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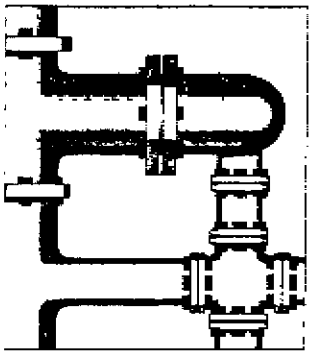
Seismic Retrofitting to Protect Lifelines: The City of Memphis, Tennessee, Memphis Light, Gas, and Water Division

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

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

city's water system, area homes and businesses will benefit from a more reliable 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.

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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

[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.

economy. When they are not accessible, businesses, particularly small retail businesses 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[12] whereas the bridges that sustained significant damage had not yet been retrofitted through the program.

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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

[12] Concrete Reinforcing Steel Institute "Performance of Reinforced Concrete Bridges in the Northridge Earthquake" Illinois 1994

Darlington's historic Main Street Central Business District to the National 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.

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

- Development of a business park on a 35-acre parcel south of 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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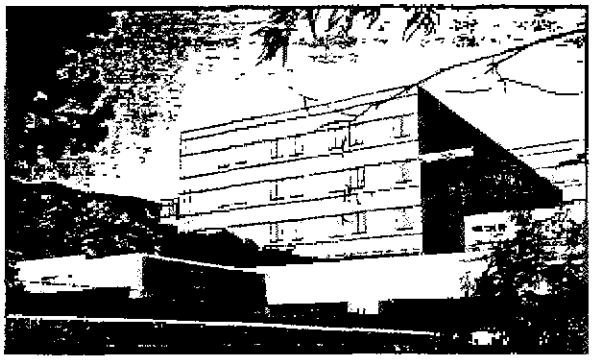
[12] City of Darlington, "Mitigation Project Summary," (Wisconsin: City of Darlington, 1993).

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.

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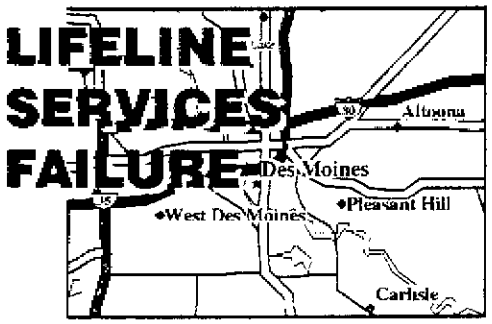

Mitigation to Avoid Business Interruption Costs: Des Moines, Iowa

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.[6]

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

[6] 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

[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.

the 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 to meet current building code standards.

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)

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 was typical of damages experienced by buildings unprotected by wind shutters in high-wind events.[24]

After the disaster, the county decided to not only rebuild the Center, but to also 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 for 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 counties to receive Federal disaster aid. Flooding occurred again in 1995, inundat-

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

ing 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 million will be spent by State and local governments.

[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.

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 to 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 affect 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 from one to two home elevations to Valmeyer, Illinois which relo-

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

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

cated 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.

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[1] 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.

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