Earthquake Risk Management: Mitigation Success Stories

California Seismic Safety Commission

Proposition 122 Seismic Retrofit Practices Improvement Program
Product 2.2 Earthquake Risk Management Tools for Decision-Makers
SSC Report 99-05

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Earthquake Risk Management: Mitigation Success Stories

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Henry Reyes, S.E. California Seismic Safety Commission

Introduction

California's next earthquake could affect your community or business!

Are you prepared?

To answer this question, you must have a clear understanding of your potential seismic risk. A comprehensive earthquake risk assessment, in conjunction with an earthquake loss reduction program, is the best way to protect the lives, property, and economic resources for which you are responsible.

This collection of *Mitigation Success Stories* demonstrates that effective earthquake risk reduction programs can be successfully implemented by public or private organizations. It introduces you to others in your community who have taken responsibility for actually reducing future losses.

This document provides five examples of how earthquake risk is actively managed in diverse communities across the state:

- **East Bay Municipal Utility District**
- **Los Angeles Unified School District**
- **Anheuser-Busch Van Nuys Brewery**
- **Berkeley Unified School District**
- **California State Building Seismic Program**

These stories describe the complexities and nuances associated with the successful implementation of earthquake loss reduction programs. The practical aspects of the risk management decision-making process are highlighted to offer valuable lessons and insight into the process. Finally,

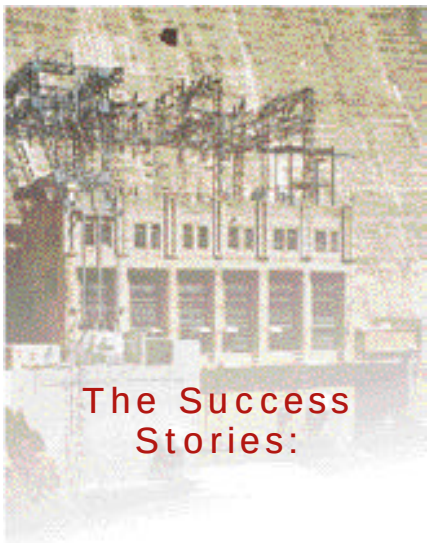
these studies show that earthquake risk management can be a financially viable endeavor, especially when all the costs of potential losses, direct or otherwise, are considered.

A brief summary of each case study follows:

- **East Bay Municipal Utility District.** Highlighted here are the actions of a large public utility in northern California that demonstrate the importance of clearly understanding the scope and magnitude of risk before making a decision to accept or mitigate it. Risk ranking is discussed, as is the importance of developing a methodical approach to assessment and mitigation.
- **Los Angeles Unified School District.** This study illustrates the steps taken by a large school district in southern California to deal with the non-structural elements in its many school buildings that contributed to its earthquake vulnerability. The study demonstrates the importance of mitigating non-structural falling hazards as a means of reducing the life-safety risk to building occupants.
- **Anheuser-Busch Van Nuys Brewery.** The actions of a single privately owned facility in southern California are the subject of this case study. Illustrated is the importance of non-direct costs (business interruption and loss of market share) in influencing the benefit-cost equation in favor of mitigation. Risk screening and ranking methodologies were employed to help focus mitigation efforts to achieve maximum loss reduction. Finally, this mitigation program was tested by an actual moderate-magnitude earthquake and passed with flying colors.
- **Berkeley Unified School District.** Described here is a situation in which public pressure and questions about school building safety prompted a small school district in northern California to initiate a risk assessment study. Perceptions of earthquake risk, prior to the assessment, underestimated the actual magnitude of the vulnerability. Also discussed are the funding difficulties and political hurdles that many public agencies must face to implement their loss reduction program.

- **California State Building Seismic Program.** This case study presents a project of the Division of the State Architect (DSA) to assess and mitigate the earthquake vulnerabilities of nearly 16,000 state-owned buildings. This study reveals how an organization with a large building inventory reviewed and effectively screened out low-risk structures, making the loss reduction effort for the high-risk ones more cost-effective and manageable.

The varying complexity of these *Mitigation Success Stories* illustrates the diversity of earthquake mitigation and loss reduction measures being undertaken across the state. The stories show that mitigation programs can greatly reduce the potential for casualties, decrease the amount of direct and indirect damages, and minimize the disruption caused by, and funds necessary for, response and recovery operations.

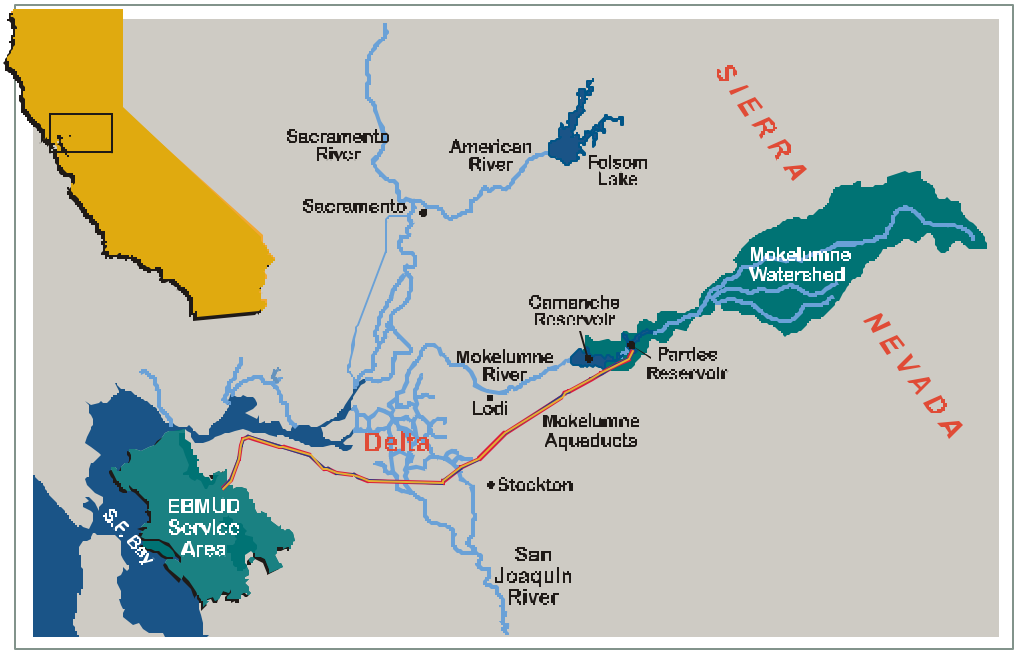


The Success Stories:

Understanding the Potential Risk

A Case Study of the East Bay Municipal Utility District

The 1989 Loma Prieta earthquake sent a clear message to the East Bay Municipal Utility District: an accurate understanding of the district's seismic risk was badly needed. Although the magnitude 7.1 earthquake was centered nearly 70 miles outside of the district's service area, it caused 113 breaks in distribution lines, including one in a 60-inch diameter raw water line. Loma Prieta caught the attention of district officials, who recognized the quake's disruption as a small foretaste of high-probability major earthquakes



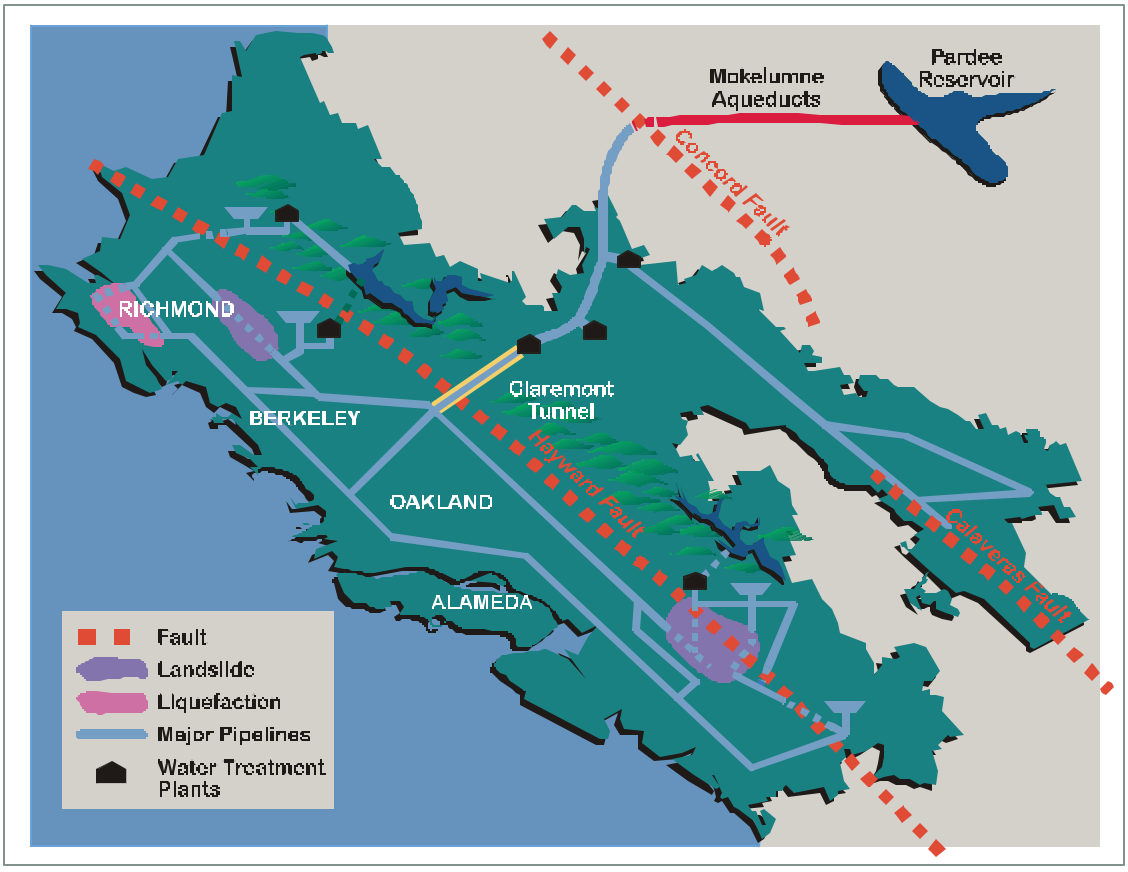
EBMUD Service Area and Water Supply

on the Hayward fault. That the district was at risk was quite clear, but the full extent of the risk was not.

EBMUD

EBMUD service area is traversed by two significant faults ...

The East Bay Municipal Utility District (EBMUD) serves about 1.2 million water customers and 600,000 wastewater customers residing in portions of Alameda and Contra Costa Counties. The water system includes a network of reservoirs, aqueducts, treatment plants, and other distribution facilities, stretching from the Sierra Nevada foothills to the eastern side of San Francisco Bay. The service area of 325 square miles includes 20 incorporated cities and 15 unincorporated communities.

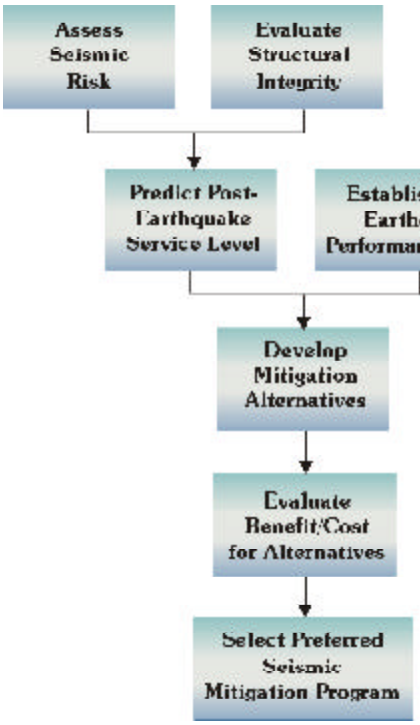


EBMUD Service Area Earthquake Hazard Map

The EBMUD service area is traversed by two significant faults, the Hayward and Calaveras, with a third, the Concord fault, located immediately to the

East. A study completed by the California Working Group on Earthquake Probabilities in 1990 indicated that the northern segment of the Hayward fault has a 28% chance of producing a magnitude 7.0 earthquake by the year 2010. When the three other most active San Francisco Bay Area faults are included, the probability for a magnitude 7.0 earthquake reaches 67% during the same period of time.

EBMUD Seismic Assessment Process



The Seismic Risk Assessment

In 1991, EBMUD undertook a comprehensive seismic risk assessment of its water supply, water treatment, and water distribution facilities. The overall program allowed for the systematic analysis of every critical system to ensure the protection of lives and rapid restoration of services to customers.

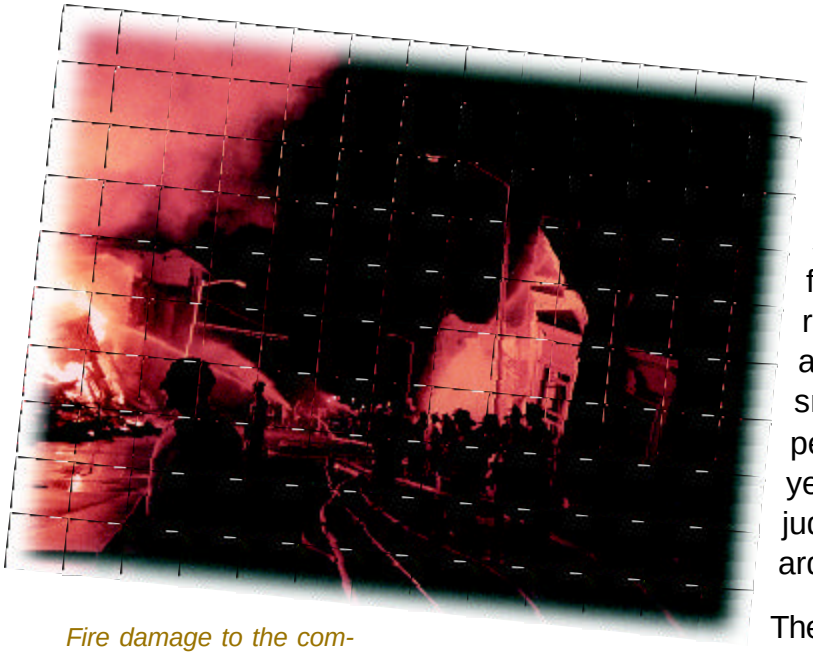
To guide the effort, specific service goals for post-earthquake performance were established. These goals included protecting public safety from direct damage (i.e., reservoir failure), maintaining water quality, ensuring fire fighting capacity, servicing hospitals and critical care facilities, as well as providing domestic water to residential and commercial customers. The abilities of the various systems to achieve the goals served as the framework through which post-earthquake performance was evaluated.

The seismic assessment began by assembling information on the existing facilities, developing the necessary seismological and geographic guidelines, establishing design criteria, and determining how facilities would fail. The information was processed using probabilistic concepts to develop an overall picture of the damage to be expected. All facilities were reviewed according to their importance within the system they supported. In addition, areas without sufficient redundancy were also identified.

EBMUD Facilities Evaluated

Facilities Evaluated	Number
Reservoirs	175
Pumping Plants	130
Treatment Plants	6
Tunnels	3
Piping	Over 6,100 km
Fault Crossings	200
Other Facilities	22

System performance levels were evaluated under four scenario earthquake events. Three of the scenario earthquakes were chosen to represent severe



Fire damage to the community associated with the disruption of fire fighting abilities following the scenario Hayward earthquake could total $140 million for a day with calm winds.

shaking in maximum credible events on the Hayward fault. Such quakes would be expected to occur once every several hundred years. A fourth earthquake of smaller magnitude, but with greater frequency, was also considered as representative of the seismicity along the Hayward fault. This smaller earthquake would be expected to occur once every 20 to 50 years. These four scenarios were judged to represent the seismic hazard in the district.

The picture that emerged from the seismic assessment was sobering. About 70% of the district's customers are located west of the Hayward fault, with most of the supply coming from the east. Four routes were available for water delivery: three water conveyance tunnels and a pipeline. Two of the tunnels bisected the Hayward fault, while the outlet pipe from the third tunnel and pipeline crosses over the fault. Severe damage to all four routes was predicted in a rupture of the Hayward fault. Additionally, many of the water pumping plants critical to the district's distribution ability were built in the 1920's and 1930's, before the advent of modern seismic codes. Even episodes of moderate shaking could inflict severe damage on these facilities.

Impact of the Scenario Hayward M7.0 Earthquake	
Service Impacts	
Percentage of Customers with Outages	63%
Time to Restore *Impaired* Service	182 days
Time to Restore Reliable Service	645 days
Direct Losses	
Repair Costs	$196M to $245M
1995/96 Operating Budget	$352M
Indirect Losses	
Fire Losses (Calm Winds)	$140M
Community Economic Loss	$1,500M

The overall vulnerability of its facilities, the lack of redundancy in several of the critical systems, and the significant earthquake hazard, made the risk to EBMUD operations considerable. For the scenario magnitude 7.0 earthquake on the Hayward fault, for instance, it was anticipated that two-thirds of the district's customers would be immediately without water. After about three days, continuing loss of supplies from sustained damage would raise that level to nearly three-quarters of customers. Furthermore,

it was estimated that it would take nearly six months to restore *limited* service to all affected customers.

The economic losses associated with this Hayward scenario earthquake were also staggering. Estimates of direct damage and repair costs for the EBMUD facilities ranged between $196 million to $245 million. Fire damage associated with the disruption of fire-fighting abilities could total $140 million for a day with calm winds. This figure becomes considerably higher if the winds are high the day of the quake. The economic loss to the communities during this extended period of service disruption was conservatively estimated to exceed $1.5 billion. It was clear to the district that complete shutdown of its system would have an unacceptable impact on its community.

The key policy decision facing the EBMUD Board of Directors was to select an appropriate level of post-earthquake system reliability and robustness.

The Mitigation Strategies

Four different capital improvement packages (CIPs) were developed, as was a priority package for essential upgrades. The packages reflected the range of possible choices for the EBMUD Board of Directors. The priority package included all the high benefit-cost mitigation measures: equipment anchoring/bracing and emergency response planning; it was considered to be the minimum effort that the district should undertake. All of the high-cost fixes, such as structural strengthening and construction of redundant systems, were included in other CIPs. The key policy decision facing the EBMUD Board of Directors was to select an appropriate level of reliability and robustness for post-earthquake system performance.

Mitigation Packages and Costs

Plan	Description	Cost
Priority Package	• Perform upgrades to protect public safety • High benefit-cost upgrades (equipment)	$13M
Package 1	All Priority Package upgrades, plus • Enable service following smallest scenario earthquake	$16M
Package 2	All Package 1 upgrades, plus • Enable limited water service for all pressure zones for maximum earthquake • Upgrade one pumping plant and reservoir per pressure zone • Emergency pumping equipment to bypass Claremont Tunnel, if damaged	$84M
Package 3	All Package 2 upgrades, plus • Upgrade all pumping plants and pressure zone • Upgrade Claremont Tunnel • Construct redundant pipeline	$189M
Package 4	All Package 3 upgrades, plus • Little or no post-earthquake disruption following all four scenario earthquakes	$360M

However, before any decision could be made, the range of

mitigation alternatives had to first be presented to the public, since the district customers would ultimately pay for the program chosen. In addition, each of the seven elected board members must answer to the voters. To ensure public backing, EBMUD developed an extensive outreach and education program.

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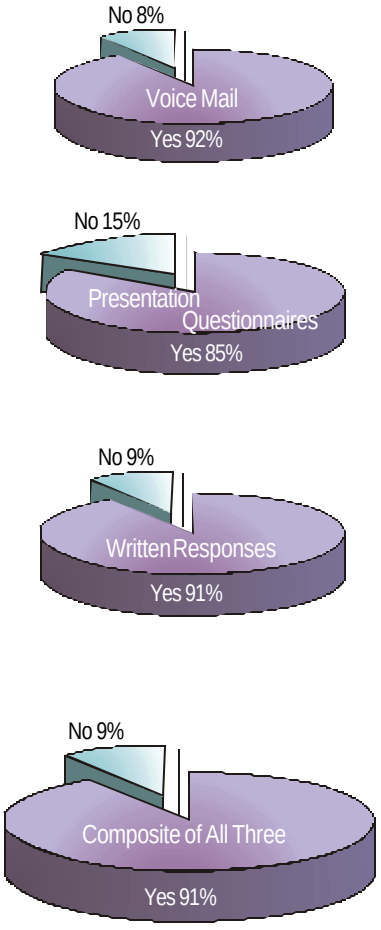
To assess what the voters might think of the program options and the proposed funding mechanisms, district staff made numerous presentations to community groups. The voters were most interested in the post-earthquake performance of the system and in how the program would improve reliability. The second most important concern was that the cost of improvements be fairly allocated by benefits received. Other frequent questions included how soon the improvements could be implemented (almost all favoring as soon as possible), how much water bills would increase, and when the next earthquake was expected. Interestingly, the cost of the program to the customer was less important to the voters than when the program would be completed.

Public Outreach Results

Do you support the proposed program?



Following every presentation, the public was asked if they approved of the proposed plans. An overwhelming 91% of the respondents favored implementing the mitigations, even with the knowledge that they would have to pay for it.

The Decision

The board chose an intermediate alternative, which greatly improved the district's capacity for ensuring operations following severe earthquakes. The approach was seen as best balancing the mitigation of seismic risk with the cost of implementation. This option provides a system that will meet the goals of providing adequate water for fire fighting as well as for drinking following the worst of the earthquake scenarios considered.

After board adoption, a detailed implementation plan, called the Seismic Improvement Plan (SIP), was

Workers use wire wrapping to improve hoop strength of the reservoir tank.

developed for accomplishing the proposed upgrades in a ten-year program. This plan divided the program into seven subprograms for tracking and reporting purposes. In addition, an independent operating group was created from within the EBMUD organization for the sole purpose of consulting, managing, and designing the seismic mitigation effort.

Creation of this separate group was considered a crucial step in the success of the seismic improvement program. Seismic mitigation monies were separated from other capital project funds to ensure that the badly needed upgrades would be installed without delay. The separation minimized the temptation to divert mitigation funding to other projects. Separation also ensured that there would continue to be an advocate for seismic strengthening within EBMUD, even when the issue of earthquake risk has lost the attention of the customers.

Funding the Mitigation Program

As noted above, the seismic improvement program was funded through direct charges to the customer water bills. The average residential customer would pay about $20 per year for the next 30 years for these improvements.

The factors used in fairly assigning costs to various users considered the two major benefits of the program: post-earthquake fire flow capacity and post-earthquake drinking water supply capacity, where each factor represents one-half the total program cost. The fire flow must be adequate to reasonably protect property from fires following earthquakes. The drinking water supply must be sufficient to ensure adequate water for essential uses—drinking and sanitation. Uses such as landscape watering were considered to be non-essential following severe earthquakes.

Mitigation Program Status

Now entering its fourth year of implementation, the EBMUD Seismic Improvement Program is in full swing, on track to meet its aggressive ten-year goal of

An EBMUD crew practices the deployment of flexible hoses to bypass a damaged section of a main water distribution line crossing a fault.

completion. Over 155 facilities have been upgraded, at a cost of about $34 million, or 17% of the total program budget.

Below is a status summary of the major seismic mitigation tasks included in the SIP:

- Planning and preliminary design for the Claremont Water Conveyance Tunnel is underway.
- The Southern Loop, a new large pipeline, is being designed to allow EBMUD to shuttle water between east and west in the southern part of the district's service area.
- Many of the older reservoirs that are either not anchored or inadequately anchored to their foundations are being reinforced.
- Many reservoir valve pits, which hold critical valves and instruments and have unstable covers, are being upgraded.
- Isolation valves with emergency bypasses for pipelines crossing the Hayward and Calaveras faults are being installed with the ability to tolerate the expected 3-5 feet of displacement on the

Hayward fault, and 2-3 feet of displacement on the Calaveras fault.

- Designs have been completed for the anchoring of critical equipment and storage shelves at the district office, maintenance, and warehouse buildings. Installation will start in conjunction with the building structural upgrades.
- Vulnerable treatment plant systems are being seismically upgraded.
- Several of the oldest, most vulnerable pumping plants are being strengthened.

Lessons Learned

Although not quite halfway through the complete project, EBMUD officials have learned several important lessons:

- Establishment of specific post-earthquake performance goals is a prerequisite in defining the scope and cost of mitigation alternatives necessary for responsible decision-making.
- Emphasis on system reliability, rather than individual facility performance, produces a cost-effective mitigation program.
- To ensure public backing of the mitigation efforts, use outreach and education to develop awareness of both the earthquake threat and the potential impact on daily life.
- Separating the seismic mitigation monies and management from other capital improvement projects helps to facilitate cost and schedule tracking, as well as to ensure that an advocate for seismic risk reduction is always present in the overall organization.

Photos and text adapted from EBMUD.

Special thanks to Mr. David Lee, P.E, and Andrea Pook of EBMUD for their assistance in developing this case study.

The Success Stories:

Nonstructural Mitigation Measures

A Case Study of the Los Angeles Unified School District

Unsecured contents, fixtures, and architectural elements can be significant life-safety hazards during episodes of strong earthquake ground motion, even when the building they are in has low collapse potential. Although structural strengthening is most often considered the only path to reduced seismic vulnerability, nonstructural upgrades are a necessary and economical protection for people and property.

Suspended, unbraced ceiling lighting typically found in LAUSD classrooms and vulnerable to damage

There are many relatively simple and cost-effective measures available to reduce the hazard from nonstructural items and ensure greater occupant safety. The suspended lighting retrofit project conducted by the Los Angeles Unified School District is an example of one such approach.

LAUSD

The Los Angeles Unified School District (LAUSD) is second in size only to the New York City School District. At present, the district is composed of over 900 schools, with a population of over 800,000 students, and employs 57,000 full-time and 24,000 part-time staff. The LAUSD provides public education services to a 708 square-mile area, serving the cities of Los Angeles, Bell, Carson, Cudahay, Gardenia, Huntington Park, Lomita, Maywood, San Fernando, South Gate, Vernon, and

Collapsed pendant light system, typical of damage sustained in the 1994 Northridge earthquake.

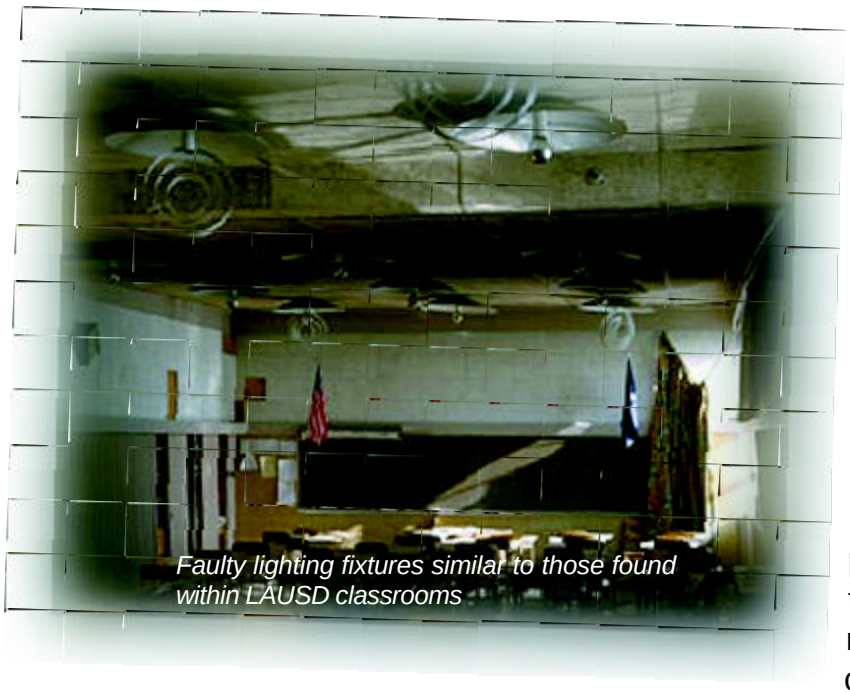
West Hollywood; portions of 18 other cities; and the unincorporated areas of Los Angeles County.

The 1994 Northridge Earthquake

In the 1994 Northridge earthquake, 5500 buildings owned by LAUSD were damaged, with total losses currently estimated at $134 million. Seven hundred and fifty-two classrooms were deemed unsafe at 64 district schools. The vast majority of damage was to nonstructural elements, with suspended ceiling and embedded pendant lighting systems being the primary contributor. In the week following the earthquake, 88% of the school sites were reopened, but clean-up efforts were extensive throughout the district.

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 embedded pendant lighting systems. Many such lights fell from classroom and hallway ceilings during the strong shaking. The quake struck at 4:31 am, so no one was in the schools, but had students and teachers been present, some would have been injured or killed by the falling light fixtures.

The Northridge earthquake showed just how hazardous the existing lighting systems were to building occupants. LAUSD decided to ret-



Faulty lighting fixtures similar to those found within LAUSD classrooms

rofit or replace the high-risk suspended ceiling and embedded pendant lighting systems in its classrooms to reduce the high risk of injury to the more than 800,000 school children during future earthquakes.

The Mitigation Program

A detailed benefit-cost analysis was completed for the nonstructural mitigation project prior to its implementation as a tool to help guide the decision-making process. The analysis considered not only the obvious financial costs of direct classroom damage and disruption associated with light system collapse, but also the difficult-to-quantify issue of student safety. Because earthquakes can occur at any time in the 24-hour cycle, the probability that people will be present and injured tends to be relatively low because most classrooms are occupied for about a third of the day during three-quarters of a year. However, if earthquakes were to strike during school hours, the injury and death rates would be much higher than the average assumed for a 24-hour or 365-day period. Given the potential for high school-hour injury and death rates, the mitigation project was considered both worthwhile and very cost-effective.

Robert T. Stafford Disaster Relief and Emergency Assistance Act

FEMA provides funding for hazard mitigation activities through the Disaster Relief Act of 1974, P.L. 93-288, which was amended in 1988 by P.L. 100-707 (the Robert T. Stafford Disaster Relief and Emergency Assistance Act.) Two distinct sections of the act provide funding for loss reduction measures: Section 404 and Section 406.

Section 404

Section 404, the Hazard Mitigation Grant Program (HMGP), enables FEMA to make grants to eligible applicants to fund cost-effective measures aimed at preventing future damage. The HMGP assists state and local communities in implementing long-term mitigation measures.

Section 406

Section 406 provides funding for mitigation measures to be added to the repair or replacement of public facilities damaged in a declared disaster. This funding is above and beyond the cost to repair the facility to its pre-disaster conditions.

Under Section 406 of the Stafford Act, the Federal Emergency Management Agency (FEMA) paid $3.1 million to repair the LAUSD lighting systems damaged in the Northridge earthquake. In addition, $45 million was obligated under Section 404 of the Stafford Act (the Hazard Mitigation Grant Program) to reinforce the lights of the same vulnerable design that did not sustain damage. The estimated project costs for replacing or strengthening these lighting systems district-wide averaged approximately $3 per square foot.

The estimated project costs for replacing or strengthening the vulnerable lighting systems district-wide averaged approximately $3 per square foot.

With the expenditure of these funds, LAUSD is confident that the 800,000 school children enrolled district-wide are in a much safer environment and have much less chance of injury or disruption of their education should other earthquakes strike.

Text adapted from Federal Emergency Management Agency (FEMA) publication, ***Reducing Risk through Mitigation: Report on Costs and Benefits of Natural Hazard Mitigation.***

Photos courtesy of the EQUIIS Photographic Database and Henry Reyes, S.E., California Seismic Safety Commission.

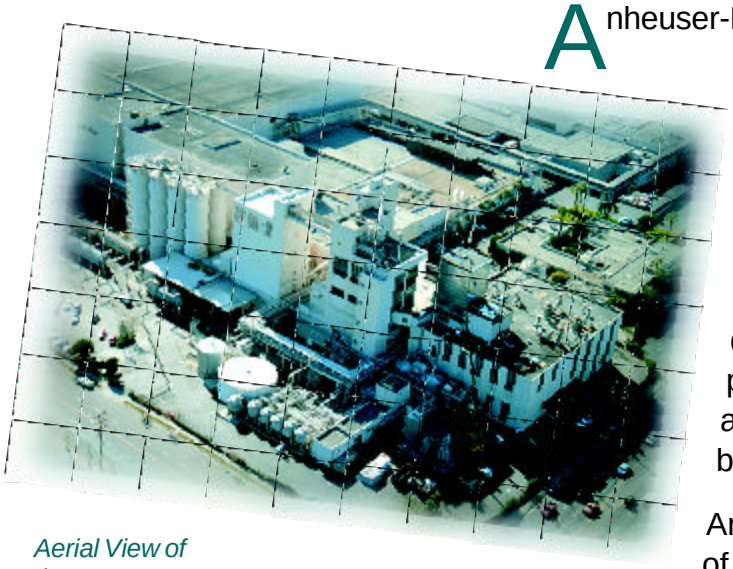
The Success Stories:

Where Business Interruption Matters

A Case Study of the Anheuser-Busch Van Nuys Brewery

Earthquake mitigation is beneficial for individuals, businesses, and governments. Of the three, businesses tend to focus most on the associated economic benefits of mitigation. If the functioning of a single facility supports a large segment of a business' profit base, it is critical to protect against disruption of its operations. Consideration of the benefits associated with avoiding large business interruption losses makes seismic risk mitigation more economically appealing.

The Brewery



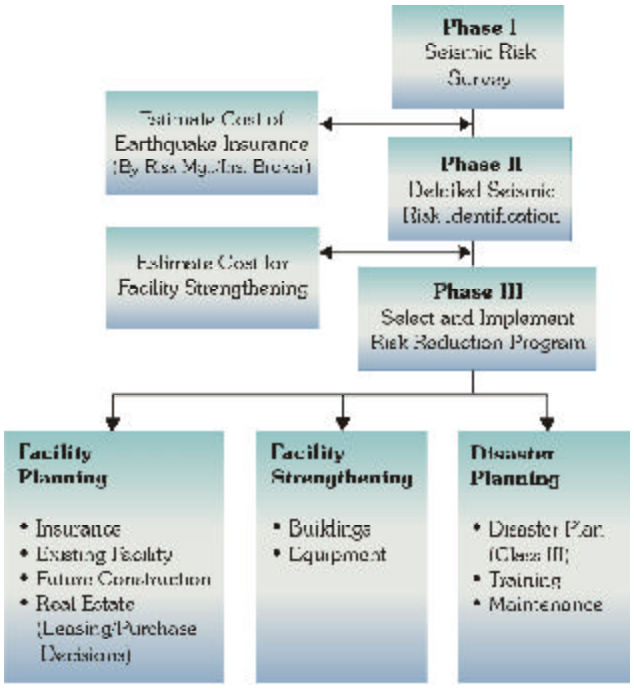
Aerial View of the Van Nuys Brewery

Anheuser-Busch operates a large brewery in Van Nuys, California, just a few miles from the epicenter of the January 17, 1994 Northridge earthquake. This facility was originally constructed in 1954 and was later expanded in 1981. The complex serves the company's markets throughout the Southwest and Pacific regions, with an annual production of nearly 12 million barrels. The complex includes a number of large buildings with a total replacement value of more than $1.3 billion.

Anheuser-Busch has a unique understanding of its seismic risk. In the 1971 San Fernando earthquake, the Van Nuys brewery was damaged and beer production was interrupted for a prolonged

period of time. During this disruption, competitors were able to make large gains into the Anheuser-Busch market share. This significant financial loss motivated Anheuser-Busch to place greater value on seismic design in both repaired and new facilities. In fact, a new Anheuser-Busch brewery built in Fairfield, California, in the mid 1980's was designed to seismic standards much higher than those provided in the then-current building code.

Anheiser-Busch Seismic Risk Reduction Program



The Risk Assessment Program

In the early 1980s, Anheuser-Busch initiated a comprehensive risk reduction program for the older Van Nuys brewery to control future damages by decreasing the vulnerability of the buildings and equipment within the facility. The goal was to ensure that production following future severe earthquakes would be minimally interrupted. This tolerance level was established from reviewing the results of numerous benefit-cost analyses that considered many different mitigation options. All of the analyses attended to the benefits associated with preventing a prolonged loss of production capacity and minimizing any potential loss of market share following severe earthquakes. These benefits were balanced in the benefit-cost analysis with the direct costs of installing the building and equipment upgrades.

Partial Summary of Seismic Risk by Structure

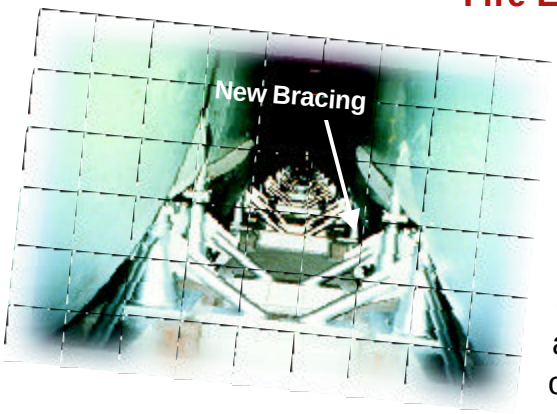
Structure	Construction	Year of Design	Seismic Risk	Probable Maximum Loss
Power Plant	Concrete	1963	High	35%
Fire Water Tank	Steel Plate	1953	Very High	>50%
Fuel Oil Tank	Steel Plate	1953	Very High	>50%
Fire Pumphouse	Prefab. Metal	1953	Low	10%
Pipeway Bridges	Steel	1966	High	30%
Substation	Equipment	1970's	High	35%

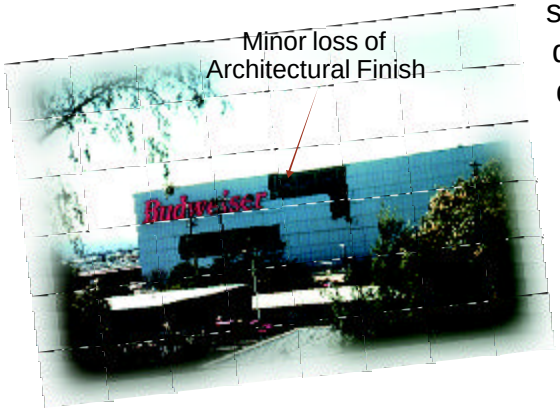
The brewery buildings and equipment were assessed for risk, and those with unacceptable levels were seismically upgraded,

Beer Vat Supports Before and After being Braced

without affecting daily operations. Seismic reinforcements were designed for a number of buildings and the critical equipment therein, including buildings housing beverage production and large horizontal tanks for beer fermenting, storage, and aging. Other low-risk buildings, less important to operations and judged not to be life-safety hazards, were screened out of the process, thereby ensuring the most efficient use of limited resources. The total cost of the strengthening program was about $11 million, less than 1% of the total facility replacement cost.

The Earthquake





Typical Damage Sustained to the Low-risk, Unstrengthened Buildings during 1994 Northridge Earthquake

The 1994 Northridge earthquake produced very strong ground motion, causing partial collapses and extensive damage to many buildings in the immediate vicinity of the brewery. However, post-earthquake surveys conducted by Anheuser-Busch's engineering consultants showed that none of the retrofitted structures sustained significant damage, nor did equipment essential to the brewery's operations. Additionally, there were no major employee injuries associated with the earthquake. Other on-site buildings and equipment that had not been strengthened in the 1980s did sustain damage, requiring about $17 million in repairs. The brewery was quickly returned to nearly full operation in seven days following minor cleanup and repairs, and the restoration of the off-site water supply. Anheuser-Busch lost none of their pre-earthquake market share, which had been the overriding goal of the seismic risk reduction program.

The Payoff

Anheuser-Busch estimated that their facility would have suffered a direct property loss of about $350 million from the Northridge earthquake had there been no seismic strengthening. This averted damage is more than 30 times the actual cost of the brewery's loss control program. Conservative estimates of direct and business interruption losses at the brewery—had there been no

In Contrast . . .

Hakutsuru Sake Brewery

The Hakutsuru Sake Brewery in Kobe, Japan, was subjected to severe ground shaking in the 1995 Great Hanshin earthquake. The very strong ground shaking intensities at the Hakutsuru site were comparable to those at the Anheuser-Busch Van Nuys Brewery a year earlier. However, the unretrofitted sake fermentation tanks, similar to the Van Nuys beer vats, collapsed because of the lack of bracing, resulting in a complete shutdown of sake production for nearly 8 months. In contrast, the well-braced Van Nuys beer vats sustained no damage in the Northridge earthquake and beer production was not disrupted.

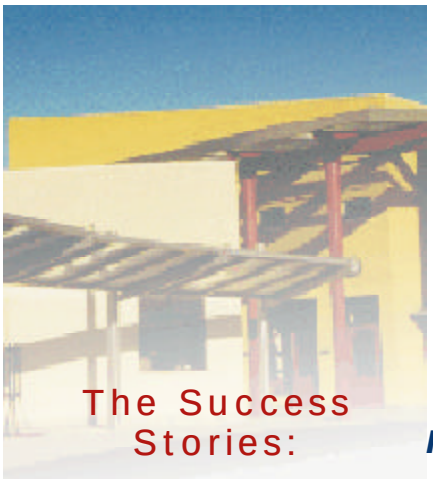
Failed Fermentation Tank Supports

strengthening—could have exceeded $750 million, over 60 times the cost of the mitigation program. In turn, market share losses would have exceeded the direct and business interruption losses. Clearly, the loss control program paid for itself in the Northridge earthquake. The Anheuser-Busch case study shows how effectively mitigation measures can protect corporate balance sheets.

The Brewhouse Before and After Seismic Retrofitting.

Photos courtesy of EQE International, Inc.

Running the Numbers	
Program Costs	
Facility Replacement Value	$1,300M
Mitigation Costs	$11M
Strengthening Cost Breakdown	
Power Plant Building:	
Steel Portion	$22/sqft.
Concrete Portion	$25/sqft.
Substation:	
Equipment (93 units)	$18/sqft. ($540/unit)
Avoided Loss	
Direct Damage Avoided	$350M
Indirect Damage Avoided	$400M
Total Damage Avoided	$750M
Benefit/Cost Ratio = $750M/$11M = 68	



The Success Stories:

Public Leadership and Expectations

A Case Study of the Berkeley Unified School District

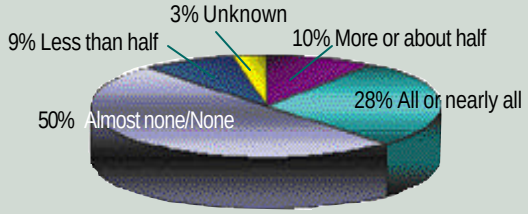
Earthquake preparedness and hazard mitigation are not the most pressing daily problems for most public and private institutions in California. Public school districts are no exception. Most school administrators and teachers have many other items on their "TO DO" lists. Many also hold the popular, but incorrect, idea that school buildings constructed under the auspices of the California Field Act are safe by definition. Many school officials and parents think that preparedness consists of having water bottles and granola bars stored at school sites. Similarly, they point to some bookcases and file cabinets bolted to walls as evidence of a hazard mitigation program.

Without some other motivation, earthquake preparedness and hazard mitigation would continue to remain a low priority. In the case of the Berkeley Unified School District (BUSD), the Loma Prieta earthquake started the seismic safety ball rolling. BUSD initiated its earthquake risk assessment and hazard mitigation program because parents and the school board became concerned about potential school damages in earthquakes. The BUSD story shows how a community came together to make earthquake preparedness a top district priority.

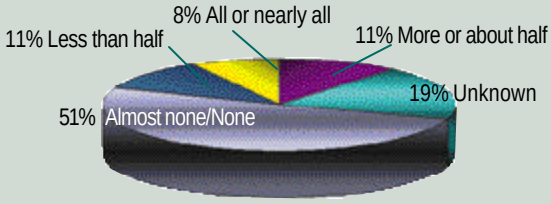
Public School Seismic Safety Survey

A survey reported in June 1999 by the University of California, Berkeley Graduate School of Journalism for the *Los Angeles Times* of nearly 200 public school districts in the nine Bay Area counties, as well as Los Angeles and Orange counties, revealed the following:

Structural Evaluations:
Only 28% of the surveyed districts have seismically evaluated all or some of their buildings. Nearly 50% had evaluated none or nearly none.

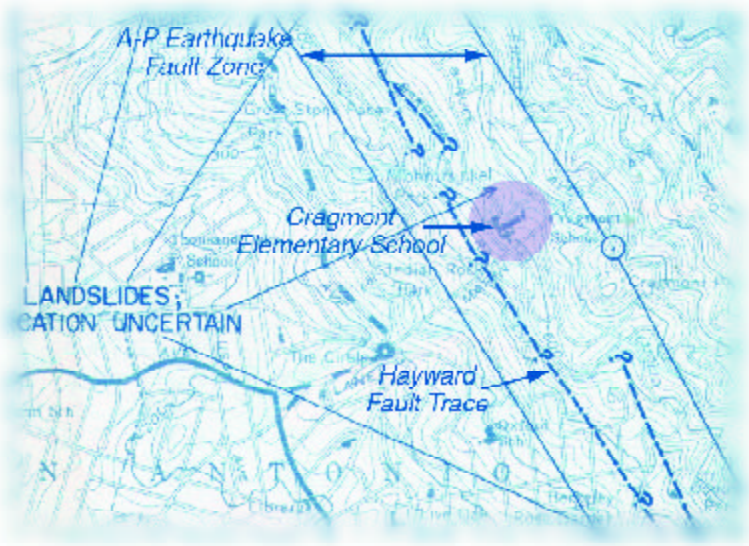


Retrofits Needed:
Yet, nearly 51% of the surveyed districts believe their buildings do not need any seismic retrofitting.



BUSD

The Berkeley Unified School District (BUSD) serves about 9,500 students primarily within the City of Berkeley, California. BUSD is a typical, older urban school district, comprising twelve elementary schools, three middle schools, one high school, an alternative school campus, and several support buildings. The district's newest building, Cragmont Elementary School, was constructed in 1965, but most of its other schools were built in the 1920's and 1930's.



Cragmont Elementary School is located within the Alquist-Priolo Earthquake Fault Zone.

BUSD is located in Alameda County, one of the most seismically active areas in the country. The Hayward fault cuts through the eastern edge of the district boundary, and several of the district's campuses are located in close proximity to the fault trace. Within the Alquist-Priolo Earthquake Fault Zone, an area about ¼ mile wide along known faults in California, new construction must be reviewed and specially engineered. Cragmont Elementary is within the Alquist-Priolo Earthquake Fault Zone for the Hayward fault.

The Earthquake

Most of BUSD's buildings were older, built mostly in the 1920's and 1930's.

The October, 1989, Loma Prieta earthquake caused little damage in Berkeley, but it did alert a number of parents to how poorly prepared the school district was for a future, more proximate earthquake. In late October of that same year, several inquisitive PTA mothers queried the principal of their children's school about its earthquake preparedness plans and emergency supplies. Dissatisfied with the situation at that school, they took their concerns to the School Board. In talks with a high-ranking dis-

trict administrator, they determined that the district's emergency plans were out-of-date, teachers and staff weren't trained in disaster response, communications equipment was scarce and outmoded, and few first aid, water, or food supplies were stored in any facility.

The mothers took this information back to their PTA group and, in November 1989, the individual PTA involved the larger PTA Council in discussions with the school board. The board shared the parents' concern for the lack of resources. During December 1989 and January 1990, the PTA Council members gathered information on earthquake risk from various Bay Area seismic safety information sources. A wealth of the collected information was presented to the school board every time it met in those months.

... in part because of the PTA lobbying efforts, the school board decided in February 1990 to spend $193,000 for comprehensive earthquake planning and preparedness.

Among the salient points consistently mentioned by the parents were: (1) the high probability of a damaging earthquake on the Hayward fault, (2) the location of a few of BUSD's schools near that fault, and (3) the potential for strong ground shaking all over Berkeley during an earthquake centered on that fault. The PTA Council also reminded board members of the Katz Bill, the California law requiring that schools plan for earthquakes and mitigate their nonstructural hazards.

Finally, in part because the geologic observations and risk information were persuasive, and in part because of the PTA lobbying efforts, the school board decided in February 1990 to spend $193,000 for comprehensive earthquake planning and preparedness. The funding came from the District's Reserve for Economic Uncertainties, an emergency fund required by the state of all school districts.

Following both the specifications of the Katz Bill and the recommendations in a 1989 California State Department of Education report, BUSD undertook the following tasks:

- Developing a comprehensive, district-wide disaster preparedness plan and site-specific plans for all schools and all departments.

The Katz Bill

Adopted in 1984, the Katz Bill (California Education Code Sections 35295, 35296, & 35297) requires that all public and private elementary, middle and high schools with enrollments of 50 or more students establish an "earthquake emergency system." Specifically, the bill requires schools to develop earthquake response and recovery plans, conduct periodic duck-and-cover drills, train staff and students for earthquake safety and response, and mitigate seismic hazards in school buildings. However, since no funding has been appropriated by the State Legislature to support school preparedness efforts and there is no real penalty for non-compliance, very few California schools have developed and implemented comprehensive earthquake preparedness and mitigation programs as intended by the bill.

- Training all staff in the elements of the plans, as well as an instruction program in first aid and CPR staffed by district personnel.

Whittier/Arts Magnet School was identified as being a high-risk structure with the potential for collapse in a serious Hayward earthquake.

- Acquiring and stockpiling emergency and medical supplies for all district schools, back-up communications equipment using a variety of power sources, and two days' worth of food and water at each school.
- Completing an engineering study of the structural hazards at several schools and nonstructural hazards at each school.

Jefferson Junior High School in Long Beach was one of many public school buildings that sustained heavy damage in the 1933 Long Beach earthquake and initiated numerous early efforts to improve public school seismic safety.

The Engineering Study

The results of the engineering study for the first six schools were delivered to the school district in September, 1990. The report indicated that two of the district's elementary schools, Whittier/Arts Magnet and Cragmont Elementary, were potential collapse hazards in a serious Hayward fault earthquake. This news was especially distressing since Cragmont was the flagship Berkeley school. Prior to retrofitting the school, the site required further geological investigation. The geological investigation revealed a number of problems that made

seismic retrofitting of the existing school almost impossible.

Many people were surprised and shocked by the engineering report, perhaps because they believed in the inherent safety of Field Act schools. The Field Act, enacted following the 1933 Long Beach earthquake, when many school buildings were severely damaged, established the practice of building California schools to more rigorous standards than those offered in the conventional building code. Act provisions have been updated many times over the last 60 years as the understanding of earthquakes and building response has improved. However, a school that met the 1965 Field Act design and construction regulations might not meet the 1991 regulations, and may be considered unsafe.

All of the BUSD schools were built under older Field Act provisions.

Luther Burbank School in Long Beach sustained significant damage in the 1933 Long Beach earthquake.

Additionally, with the seismic report of the first six sites already in print, the school board was advised that it had a legal imperative to act to protect the children in the hazardous schools. In the meantime and quite coincidentally, the United States Geological Survey (USGS) published, and disseminated in millions of Sunday newspapers, a tabloid booklet called "The Next Big Earthquake in the Bay Area May Come Sooner Than You Think". This booklet reported the new results of geological studies on Bay Area earthquake probabilities: they were even higher than previously estimated–a 67% chance for a damaging earthquake on a major Bay Area fault in the next 30 years.

In 1990, United States Geological Survey (USGS) estimated that there was a 67% chance for a damaging earthquake on a major Bay Area fault in the next 30 years.

Further impetus to close the hazardous schools came from two additional players. The Office of the State Architect (OSA, now the Division of the State Architect), the California state agency responsible for the structural safety of California schools, reviewed the engineering report and concurred with its conclusions. It happened also that the parent of a child in one of the suspect schools was a prominent structural engineer. Not only did he agree with the findings, but he also wrote a long letter to the district and met with the Assistant Superintendent. His ability to speak as both a technical specialist and a concerned parent had an immediate effect. The Superintendent recommended closure of the

high-risk buildings at both school sites. The School Board approved this recommendation. The board further voted to evaluate all the other buildings in the district.

The district was faced with challenges in financing the engineering study, the movement of the students, and the preparation of space to house the students. The Associate Superintendent, Anton Jungherr, provided the financial and operational leadership needed to finance the improvements and organize the efforts of the district facilities staff and the community process. A key hire was the leader of the PTA who had been instrumental in raising public awareness of the issue. She proved invaluable in pressuring the State of California into helping the beleaguered district fund a portion of the costs.

Following the engineering survey, the seismically unsafe Cragmont Elementary School was ordered vacated by the School Board.

In February, 1991, BUSD received the structural risk assessment reports for the rest of its school sites – and the news was not good. The engineers had identified significant structural deficiencies in six additional buildings. Three more elementary schools were found to be potentially hazardous, two of which were non-ductile concrete frame buildings, and one was a wood frame structure built in the 1920s. The non-ductile concrete cafeteria at Berkeley High School was also ranked as a serious collapse hazard. In response to these reports, the district changed the use or completely vacated the newly identified high-risk structures.

BUSD's first move to finance the program was to issue Certificates of Participation (COPs).

Finding the Funding

BUSD's first financial move was to issue Certificates of Participation (COPs). This is a method of borrowing against the property value of the school

district. The COPs paid for the relocation effort necessary to immediately address the student safety issue, as well as the district-wide engineering study. The Associate Superintendent worked against an extremely tight schedule in order to receive this financing in time to avoid finishing the fiscal year with a deficit.

The State Allocation Board is a state agency that allocates state funding for school facilities in California.

At the same time, an application was made to the State Allocation Board (SAB) for grants to "modernize" the seismically unsafe portions of the two schools already found to be hazardous. The State Allocation Board is a state agency that allocates state funding for school facilities in California.

Alquist-Priolo Act

Passed in 1972, the Alquist-Priolo Earthquake Fault Zoning Act's main purpose is to prevent the construction of buildings used for human occupancy on the surface trace of active faults. This state law was a direct result of the 1971 San Fernando Earthquake, which was associated with extensive surface fault ruptures that damaged numerous homes, commercial buildings, and other structures.

The Act specifically prohibits public school buildings from being constructed within the so-called Alquist-Priolo Earthquake Fault Zones ("Special Studies Zones" prior to January 1, 1994), regulatory regions around active faults that average about one-quarter mile wide.

The chief concerns of the SAB with respect to BUSD's request were that funding BUSD would set a precedent for other urban school districts in California to request retrofit money. BUSD, like many urban districts in California (and the rest of the country), consists of typically older school buildings whose safety is considered to be questionable because: (1) the buildings were built before the 1971 San Fernando earthquake, which brought about a dramatic change in seismic building codes, and (2) they were sometimes sited in fault zones before the 1972 Alquist-Priolo Earthquake Fault Zoning Act prohibited that for schools. It was also thought by those in charge at the SAB to be a most inopportune time for the State of California to be setting such a precedent, since it was becoming clear that the state budget deficit was approaching $13 billion.

SAB was consistently reluctant to fund BUSD seismic strengthening project and create a new statewide precedent.

The school district also applied to the Federal Emergency Management Agency (FEMA) for hazard mitigation grants. In the counties affected by the Loma Prieta earthquake, FEMA offered matching funds to public and private sector organizations proposing hazard reduction projects. By 1998, the BUSD had been promised more than $6 million in matching funds from FEMA for its seismic strengthening program.

... BUSD raised serious questions about the equity of school facilities funding in California

Over time, and despite repeated requests, the SAB was consistently reluctant to fund the BUSD seismic strengthening project; on one occasion it refused approval on the grounds that the relatively newer 1965 Cragmont school buildings were less than 30 years old and therefore not eligible under SAB policy guidelines for modernization. Matching funds for the other high-risk school building were also not approved because modernization projects are usually not allowed to use more than 5% of total monies for structural rehabilitation. The state further constrains that the total expenditure on modernizing and structurally retrofitting a school building does not exceed 75% of the building's total replacement value (as defined by the state); the potential costs for the structural upgrades would approach that cap.

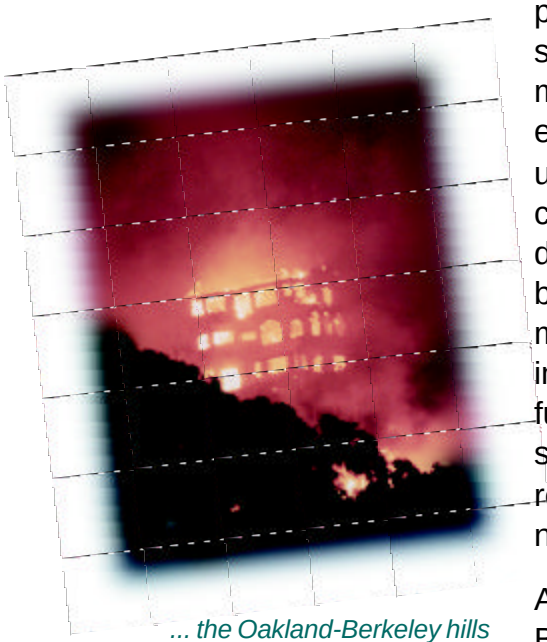
BUSD determined that it was necessary to float a local bond issue to finance a 10-year-phased school reconstruction plan.

Nonetheless, the district continued initiatives to get money from the state. In so doing, it has raised serious questions about the equity of school facilities funding in California in the recent past. Nearly all of the State Allocation Board funds to school districts go to build new schools in suburban areas, yet it is the voters in urban areas that give the school bonds their winning margins. Before 1992, $4.9 billion in state school bonds had been approved by California voters, but less than 10% of those funds were given to older urban districts. For example, prior to 1992, Alameda County received one-quarter of 1% of the total and San Francisco County received 1%.

In response to this perceived inequity, legislators from the East Bay succeeded in adding, to a pending state schools bond on the June, 1992 ballot, two propositions (152 and 155) to increase monies available to older urban districts. Proposition 152, for example, allowed for up to $570 million of its total $1.9 billion to be used for financing the seismic upgrade of old school structures.

A New Funding Approach

The school district determined that it was necessary to float a local bond issue to finance a ten-year phased school reconstruction plan. The plan included both seismic retrofitting for the vulnerable structures and needed modernization for all the schools in the district. The modernization would involve, by law, bringing all the schools up to speed with fire codes, other pertinent structural codes, child welfare regulations, and disabled accessibility standards. School board members and school administrators began to think strategically about the best time to put the measure on the local ballot, especially in light of the growing budget crisis and recession in California. They were further worried about their prospects for getting the necessary 67% approval to pass the measure, since similar bond referenda had recently fallen a little short of that figure in neighboring communities.



... the Oakland-Berkeley hills caught on fire in October 1991.

As they were considering all the possibilities, the Oakland-Berkeley hills caught on fire in October 1991. Though no schools were damaged, some came frightfully close. That the fire burned the area underlain by the Hayward fault did much to remind people that earthquakes cause fires too, and to raise the hazard awareness of the citizens in the community. The fire in their own backyards showed people, as the distant Loma Prieta earthquake had not, of how vulnerable the schools were to catastrophe. Shortly after the smoke cleared, the school board decided to put Measure A for Schools on the June 1992 ballot. The measure proposed to raise $158 million for school reconstruction, of which $90 million was to be spent on seismic retrofitting.

Demolition of seismically unsafe Cragmont Elementary School was done to accommodate the construction of a new, modern campus after passage of Berkeley's Measure A.

The fire, as well as an effective campaign, led the voters of Berkeley to pass Measure A by 70.7%, one of the largest victory margins for any bond measure in the State of California. On the same day, the State School Facilities Bond

Measures, Propositions 152 and 155, also passed by a significant margin. For the first time since the use of state bond measures, older urban districts gained access to SAB-distributed funds for substantial renovation projects.

Seismically upgrading the two Berkeley High School buildings was the first school earthquake retrofit project to be funded with California school bond money.

At the end of June, the SAB finally authorized a state contribution to the Whittier/Arts Magnet modernization project, a project first proposed in October 1990. Later, near the end of June 1993, the SAB approved the repair of two Berkeley High School buildings – the first school seismic retrofit project ever to be funded with California school bond money.

Project Status

Earthquake planning and hazard mitigation in the Berkeley Unified School District did not happen quickly, and required commitment and hard work. However, BUSD personnel, students, and their parents are better prepared and trained for the next big earthquake now than they ever were before. And they are all working, studying, and teaching in a much safer environment.

Construction Costs for Selected Campuses

Campus	Project Scope	Costs
Cragmont	New Campus	$197 per sqft.
Washington	Retrofit Only	$106 per sqft.
Whittier/Arts Magnet	Retrofit Only	$82 per sqft.
Columbus	New Campus	$199 per sqft.
Berkeley High	Retrofit Only	$127 per sqft.

Seismic strengthening of all of the high and moderate risk schools, 13 campuses in all, will be completed or nearing completion by the ten-year anniversary of the Loma Prieta earthquake.

The new Columbus Elementary School replaces its seismically unsafe predecessor.

The lessons from the BUSD experience are clear:

- Ordinary citizens can take the initiative to ensure that adequate seismic preparations have been made by the public agencies in their community.
- Understanding the potential risk is key to sound decision-making.
- The public has high expectations of school performance in earthquakes, but voters are willing to contribute to improving school safety.
- Diligent pursuit of public funding is required for success.

Text adapted from the California Governor's Office of Emergency Services Earthquake Program publication, ***Unacceptable Risk: Earthquake Hazard Mitigation in One California School District****.*

For their assistance and support in the development of this case study, special thanks are due to Arrietta Chakos, City of Berkeley, and Lewis Jones, Berkeley Unified School District.

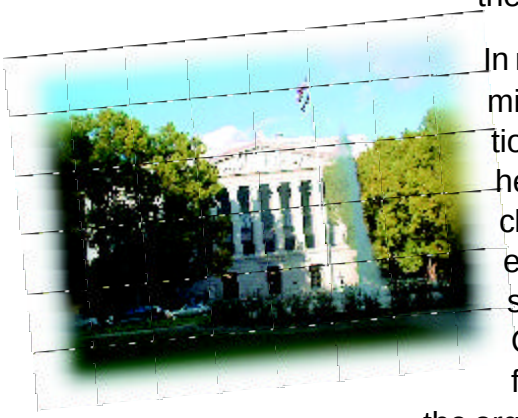
Photos courtesy of the EQUIIS Photographic Database and Berkeley Unified School District.

The Success Stories:

The California State Building Seismic Program

Managing Mitigation for Large Inventories

Many organizations with large building inventories are aware that they have a significant earthquake risk. However, due to the inventory's size, the problem may seem too big to manage. Fearing that the cost of upgrade for so many buildings may be much higher than could reasonably be financed, many organizations elect to manage the problem after the fact—by repairing damage when it occurs. However, this is not prudent management; it leaves the organization vulnerable to extensive asset loss and may place their employees and the public at substantial risk.



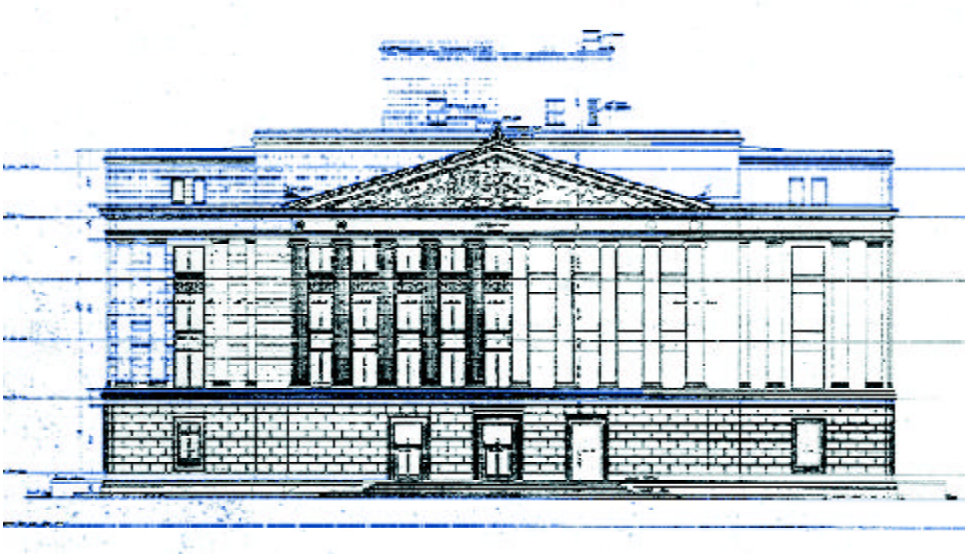
The Jesse Unruh Legislative Office Building in Sacramento was identified as being seismically vulnerable and was strengthened using Proposition 122 monies.

In most large inventories, the principal sources of seismic risk will be concentrated in a relatively small portion of the portfolio. A thorough risk assessment can help to make the problem manageable when it includes screening to eliminate from consideration properties at negligible risk and to focus available resources on properties at the most significant risk. Once the principal sources of risk have been identified, the mitigation program can be coordinated with the organization's overall asset management plan so that high-risk structures can be mitigated through normal attrition and acquisition procedures.

The efforts undertaken by the California Division of the State Architect to assess and mitigate the earthquake vulnerabilities of nearly 16,000 state-owned buildings is an excellent example of how a seemingly overwhelming problem of managing earthquake risk can be methodically reduced and dealt with.

Proposition 122

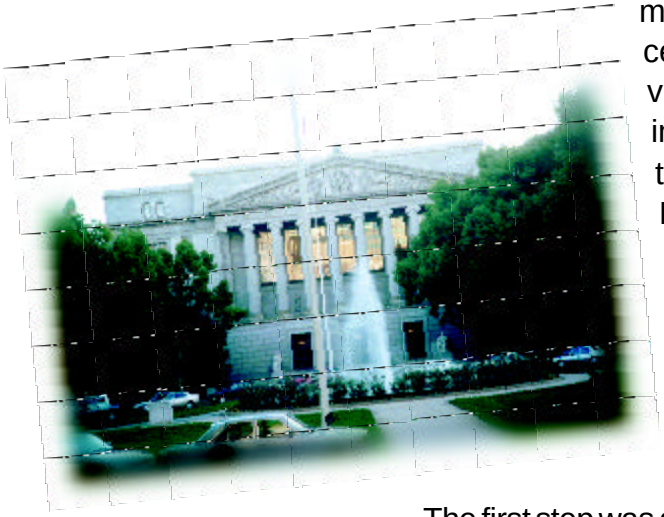
In 1990, the California Legislature enacted the Earthquake Safety and Public Buildings Rehabilitation Bond Act (SB 1250, Torres), authorizing $300 million in general obligation bonds through Proposition 122. Most of the bond monies - $250 million - were earmarked for financing the, "retrofit, reconstruction, repair, replacement or relocation of State buildings" (exclusive of UC and CSU buildings and other leased facilities which are addressed under separate legislation) identified as seismically hazardous.



The remaining $50 million was allocated to local governments through financial assistance to help mitigate their essential service buildings. The Division of the State Architect (DSA) was assigned the task of evaluating the inventory of buildings and managing the mitigation program, in consultation with the Seismic Safety Commission and its Public Buildings Priority Committee.

Developing the Evaluation Process

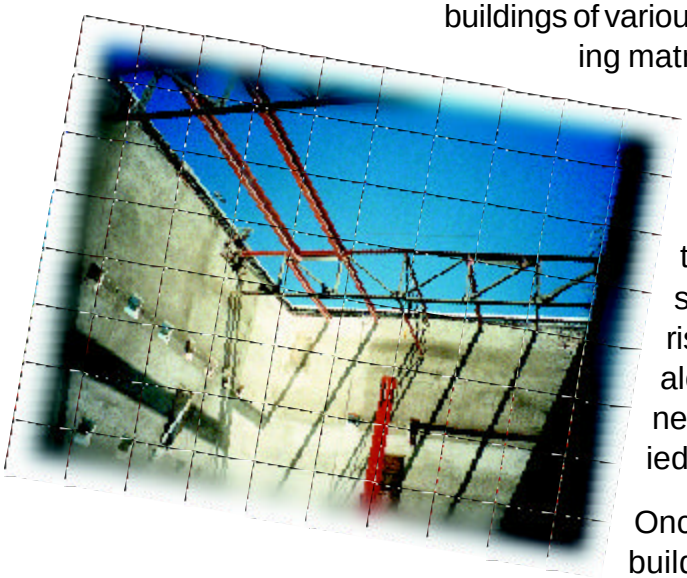
In order to fulfill its mandate, DSA developed a comprehensive building risk evaluation and mitigation prioritization process. The process was designed to identify the potential vulnerability for each of the 16,000 buildings, and to evaluate its seismic risk relative to other buildings in the inventory. Recognizing that the number of buildings in need of seismic retrofitting would require a budget exceeding the available funding, DSA placed particular emphasis on ranking the buildings to determine which ones were high priorities for retrofit or replacement.



The Library and Courts Building in Sacramento was identified as a high-risk building by the DSA 5-Step process. To mitigate the seismic risk, as well as preserve its historical significance, the roof of the building was removed to accommodate the installation of new strengthening measures.

The first step was a building vulnerability assessment, which included consideration of site soil type; potential ground shaking intensity and other geotechnical factors; the structural, mechanical and electrical systems' capabilities to withstand earthquakes; and the occupancy, function, and future use of each building.

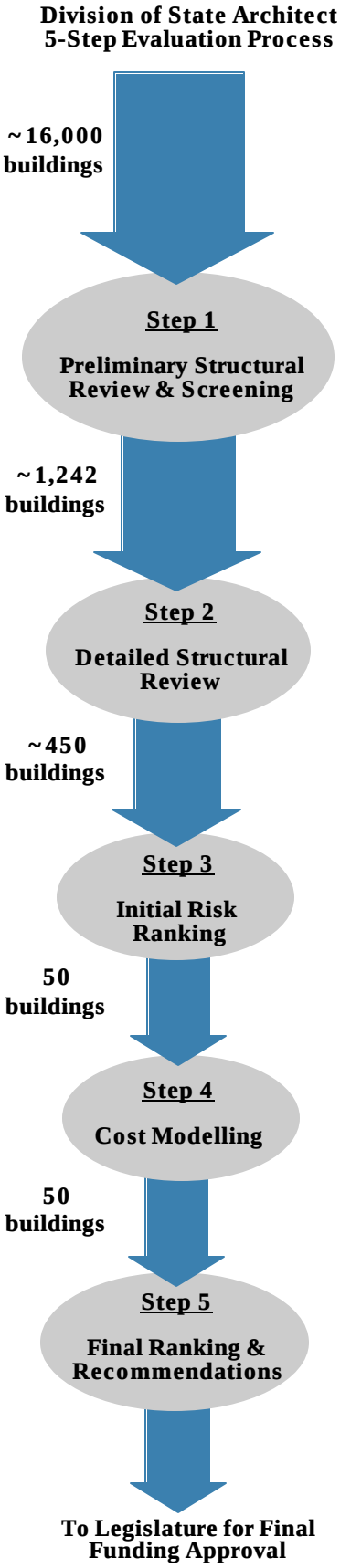
To consistently rate the seismic risk for the many different buildings of various functions, DSA established a risk-ranking matrix. Each building was assigned a "Risk Level" ranging from "I" for a building which is expected to have nearly perfect performance, to "VII" for a building which is considered unsafe in its current condition (even without an earthquake) and should be vacated immediately. These risk levels served as a common "yardstick" along which the consulting structural engineers could place each building they studied.



Once a specific risk level was assigned to a building, the acceptability of that risk was judged against the building's function. Essential facilities were defined as less tolerant of risk. For instance, hospitals and emergency communications centers should remain operational following a major earthquake. On the other hand,

a warehouse or other less important facility would be allowed to sustain greater damage, resulting in greater downtime and disruption of use. The general principle was established that all buildings should withstand earthquakes without collapse, with occupants able to exit safely, and such that functions can be resumed or relocated in a timely manner consistent with the need for services after earthquakes.

The former Broadway department store building in downtown Los Angeles was modernized and seismically strengthened to house more than a dozen state agencies currently scattered throughout the city in other high-risk buildings.



The 5-Step Evaluation Process

The evaluation methodology employed by DSA was named the "5-Step Evaluation Process," where each subsequent step entailed a more rigorous level of technical evaluation.

Step 1 – Preliminary Structural Review & Screening

First, DSA distributed a general building survey to all state agencies that owned buildings. This was intended to collect the basic data necessary to conduct a preliminary structural assessment and to screen out the structures with obviously low vulnerabilities. As a first step, 2,000 buildings were eliminated from further consideration either because they were slated for vacating or demolition within the next five years, they were small (less than 1,500 square feet), or had little or no occupancy. Of the remaining 14,000 buildings, only 1,242 (8%) with the highest rankings were forwarded to the next step.

Step 2 - Structural Review

In the second step, DSA staff engineers reviewed each forwarded building survey to determine respective seismic vulnerabilities. This involved additional engineering analysis based upon available drawings, soils reports, structural calculations, and expected site seismicity. Structures with the most significant performance concerns, about 450 buildings (36%), were passed onto the next step.

Step 3 - Initial Risk Ranking

The principal intent of the legislation and the bond act was the reduction of the population at risk due to earthquakes. It was therefore necessary to consider "population" in order to assist in establishing mitigation priorities. As expressed by "effective occupancy", population for each building was defined as the product of its allowable occupancy as established in the California Building Code (CBC) and the hours of use.

Following calculation of the population at risk in each building, the combined factors of building vulnerability and population were used to prioritize the properties in terms of seis-

mic risk. The resultant list identified the buildings representing the highest potential risk to occupant life safety.

The 50 most vulnerable buildings from that exercise were then selected and assigned to private consultants for more detailed evaluation and assignment of a "risk level" in accordance with DSA criteria. The number selected for more detailed evaluation was determined in light of limited time and funds for mitigation. Initially, approximately 100 buildings were considered, using an allowance of $100 per square foot as a guide to potential retrofit costs. Those 100 would have required a total of approximately $800 million for upgrade, which vastly exceeded the $250 million provided by Proposition 122. The final 50 buildings selected required $300 million in mitigation costs, a value more consistent with the available funds.

The new Hyram W. Johnson State Office Building in San Francisco was built to replace several high-risk buildings that previously housed several state agencies. The new building is immediately adjacent to the historically significant old State Office Building, which also was strengthened and modernized to reduce its seismic risk.

Step 4 - Cost Models

In the fourth step, cost models were developed for three mitigation scenarios: (1) structural retrofit only (for buildings that may have recently undergone recent building system renovation); (2) full retrofit of the structure and other building systems; and (3) complete replacement of the building. These cost models considered the anticipated "hard costs" for the structural and mechanical upgrades, all "soft costs"

for fees and inspections, and other related costs for moving, temporary leasing, relocation of telephone and data systems, and other applicable items.

Aware of the difficulties of accurately calculating remodeling and retrofitting costs, DSA and the cost estimators decided that it was impractical and ineffective to attempt to develop detailed cost estimates for each building and option. Therefore, a series of generic "unit costs" was developed to provide a reasonable estimate of the probable cost of each element within the total cost. These unit costs were derived from a database of actual completed state projects.

The East Block Building at San Quentin Prison was identified as being a high-risk building requiring retrofitting.

Based on the estimate of potential costs, Benefit-Cost Ratios (BCR) were developed to help determine the most cost-effective utilization of the available mitigation monies and to set priorities. The BCR was defined as the cost of mitigation divided by the effective occupancy. If all the buildings were at the same risk level (with similar anticipated performance in an earthquake), the BCR could be stated as dollars expended in relationship to the number of lives protected.

Step 5 - Final Recommendations

The final step of the evaluation process involved assigning priorities to buildings for retrofit or replacement, and forwarding those recommendations to the Department of Finance and the Legislature for consideration. Life safety was the overriding priority of the State Building Seismic Program. The final recommendations were intended to mitigate the buildings with the greatest threat to life safety, which meant choosing buildings with the highest risk level.

Life safety was the overriding priority of the State Building Seismic Program.

Once a building was identified as high risk, DSA had to recommend the type of mitigation to use. To determine whether a building should be retrofit or replaced, as well as to ensure consistency in the recommendations, DSA established certain thresholds. If the cost of retrofitting ex-

ceeded a certain percentage of the replacement cost (cost of new construction), the final recommendation favored replacement, as a new building with a longer period of usage was considered more desirable. A series of graduated thresholds was developed for different types of building functions. For instance, if the retrofit costs for an office building were less than 60% of the estimated replacement cost, retrofitting would proceed. Similarly, the threshold for hospitals was set at 80%.

In deciding whether a building should be retrofitted or replaced, certain thresholds were established by the DSA.

Asset Management

The application of sound asset management principles was an integral part of California's statewide mitigation efforts. As buildings are considered for mitigation, it is essential to consider the long range needs of the various agencies and their capital outlay plans. Therefore, the Governor's Asset Management Program and the State Building Seismic Program worked together as partners in the reduction of seismic risk in state-owned buildings.

DSA carefully coordinated identifying state buildings for use of Proposition 122 funding with the Asset Management Program and with the planning efforts of affected agencies. Many of the state-owned buildings recommended for mitigation by DSA were already designated by the Department of General Services (DGS) for replacement or renovation under the Asset Management Program. The Asset Management Program has access to a variety of funding sources and approaches, which eased the demand for seismic mitigation funds. Additionally, utilization of private sector development techniques and funding resources helped enable completion of more projects in a shorter period of time. Thus, the partnership with the Asset Management Program allowed for addressing seismic risk reduction in a holistic manner, effectively accomplishing more than the seismic funds alone would have allowed.

California Asset Management Coordinating Council

In 1991, Governor Wilson signed Executive Order W-18-91, creating the California Asset Management Coordinating Council and outlined the criteria for creation of the first long-term strategic plan for the State of California's office space needs. The result is a series of regional plans across the State which provide for comprehensive management of the State's real estate assets. The regional plans are the basis of the Governor's Asset Management Program (administered by the Real Estate & Building Division) and is intended to cut costs and improve efficiency.

The strengthening of East Block Building at San Quentin Prison.

Since final legislative approval in 1997, nine of the 50 buildings identified as being high seismic risks have been mitigated. Twelve more are in the process of being strengthened or replaced, and the remainder are in the planning and design stages, with work scheduled to begin within the next few years. Of the $250 million dollars allocated to the State Building Seismic Program, about $40 million remains unallocated, allowing for the strengthening of ten additional buildings ranked as seismically vulnerable and a high-risk to occupants.

Special thanks are due to Joel McRonald, California Department of General Services, for his assistance and support in developing this case study.

Photos courtesy of the California Department of General Services, Turner/Vanir Construction Management, Page & Turnbull, and EQE International, Inc.

The Success Stories:

Conclusions

The preceding *Mitigation Success Stories* illustrate the efforts of Californians to improve earthquake safety and minimize the potential for future catastrophic losses in their communities. The stories provide snapshots of public and private earthquake loss reduction and risk management projects completed or currently underway in California. They demonstrate that many Californians believe it is both possible and important to protect lives, property, and economic well-being against the impacts of California's inevitable next earthquake.

Review of these case studies can provide valuable insights into the earthquake risk management decision-making process:

- ***Earthquake risk is real.*** In all five case studies, key decision-makers recognized the potential for strong earthquake shaking, large enough to cause injury or deaths, extensive damage, and prolonged disruption of normal operations. Nearly every location within California is vulnerable to damaging earthquakes and could lose buildings and infrastructure. Every manager in California, whether in the public or private sector, has a responsibility to understand and manage this risk.

- ***Understanding the risk is key to responsible decision-making.*** Before any decisions are made or mitigation actions initiated, make a methodical assessment of the size and scope of the earthquake risk. In the East Bay Municipal Utility District, Anheuser-Busch, Berkeley Unified School District, and State of California case studies, systematic assessment efforts were the first step in the overall mitigation process. The assessments identified specific vulnerabilities and their implications for overall post-earthquake performance. This allowed for the pinpointing of critical facilities, helped in prioritization of specific mitigation tasks, and permitted the screening-out of risks considered acceptable.

- ***All potential losses must be considered.*** Costs are not limited to those associated with direct property damage. Prolonged loss of service or failing to meet public expectations will impose large costs immediately and over time following earthquakes. One of the key influences on the selection of the East Bay Municipal Utility District's mitigation scheme was the estimated $1.5 billion in community economic losses that could be sustained if no action were taken. Similarly, both the Los Angeles and Berkeley Unified School Districts had to include in their analyses the public expectation that children must be protected from serious injury or death while at school.

- ***Earthquake mitigation really does work.*** The ability of the Anheuser-Busch Van Nuys brewery to resume full operations within a few days of the devastating 1994 Northridge earthquake illustrates the benefits of mitigation. Contrasting the Anheuser-Busch success with the losses sustained by the same facility following the 1971 San Fernando earthquake, as well as with those sustained by a similarly constructed sake brewery in Japan, makes it

clear that an earthquake mitigation program reduced earthquake losses and ensured a desired level of post-earthquake performance. The Anheuser-Busch Van Nuys brewery is the best example of a retrofitted facility being tested by a major earthquake, and passing.

Each manager must anticipate the question – *Are you prepared for California's next earthquake?*

The organizations showcased in these *Mitigation Success Stories* have already answered this question, and they are clearly taking the necessary preparedness steps.

Can you make the same claim?

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References

Board of Education. 1994. Report No. 5. Los Angeles Unified School District (LAUSD). Los Angeles, CA: LAUSD.

California Department of General Services. (DGS) 1994. State Building Seismic Program, Report and Recommendations. Sacramento, CA: DGS.

California Governor's Office of Emergency Services (OES) Earthquake Program. 1993. *Hazard Mitigation Case Study: Unacceptable Risk. Earthquake Hazard Mitigation in One California School District.* Oakland, CA: OES.

Chakos, Arrietta. 1999. Assistant to the City Manager, City of Berkeley, California. Personal communication.

East Bay Municipal Utility District (EBMUD). 1999a. *1998 Annual Progress Report – Seismic Improvement Program*. Oakland, CA: Seismic Improvement Program, EBMUD.

East Bay Municipal Utility District (EBMUD). 1998b. *1997 Annual Progress Report – Seismic Improvement Program*. Oakland, CA: Seismic Improvement Program, EBMUD.

EQE International Inc. (EQE). 1994. "The Northridge Earthquake: Four examples of Proactive Risk Management." *Proactive Risk Management*. Oakland, CA: EQE.

Federal Emergency Management Agency (FEMA). 1997. *Report on Costs and Benefits of Natural Hazard Mitigation*. Washington, D.C.: Mitigation Directorate, FEMA.

References - cont'd

Jones, Lewis. 1999. School Construction Manager, Berkeley Unified School District (BUSD), Berkeley, California. Personal communication.

Lee, David. 1999. Senior Engineer, Design Section, Seismic Improvement Program, East Bay Mud Utility District (EBMUD), Oakland, California. Personal communication.

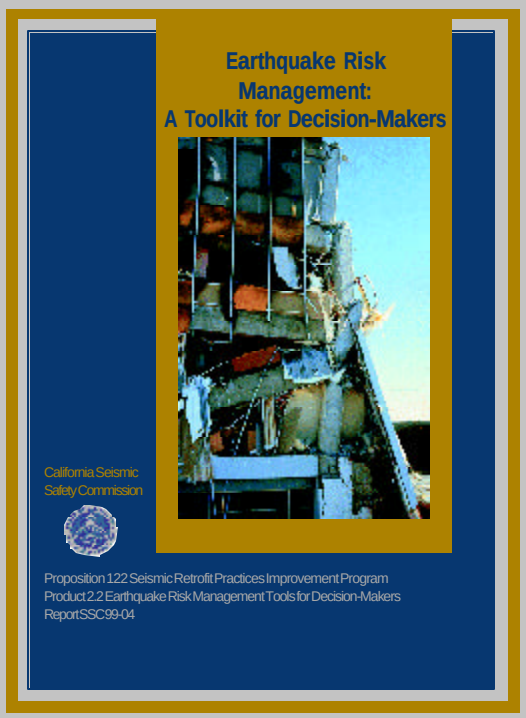
McRonald, Joel, 1999. Chief, Seismic and Special Programs. California Department of General Services. Personal Communication.

Reiterman, Tim (Editor). 1999. "Quake Risk a Big Unknown for State's Public Schools." *Los Angeles Times*. June 27: A1, A24, A25.

Where Can I Get More Information?

More detailed information on earthquake risk assessment and hazard mitigation is available in the California Seismic Safety Commission publication:

Earthquake Risk Management: A Toolkit for Decision-Makers (ssc report 99-04)



This valuable resource provides a step-by-step approach to the earthquake mitigation process as well as an in-depth discussion of the critical issues facing any decision-maker in California.

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