the amount of Federal money available under HMGP. For each Presidentially declared disaster, the amount of HMGP money available is based on 15 percent of the Federal funds spent on the Public and Individual Assistance programs in response to the disaster, minus administrative expenses.

FEMA can fund up to 75 percent of the eligible costs of each mitigation project. State and local governments can request funding for projects to protect either public or private property that meet the minimum HMGP criteria. The HMGP criteria are designed to encourage the most cost-effective and appropriate projects to be selected for funding. Under HMGP, the mitigation projects are not limited to addressing the hazard that caused the disaster declaration; however, the mitigation projects must be part of the overall mitigation strategy for the disaster area. The state sets priorities and allocates funding among applicants that meet state program objectives. The HMGP objectives are to:

- Prevent future losses of lives and property due to disasters;
- Implement State or local Hazard Mitigation Plans;
- Enable mitigation measures to be implemented during immediate recovery from a disaster; and
- Provide funding for previously identified mitigation measures that benefit the disaster area.

Under Section 406 of the Stafford Act, mitigation projects may also be identified and funded, for eligible Public Assistance projects. The Public Assistance Program provides funding for the repair, restoration, or replacement of damaged facilities belonging to governments and to private nonprofit entities, and for other associated expenses, including emergency protective measures and debris removal. Addi-

[4] Major Disaster Declaration is made by the President to supplement the efforts and available resources of States, and local governments, in alleviating the damage, loss, hardship, or suffering caused by a disaster. The Declaration must be requested by the state.

tionally, the program allows for the funding of mitigation measures related to the repair of the existing damaged facility. The measures must either be required by code or be cost-effective, and comply with program guidance. FEMA will fund at least 75 percent of the eligible costs of the mitigation measure.

Under the National Flood Insurance Program (NFIP) and reform legislation enacted for it in 1994, FEMA is also establishing the processes and regulations to fund flood mitigation implementation. In contrast to the two programs cited above, this flood mitigation assistance (FMA) will be granted before flood disasters transpire. However, by requiring that the flood mitigation implementation benefit the National Flood Insurance Fund, quantifiable flood loss reduction will result. The thinking of the Congress in authorizing the flood mitigation assistance is clear—investing in mitigation measures targeted at high-risk areas before disaster strikes, can pay dividends.

While FEMA does have other grant programs that support State and local mitigation activities, these three programs - 404, 406, and FMA - are the principal sources of funds with which FEMA supports the actual implementation of mitigation measures. The projects funded by the two post-disaster programs have provided, and will provide, benefits. The case studies which follow, however, will also demonstrate the indispensable role that pre-disaster mitigation implementation can fulfill.

"...investing in mitigation actions targeted at high-risk areas before disaster strikes, can pay dividends."

As part of FEMA's goals over the next 4 years, one of the major areas of activity will be devoted to establishing a Pre-Disaster Mitigation Fund Program. The program will provide financial incentives for communities in high-risk areas to better protect vulnerable infrastructure and buildings before disasters occur. In FEMA's fiscal year 1997 budget, Congress has allocated $2 million to initiate this effort. However, to make the program viable, the funds available for pre-disaster mitigation projects need to be greatly increased.[5]

■ ■ ■

[5] Witt, James L., "Creating the Disaster-resistant Community," *American City & County*, January 1997.

V. Case Studies

The case studies that follow illustrate the different ways in which mitigation measures can be implemented to reduce the impacts of natural hazards to lives and property. The case studies are representative of risk situations in many locations across the country, and demonstrate some of the mitigation measures that can be taken to address those risks. The difference in the size and complexity of the case studies illustrates the diversity of mitigation measures which are being undertaken.

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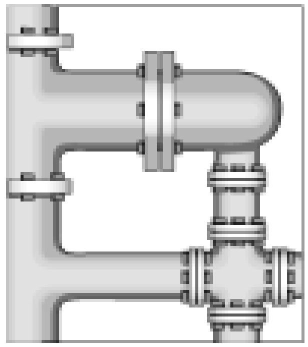
Seismic Retrofitting to Protect Lifelines: The City of Memphis, Tennessee, Memphis Light, Gas, and Water Division

In many high and moderate seismic risk areas, earthquakes pose a tremendous threat to lifeline services, such as power, water, and infrastructure systems. Nowhere is there a clearer example of such a threat than in the City of Memphis, Tennessee.

The City of Memphis is located within the impact area of the New Madrid fault system. The Center for Earthquake Research and Information at the University of Memphis has reported a 40% to 60% probability of a New Madrid Seismic Zone earthquake in the magnitude of 6.0 to 6.3 within the next 15 years. Therefore, it is only a matter of time before lifelines in the City of Memphis experience the impact of a significant earthquake.

In recognition of the risk posed to lifelines in the New Madrid area, the Memphis Light, Gas, and Water Division has initiated a seismic retrofit project to protect its Davis Water Pumping Station (located in Southeast Memphis), and to enhance the survivability of the connections between the water distribution lines in one-third of the city's production wells. The seismic retrofit of the Davis Water Pumping Station will involve the strengthening of supporting structures and tying together of components so that they will vibrate as a unit during an earthquake. To achieve this mitigation objective, Memphis Light, Gas, and Water plans to: reinforce and anchor masonry walls; strengthen steel frames; improve the connection between concrete walls and roof systems; secure and/or anchor pipes and valves; brace



pipelines and equipment for water treatment and control; and protect an overhead crane. The retrofitted Davis Water Pumping Station's useful life is calculated to be over 100 years.

The total cost for the Davis Water Pumping Station project is $448,000. A grant through FEMA's Hazard Mitigation Grant Program, announced on November 21, 1996, will provide 75 percent of the funding. By comparison, the estimated cost to replace the pumping station in the event of a large earthquake is over $17 million dollars. Additionally, each day the water pumping station is not in service costs $1.4 million in lost services. The total projected savings in the estimated value of the loss of services from the Davis Water Pumping Station Retrofit, factoring in the probability of an earthquake, is $112 million.[6]

The second half of the earthquake mitigation project is to replace 55 of the city's 170 rigid production well connectors with flexible connectors which better withstand the ground motions and displacement often caused by seismic activity. The project involves installing a flexible connection between the rigid well pipe and the collecting main. The flexible connectors will allow for a 30-degree rotation and an 8-inch expansion of the connection without breakage. It has been estimated that the connectors will increase each well's seismic capacity to withstand a 6.5 to 7.5 magnitude earthquake, depending on the location of the earthquake in the New Madrid fault system. The cost for engineering, parts, and labor of retrofitting each well's connectors is $9,280 (for a total project cost of $510,400), 75 percent of which will be paid for using HMGP funds. This investment will help Memphis Light, Gas, and Water to avoid estimated losses of $188,000 per day for each well connector damaged in a future event.

The retrofitting of the Davis Water Pumping Station will prevent an estimated loss of $1.4 million in services per day in the event of an earthquake. Increasing the well connectors to withstand a 6.5 to 7.5 earthquake, at a cost of $9,280 per connector, prevents an estimated loss of $188,000 a day for each connector damaged in a future earthquake.

While it is clear that the direct economic benefit of this mitigation effort more than justifies its expense, it is equally important to recognize that the Memphis Light, Gas, and Water project will also provide substantial indirect benefit to the community at large. By protecting the Davis Water Pumping Station and many of the connectors in the city's water system, area homes and businesses will benefit from a more re-

[6] Allen & Hoshall, Inc, "Seismic Risk Assessment Study and Seismic Mitigation Plan," November 1989.

liable water supply in the aftermath of an earthquake. This supply will reduce the need for communities to import potable water or provide alternative sanitation facilities for its residents and businesses. The continuance of water services will allow many businesses to remain open after an earthquake, which will reduce economic and social costs caused by business interruption. The retrofit effort can also help ensure the availability of adequate water resources for emergency services, which will aid in firefighting and the maintenance of public health and sanitation during the immediate aftermath of an earthquake.

The Memphis Light, Gas, and Water mitigation project is an effort that will provide benefits far outweighing the project's costs. It is a strong example of mitigation that provides substantial community protection while still making good economic sense.

■ ■ ■

Reinforcement of Highway Bridges: Caltrans

In many high-risk seismic areas, State and local governments have decided to reduce the vulnerability of critical infrastructure to earthquakes through retrofitting. An excellent example of such activity is found in the case of the longstanding programs of the State of California's Department of Transportation (Caltrans) which provides seismic resistance upgrades to highway bridges across the state.

Caltrans first established its bridge retrofit program in 1971 in response to the high seismic threat posed to the majority of California communities. The program utilizes State funding and partial funding from the Federal Highway Administration to pay for necessary retrofit activities. The on-going program has been implemented in numerous phases. The initial program consisted of using steel cables to restrain sections of 1,262 bridges. This effort cost over $54 million and was completed in 1989. After the 1989 Loma Prieta Earthquake, 1,039 bridges were identified for strengthening at a cost of $769 million; and after the 1994 Northridge Earthquake an additional 1,157 bridges were identified for strengthening at a cost of $1.05 billion. As of January 1997, 1,305 of the identified bridges have been strengthened, and an additional 923 bridges are currently under construction. The next phases of the Seismic Retrofit Program will identify and strengthen local and toll bridges.

With an average size for a retrofitted bridge equaling approximately 26,715 square feet, the average cost per square foot for retrofitting is $31.71. By contrast, if a bridge were to be destroyed in an earthquake, a new bridge would typically cost between $90-$120 per square foot in construction occurring on a normal schedule. This does not include the cost of demolition of the old bridge, which is typically $30 per square foot. Using this data, an average bridge replacement cost after an earthquake would total about $135 per square foot. This infers that the average bridge retrofit cost is about 22.7% of the replacement cost.[7]

This percentage, however, does not tell the whole story. First, Caltrans has confirmed that the cost data for retrofitting bridges in California is skewed upward by some very large, difficult, and expensive retrofits that were undertaken in the San Francisco Bay area since the program was initiated. Second, when bridges are destroyed in an earthquake, there is often good reason to rebuild the bridge on a rush schedule in order to reopen critical traffic arteries, restore the local economy, and facilitate a more rapid recovery. Such a rush schedule requires payment of substantial overtime to construction workers, and increases premiums paid to contractors for early completion. Finally, a large disaster event can produce shortages of construction labor and materials because of the large amount of construction that must take place in a short period of time. This can increase the cost of labor and materials in the post-disaster environment, which will further increase replacement costs. This has been a problem experienced in numerous disasters, including Hurricane Andrew[8] and the Northridge Earthquake.[9]

The typical cost per square foot for retrofitting bridges is $32. The typical cost for a replacement bridge is $135. Thus, the average bridge retrofit is about 22.7% of replacement cost.

After analyzing replacement and retrofit costs, the results indicate that on the basis of direct costs alone, retrofitting is worthwhile. These results, however, do not take into account the significant indirect benefits of retrofitting that accrue to the residents of the earthquake area. Traffic arteries are critical to the functioning of any local economy. When they are not accessible, businesses, particularly small retail busi-

7 Mark Yashinsky, Caltrans Office of Earthquake Engineering, California Department of Transportation, Telephone Interview, January 1997. The size figure used is an average of the sizes of a sample of 1061 retrofitted bridges.

8 P. Michael Laub ,"Insurance Companies, Banks, and Economic Recovery in South Florida in the Wake of Hurricane Andrew," (Washington, DC: FEMA, 1993), pp. 4-7.

9 *Wall Street Journal*, 21 April 1994, Sec. A, p.5.

nesses that depend on traffic accessibility, are adversely affected and people may not be able to travel to and from their places of work. Thus, the maintenance of traffic artery accessibility is an important aspect of the community that enables citizens to maintain their occupational and personal lives after a disaster, which in turn facilitates and promotes economic recovery.

While this analysis demonstrates the cost-effectiveness of the seismic retrofitting of highway bridges, actual disaster experience proves this point. In the Northridge Earthquake, there was visible and highly extensive damage to several highway bridges. However, the bridges retrofitted by Caltrans sustained little or no damage[10] whereas the bridges that sustained significant damage had not yet been retrofitted through the program.

■ ■ ■

Historic Structures and Community Development: Darlington, Wisconsin

Historic structures add personality, charm, and a sense of history to many American communities. When historic structures are located in high-risk areas, and community leaders decide to take action to protect the historic character of their communities, mitigation measures must be compatible with these desires.

Such is the case in the City of Darlington, located in the Southwestern part of Wisconsin in an area of rugged hills, ridges, and river valleys. Located on the slopes of the Pecatonica River, the downtown area is crossed by the river, which has a well-defined floodplain, and several community parks located along the riverfront.

The city was settled in the 1850's as a commercial point along an early trade route between Galena, Illinois and Mineral Point, Wisconsin. The downtown area has several buildings of architectural and historical significance such as the Lafayette County Courthouse which has been on the National Register of Historic Places since 1978. In 1994, the State Historical Society of Wisconsin nominated Darlington's historic Main Street Central Business District to the Na-

[10] Concrete Reinforcing Steel Institute, "Performance of Reinforced Concrete Bridges in the Northridge Earthquake," (Illinois: 1994).

tional Register of Historic Places.

In addition to the reduction in potential damages from the flood mitigation, Darlington's environment was made safer, its aesthetic quality was heightened, the city's economic development potential was increased, and the natural function of the floodplain was restored.

The City of Darlington experienced flooding in 1950, 1959, 1969, 1990 and 1993 with the 1990 flood event being one of the worst. Rushing waters from the swollen Pecatonica River washed out bridges and roads, and caused extensive crop damage, damage to dozens of homes and businesses, sewer back-up, debris build-up in streams, power outages, and damage to the area's hiking trails. High water levels forced the closing of all major highways into the city and created islands of high ground. Several fuel and chemical storage tanks which are located along the River were damaged and damage was reported at the city's wastewater treatment plant. In the historical downtown area, approximately 30 businesses were damaged, and flooding was so severe that several downtown residents had to be evacuated by motorboat. Outside of the downtown area, homes were inundated as flood waters rose 7 feet above flood stage. In all, the damages in Darlington during the 1990 flood event accounted for the vast majority of damages experienced in Lafayette County, which totaled approximately $2.8 million. [11]

Darlington's history of flooding and associated damages indicate that mitigation measures would be appropriate and could end the cycle of repetitive flood damage. After the 1993 flood, the City of Darlington decided to undertake an extensive flood mitigation project. The project involved the following elements:

- Floodproofing 12 structures in the downtown area, and acquisition and relocation of 15 additional structures. The floodproofing consisted of filling the basements with sand and suitable fill, elevating the first floors, constructing vestibules, and installing removable floodshields. Floodshields in the interiors of the buildings would allow water to infiltrate the vestibules. The vestibules were constructed with drainholes and made of material that can easily be hosed down after a major flood. These floodproofing designs conformed to the Secretary of the Interior's Standards for Building Rehabilitation and Guidelines for Rehabilitating Historic Homes, and the floodplain management requirements of the State of Wisconsin Natural Resource Code 116.
- Development of a business park on a 35-acre parcel south of

[11] Wisconsin Department of Natural Resources, "The Floods of 1993: The Wisconsin Experience," (Madison: 1993).

Darlington using Economic Development Administration funds to provide the necessary infrastructure. This consists of a water main, gravity sewer and force main, on-site sewage lift station, an access road and drainage improvements. After completion of these improvements, several of the businesses in the flood prone areas of the city that are acquired would be moved to this parcel for the business park.

- Conversion of the acquired land near the river to a park and campground.

Federal, State, and local outlays for the mitigation project totaled $3.4 million[12] representing 78 percent of total project funds (58 percent came from FEMA, and 20 percent from the Economic Development Administration). The remainder of the funds for the project came from State and local contributions, as well as from local financial institutions and the resources of local property owners.

In addition to the reduction in potential damages this mitigation project produced a number of other indirect benefits. Darlington's environment was made safer, its aesthetic quality was heightened, the natural function of the floodplain was restored, and the city's economic development potential was increased. For example:

- By relocating many of the storage tanks and distribution systems for fuel oil, propane, and natural gas, the flooding threat to these resources has been almost entirely eliminated. This has significantly reduced the potential for pollution or explosion associated with these sites.
- Businesses that use and maintain varying quantities of hazardous materials were relocated outside the floodplain, thereby eliminating the threat of hazardous material dispersion by floodwaters.
- The removal of structures and associated materials from the floodplain reduced the potential for dangerous floating debris during floods.
- The open space created by removal of structures from the floodplain increased the area's aesthetic quality and created recreational opportunities. This has benefited not only the look of the downtown area, but has also increased the economic potential of nearby businesses, since the improved downtown area is now more attractive to shoppers and store patrons.

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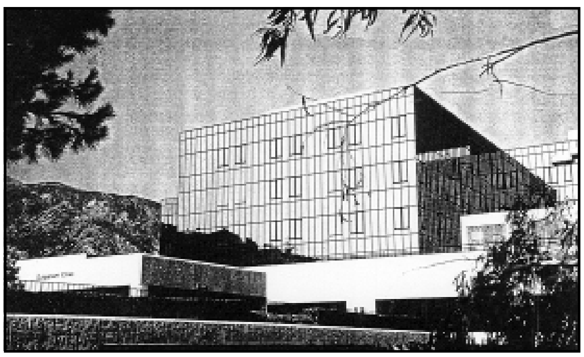
[12] City of Darlington, "Mitigation Project Summary," (Wisconsin: City of Darlington, 1993).

Critical Facility Mitigation: Olive View Medical Center in California and FEMA's Seismic Hazard Mitigation Program for Hospitals

Many States and communities over the years have decided that it is in their best interest to begin mitigating the natural hazard risks posed to critical facilities, such as hospitals. A prominent example of such mitigation can be found in the case of the Los Angeles Olive View Medical Center, in California. The 850-bed Los Angeles Olive View Medical Center, which cost approximately $23.5 million to build, was dedicated in November 1970.[13] The Center was built according to the 1965 Los Angeles Building Code, which did not contain many of the seismic protection provisions found in the 1973 building code.



In 1971, the Sylmar Earthquake (more commonly known as the San Fernando Earthquake) destroyed most of the building, caused three deaths on-site, and forced the evacuation of the structure.[14] When the hospital was replaced in 1988, it was designed and constructed to new statewide performance standards and enforcement procedures for hospitals intended to maintain functionality following earthquakes. The cost of replacement was $48 million (1988 cost).[15]

The new seismic provisions proved worthwhile when the Northridge Earthquake struck the Los Angeles area in 1994. In that event, the Olive View Medical Center sustained only minor damage totaling $6.6 million, or 11 percent of the total replacement cost ($60 million in 1996 dollars). Furthermore, the building damage sustained in 1994 was repairable and the facility was fully operational within four weeks, which was not the case with the 1971 earthquake. The valuable medical services provided by Olive View continued to benefit the community.

This case illustrates the value of seismic mitigation for hospitals in areas of high earthquake risk. Because of successes such as Olive View, FEMA has established a program to encourage such mitigation. After the Northridge Earthquake, the Seismic Hazard Mitigation Program for Hospitals (SHMPH) created an optional alternative to the Damage

[13] U.S. Department of Commerce, National Bureau of Standards, "Engineering Aspects of the San Fernando Earthquake," Building Science Series #40, (1971).

[14] Los Angeles County Earthquake Commission, San Fernando Earthquake, (Los Angeles: 1991), pp. 24,25.

[15] In 1996 dollars the cost of this building is estimated to be $58 million.

Survey Report (DSR) process that FEMA traditionally uses to calculate the amounts of disaster assistance to be given to public facilities after disasters. The program is designed to accommodate hospital facilities that were structurally damaged in the Northridge Earthquake, and that were constructed prior to 1973 when Californnia established special seismic safety regulations for hospital construction. The SHMPH provides funding specifically for mitigation measures that are likely to significantly improve a building's seismic performance. These funds are provided on a Federal/non-Federal cost-share basis.

The SHMPH will provide a fixed grant amount for each square foot of building area. This grant amount per unit area was developed according to a specific cost-estimation methodology, which was based on a database of actual construction costs for similar projects. The use of this fixed grant formula will avoid a time-consuming, detailed analysis of each individual project design.

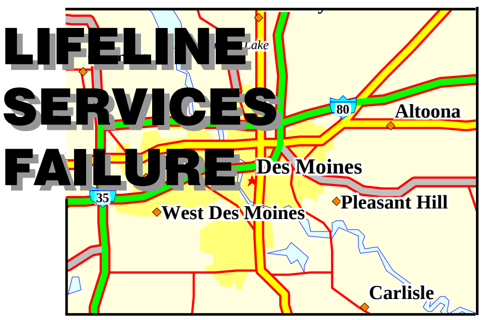
In the 1971 San Fernando Earthquake, the Olive View Medical Center was rendered uninhabitable and had to be evacuated permanently. The Center was rebuilt with stricter seismic standards in 1988. As a result, the 1994 Northridge Earthquake caused only minor damage which totaled only 11 percent of the replacement cost.

The grant amount in each case will be sufficient to raise the seismic resistance of the qualifying hospital buildings to Immediate Occupancy or Damage Control standards. These standards refer to a condition in which the hospital would be functional immediately after an earthquake with only minor non-structural damages which pose a low-risk of serious injury. Because of the extent of the upgrade work funded by the SHMPH, there is no need for additional funding for the permanent repair of damages beyond the SHMPH determined amount.

FEMA established SHMPH because improving the performance of general acute care hospital facilities will provide significant benefits following any major earthquake in the area. For example, the need to evacuate non-ambulatory patients from older, damaged hospital buildings will be eliminated, and emergency services needed for the treatment of disaster victims immediately following the earthquake will proceed uninterrupted.

The SHMPH provides a broader availability of funding for the repair of hospital buildings damaged by the Northridge Earthquake, as well as more flexible provisions for its use by the eligible hospital institutions. The funding amount is based on the cost of upgrading the entire qualifying hospital building, rather than just the damaged element. In addition, at the choice of hospital institutions, the funds may be used for “improved projects” involving the replacement of damaged facilities with more modern facilities designed to serve the same geographic community.

Approximately 22 hospital complexes in the 3-county Northridge Earthquake disaster zone are eligible for participation in the SHMPH. It is expected that more than $2 billion in Federal, State, local, and private funds will be expended in this mitigation program over a period of up to 15 years, and that more than 50 percent of these funds will be used to construct new, updated hospital buildings, which will serve to improve health care delivery in times of disaster.



Mitigation to Avoid Business Interruption Costs: Des Moines, Iowa

Lifeline services, like water, electricity, and telephone services, are an ongoing requirement for the economic well-being of a community. The floods of 1993 in Des Moines, Iowa, provide an example of how a failure in lifeline services can cause substantial business interruption.

In July of 1993, the levee which had previously protected the Des Moines Water Works facility from inundation, was over-topped allowing flood waters to enter the facility. Since the treatment plant and associated equipment were under flood water, the plant could not be operated. Over 250,000 customers were without water service for 11 days. In addition to the loss of potable water for this period, sanitation and fire hazard concerns forced a large percentage of area businesses to close their doors until water service was restored.

Direct costs associated with the damage to the Des Moines Water Works facility totaled over $12 million. Fortunately, the majority of this cost ($10 million) was covered by a private sector insurance policy which included a rider for flood damages. The additional flood coverage cost an additional $2,000 a year to the insurance policy, but proved to be a worthwhile investment for the Des Moines Water Works.[16]

Beyond property damages, costs were incurred for emergency restoration of water services and the provision of immediate measures to

[16] Telephone interview with Tamera Mason, Des Moines Water Works, January 1997.

protect the facility from additional flooding. The cost of these measures, which included debris removal, emergency sandbagging, pumping, and levee repair, totaled just over $2 million. FEMA, through the Public Assistance Program, paid a 90 percent share of these expenses. In addition, the Des Moines Water Works reported a $2 million dollar loss of revenue during the flooding period.[17]

Beyond the direct costs, an often overlooked and more far-reaching cost of lifeline service failure, were the costs to area businesses as a result of business interruption. Only a small percentage of the businesses in Des Moines reported closing due to direct flood damages. However, over 40 percent of the businesses were closed for some period of time due to the lack of water service. Even businesses that do not rely on water for production or operation were forced to close due to health, sanitation, and fire safety reasons. This resulted in losses associated with lost staff productivity, the reduction in product inventory, and the loss of sales revenue. In addition, these businesses continued to pay for their fixed operational costs, such as building mortgage and rent, which are ongoing regardless of whether the business is in operation. In all, business losses in the Des Moines area have been estimated at between $200-500 million.[18]

Following the 1993 floods, the University of Delaware's Disaster Research Center conducted a survey of over 1,000 businesses in the Des Moines area to determine the affects of the loss of water service. Of the businesses surveyed, over 80 percent reported being without water as a result of the flooding, nearly 40 percent lost sewer service, and 42 percent reported having to close for some period of time. The median number of hours that all business were closed was 96 hours (business and professional services reported the greatest number of hours of business interruption with a median of 120 hours). Of those businesses forced to close as a result of the flooding, over 90 percent carried no business interruption insurance.[19]

The University of Delaware survey also compared the attitudes of businesses in Des Moines to the attitudes of businesses in Memphis, Tennessee, which did not experience loss of water service during the 1993 floods. The Des Moines businesses were more aware of the affects of an interruption of lifeline services. When the survey asked the

[17] Telephone interview with Tamera Mason, Des Moines Water Works, January 1997.

[18] Tierney, Kathleen J., Joanne M. Nigg, and James M. Dahlhamer, "The Impact of the 1993 Midwest Floods: Business Vulnerability and Disruption in Des Moines" in Disaster Management in the U.S. and Canada, Second Edition by Richard T. Sylves and William L. Waugh, Jr., (Illinois: Charles C. Thomas, 1996), pp. 215.

[19] (*ibid.,* 215).

A rider to the Des Moines Water Works insurance policy to cover flood damages cost $2,000 a year and covered $10 million of the flood damages sustained during the floods of 1993.

Less than 10 percent of the businesses that were closed during the 11 day lapse in water service had business interruption insurance. The business losses in the Des Moines area have been estimated at between $200-500 million.

Des Moines respondents how disruptive the water outage was to their operations, 82 percent of the businesses responded that it was either disruptive or very disruptive to their businesses.

One of the important conclusions of the business interruption study is that mitigating damages to structures and building contents is not enough to ensure continuity of business operations. Business interruption is very often attributable to factors originating outside the business property, such as lifeline failures. This demonstrates that businesses need to be concerned about the level of natural hazard mitigation provided throughout their community, as well as mitigation of their own facilities. In addition, the Des Moines example demonstrates that communities need to pursue community-wide mitigation activity, as well as measures designed to protect individual structures. This is the only way in which to maintain the functionality of communities and local economies during a disaster.

The Des Moines Water Works has started to take action to increase the reliability of the area's water service during a natural hazard event. The emergency protection measures, which included permanently raising the protective levee around the Water Works' main facilities by 6 feet, have been maintained as a reinforcement of the levee system. In order to provide a consistent water supply for their expanding customer base, a two-step approach including the construction of a second, smaller treatment facility at another location and the use of aquifer storage, will be implemented. The second treatment facility will meet growing water demands and provide a limited back-up to the main plant if flooding should occur. Aquifer storage involves the storage of treated water in existing underground geological formations. The stored water would be used during peak demand periods, or in the event of a reduction in water supply from the main water treatment plant. The approach is also designed to provide necessary reserves for fire protection.

The experience of the City of Des Moines during the floods of 1993 illustrates how utility-related disaster costs often stretch well beyond physical damage. In many instances, the indirect costs throughout the community account for the vast majority of the losses associated with natural hazard events. In this case, the direct cost of damages to the Des Moines Water Works treatment plant was approximately $14 million, while the cost associated with the interruption of business was over $200 million. Communities need to implement mitigation measures to protect the lifeline services which are critical to businesses and other functions of the community.

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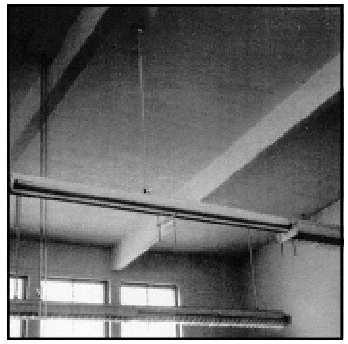
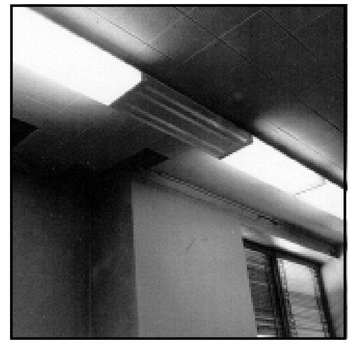
Seismic Retrofitting of Non-Structural Elements: Lighting in the Los Angeles Unified School District





Along with the structural modification of buildings, there are many non-structural measures that can be taken to protect people and property from seismic hazards. The suspended lighting retrofit project for the Los Angeles Unified School District (LAUSD) that was initiated after the Northridge Earthquake disaster provides one such example.

The LAUSD is second in size only to the New York City School District. At present, the District is composed of over 900 schools, serving a population of over 800,000 students, and employing 57,000 full-time and 24,000 part-time staff.[20] The LAUSD provides public educational services to a 708 square mile area including the Cities of Los Angeles, Bell, Carson, Cuddly, Gardenia, Huntington Park, Lomita, Maywood, San Fernando, South Gate, Vernon, and West Hollywood; portions of 18 other cities; and the unincorporated areas of Los Angeles County.

At the time of the Northridge Earthquake, the LAUSD facilities consisted of about 50 million square feet of building space, of which about 15 million square feet were illuminated with suspended ceiling and imbedded pendant lighting systems.[21] These lights have proven to be dangerous to people who are in schools subject to earthquakes, in that they tend to fall from the ceiling when impacted by strong seismic motion. The Northridge Earthquake caused hundreds of lighting units to fall onto desks in classrooms that the students and teachers would normally occupy during a school day. Fortunately, the earthquake occurred early in the morning when the schools were closed in observance of Dr. Martin Luther King, Jr. Day. As a result of this earthquake experience the LAUSD, with the support of FEMA, decided to undertake the seismic retrofitting or replacement of pendant lights to reduce the earthquake injury risk, and

The reinforcement and/or replacement of the unbraced pendant lights in the Los Angeles Unified School District will reduce the high risk of injury to the more than 800,000 school children during the next earthquake event.

[20] LAUSD Information, (visited Feb. 11, 1997) <http://www.lausd.k12.ca.us/lausd/lausd.html>

[21] Los Angeles Unified School District, Board of Education Report Number 5, (California: 1994).

to meet current building code standards.

In the Northridge Earthquake, 5500 buildings owned by LAUSD were damaged with total damages currently estimated at $134 million. Under Section 406 of the Stafford Act, FEMA funded $3.1 million for damaged, unbraced pendant ceiling and lights. In addition, $45 million was obligated under Section 404 of the Stafford Act to mitigate unbraced pendant ceiling and light systems of the same design that were not damaged. Detailed benefit/cost analyses were completed for all of these mitigation projects.

It is important to note that the rationale for funding the upgraded ceiling and lighting systems takes into account the probability that earthquakes will occur at all hours of the day (not just school hours). However, if an earthquake were to occur during school hours, the injury and death rates would be much higher than the average assumed for a 24-hour period. Given the potential injury and death rates during school hours, this type of mitigation was considered worthwhile and cost-effective.

Following the Northridge Earthquake, about $162 million was allocated by FEMA to the LAUSD. In repairing the damages from the earthquake, buildings were upgraded to current building code standards which include provisions for safe lighting. With the expenditure of these funds, FEMA is confident that the 800,000 school children of the LAUSD are in a much safer environment and have much less chance of injury or disruption of their education should another earthquake strike.

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Wind Shutter Protection: Emergency Service Center South, Dade County, Florida

Many individuals and communities facing high wind hazards have taken action to mitigate their risks. One clear example of an effective protective measure can be found in Dade County, Florida, where an emergency housing authority took action to protect its structures from hurricane-force winds.

Metro-Dade Office of Community Services administers programs aimed at reducing social and economic dependency. One of these programs focuses on providing emergency housing to families who have been legally evicted from their homes. The Emergency Service Center South (the Center) is one of the providers of emergency housing assistance in the County.

For every $1 invested in wind shutters at the Emergency Service Center South, at least $5 is saved in mitigated interior damages. Additionally, the investment reduces the risk of roof damage caused by high winds from the penetration of the building's envelope.

Since 1973, the Center has provided transitional housing to evicted families in need of assistance. As many as 150 families per year are provided with a maximum of 60 days of temporary housing in facilities owned and maintained by the Center. Families also receive counseling from a housing advisor to assist them in finding alternative living arrangements.[22] To provide these services, the Center operates and maintains four two-story concrete block buildings constructed on concrete slab, with stucco finish and concrete tile roofing. Each building contains four apartments for use by evicted families. The Center also has an administrative office.

The Center was located in one of the areas heavily damaged by Hurricane Andrew, which had winds in excess of 140 miles per hour, on August 24,1992. During the hurricane, winds and debris broke the unprotected windows on all sides of the Center's four structures, and breached the building envelopes (the system by which the building resists wind penetration). Wind was able to get inside the facilities, damage building contents, and create direct internal wind pressures that placed stress on the interior walls and roofing systems. This breaching caused $149,830 in damages to walls, furnishings, equipment, ceilings, doors, kitchen cabinets, bathroom vanities, floor coverings, and lighting fixtures.[23] The types of damage to the interior of the buildings were typical of damages experienced by buildings unprotected by wind shutters in high-wind events.[24]

After the disaster, the county decided not only to rebuild the Center, but also to take steps to mitigate the risks of sustained high-wind damage in the future. Metro-Dade received funds from private insurance to rebuild the Center. Additionally, FEMA Section 406 mitigation funding was provided for the purpose of mitigating against the Center's vulnerability to serious roof and contents damage in the future. The mitigation funding was used to pay the cost of installing wind shutters over exposed windows.

In completing the mitigation work, three alternatives were considered to achieve the objective of protecting the envelopes of the Center's four buildings. The use of galvanized steel removable storm panels and aluminum accordion shutters were determined to be the most

[22] Telephone interview with Laverne Taylor, Metro-Dade Department of Human Services, Office of Community Services, (January 1997).

[23] FEMA, Hazard Mitigation Analysis for FEMA 0955-DR-FL Damage Survey Report Nos. 19379, 32571, 32572, 32573, and 32574, (1994).

[24] FEMA, Building Performance: Hurricane Andrew in Florida, (1994). pp. 35, 37, and 54.

practical protection at the lowest cost. The total cost of installing the wind shutters to the apartments and administrative building was $30,000.[25] If the Center was rebuilt without the added protection of wind shutters, the facility would have the same risk of interior and roof damages from wind that it had prior to Hurricane Andrew.

Based on a benefit/cost analysis of the project (using projected future damages similar to those sustained during Hurricane Andrew), it was determined that every $1 invested in wind shutters at the Center would result in a savings of at least $5 in mitigated interior damages should a future event occur. The true savings, however, is likely to be much greater. The benefit/cost analysis did not take into account the additional protection that the shutters provide to the roofing system by protecting the building's envelope. In addition, the benefit/cost analysis did not calculate the savings associated with having an operational facility immediately after a future hurricane, versus a facility that would be closed due to disaster-related damages. Even without adjusting the benefit/cost equation to account for these additional benefits, mitigating wind hazards by installing shutters is clearly a cost-effective means of reducing damages associated with high winds.

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Acquisition, Elevation and Relocation of Residential Structures: The Midwest Floods (City of Arnold, Missouri)

The flood events in the Midwest during the spring and summer of 1993 resulted in record flood losses, with the total damage estimates ranging between $12 and $16 billion. About half of these damages were to residences, businesses, public facilities, and transportation facilities. In all, the nine-state disaster resulted in 50 fatalities, the flooding of more than 55,000 homes, and the designation of 532

[25] FEMA, Hazard Mitigation Analysis for FEMA 0955-DR-FL Damage Survey Report Nos. 19379, 32571, 32572, 32573, and 32574, (1994).

counties to receive Federal disaster aid. Flooding occurred again in 1995, inundating many of the same areas, though not as severe as in 1993.[26]

In response to the 1993 floods, the Director of FEMA issued a policy in September of 1993 which stated that acquisition, elevation, or relocation of flood damaged structures would be the priority of the Hazard Mitigation Grant Program (HMGP) funds during the flood recovery effort.[27] At that time, a total of $44 million in HMGP funds were available for the 9 affected states. Recognizing that this allocation would not meet the needs of tens of thousands of flood victims, Congress provided two supplemental appropriations: $200 million in 1993, and $250 million in 1994 in U.S. Department of Housing and Urban Development Community Development Block Grant (CDBG) funds earmarked for the Midwest Floods. Furthermore, U.S. Representative Harold Volkmer of Missouri and Senator Tom Harkin of Iowa sponsored amendments to the Stafford Act which increased the amount of HMGP funds for the 9 states almost fourfold. The resulting amendment changed the formula for calculating mitigation funds to 15 percent of the total Stafford Act grants. To achieve the State and local match, FEMA coordinated an intensive search on behalf of the flood-ravaged states to locate funds to serve as the non-Federal match required for FEMA's mitigation funds.

As a result of this effort, by October 1, 1996, 170 mitigation projects involving approximately 10,000 properties have been approved in the 9 states affected by the floods. Included in this count are mitigation projects funded through the HMGP and Section 1362 of the National Flood Insurance Program and the two supplemental CDBG appropriations.[28]

For the 1993 Midwest Floods, $152.3 million was available through the HMGP. Taking into account the 75/25 cost-share, another $50.7

[26] "The 1993 And 1995 Midwest Floods: Flood Hazard Mitigation Through Property Hazard Acquisition And Relocation Program (Draft Version)," FEMA Mitigation Directorate, (Washington, DC: FEMA, 1995).

[27] The HMGP, administered by FEMA, is authorized by Section 404 of the Robert T. Stafford Disaster Relief and Emergency Assistance Act of 1988. The HMGP can provide grants to State and local governments on a 75 percent Federal / 25 percent non-Federal cost-share basis to pursue eligible and cost-effective mitigation measures. For the Mid-West floods these measures were focused on elevating or floodproofing structures to comply with National Flood Insurance Program standards, or acquiring properties in a floodplain, or relocating owners of flood damaged structures to new, safe and sanitary housing outside the floodplain.

[28] Section 1362 was terminated by the National Flood Insurance Reform Act of 1994 which established as a replacement the Flood Mitigation Assistance. For the 1993 Midwest Floods, $6 million was available through the Section 1362 program.

million will be spent by State and local governments.

To be eligible for the HMGP funds, the anticipated benefits (reduction in future flood damages) of a proposed mitigation project must exceed the total project cost (benefit/cost ratio of 1.0). Using a conservative assumption of 1.5 for the average benefit/cost ratio, the anticipated total return from mitigation efforts in the Midwest, at a minimum is $304.5 million in reduced future disaster damages over the next 50 years. This calculation only takes FEMA benefits in account, and does not include benefits to other Federal Disaster Assistance programs, State and local governments, and communities at large.

In order to demonstrate the effectiveness of non-structural mitigation, in these cases acquisition or elevation, 30 communities in Illinois and Missouri with the highest repetitive loss rates in the Midwest between 1978 and 1995 were examined. A property is classified as sustaining repetitive losses if it received two flood insurance claims payments of over $1000 within a 10-year period. The 30 communities examined have a total of 4,621 repetitive loss properties which, over the period studied, received 14,654 payments through the National Flood Insurance Program for a total of $191 million. Of the 774 Midwest communities that sustained repetitive losses since 1978, 8,185 properties have received 24,766 payments for a total of $290.6 million. Thus, although the 30 highest repetitive loss communities comprise only 3 percent of the 774 communities, they total more than 56 percent of all repetitive loss properties, and 65 percent of the total dollar losses paid in the 9 Midwest states.

Using HMGP, Section 1362, and CDBG funds, approximately 5100 repetitive-loss properties were acquired or elevated, in the 30 highest repetitive-loss communities, with an estimated project cost to FEMA of $66.3 million. Thus, the cost of acquiring or elevating these properties is approximately 35 percent of total past claims (over the 17-year period studied). In addition to reducing the potential for future flood damages, the acquisition or relocation of properties in floodplains and the conversion of the property into open space provides an opportunity for the return of the natural function of the floodplain and the re-establishment of wetlands. In many communities parks and recreation areas will occupy lands where flood-prone homes once stood.

The case study of the City of Arnold, located in Jefferson County, Missouri, is a good example of the reduction in flood losses through property acquisition and a strong floodplain management program. The City of Arnold is located about 20 miles southwest of St. Louis at the confluence of the Meramec and Mississippi Rivers. The geography of the area is such that when the Mississippi River overflows its banks, the City of Arnold experiences backwater conditions at the Meramec tributary which causes river water to be forced back into the Meramec tributary, impeding normal discharge. In turn, flooding along the Meramec tributary occurs, causing backwater conditions to occur at the narrower channels of several local creeks.

The floodplains of the Mississippi and Meramec Rivers and local creeks, have been extensively developed in the last half century. Structures that began as summer or fishing cottages became year round residences. This development decreased the natural functions of the floodplain resulting in area flooding. The increased velocity and flow of the Mississippi River, due to the steady reduction of pervious surface upriver, heightened the risk of area flooding. The rate of the growth in stormwater runoff outpaced efforts of the U.S. Army Corps of Engineers to mitigate the effects of the increased runoff with structural flood barriers. Adding to the problem, Jefferson County had no procedures for stormwater management planning.

To initiate protection of existing floodplain resources and to guide future development, the City of Arnold adopted a floodplain management program in 1991. The plan included the following elements:

- A greenway to supplement the floodplain of the Mississippi River.
- Stream maintenance to clear vegetation and debris from stormwater channels, and identify and replace undersized culverts.
- Muddy Creek improvement study to determine solutions to this heavily developed area floodplain (over 100 residential properties).
- Acquisition program to purchase damaged or destroyed properties and help with relocation, thereby facilitating the creation of the greenway.
- Protection Assistance (flood insurance public education campaign) to encourage residents to buy flood insurance.
- Development of a preparedness plan to define operational procedures in future floods.
- Upgrade critical facilities to increase flood resistance of local

bridges, roads, interceptor sanitary sewer systems, and parks.

- Establish floodplain regulations to guide development that is consistent with floodplain management objectives, including a requirement that the lowest floor elevation be at least 2 feet above the 100-year flood level.
- Development of a watershed management plan for two creeks and those parts of the Meramec watershed within the county.[29]

The 1993 floods had a devastating effect on Arnold. Approximately 250 structures were affected by the high waters and 528 households applied for Federal disaster assistance, which amounted to over $2 million. Local authorities established over 60 sandbag sights to try to hold back rising waters. The city's acquisition program totaled $7.3 million; the city's floodplain management program, as an illustration of their commitment to mitigation, was a key factor in obtaining Federal assistance.

Although not as severe as the 1993 floods, the 1995 flood was the fourth largest in the City of Arnold's history. The damage was much less severe because, as the Arnold City Manager indicated, "Most of the areas affected had been bought out, so the people weren't there."[30] Only three or four sandbag sites were needed in 1995, and only 26 households applied for Federal disaster assistance. The total amount of Federal disaster assistance granted after the 1993 floods was over $2 million. After the 1995 floods, assistance was less than $40,000.

In Arnold, Missouri, the total amount of Federal disaster assistance granted after the 1993 floods was over $2 million dollars. After the floods of 1995, the fourth largest flood in Arnold's history, the damage was less then $40,000 as a result of non-structural mitigation—the acquisition of flood-prone or flood-damaged properties.

In addition to illustrating the value of acquisition, the Arnold, Missouri case highlights the value of planning as a mitigation tool. The recognition of the problem and its extent, and development of plans to solve the problem, prepared the city to respond to the 1993 floods with a long-term solution for mitigating against future flood damages. The city created land use plans which included changes to lessen the impacts of future disasters, and they developed organizational plans to implement the land use strategies. Capital improvement plans to obtain the funds needed to accomplish the city's goals were also developed. When combined with the outside assistance these plans facilitated, the city was able to go a long way towards reaching a long-term solution to sustaining flood damages. The experience of 1995 documented these accomplishments.

The mitigation projects in the Midwest ranged in size and complexity

[29] American Planning Association, for FEMA "The 1993 Midwest Floods: The Case of Arnold, Missouri (Draft Version)," (Washington, DC: 1997).

[30] FEMA, Region VI, "Out of Harm's Way: The Missouri Buyout Program," (1995).

from one to two home elevations to Valmeyer, Illinois which relocated a significant portion of the town to a new location, to Wakenda, Missouri which acquired and demolished all the town's structures, and disincorporated. What all these projects hold in common is that they reflected the communities' visions of themselves. Communities must be aware of their risks and plan accordingly, weighing mitigation alternatives with community needs.

■ ■ ■

Regulation of Unreinforced Masonry Buildings: Earthquake Hazard Reduction Ordinance in Los Angeles, California

State and local governments can reduce the natural hazard risks in their communities without directly funding the mitigation measures.

When the hazard is of such severity and magnitude to demand community-wide action, local ordinances can be designed and used to promote hazard mitigation goals.

One example of the use of such ordinances can be found in the City of Los Angeles, California. In the event of an earthquake, the city's large number of Unreinforced Masonry Buildings (URMs) posed a significant threat of increased injuries and economic losses. In 1981, city officials enacted the Earthquake Hazard Reduction Ordinance, commonly known as Division 88 (the numerical section of the city code), to reduce the earthquake risks to URMs. The ordinance required nearly 8,000 URM owners to make either structural improvements over a time period of several years, vacate the building, or face demolition.[31] The success of the mitigation requirements contained in the ordinance depends on compliance. By 1996, one-third of the URMs were vacated or demolished, and approximately 95% of the remaining URMs were in compliance with the ordinance.[32] For most owners compliance hinged on the economics of the seismic repairs, i.e., the initial expense as well as the amount building owners could recover through rent increases and upon resale.

[31] The information in this case study is based on "The Economics of Retrofitting California's Unreinforced Masonry Building Stock" by Harold C. Cochrane, FEMA, January 1997.

[32] Information provided by Mary C. Comerio, March 1997.

The study performed on Los Angeles' Earthquake Hazard Reduction Ordinance for unreinforced masonry (URM) buildings showed that compliance with the ordinance tended to raise sale prices by 37%.

The ordinance requirements apply to all URMs in Los Angeles that were constructed (or were under construction) before October 6, 1933.[33] The ordinance required the city's Earthquake Safety Division to evaluate and classify suspect buildings. The classification served as a mechanism to prioritize compliance with the ordinance and to differentiate among strengthening requirements.[34] All structures covered under the ordinance were classified in four primary groups, with the most restrictive class (and the first to be cited) considered "essential". An "essential" classification includes buildings needed for emergency use after an earthquake such as hospitals, fire stations, and police facilities. The other classification groups are based on a combination of structural integrity, occupant load, and historical importance.

With this classification system, the city then established a schedule to cite structures identified as hazardous. The schedule for citing structures ranged from "immediately", for those buildings deemed "essential" to within 4 years for the "low risk" buildings. The ordinance called for all buildings to be brought into compliance within 15 years.

When a structure was cited, an owner had several options to extend or alter this time limit. A partial compliance provision allowed owners the option of installing wall anchors within 1 year of notification, thereby extending the time to comply for up to 10 years, depending on the building's classification. Owners also had the option of appealing their property's classification, changing the use of the building, or demolishing the property entirely. However, for some buildings the latter two options were constrained by Los Angeles rent control provisions which require, in part, that owners pay relocation compensation to evicted tenants.

A repeat sales analysis, performed by Hal Cochrane, Ph.D, on the unreinforced masonry building stock concluded that owners of URMs did not suffer capital losses from compliance with the ordinance. The analysis studied repeat sales of a group of URMs occurring after the ordinance was passed, from approximately the early 1980's to 1991, and a control group which was not affected by the URM ordinance. A total number of 598 units were analyzed. The control group consisted of 459 observations, with 139 observations in the URM group. The results of the study indicated that over time, owners of the URMs recouped the costs imposed on them by the ordinance. The ordinance did not hurt resale value, and retrofitting enhanced them.

[33] This is the date on which the Los Angeles building code was revised as a result of the 1933 earthquake in Los Angeles and Long Beach.

[34] Comerio, Mary C., "Impacts of the Los Angeles Retrofit Ordinance on Residential Buildings," Earthquake Spectra, Vol. 8, No.1, pp. 80.

Compliance with the ordinance, or demolition of the URMs actually resulted in an increased sale price of upgraded URMs. After normalizing for initial price, time between sales, occupancy type, notification, sales date and time to compliance, compliance tended to raise the sale price by 37 percent. A small percentage of the URM owners found alternative, and highly profitable, uses for the cleared URM sites which raised the sale price by 52 percent.

The ability of the majority of the URM owners to recoup, over time, the added costs imposed by the ordinance is explained by the following factors. In the short run, the supply of rental structures is fixed. In addition, if the rental market were unregulated, the demand for rental space, and the pricing of it, would be shaped by underlying economic forces such as population density and income. Also, logic says that a renter's awareness of the health and safety risks posed by URMs would affect his willingness to pay for shelter. However, results indicated that public (particularly the low income public) perception of risk is highly skewed, and earthquake risks are all but ignored.[35] Given these factors, the impact of the ordinance was easy to predict. Some building owners, unable to justify the required investments, chose to vacate and demolish their structures. Typically, the least profitable buildings are abandoned first, permitting the owner to redevelop the site. In such instances, site value (land and location) composes nearly all the property's worth. The resulting reduction in housing supply should benefit owners of the remaining URM stock, thus nudging rental prices higher; how much higher would depend on the responsiveness of renters to the smaller supply of rental housing.

The evidence gathered in the repeat sales analysis indicates that the cost of retrofitting was borne by the tenant through increased rental rates. Rental price increases must be approved by the Rent Stabilization Division of the City's Community Development Department. Another URM study conducted by Mary C. Comerio, Ph.D. found that one-third of the residential building owners applied for rent increases. On average, a 20% rental increase was granted.[36] The residential URMs are predominantly low income housing; therefore, rental increases are a sensitive issue. However, rental increases should be weighed against the life safety improvements due to the retrofitting, and the decreased probability of these low-cost housing units being permanently damaged in the event of a major earthquake.

The important point is that substantial mitigation was achieved

[35] Kunreuther, Howard, et.al. "Disaster Insurance Protection: Public Policy Lessons", (New York, Wylie, 1978); and Palm, R.I. "Natural Hazards: an Integrative Framework for Research and Planning", (Baltimore, Johns Hopkins University Press, 1990).

[36] Comerio, Mary C., "Impacts of the Los Angeles Retrofit Ordinance on Residential Buildings," Earthquake Spectra, Vol. 8, No.1, pp. 79-94.

through the imposition of the Earthquake Hazard Reduction Ordinance which allowed housing market owners and renters time to adjust to the regulations applied to them. While the enforcement of the ordinance affected URM owners to varying degrees, the disruption to the housing markets was relatively minimal on average. The ordinance did not cause owners of URMs to suffer capital losses. The end result was a housing stock with less potential for fatalities and injuries from damage in future earthquakes.

■ ■ ■

Land Use and Building Codes: Florida’s Coastal Construction Control Line

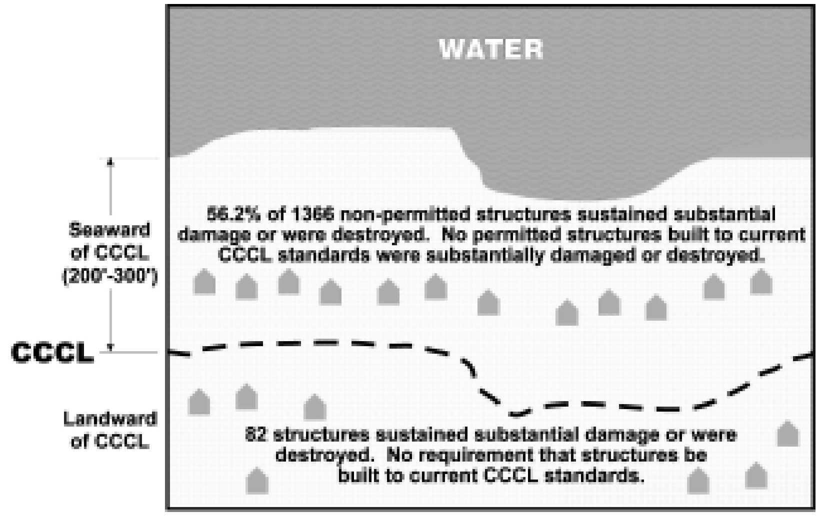
Coastal communities are vulnerable to extensive building damage due to wind forces and storm surges associated with hurricanes. Mitigation measures, however, can be implemented to reduce the extent of sustained building damage. Two of the most effective tools for mitigating damages, land use and building code requirements, have been implemented by the State of Florida with impressive results during Hurricane Opal in 1995, through its Coastal Construction Control Line (CCCL) regulation.

At the local or county level of government, construction along and near the Florida coastline is generally governed by the Standard Building Code and the National Flood Insurance Program (NFIP) construction requirements, which are both enforced by the local or county governments. As required, communities participating in the NFIP must adopt and enforce a floodplain management ordinance that meets or exceeds NFIP construction requirements, and enforce the NFIP construction requirements in the Special Flood Hazard Areas[37] as identified in the Flood Insurance Rate Maps (FIRM) issued by FEMA. In exchange for adopting the ordinance and enforcing the NFIP construction require-

During Hurricane Opal, none of the 576 major habitable structures located seaward of the CCCL and permitted by the State under current standards sustained substantial damage. By contrast, 768 of the 1366 pre-existing major habitable structures seaward of the CCCL sustained substantial damage.

[37] A Special Flood Hazard Area is an area below elevation of the base flood. The base flood, also referred to as a 100-year flood, is a flood that has a 1% probability of being equaled or exceeded in any given year and is the basis for the regulatory requirements of the NFIP.

ments, individuals and businesses within the communities are eligible to purchase flood insurance.



During the 1980's, the State of Florida's Department of Environmental Protection established a Coastal Construction Control Line (CCCL) to increase the standards that guide land use and building construction standards in high hazard coastal areas. The CCCL defines the zone along the coastline subject to flooding, erosion, and other impacts during a 100-year storm. Properties located seaward of the CCCL are subject to State enforced elevation and construction requirements. The CCCL foundation and elevation requirements seaward of the CCCL are more stringent than NFIP coastal (V-Zone) requirements. Likewise, the CCCL wind load requirements seaward of the CCCL are more stringent than the wind load requirements of the Standard Building Codes.

With the exception of the coastline within Bay County, Florida, the CCCL was adopted by the State between 1982 and 1991 and reflects anticipated 100-year storm impact zones.[38] Structures located seaward of the CCCL that were built prior to enactment of the regulations are deemed as non-permitted structures, and are at an increased risk of sustaining hurricane damage. Structures built after the adoption of the CCCL require a special building permit from the Division of Environmental Protection Permitting prior to construction, which certifies that the builder will adhere to the more stringent set of building standards which are designed to enable structures to withstand the forces of the 100-year hurricane.

On October 4, 1995, Hurricane Opal struck a portion of the Florida coastline as a Category 3 hurricane with 110-115 miles per hour winds. Most of the resultant structural damage appeared to be caused by coastal flood forces — storm surge, wind-generated waves, flood-induced erosion, and floodborne debris.[39] In the Florida Panhandle, 852 major habitable structures sustained substantial damage (770

[38] A setback line was established by the State in 1975 and did not include all areas subject to 100-year storm impacts. After Hurricane Opal, the State adopted an interim CCCL for Bay County on an emergency basis. The new line, 100 feet landward of the pre-Opal line, became effective on October 16, 1995. Bay County structures damaged or destroyed during Hurricane Opal were not subject to CCCL construction requirements.

[39] FEMA, Mitigation Directorate, "Hurricane Opal in Florida: A Building Performance Assessment," (Washington, D.C: 1996).

structures were seaward of the CCCL and 82 structures were landward of the CCCL).[40] The Florida Department of Environmental Protection reported that more structures were damaged or destroyed due to wave erosion impact in Hurricane Opal than in all other coastal storms that have occurred in Florida over the past 20 years combined. However, CCCL-permitted structures were not damaged in Hurricane Opal.

According to the Florida Department of Environmental Protection, none of the 576 major habitable structures located seaward of the CCCL and permitted by the State under current standards sustained substantial damage.[41] By contrast, 768 of the 1366 pre-existing major habitable structures located seaward of the CCCL and either not permitted by the State, or constructed prior to State permitting requirements, sustained substantial structural damage during the storm.

Major Habitable Structures Seaward of the CCCL: Damages Sustained

	Structures Built to CCCL Standards *(576 Total)*	Structures NOT Built to CCCL Standards *(1,366 Total)*
Structures NOT substantially damaged	576	598
Structures substantially damaged	0	768
Percentage of structures substantially damaged	0%	56%

The major habitable structures that sustained substantial damage were all non-permitted structures not built to CCCL standards. The performance of the CCCL-permitted structures exposed to the same conditions as the non-permitted structures clearly shows how important a role more stringent land use and building codes can play in reducing damages from major storms such as Hurricane Opal.[42]

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[40] Major habitable structures include single family dwellings, multi-family dwellings, and hotels/motels. Substantial damage occurs when the cost of repairing the structure to its pre-disaster condition equals or exceeds 50% of the market value of the structure prior to the disaster.

[41] Environmental Resource Permitting, "Hurricane Opal, Executive Summary of a Report on Structural Damage and Beach and Dune Erosion Along the Panhandle Coast of Florida," (1995).

[42] Florida Department of Environmental Protection, Bureau of Beaches and Coastal Systems, Division of Environmental Resource Permitting, "Hurricane Opal, Executive Summary of a report on structural damage and beach and dune erosion along the panhandle coast of Florida, (1995).

Building Codes: A Simulation of the Northridge Earthquake in Los Angeles, California

One of the most important tools of earthquake mitigation is building codes. Implementation of modern building codes with standards designed to mitigate the effects of natural hazards is a key element in strategies to reduce damages from such events. Building codes require buildings to be strengthened at the time when it is most cost-effective — at the point of construction.

The benefits of mitigation can be demonstrated through the application of a decision-support tool recently developed by the National Institute of Building Sciences (NIBS) under a cooperative agreement funded by FEMA. This tool, known as HAZUS (Hazards U.S.), is a nationally applicable standardized methodology for estimating earthquake losses at the regional or local scale. These loss estimates can be used by local, State, and regional officials to plan and stimulate efforts to reduce risks from earthquakes and to prepare for emergency response and recovery. HAZUS also provides FEMA with a basis for assessing the nationwide risk of earthquake losses.

HAZUS, which is a geographic information system-based computer program, has been developed by a consortium of natural hazard loss experts that includes earth scientists, engineers, architects, economists, emergency planners, social scientists, and software developers.

Using HAZUS, simulations of the 1994 Northridge Earthquake were conducted under three different assumptions (scenarios). The variable in each scenario was the type of building code used in construction of Los Angeles area buildings. These simulations produced damage estimates, expressed as direct economic losses, under the three assumed conditions and are described below:

1. **Scenario with All Structures Designed to High Seismic Design Standards**

   This scenario simulates a case where all buildings are constructed to the current seismic design standards for Los Angeles County. This is representative of a “best case” situation where the entire building stock is assumed to conform to the current design and construction standards.

2. **Baseline Scenario**

This scenario simulates the best effort to represent the current structural composition of Los Angeles County. The area has undergone a series of seismic design code changes and construction practice changes over the time period in which the buildings were built and renovated.

3. **Scenario with all Structures Constructed without Seismic Design Standards**

This scenario simulates a case where all structures in Los Angeles are constructed without any consideration of seismic design standards. This is a "worst case" scenario in which it was assumed that no seismic design standards were ever adopted in Los Angeles County.

The estimated economic losses from these three scenarios are indicated in the following table. Note that, while HAZUS can be used to estimate long-term effects on the regional economy, these indirect losses were not included in the figures shown in the table below.

If the Los Angeles area had been built to high seismic design standards prior to Northridge, a similar earthquake event would result in $11.3 billion in reduced losses, and a full $28.4 billion in reduced losses as compared to a situation where no seismic standards were in place.

Direct Economic Losses for the Three Los Angeles County Scenarios (Northridge-Like Event)

Scenario	Economic Losses ($ Billions)			
	Buildings	Contents	Income	Total
1. High Seismic Design Standards	10.2	3.9	2.5	16.6
2. Baseline	15.8	4.8	7.3	27.9
3. No Seismic Design Standards	24.9	5.7	14.4	45.0

As indicated in the table, the model predicts direct losses in the form of income lost to individuals and businesses, as well as losses due to damage of buildings and their contents. The simulations show that if the Los Angeles area had been built to high seismic design standards, an event similar to Northridge would result in $11.3 billion less in losses than if baseline assumptions were used, and a full $28.4 billion less in losses when compared to a situation where no seismic standards were in place.

The figures shown in the table do not consider the cost of building to higher seismic design standards. However, these resulting losses are still significantly lower than the losses that would be anticipated from a similar event in the greater urbanized areas of downtown Los Angeles (for example, a 6.7 Santa Monica or Newport-Inglewood event.)

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Planning for Mitigation Implementation: Beebe Medical Center: Lewes, Delaware

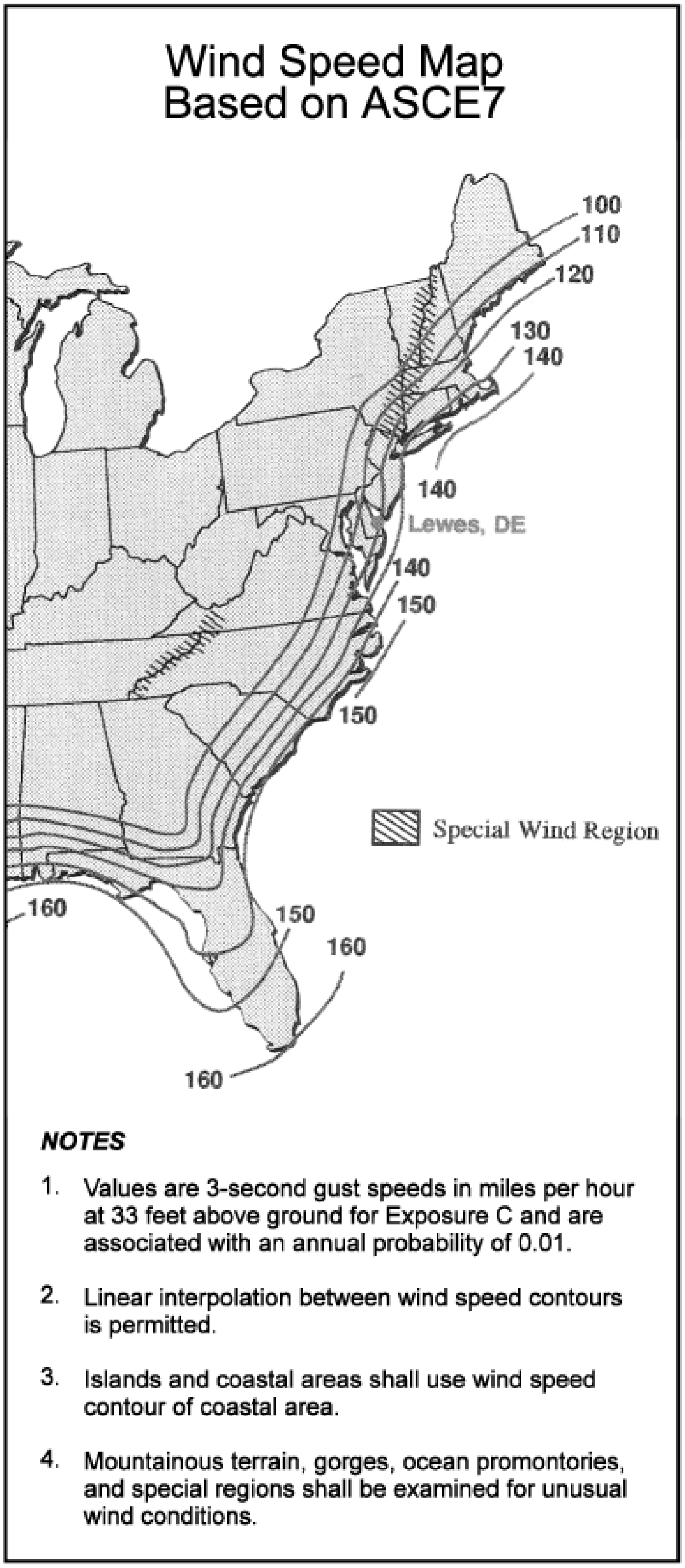
Assessment of risks and determination of measures that mitigate them are critical first steps in reducing losses from natural hazards. FEMA conducted a comprehensive mitigation assessment of the Beebe Medical Center in Lewes, Delaware, to determine how the structure would endure the brunt of a major storm event, primarily a wind event, such as a hurricane.

> *Based on the hazard identification study, the Beebe Medical Center has recognized the importance of incorporating mitigation measures into their capital improvement budget. Over time, the mitigation capital improvement funds will be used to replace inexpensive plywood shutters with more permanent types of storm shutters which provide a greater degree of protection and can be used to protect against more than one event.*

The Beebe Medical Center (Medical Center) offers care in the medical specialties of cardiology, critical care, endocrinology, family practice, internal medicine, neurology, obstetrics/gynecology, oncology, hematology, pediatrics, and pulmonary medicine. The Medical Center also offers care in many surgical specialties including orthopedics, urology, and vascular surgery, and additional services including physical therapy, radiology, a clinical laboratory, a school of nursing, an adult day care center, and a home health agency.

The service area for the Medical Center is the fastest growing population center in Delaware. Eastern Sussex County grew 24% in the 10 years from 1980 to 1990. Because of the attractiveness of the area for retirement, the over-45 age group is the fastest growing segment of the population. The area's estimated population in 1993 was 60,600. The Medical Center admissions in 1993 were 5130, or 8.5% of the population. Because the Delaware resort beaches are nearby, the population, and thus the service requirements, expands exponentially during the peak vacation periods.

The Beebe Medical Center comprises approximately 12.8 acres in the heart of Lewes. The Medical Center consists of nine buildings including a parking garage, a utility building, and two mobile offices. The



original building was constructed in 1921, and additional buildings were constructed in 1938, 1963, and 1985. Over the years, many floors and wings were added to these buildings, and a professional building, the nursing school, the Home Health Agency, and the convalescent center were added, as well. The new clinical center opened in November 1995.

The risk of storm surge or flooding due to extended periods of heavy rain is low. However, if such flooding occurred, the only two major traffic arteries into Lewes would be inundated. In addition, there is some risk of flooding inside the Medical Center property. Lewes is not in an area of significant seismic activity and thus, earthquake hazard is low. However, the risk of significant damage from high winds and hurricanes is high.

The successful operation of the Medical Center in conditions when the peak wind reaches 120 miles per hour is considered a reasonable goal. From experiences with previous hurricanes, the following can be expected to occur in the Lewes area during a storm with winds of that magnitude:

- The electrical power supply would be interrupted for days, or possibly weeks.
- Water supply and wastewater treatment might be interrupted as a consequence of electrical power interruption and damage to facilities.
- Rain and storm surge would cause street flooding.
- High winds and windborne debris would penetrate building envelopes.
- Penetration of building envelopes would allow both wind and rain to damage building interiors and their contents.[43]

It is essential that building elements such as

[43] Greenhorne & O'Mara, Inc. for the Federal Emergency Management Agency, "Hazard Mitigation Assessment of the Beebe Medical Center – Lewes, Delaware," (Maryland: 1996).

windows and doors be designed to withstand the same wind pressure as the primary structure. If high-speed winds penetrate window or door openings and enter the Medical Center's primary patient care buildings, the wind pressures would destroy portions of the suspended ceilings and pose a threat to many patients. This would also threaten to interrupt essential services that are routed through the ceilings. Wind would also pick up and carry internal debris, adding to the hazards.

On the previous page is a map of the United States showing wind speeds with a 1% chance of occurrence within any given year. The extent of the areas subject to the threat of high winds illustrates that there are many other medical facilities along the east coast that are subject to the same risks as the Beebe Medical Center.

The mitigation assessment for the Beebe Medical Center developed a series of recommendations. The highest priority recommendations consisted of two alternatives:

1. Construction of plywood covers for installation over doors and windows after a warning of a severe hurricane has been received;
2. Installation of permanent storm shutters which can quickly be closed once a warning has been received.

Although the first alternative is less expensive, it involves significant assemblage and usage of manpower to install plywood covers after a warning has been received and before a hurricane strikes. Depending on how much time is available, achievement of the desired degree of protection may be uncertain. The total cost of the plywood covers, including installation, is $37,660, with 643 work-hours needed for installation. In terms of installation costs, and probably material costs, this approach would provide protection for only one hurricane event. The cost of the second alternative, providing the permanent storm shutters, would be approximately $283,000.

The cost estimates illustrate the important tradeoff faced by the center in developing its mitigation plan. The Beebe Medical Center's approach has been to sign a contract with a local contractor to provide the inexpensive plywood shutters should a hurricane warning be received. Meanwhile, each year's capital improvements budget includes some funds to provide the more permanent types of storm shutters, which provide a greater degree of protection and can be used to protect against more than one event.

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Seismic Retrofitting of Buildings: University of California at Santa Barbara

For many older facilities, one mitigation option to protect against seismic hazards is the seismic rehabilitation of existing structural elements. An example of the benefit of such mitigation measures can be found through an analysis of the case of North Hall at the University of California at Santa Barbara.

The North Hall facility is a three-story reinforced concrete structure which was designed and built in 1960. The facility was partially rebuilt in 1975 by adding interior and exterior shear walls to provide additional seismic resistance. This retrofitting for earthquake resistance was the result of fortuitous circumstances. It was originally thought that the building was designed to the 1958 seismic load resistance building code, which did not prescribe the more modern types of earthquake resistant construction. However, a 1973 engineering investigation discovered that the building was instead designed for only one-tenth of the 1958 requirements, creating unsafe conditions at the facility. Fortunately, the construction work to correct the original design errors occurred at about the same time that the Uniform Building Code was being revised to include substantial earthquake resistance provisions. The decision was then made to rebuild the structure according to the provisions of the revised building code; the upgrade made the North Hall Building the only building on campus built to that advanced level of seismic standards.

> *When an earthquake struck Santa Barbara in 1978, the damage to North Hall, for which retrofitting was done at 20 percent of replacement cost, was minor. Total damages to unretrofitted buildings on the University campus was $3.8 million.*

The 1976 cost of the seismic retrofit was $288,000 for this three-story building with a total floor area of 24,480 square feet. Thus, the cost of the retrofit was $11.76 per square foot. The 1976 cost of replacing the building would have been about $60.00 per square foot. Thus, the retrofit cost was about 20 percent of the replacement cost. Present replacement costs for this building would be about $150.00 per square foot.[44]

[44] Information from Stanley H. Mendes, Inc., Structural Engineer, Santa Barbara, California. Mr. Mendes was the engineer who discovered the original design error and advised on the retrofitting.

The timing of the work could not have been better. In 1978, approximately 2 years after work was complete, an earthquake struck Santa Barbara. Because the mitigation work had been completed on the North Hall, the damage to that structure was very minor, and did not impact structural integrity. By contrast, substantial damage was sustained by the unretrofitted buildings on the campus that were not built to the provisions of the new building code. Total damage to unretrofitted buildings on the University campus alone came to over $3.8 million. On the basis of direct costs alone, retrofitting to the provisions of the 1976 building code proved to be cost-effective.

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Land Use and Building Requirement in Floodplains: The National Flood Insurance Program

Perhaps the most cost-effective way to reduce damages due to natural hazards is to incorporate mitigation measures into site planning and the design and construction of buildings; this can often be accomplished at little or no incremental cost. For most hazards, the mitigation measures can be included in local land use plans, land development and zoning ordinances, or the national building codes adopted at the State or local levels. The National Flood Insurance Program (NFIP) is illustrative of the savings that can be achieved through these mitigation measures.

The National Flood Insurance Program (NFIP) was established by the National Flood Insurance Act of 1968, and was strengthened by the Flood Disaster Protection Act of 1973. The key component of the program is the requirement that the NFIP offer flood insurance only in those communities that adopt and enforce floodplain management ordinances that meet minimum criteria established by FEMA. Also critical to the success of the NFIP has been the $1 billion undertaking to identify and map the nation's floodplains. This mapping effort has helped increase public awareness of the flood hazard, and has provided the data necessary to actuarially rate flood insurance and develop community floodplain management programs.

Since inception of the program, over 18,700 communities have chosen to adopt floodplain management ordinances and participate in the program. Nearly all communities in the nation with significant flood hazards are participating in the program. The floodplain management ordinances require that residential buildings be elevated to or above the base flood elevation (BFE), which is defined as the elevation of the flood that has a 1% chance of occurring in any given year (also called the 100-year flood). This elevation is determined through hydrologic and hydraulic modeling. Non-residential buildings must either be elevated or floodproofed to the BFE. Additional requirements prevent the obstruction of the floodway portion of the floodplain and provide guidance to buildings exposed to hazards, such as wave impact in coastal areas.[45]

Buildings that are built or substantially improved after the date of a community's first Flood Insurance Rate Map (FIRM) are referred to as post-FIRM, and are charged actuarially sound insurance rates that fully reflect the building's risk of flooding. Buildings constructed prior to the issuance of a FIRM for a community are classified as pre-FIRM and pay an insurance premium based on chargeable rates that are subsidized by tax dollars. This subsidy was provided both to offer an incentive for communities to join the NFIP and to make affordable insurance available for buildings constructed prior to the availability of flood hazard mapping for a community, without full knowledge of the risk.

The effectiveness of NFIP-compliant community floodplain management regulations and ordinances in reducing flood damages can be directly measured by comparing the flood insurance claims of buildings constructed according to those standards with the claims of buildings constructed prior to the adoption of the requirements by the community. The NFIP is nearly 30 years old and therefore adequate claims data for the comparison are accessible by computer. To date, the data represents over 804,189 losses closed and 620,920 losses paid since 1978. Overall, although there is considerable variation in how well communities implement their floodplain management regulations, the data cumulatively demonstrates that mitigation works, significantly reduces damages, and is cost-effective. Historical claims since 1978 demonstrate that pre-FIRM buildings constructed to NFIP minimum standards sustain 77.1% less losses than pre-FIRM buildings that were not built to such standards. Post-FIRM buildings experience fewer claims in total and, when claims are filed, the losses are less severe than in pre-FIRM construction.[46]

"...the data cumulatively demonstrates that mitigation works, significantly reduces damages, and is cost-effective."

The effectiveness of NFIP floodplain management regulations in reducing flood damages can also be demonstrated by comparing the

[45] The floodway is the channel of a river or other watercourse and the adjacent land areas that must be reserved in order to discharge the base flood without cumulatively increasing the water-surface elevation more than a designated height.

[46] Program standards result in a 25.4% reduction in the severity of losses among those buildings that are damaged by floods and a 69.2% reduction in the frequency of those damages. These numbers combine to produce the reduction in expected annual loss relative to building value of 77.1%.

cumulative loss experience of new buildings with buildings that pre-date those regulations. Between 1978 and the end of 1995, the actuarially-rated flood insurance policies in special flood hazard areas generated a surplus of $169 million for the National Flood Insurance Fund after claims and other expenses of the program were paid. By contrast, subsidized policies on buildings in the special flood hazard area yielded a $1.5 billion deficit. This occurred even though the premiums on policies for the actuarially rated buildings are, on the average, less expensive than policies on the subsidized buildings.

Since the beginning of 1975, over 2 million buildings have been built in the special flood hazard areas of communities that participate in the NFIP. These structures are protected against the 100-year flood because these communities adopted and were enforcing floodplain management ordinances which meet program requirements. As of 1995, FEMA has estimated that each year the community floodplain management ordinances, prevent over $770 million of flood damages to buildings and their contents. This figure was calculated using the difference in historical loss experience between pre-FIRM and post-FIRM buildings under the NFIP in order to project losses that would have occurred if the 2 million buildings had not been built to NFIP minimum standards.

Buildings built to NFIP minimum standards sustain 77.1% less losses than buildings that were not built to such standards. As of 1995, it is estimated that each year community floodplain management ordinances prevent over $770 million in damages to buildings and their contents.

Another indicator of the NFIP's success in reducing flood damages is the change in the distribution of flood insurance policies that are post-FIRM as compared to those that are pre-FIRM. One of the expectations of the NFIP was that over time the existing stock of floodprone buildings would be upgraded or replaced by new buildings that were protected from flood damages. As this occurred, the subsidy on insurance for existing buildings would shrink and eventually disappear, and the program would become fully risk-based. The change in distribution of NFIP policies over time indicates that substantial progress has been made in reaching the objective of reducing the stock of floodprone buildings. At the beginning of 1978, nearly 78% of the policies were for pre-FIRM buildings located in special flood hazard areas. By the end of 1995, subsidized policies on these pre-FIRM buildings constituted only 34% of the policy base. This change in the distribution of policies reflects both the new construction that has taken place since 1978, and the elimination or upgrading of pre-FIRM structures that pre-date the NFIP.

What is most impressive about the success of the NFIP is the program's cost-effectiveness. The cost of meeting community floodplain management requirements is generally less than 5% of total construction costs. Additionally, in some instances there has been no increase in construction cost, since NFIP requirements can be met through sound land-use planning; by choosing a comparable location outside of the floodplain; through no cost modifications to the property's grading plan; or by selecting a foundation type or architectural style that lends itself to elevation (e.g., constructing the building on piles or columns or on a crawl space instead of on a slab). When there are costs associated with meeting NFIP performance standards, often the increased costs are offset by other benefits such as improvements in view, provision of low cost covered parking beneath an elevated building, and other amenities.

As this case study indicates, the cost of meeting NFIP requirements represents an up-front investment that reduces long-term flood damages. Through the program, any added costs associated with the decision to build in the floodplain are borne by the property owner. Because the owner assumes responsibility for residual damages through the increased construction costs and an annual flood insurance premium, no cost is borne through disaster assistance and uninsured private losses.

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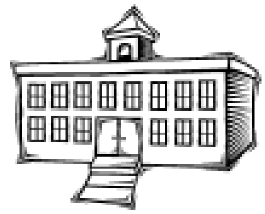
Acquisition/Relocation from Multiple Hazards: The Castaic School District in California

The case studies presented so far in this report have a single hazard mitigation focus. Castaic Union School District, located in southern California, is a case study which demonstrates the threat from multiple hazards. After the 1994 Northridge Earthquake, Castaic Union School District conducted a study of the earthquake-related risks that threatened their elementary and middle schools, and administration buildings. The assessment revealed that earthquake-related structural damage was not the only risk the school District faced.

As of 1993, the District maintained and operated 63 buildings (77,000 square feet of usable space) in Northern Los Angeles County, that consisted of a mix of permanent and portable structures with construction dates as far back as 1917. These structures service approximately 1,200 students and 115 staff. The San Andreas and San Gabriel fault systems, two of the most active faults in the country, pass through the area in which the District is located. In addition, the U.S. Geological

Survey has concluded that significant new earthquake activity may occur along both the San Andreas and San Gabriel systems. The San Gabriel fault system has had fewer large earthquakes than expected over the last 200 years; while 17 large earthquakes would be expected, only two such events have occurred. Also, the San Andreas fault system has historically experienced a large earthquake every 170 years, and it has been 140 years since the last large seismic event (the 1857 Fort Tejon earthquake).



These factors led the Castaic Union School District to conclude in their study that the probability of a large earthquake affecting their facilities was high. They also learned however, that the risk went well beyond possible damages caused by ground shaking. Along with the expected seismic damage, the study revealed two additional threats: flooding from the Castaic Dam and fire or explosion from a rupture in nearby oil pipelines.

The District's risk assessment study indicated that the school buildings were located within the inundation area of the Castaic Dam (located only 1.7 miles upstream). If the dam were to fail, the school buildings and their occupants would be inundated with catastrophic flooding. The 2,200-acre reservoir above the dam could release nearly 105 billion gallons of water, inundating the area below the dam with 50 feet of water. In 1992, the California Department of Water Resources (DWR) re-examined the seismic performance of the dam. Based on the 1992 and previous analyses, the DWR considers the dam to meet all current safety requirements, and able to resist failure due to the maximum credible earthquake.[47] However, the district's risk assessment concluded the probability the Castaic Dam will fail is never zero. In a catastrophic earthquake, the seismic ground motion could exceed the dam's design basis, and other factors such as flooding, high-water levels, or large landslides flowing into the reservoir, could lead to the dam's failure.

Along with the threat posed by the Castaic Dam, the study also revealed that the buildings were at high risk of damage from both fire and explosion should nearby pipelines fail. Two high pressure crude oil pipelines currently cross the campus (a 1925 gas-welded pipeline, and a 1964 modern arc-welded steel pipeline), both of which could rupture during ground shaking or ground displacement in earthquakes. An analysis of the lines and the fault conditions near the Dis-

[47] According to the DWR, the Castaic Dam is designed to resist both the maximum credible earthquake and the probable maximum precipitation flood. The dam's spillway has several times the capacity of creeks flow of record, and the dam's freeboard can easily handle any potential landslide which might occur into the lake. Additionally, the dam provides incidental flood control benefits downstream.

trict indicated that the 1925 line had a 35% chance of failure somewhere in the Castaic area as a result of any large earthquake. The study also revealed that during the 1994 Northridge Earthquake, both oil lines sustained some damage within 25 miles of the Castaic School District.[48]

This information caused alarm about the safety of the District's facilities. In the event of a pipeline failure, a fire or explosion could result from the ignition of the released oil, putting both facilities and people at great risk. Additionally, the ability to prevent a nearby fire from spreading would be limited by the decreased reliability of water lines and hydrants, as well as the increased demands on emergency fire services after an earthquake.

Using the results of the District's risk analysis, it was determined that the potential economic costs from either a dam failure or oil pipeline break following an earthquake were enormous. The first potential cost to the School District would be incurred from both building and content damage. Replacement of the school buildings would cost an estimated $7.7 million in direct construction costs (1995 dollars). Second, if such an earthquake occurred, alternative school facilities would have to be located and rented at an estimated cost of over $500,000 per year. Third, the community would have to absorb the costs of losing the educational services provided by the District in the time period between the actual loss of the facilities and the relocation to temporary facilities. The School District calculated the cost of the lost public services based on the operating expenses required to provide the services. The daily cost of lost educational services was estimated at $28,601.[49]

Whether due to direct earthquake damage, dam failure, or a break in the nearby oil pipeline, the cost related to the loss of the school facility would total $7.7 million in direct construction costs, $500,000 a year in rental of temporary school facilities, and a daily $28,601 loss in educational services during the transition to temporary facilities.

In addition to these direct and indirect financial losses, the risk of earthquake-related casualties in the District's facilities was determined to be significant. In an earthquake-induced dam failure, the predicted speed of inundation on the campus caused the risk of casualties to be very high. When calculating this risk, a casualty rate of 250 individuals was determined based on the average hourly rate of campus usage in a typical week. However, in the event of a dam failure during school hours, the loss of life could be as high as 1200 students and

[48] Goettal & Horner, Inc. "Benefit-Cost Analysis: Relocation of the Castaic Elementary and Middle Schools and District Administrative Offices", (February 1996).

[49] (*ibid*., February 1996).

115 faculty members. In an earthquake-induced potential pipeline failure, the District calculated a casualty rate of 9 individuals and injury rate of 45 individuals. Once again, the actual number of casualties increases dramatically if the earthquake and pipeline failure occurs during school hours.[50]

Through the cost-benefit analysis, the District determined that the most feasible method to reduce their risks would be to condemn the structures on the old, high-risk site and relocate the campus to a low-risk area. Given the nature and severity of the potential hazards, mitigation options other than relocation were judged infeasible.

Once the decision had been made to relocate, the District went to work to identify an alternative site for the school facilities. The selected location for the campus was completely out of the dam inundation area and far removed from the high-pressure oil pipelines. Thus, the risk posed by the dam and oil pipelines hazards would be eliminated. While the campus would still be within an active earthquake fault area, the new campus building would be constructed to fully conform to 1995 building code provisions, thus making them more resistant to seismic damage than the buildings being replaced.

The District then agreed to turn the land over to the Newhall County Water District as soon as the relocation effort was underway. The old school property is located above two active wells, which the water district can use to supply their customers in Castaic. In doing so, they changed the property deed to restrict human habitation and development, and to return the site to natural open space.

The Castaic School District financed the relocation effort through a combination of grant money from FEMA and the sale of bonds. The District applied for and received a $7.2 million grant through FEMA's Hazard Mitigation Grant Program for the market value of the property, including the existing structures and infrastructure. The district used this funding, plus $20 million generated by school bonds, to rebuild the elementary school, district office and middle school; and to relocate the elementary school students into temporary buildings during the construction of the new facilities. The new middle school opened in the fall of 1996, and plans call for the new elementary school to open in August 1997.[51]

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[50] (*ibid*., February 1996).

[51] Los Angeles Times, "Big Changes in Store for Castaic Elementary", 18 August 1996, Page AV1.

Seismic Retrofitting to Avoid Business Disruption: Anheuser-Busch, Los Angeles, California

> *"Mitigation saved the Anheuser Busch facility in Los Angeles after Northridge. The Anheuser-Busch Engineering Department retrofitted the plant to conform to the LA seismic code—and the plant was functioning within days of the quake.*
>
> *"Without those revisions—they would have sustained more than $300 million in direct and interruption losses."*
>
> JAMES L. WITT, DIRECTOR
> FEDERAL EMERGENCY
> MANAGEMENT AGENCY

Mitigation is a concern of everyone: individuals, businesses and governments. Of the three, businesses need to focus the most on the associated economic benefits of mitigation. With any business, if a large segment of its profit base is supported by the functioning of one facility, protection against disasters is critical.

Anheuser-Busch operates a large brewery just a few miles from the epicenter of the January 17, 1994 Northridge Earthquake.[52] This facility serves the company's markets throughout the Southwest and Pacific regions. In light of the area's high earthquake hazard, Anheuser-Busch initiated a risk reduction program at the brewery in the early 1980s. A risk assessment of critical buildings and equipment was performed, and those with unacceptable levels of risk were seismically upgraded, without impacting daily operations. Seismic reinforcements were designed for a number of buildings and the critical equipment contained within, including buildings housing beverage production and vats where the beer is stored and aged.

The Northridge Earthquake produced very strong ground motion, causing extensive damage in the immediate vicinity of the brewery. However, post-earthquake surveys conducted by the company's engineering consultants, indicated that none of the retrofitted structures sustained damage. On-site facilities of lesser importance had not been strengthened and consequently sustained damage, requiring repairs. However, none of the vats which are essential to the brewery's operations, was damaged. The brewery was quickly returned to nearly full operations following minor cleanup, repairs, and restoration of the off-site water supply.

> *The Anheuser-Busch brewery business interruption cost could have exceeded $300 million from the Northridge Earthquake had seismic strengthening been omitted. This is more than 15 times the actual cost of the brewery's loss control program.*

Anheuser-Busch conservatively estimates that had seismic strengthening not been performed, direct and business interruption losses at the brewery could have exceeded $300 million. According to Anheuser-Busch, this is more than 15 times the actual cost of the loss control program. Clearly, this

[52] The following information was taken from "The Northridge Earthquake: Four Examples of Proactive Risk Management," Proactive Risk Management, (California: EQE International, 1994).

loss control program paid for itself in the Northridge Earthquake event. While this is but one example, the Anheuser-Busch case study indicates that mitigation measures can strengthen corporate balance sheets.

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VI. Summary and Conclusions

Mitigation against the effects of natural disasters is a community-based undertaking that is long-term in outlook. It requires the efforts of the Federal, State, and local governments; non-profit organizations; and profit-making businesses. Mitigation often requires a structuring of incentives and relies on a recognition of the risks of natural disasters, and the development of new methods to reduce these risks. Most of all, successful mitigation requires leadership. FEMA has exercised such leadership and, with the partnership of the Congress, has made progress in lessening the likelihood that future natural disasters will be as severe as they have been in the past.

Although we cannot stop natural disasters from occurring, we can lessen their impact on people, communities, and the nation as a whole through effective and often creative mitigation. While the case studies presented here provide only a snapshot of the mitigation efforts being implemented across the country, they clearly demonstrate that loss of lives and property can be reduced through cost-effective mitigation measures.