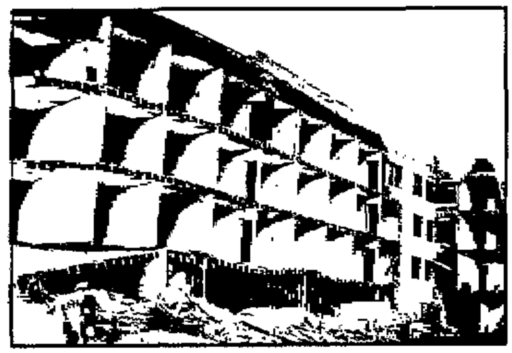
Regulation of Unreinforced Masonry Buildings: Earthquake Hazard Reduction Ordinance in Los Angeles, California



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. Owner's 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.

[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

The important point is that substantial mitigation was achieved 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.

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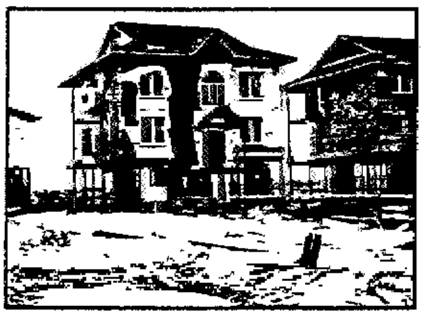
Land Use and Building Codes: Florida's Coastal Construction Control Line

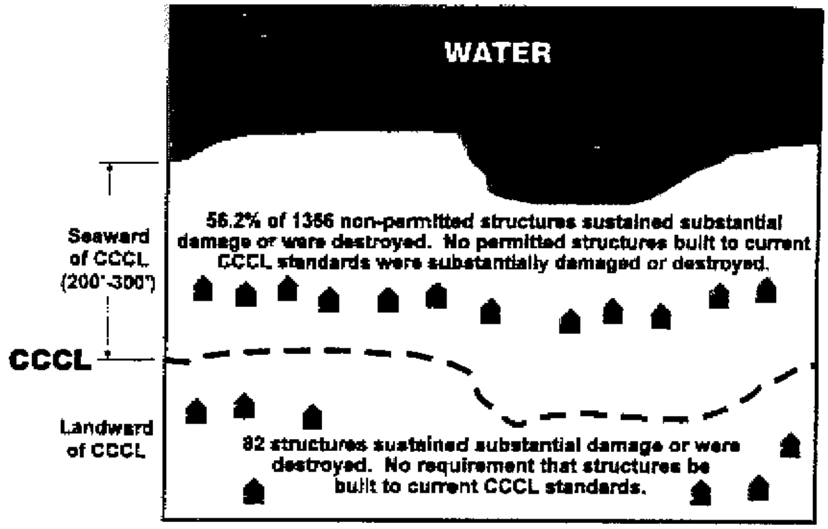


Coastal communities are vulnerable to extensive building damage due to wind forces and storm surges associated with hurricanes. Mitigation measures however, can be implemented to reduce the extent of sustained building damage. Two of the most effective tools for mitigating damages, land use and building 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 requirements, individuals and busi-

> *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.*

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 nesses 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 structures were seaward of the CCCL and 82 structures were

[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 15, 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).

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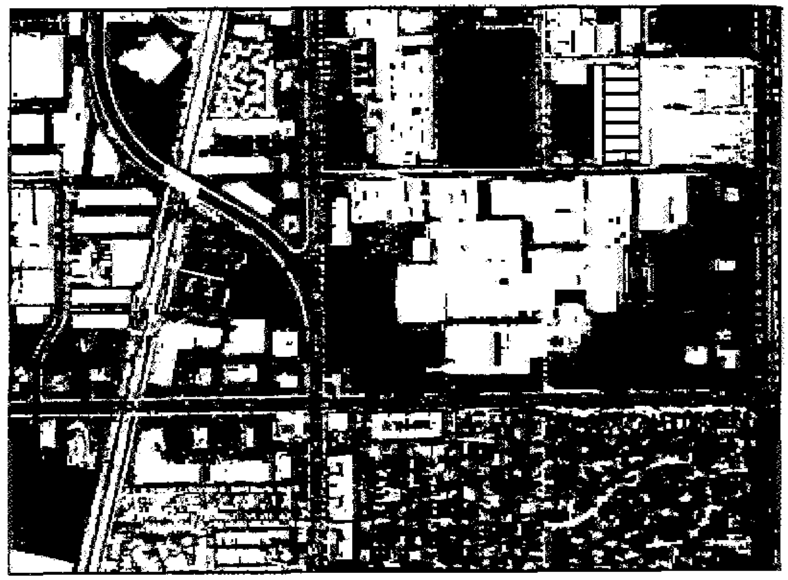
40 Major habitable structures include single family dwellings, multi-family dwellings, and hotels/motels. Substantial damage occurs when the cost of repairing the structure to its pre-disaster condition equals or exceeds 50% of the market value of the structure prior to the disaster.

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 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.

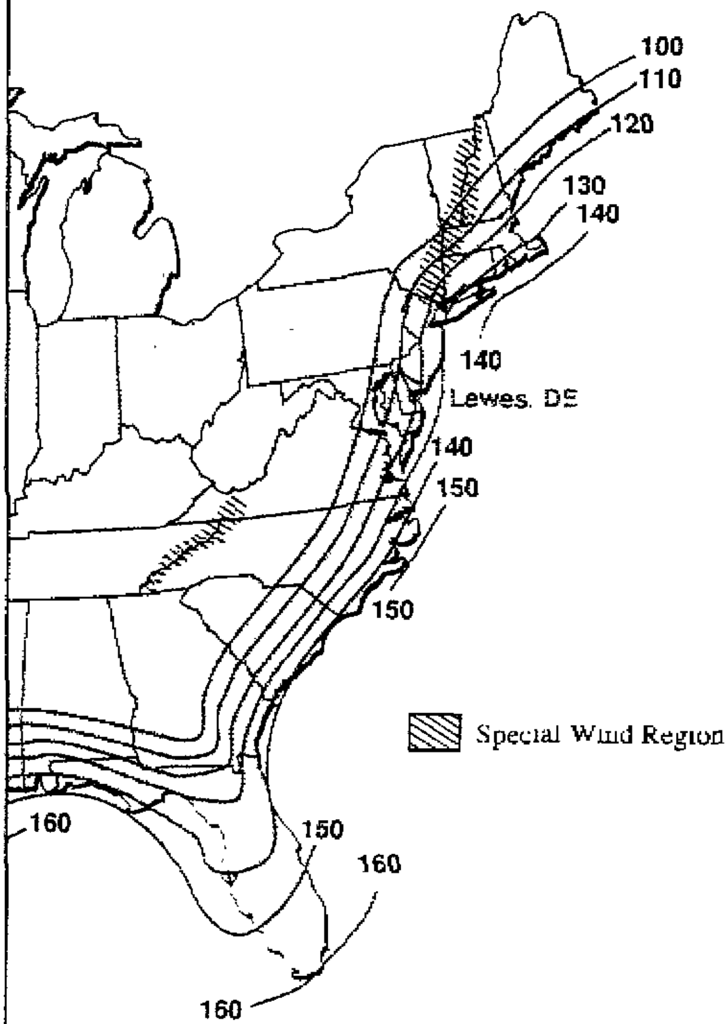
Based on the hazard identification study, the Beebe Medical Center has recognized the importance of incorporating mitigation measures into their capital improvement budget. Over time, the mitigation capital improvement funds will be used to replace inexpensive plywood shutters with more permanent types 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.

Wind Speed Map Based on ASCE7



NOTES

1. Values are 3-second gust speeds in miles per hour at 33 feet above ground for Exposure C and are associated with an annual probability of 0.01.
2. Linear interpolation between wind speed contours is permitted.
3. Islands and coastal areas shall use wind speed contour of coastal area.
4. Mountainous terrain, gorges, ocean promontories, and special regions shall be examined for unusual wind conditions.

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]

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

It is essential that building elements such as 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 predate 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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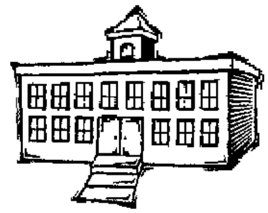
Acquisition/Relocation from Multiple Hazards: The Castaic School District in California

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 stu-

[48] (*Ibid* February 1996)

[49] (*Ibid* February 1996)

dents and 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.[32] 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.

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

Clearly, this 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.

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