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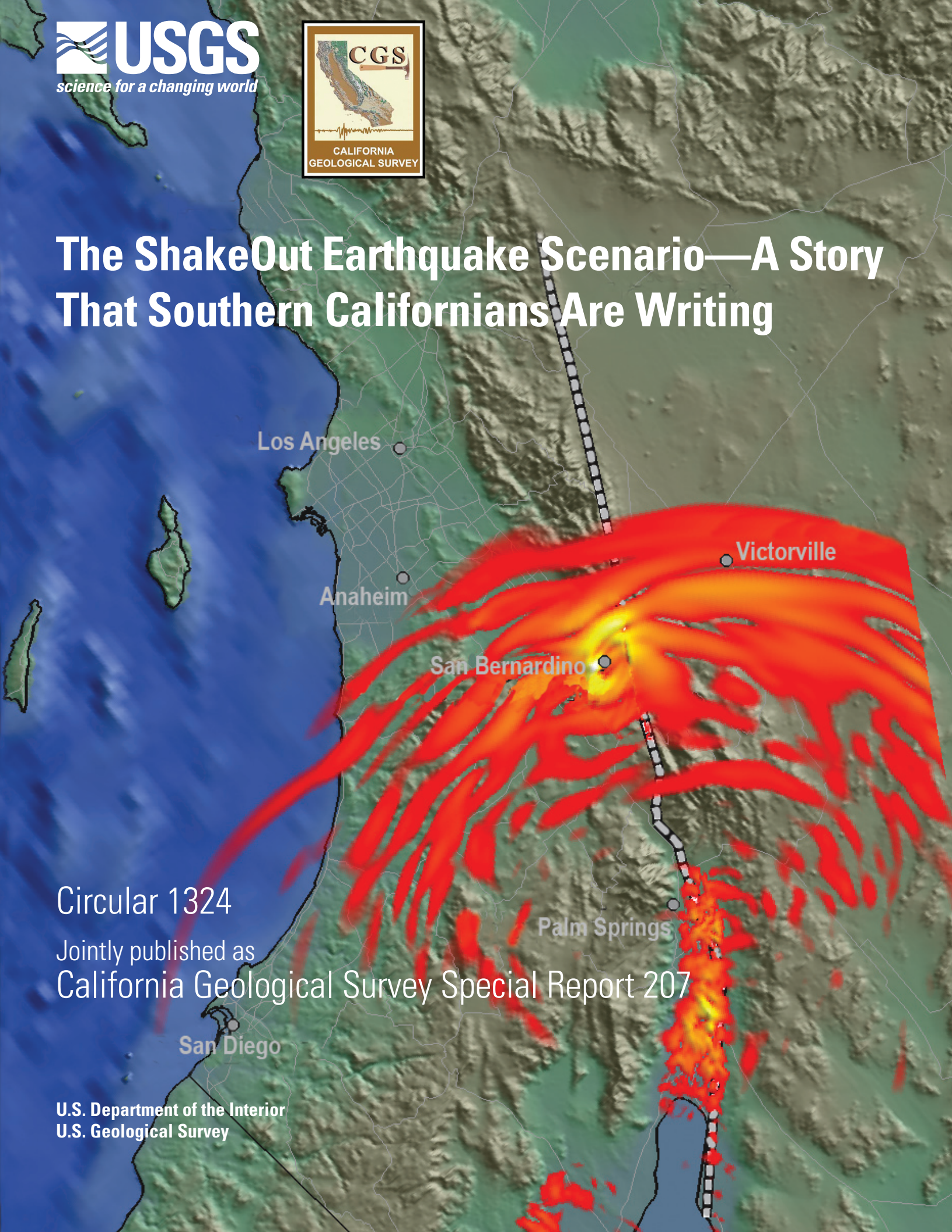
The ShakeOut Earthquake Scenario—A Story That Southern Californians Are Writing



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California Geological Survey Special Report 207

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By Suzanne Perry, Dale Cox, Lucile Jones, Richard Bernknopf, James Goltz, Kenneth Hudnut, Dennis Mileti, Daniel Ponti, Keith Porter, Michael Reichle, Hope Seligson, Kimberley Shoaf, Jerry Treiman, and Anne Wein

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FRONT COVER—Ground motion for the ShakeOut Scenario earthquake 60 seconds after the southern San Andreas Fault first begins rupturing. Yellow shows the highest amplitudes of ground motion. (Simulation by Rob Graves of URS Corporation for the Southern California Earthquake Center on high-performance computers at the University of Southern California; image courtesy of Geoff Ely, University of California San Diego/San Diego Supercomputer Center.)

BACK COVER—Within the ShakeOut Scenario study area are many neighborhoods like this one, at severe risk from fire following earthquake. Here, tightly packed wood buildings will enable small fires to spread and merge into conflagrations that can burn dozens of blocks. Fire following earthquake can have devastating consequences, as tragically seen after the 1906 San Francisco, 1923 Tokyo, and 1995 Kobe earthquakes. It is a significant threat in urban areas of California and doubles the fatalities and economic losses in the hypothetical ShakeOut earthquake. (Google Earth image.)

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The ShakeOut Earthquake Scenario—A Story That Southern Californians Are Writing

By Suzanne Perry, Dale Cox, Lucile Jones, Richard Bernknopf, James Goltz, Kenneth Hudnut, Dennis Mileti, Daniel Ponti, Keith Porter, Michael Reichle, Hope Seligson, Kimberley Shoaf, Jerry Treiman, and Anne Wein

Introduction

The question is not *if* but *when* southern California will be hit by a major earthquake—one so damaging that it will permanently change lives and livelihoods in the region. How severe the changes will be depends on the actions that individuals, schools, businesses, organizations, communities, and governments take to get ready. To help prepare for this event, scientists of the U.S. Geological Survey (USGS) have changed the way that earthquake scenarios are done, uniting a multidisciplinary team that spans an unprecedented number of specialties. The team includes the California Geological Survey, Southern California Earthquake Center, and nearly 200 other partners in government, academia, emergency response, and industry, working to understand the long-term impacts of an enormous earthquake on the complicated social and economic interactions that sustain southern California society. This project, the ShakeOut Scenario, has applied the best current scientific understanding to identify what can be done now to avoid an earthquake catastrophe. More information on the science behind this project will be available in *The ShakeOut Scenario* (USGS Open-File Report 2008-1150; http://pubs.usgs.gov/of/2008/1150/).

The "what if?" earthquake modeled in the ShakeOut Scenario is a magnitude 7.8 on the southern San Andreas Fault. Geologists selected the details of this hypothetical earthquake by considering the amount of stored strain on that part of the fault with the greatest risk of imminent rupture. From this, seismologists and computer scientists modeled the ground shaking that would occur in this earthquake. Engineers and other professionals used the shaking to produce a realistic picture of this earthquake's damage to buildings, roads, pipelines, and other infrastructure. From these damages, social scientists projected casualties, emergency response, and the impact of the scenario earthquake on southern California's economy and society. The earthquake, its damages, and resulting losses are one realistic outcome, deliberately not a worst-case scenario, rather one worth preparing for and mitigating against.

Decades of improving the life-safety requirements in building codes have greatly reduced the risk of death in earthquakes, yet southern California's economic and social systems are still vulnerable to large-scale disruptions. Because of this, the ShakeOut Scenario earthquake would dramatically alter the nature of the southern California community. Fortunately, steps can be taken now that can change that outcome and repay any costs many times over. The ShakeOut Scenario is the first public product of the USGS Multi-Hazards Demonstration Project, created to show how hazards science can increase a community's resiliency to natural disasters through improved planning, mitigation, and response.

The ShakeOut Scenario Is Not a Prediction

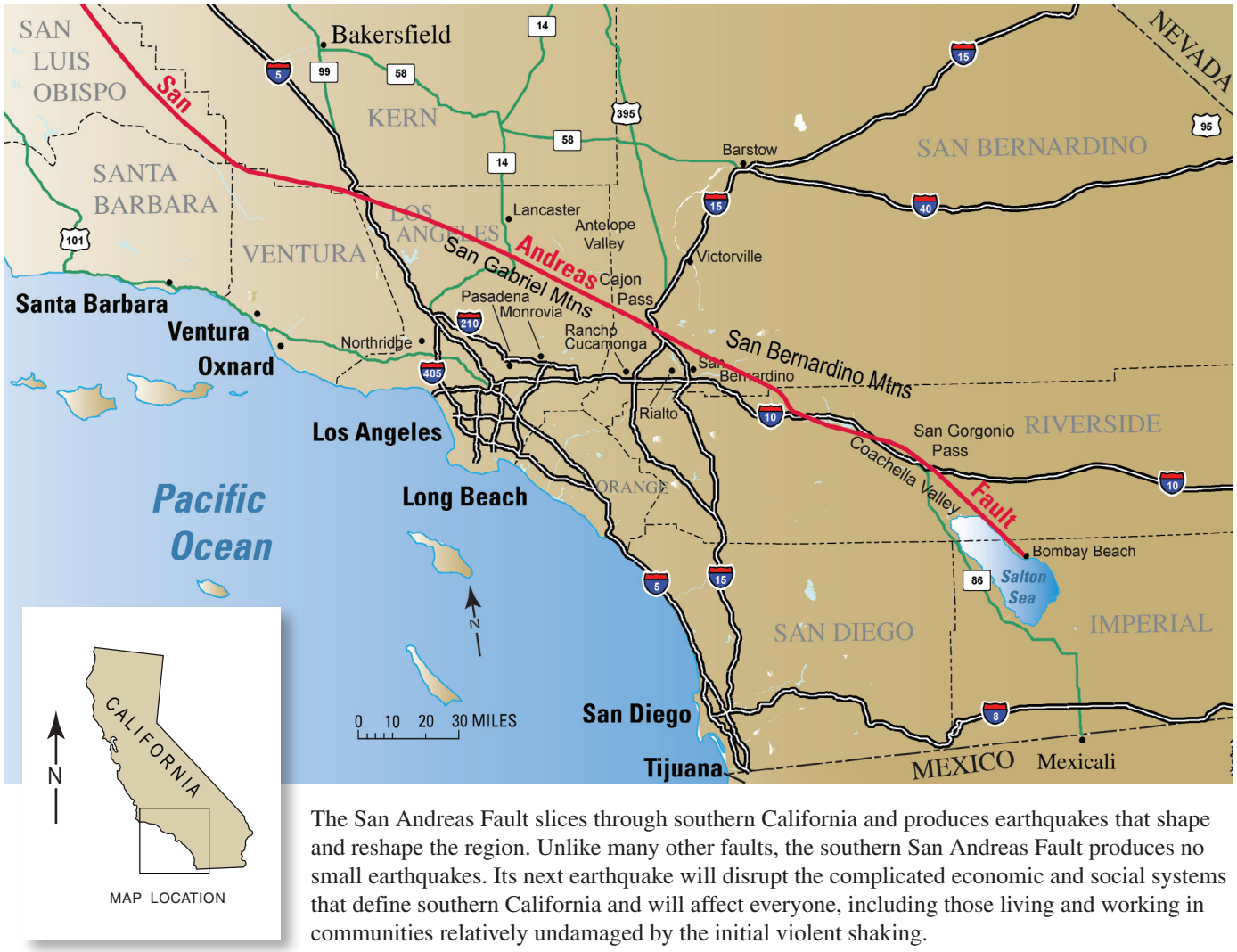
On November 13, 2008, the ShakeOut Scenario earthquake and projected damages will be used as a basis for public drills and emergency

response exercises, and so this hypothetical earthquake has been arbitrarily assigned a date, a time, a plausible collection of aftershocks, and even local weather conditions. Because it is a scenario for planning, it provides detailed numbers, including casualties, collapsed buildings, and business losses. Yet, the ShakeOut earthquake is not a prediction. Certainly, a large earthquake involving this part of the San Andreas Fault is highly probable. In fact, scientists have determined that this is the most likely source of a large earthquake in all of California (see *Forecasting California's Earthquakes—What Can We Expect in the Next 30 Years?*, U.S. Geological Survey Fact Sheet 2008-3027; http://pubs.usgs.gov/fs/2008/3027/).

When the next San Andreas Fault earthquake does happen, some things are inevitable—the fault rupture will break any road, track, or pipe that crosses it, and intense shaking will damage or destroy buildings that weren't constructed to withstand it. The next earthquake will be different in details from the ShakeOut earthquake, and its total damages and losses will differ, because each earthquake produces its own patterns of shaking and damage. However, the widespread, regional effects will be similar, and so will the long-term social and economic impacts. Getting prepared for the ShakeOut earthquake will help southern Californians withstand other earthquakes of comparable size. If we take no additional actions for preparedness and mitigation, and the ShakeOut earthquake does occur, it will cause some 2,000 deaths, 50,000 injuries, $200 billion in damage, and severe, long-lasting disruption. These numbers can climb with each damaging aftershock.

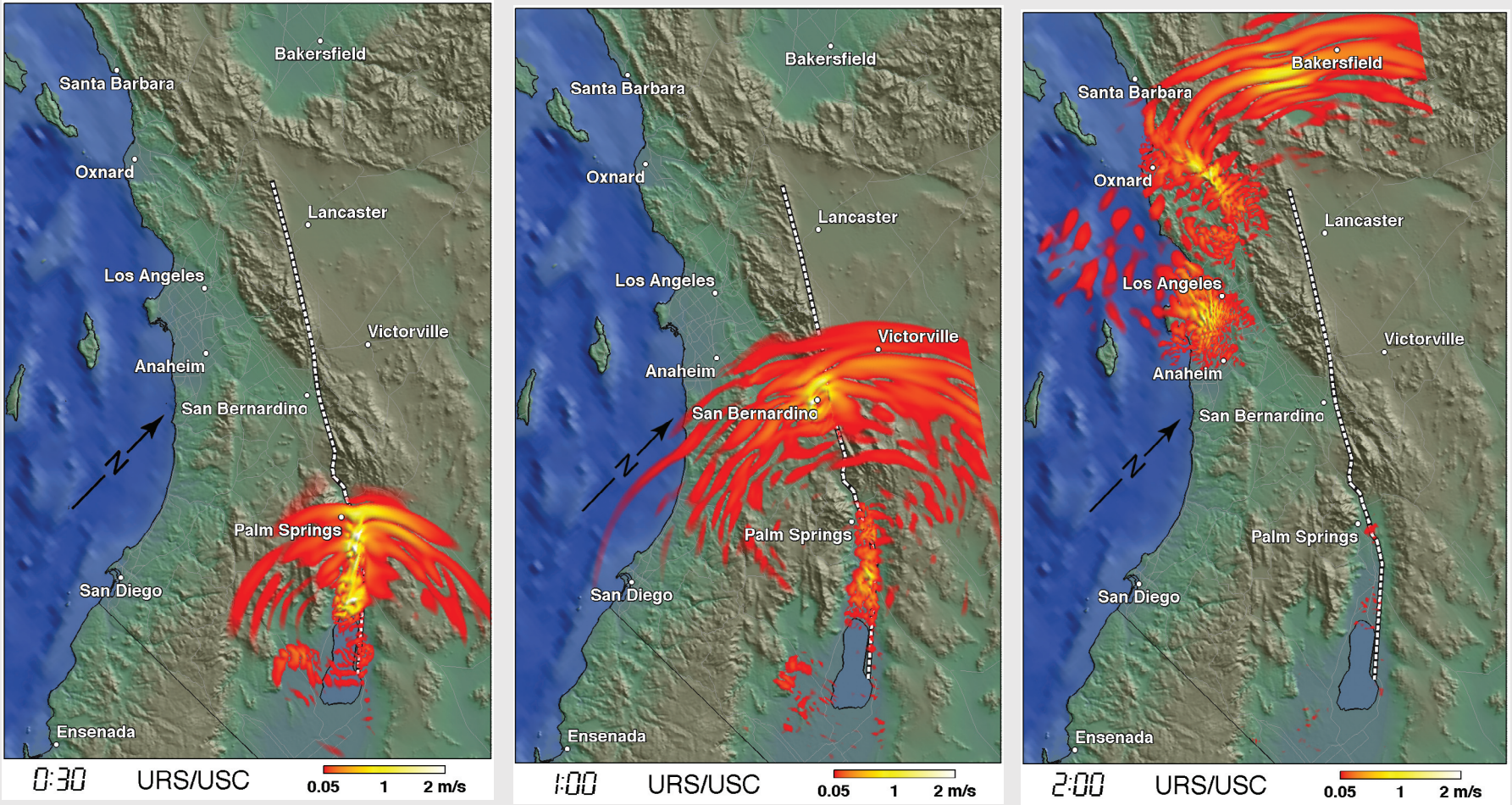
LIFELINES CROSS THE FAULT

The Cajon Pass is one of five major "lifeline corridors" that are the veins and arteries through which economic life circulates in southern California. These lifeline corridors allow commuters, goods, telephone and Internet lines, electricity, water, gas, and fuels to move through the mountains that surround southern California. Because most of the corridors must cross the southern San Andreas Fault, future earthquakes are certain to sever the lifelines in one or more of these corridors and cause significant economic disruption by interrupting the movement of goods from the ports of Los Angeles and Long Beach. (USGS photo by Lucile Jones.)



The San Andreas Fault slices through southern California and produces earthquakes that shape and reshape the region. Unlike many other faults, the southern San Andreas Fault produces no small earthquakes. Its next earthquake will disrupt the complicated economic and social systems that define southern California and will affect everyone, including those living and working in communities relatively undamaged by the initial violent shaking.

THE EARTHQUAKE ADVANCES



These computer-generated snapshots show ground motions for the ShakeOut Scenario earthquake, in meters per second (m/s; 1 m/s is about 3.3 feet per second). Yellow indicates higher amplitudes of ground motion. The snapshots show three points in time—30 (left), 60 (center), and 120 (right) seconds after the southern San Andreas Fault (dashed white line) first begins rupturing at Bombay Beach, on the eastern shore of the Salton Sea. Note that some areas remain orange colored for much longer than others, indicating extended, intense shaking in some of the sedimentary basins of southern California. (Simulation by Rob Graves of URS Corporation for the Southern California Earthquake Center on high-performance computers at the University of Southern California; images courtesy of Geoff Ely, University of California San Diego/San Diego Supercomputer Center.)

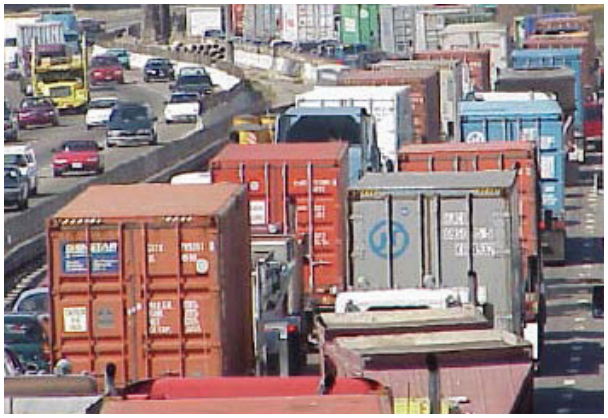
The ShakeOut Scenario Narrative

Much like a movie script, the following fictional narrative will guide those participating in the ShakeOut Earthquake Scenario public drills and emergency response exercises on November 13, 2008. More effectively than any statistics, this narrative describes what this magnitude 7.8 earthquake would be like in southern California if no additional actions are taken for mitigation or preparedness.

November 13, 2008

Thursday 9:50 a.m. (… 10 minutes before the quake begins…)

By mid-morning on this workday, 200,000 commuters have made their way from Kern, Riverside, and San Bernardino Counties into the Los Angeles area. These drivers trade a lengthy commute for the lower cost of housing in fast-growing communities like Victorville and Lancaster, on the far side of the San Andreas Fault. Others cross the fault in the opposite direction, to employers in high desert communities. The commuters have joined 7.5 million other southern Californians in workplaces constructed of steel, concrete, brick, or wood. Of the many millions of homes and workplaces, only a fraction are covered by earthquake insurance.



A steady flow of trains crosses the San Andreas Fault at multiple locations, moving goods between cargo ships at the Ports of Los Angeles and Long Beach and the rest of the country. Trucks are also on the move nonstop, carrying goods through narrow passes cut in the San Gabriel and San Bernardino Mountains. These "lifeline corridors" are the veins and arteries that sustain economic life in southern California. Sharing these passes with cars, buses, trucks, and trains are pipelines carrying natural gas and fuels; water conveyance tunnels, pipes, and aqueducts; electrical transmission towers and lines; and the telecommunications cables that connect people by phone and Internet—connecting banks and clients, suppliers and providers, buyers and sellers, friends and families, headquarters and field offices. Like the commuters, they all cross the San Andreas Fault.

Thursday 9:52 a.m. (… 8 minutes before the quake begins …)

The San Andreas Fault slices through California, marking the boundary between the Pacific and North American tectonic plates. Along this boundary, the plates try to slide past each other, but near the surface they are locked by friction and deform instead of moving, storing up strain energy. Eventually and suddenly, the friction will give way and the plates will slip, creating a powerful earthquake. This earthquake will rupture the Earth's surface and release stored energy in seismic waves that travel out in all directions, shaking the ground as they go. On the southern San Andreas Fault, an earthquake rupture and energy release occur on average every 150 years—but the last time was more than 300 years ago.

The next earthquake is about to begin. It will not be the biggest earthquake that has ever occurred on the southern San Andreas Fault, but it will be big enough to change southern California markedly for untold years to come. It will wreak economic havoc on many who are unharmed by the initial shaking and damage.

Thursday 9:55 a.m. (…5 minutes before the quake begins…)

It is sunny with a light breeze. Fortunately, today there will be no Santa Ana winds. Throughout the region, cars flow to the pulse of traffic lights. Rush hour traffic has cleared, and the workday is well underway in offices, warehouses, factories, and stores. Many of the older buildings and even a few newer ones are constructed in ways that make them vulnerable to earthquake shaking. Schools are full of students, as well as furniture and equipment that will topple in a earthquake, and heavy objects that will become airborne.

Thursday 10:00 a.m. (...the quake begins...)

The San Andreas Fault suddenly awakens at Bombay Beach, northeast of the Salton Sea, and the rupture shoots northwest along the fault at 2 miles per second, sending seismic energy waves out in all directions. In an instant, the ground on the two sides of the fault is offset nearly 44 feet, changing the political and geographic boundary between Imperial and Riverside Counties.

Thursday 10:00:30 a.m.

As the earthquake's rupture front travels up the fault, it sends out seismic waves that shake the ground, shifting emergency generators, overturning computers, cracking airport runways, and igniting fires. By now, the thick sediments of the Coachella Valley are resonating, with the earthquake waves bouncing between the rock walls of the valley's edges. Strong shaking will continue here for nearly a minute.

The life-safety provisions of California's building codes have been improved over the years, and the many fairly new homes in the Coachella Valley suffer only minor damage. Yet every item inside these homes, if not secured, is heading to the floor. Shattered TVs and other home electronics create treacherous carpets of glass and cords.

Many older buildings suffer structural damage. Many older concrete buildings quickly collapse, trapping occupants. The rupture front continues its advance to San Gorgonio Pass and dismantles the ten miles of Interstate 10 freeway that straddles the San Andreas Fault. The eastern part of Riverside County is now cut off from the western part.

Thursday 10:01:00 a.m.

Most people in Los Angeles and Ventura Counties are not yet aware of what is happening as the earthquake pounds the Coachella Valley and heads their way. By now

the first waves have crashed through the Cajon Pass, severing the I-15 freeway, bending rail lines, and derailing a train. Roads, previously throughgoing across the fault, now end abruptly and pick up again 15 feet to the right.The strong shaking also sends landslides across the rails and roads. Pipelines snap and electrical transmission lines fail. Spraying fuel ignites, causing an explosion.

Strong shaking begins to reverberate in the sediment-filled basins of the Inland Empire. Old warehouse districts and historic downtowns are crumbling, and many of their old, unretrofitted buildings have trapped or killed the people inside. Many older concrete buildings have collapsed, and many older woodframe buildings have shifted off their foundations, breaking gas and water lines in the process.

The Coachella Valley is still shaking.

Thursday 10:01:30 a.m.

Over geologic time, the motion of tectonic plates has pushed the mountains of southern California up, while fire, rain, and rivers have brought the mountains down, piece by piece, filling basins with sediments and creating low, flat areas. Like many cities, Los Angeles was built atop sediments. Some of the seismic waves now reach these sediments and find easy territory in which to move back and forth, shaking vigorously long after the waves fade elsewhere. Strong shaking will continue in Los Angeles for 55 seconds, to the shock of residents who remember the strong shaking during the 1994 Northridge earthquake, which lasted only 7 seconds.

The seismic waves that reverberate in the sedimentary basins are big, long waves. Many buildings ride them like boats in choppy seas, but some are not so resistant. The prolonged, strong shaking heavily damages and sometimes collapses hundreds of old brick buildings, hundreds of older commercial and industrial concrete buildings, many woodframe buildings, and even a few, fairly new high-rise steel buildings. The building damage causes tens of thousands of injuries and hundreds of deaths, and strands many thousands of people without homes or jobs.

Buried in the sediments are the water and sewer pipes that maintain the cities. Many of these pipes crack when the earthquake waves deform the ground.

In the newer houses, the primary damage is to contents. Kitchen floors have disappeared under heaps of cooking oil, syrup, flour, and smashed dishes, but there is no water in the taps to start cleaning.

Power is out so stoplights are dark and electric trains are suddenly immobilized. Buses, cars, and trucks become gridlocked, and many drivers will experience this earthquake as taillights for hours, to the horizon. Eventually, many will open their car doors and not look back as they begin the long walk home, perhaps envied only by people sitting in the dark, waiting to be rescued from stalled and stifling elevators.

Thursday 10:02 a.m. (…2 minutes after the quake began…)

At last, the fault has stopped rupturing, but seismic waves continue to advance into Bakersfield, Oxnard, and Santa Barbara—here the shaking is just beginning.

Across southern California, the power is out. Emergency generators that have been secured against earthquake shaking are still functional and now kick on. The shaking has finally stopped in the Coachella Valley—but the aftershocks are just beginning.

Throughout southern California in the next few months there will be tens of thousands of earthquake aftershocks large enough to feel. There will be dozens large enough to cause additional damage and to imperil victims and rescuers. Some of the aftershock damage will be to people's psyches. Big earthquakes are traumatic, and each new bout of shaking increases stress, especially in children who are cut off from their families.

In the areas of strong shaking, many mobile homes have collapsed off supports, snapping water, gas and sewer lines, and blocking rescue routes. Mobile homes installed snugly in shallow pits, or braced for earthquakes, are still intact.

The State highway system has fared well. A $6 billion investment in seismic retrofitting has paid off, and the only highway deaths have been in crashes caused by intense earthquake shaking. However, the long duration of shaking has taken its toll on bridges and overpasses within local jurisdictions, where the retrofitting process is not completed, or not yet begun.

No hospitals have seen complete collapses, but many hospital buildings are nonfunctional. Some hospital structures survived the shaking but must close due to nonstructural damage such as water pipes that break and flood.

Thursday 10:05 a.m. (… 5 minutes after the quake began …)

The U.S. Geological Survey posts preliminary information about the earthquake. Learning that the magnitude is 7.8, the world turns its attention to southern California. Locally, news helicopters take to the air to begin spot coverage of the devastation. With power out, residents turn to their radios or talk to those they meet in the streets, searching for any information.

Across the region, phone systems, including cellular and 911, are unusable, overwhelmed by the vast number of attempted calls.

Thursday 10:30 a.m. (… 30 minutes after the quake began…)

Emergency operations centers are activating, and police, fire, and medical personnel shift into

emergency response mode, focusing on localized incidents with any means available. They react quickly, according to their training and earthquake plans established in advance.

All over the region, a foreseeable tragedy unfolds. Buildings that engineers knew were going to perform badly, have performed badly. These are older buildings, constructed with little earthquake resistance. The experts have names for them—non-ductile reinforced concrete, tilt-up concrete, unreinforced masonry, soft-stories—and hundreds of these buildings have now followed their reputations into the dust. Thousands of other structures are still standing, but so gravely damaged that they can never be used again.

While the earth still shakes in places far from the earthquake's origin, people in the earliest hit areas are beginning to confront damaged buildings and to help those who are trapped or hurt. Lacking gloves, crowbars, and training, some people claw through debris with bare hands. Ultimately, 95 percent of those who are rescued will be rescued by other victims, as has been seen in earthquake disasters worldwide.

Air traffic is being diverted from southern California.

As people start to assess their situations, millions of them discover they are cut off from their families, with no way to learn the fate of their loved ones or homes. This realization also hits first responders as they move out to help; they understand that the disaster may seem to be over but is just beginning.

Fires are starting in countless ways. Power lines arc… gas appliance lines snap… chemicals spill and mix… a lamp hits a sofa, unnoticed with the power out and the earth shaking, then the power returns and the sofa starts to smolder… Most of the fires start small, but not all are discovered right away. In any case, the phones don't have dial tones. Even if they did, in a disaster this big and widespread, there are not enough emergency personnel to immediately respond to every call for help. Worse, response is slowed by roads that are impassable due to damage, building debris, or abandoned cars. Worse still, in many places the water system is damaged, leaving inadequate water pressure for fire fighting.

Once started, a small fire needs only minutes to engulf a home or workplace. Around southern California on this day, there will be 1,600 fires large enough to warrant a 911 call. The stronger the shaking, the greater the number of fires ignited. In areas with densely packed, woodframe buildings, some of these ignitions will combine, spreading into conflagrations that burn dozens of blocks.

As soon as the shaking stops, experts race to inspect dams around the region. A few are found to be leaking at the toe—a sign of potential failure. Emergency responders are spread even

thinner when they must begin the evacuation of downstream areas. No dam failures will occur in this particular earthquake.

Thursday 10:33 a.m. (… 33 minutes after the quake began…)

A magnitude 7.0 aftershock begins near the Salton Sea and ruptures to the south. Luckily, this is a relatively unpopulated area. Shaking and its effects are felt throughout Imperial and San Diego Counties, as well as in Mexicali, Mexico. Damage to a dam in San Diego County requires an evacuation. Teams of firefighters from San Diego County had been getting ready to come north to help with the initial earthquake's aftermath, but are now diverted to respond to the strong aftershock affecting their own county.

Thursday 12:00 noon (…2 hours after the quake began…)

Smaller fires are merging into larger fires in parts of the region where shaking was high and wood buildings are in close proximity. World and national news coverage is focused on urban Los Angeles, especially on a few collapsed buildings. This media focus makes the damage seem even worse than it is, and also more localized. It will be several days before a clear picture emerges of damage around the region.

Fire departments in Arizona and the San Francisco Bay area start to mobilize, but mutual aid is hindered because so many roads into the affected region are impassable. By now, some hospitals are beginning to receive and treat the injured, but with routes and communications disrupted, ambulances struggle to reach victims and get them to hospitals.

November 14, 2008

Friday 03:17 a.m. (… 17+ hours after the quake began…)

A magnitude 7.2 aftershock begins near San Bernardino and ruptures west along the base of the San Gabriel Mountains. This earthquake is considerably larger than 1994's magnitude 6.7 Northridge earthquake, which killed 33 people and cost more than $40 billion. The rupture stops 18 miles east of Pasadena, near Monrovia. The location and size of this earthquake are devastating to the already-weakened infrastructure and overextended emergency response resources. The aftershock triggers damaging aftershocks of its own.

Friday 07:00 a.m. (… 21 hours after the quake began…)

By now, a Presidential Disaster Declaration has been issued, and Federal resources have been committed. The Federal Emergency Management Agency (FEMA), the California Governor's Office of Emergency Services

(OES), and Operational Areas for emergency management have set up a Joint Incident Command Center. Communications remain difficult. Ham radio operators begin to assist official responders.

Since first hearing about the earthquake, people outside southern California have been trying to reach family and friends here. Very few have succeeded.

Friday 09:02 a.m. (…23+ hours after the quake began…)

A magnitude 5.6 aftershock rattles residential areas in Rancho Cucamonga. This is a bit bigger than the 1990 Upland earthquake that caused more than $10 million in damage.

Friday 10:00 a.m. (…24 hours after the quake began…)

Utility companies are working around the clock to restore services, yet most people in the areas of heaviest shaking lack electricity, natural gas, and water. Utility workers, like transportation crews, medical staff, and emergency responders, push themselves to do their crucial jobs despite concerns about their own families.

Donations of money, services, and material are arriving from all parts of the United States, and a few Red Cross shelters have opened at public schools and undamaged recreation centers, where food, water, and personnel are available. Most people, particularly in heavily damaged areas, are camped outside.

By now, most stranded motorists have been rescued, and some families are at last reuniting. To get around, emergency responders are using helicopters and any other means of transportation that works, while residents are using bicycles and four-wheel-drive vehicles.

November 15, 2008

Saturday 11:32 p.m. (… 2+ days after the quake began…)

A magnitude 5.7 aftershock occurs with an epicenter in Rialto. This is as large as the 1991 Sierra Madre earthquake that killed one person and caused $40 million in damage.

Fear of looting far exceeds the reality, yet by now many fearful rumors are circulating. Despite official assurances to the contrary, concern grows that if dead bodies are not recovered and transported away, they will cause disease outbreaks. Some are convinced that earthquake scientists are hiding knowledge that an even bigger earthquake is imminent.

November 16, 2008 *(… 3 days after the quake began…)*

It is getting easier for people outside southern California to make contact with friends and family here. Urban search and rescue teams continue to make rescues, but at a declining rate. Firefighters have extinguished most of the major fires, except where some conflagrations have merged into super-conflagrations—monster fires that consume everything for hundreds of blocks.

Many medical staff members have worked without sleep since they first began responding to the disaster. Seriously damaged hospitals have been evacuated, and open-air trauma centers have been set up in adjacent areas. There is a very short supply of medical equipment such as kidney dialysis machines. Some patients are being med-evacuated outside the region, to hospitals in Nevada, Arizona, and other parts of California. Undamaged hospitals have an influx of earthquake victims with crush injuries, broken bones, and trauma. This increased patient load is not distributed evenly, and some undamaged hospitals are dramatically overloaded, while others receive few patients.

By now, Red Cross shelters have been set up throughout the accessible parts of the affected areas. The donation and distribution of money, services, and material have intensified, yet unmet needs are widespread. A coordinated effort among local, State, and Federal government agencies is starting to bring water and food into the region. Our "just in time" economy does not stockpile goods in warehouses.

The National Guard has been mobilized to handle specialized, earthquake-related law enforcement duties, allowing local law enforcement to return to regular duties. The fear of looting, intensified by media emphasis, begins to abate. Police and security personnel maintain cordons around sites of building collapse, but tenants and owners are allowed to reenter certain other damaged buildings on a very limited basis.

Mid-December, 2008
(…About a month later…)

By now, most gas and electric services have been restored, even in the heavily damaged areas closest to the San Andreas Fault. Landfills store millions of tons of fresh debris. Most of the major roads have reopened, but they are lined with heaps of debris. Small bridges that went down or remain damaged are keeping many local roads closed. Some freeways also remain closed for repairs, where bridge retrofitting prevented collapse but not all damage. Many commuters who work far from home are unable (and some are

unwilling) to be back at work regularly. Tens of thousands of people are still without permanent shelter or jobs—or both—because their buildings sustained so much damage.

In the areas where shaking was not severe, most of the water service has been restored, although even in those areas a few communities continue to repair their water systems. Most people with running tap water have been warned to boil their water, because of confirmed or possible contamination due to cracks in the water conveyance system, particularly in areas where the sewer system also incurred damage. It will take a year or more for all the water systems to be certified as safe.

In scattered areas throughout southern California, people still cannot flush toilets because of damage to sewer pipes. Plenty of water is stored in the ground and in reservoirs, but near the fault it is not reaching some homes, schools, and businesses that need it. By now, many of these communities have determined that it will be cheaper and faster to replace rather than hunt for and repair every break in their water systems. So many communities have placed orders for pipes and connectors that the orders are heavily backlogged and there is debate about whose orders should receive priority.

A magnitude 6 aftershock with an epicenter in Cajon Pass offsets restored rail lines and disrupts the movement of goods from the ports once again.

In places without serious structural damage and with water service, businesses have reopened and are trying to get back to normal. Most had not secured their computers, their stock, or their files, or had these resources destroyed when unsecured water pipes broke. The few businesses with earthquake insurance now have the capital to move forward. Other businesses that survived the earthquake with little damage are nonetheless struggling because suppliers have not reopened or customers and employees are unable to reach them easily. Manufacturing plants that have resumed production are facing delays and additional costs to transport goods out of the region; some of their customers are considering other options.

Some residents have left the region to stay with family or friends, due to damage to schools and homes, or loss of jobs. At this point, most still expect to return.

Almost all the public K-12 schools and community colleges have reopened. Only a few of their buildings suffered structural damage, because they have special construction and inspection standards, regulated by the Field Act. In these schools, most of the nonstructural damage has been cleared, although undamaged furniture, equipment, and supplies are at a premium in many places. Class sizes are smaller where families have relocated to less damaged areas or are keeping kids at home. Not all teachers are back on the job.

Universities and private schools are not protected by the Field Act. Many have buildings that have not been retrofitted and thus have incurred significant damage. Some university students have now transferred outside the region.

May, 2009 *(…6 months later…)*

Water is back in faucets, sinks, and air conditioning units across the region, but it is too late for many businesses, especially smaller businesses that lacked the resources to wait out the bad times.

Businesses forced to close have a domino effect, and as the chances diminish for regaining jobs or finding new ones, more and more people are struggling to rebuild their lives.

By now, some faith communities have been forced to disband, due to severely damaged buildings and dwindling congregations.

Competition for building materials and construction crews is fierce. In communities that had been proactive in disaster planning, rebuilding is well underway. Other communities are still grappling with the complicated procedures and paperwork needed to launch post-disaster reconstruction.

Scattered around the region, there are multifamily residences that remain uninhabitable, with tenants still living outdoors.

Financial institutions face a growing number of loans in default, as businesses fail and individuals give up on recouping their losses.

November, 2010 *(… 2 years later…)*

Has this earthquake caused a disaster or a catastrophe?

Are things looking up? Is life getting back to normal for most people? Have most residents returned to their homes? Have most lifestyles and businesses resumed?

or

Are things still going badly? Has recovery faltered? Have the systems that support life in southern California been too severely damaged? How many people have found their lives unbearably difficult since the earthquake struck? How many people have lost what matters most to them?

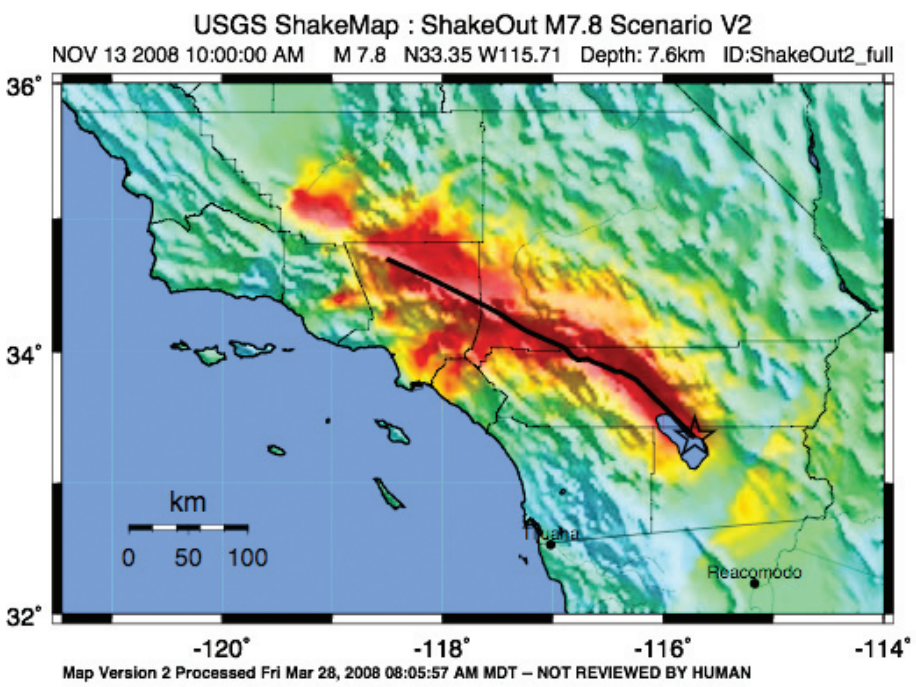
Southern Californians have the opportunity to work together to write this ending. In fact, by intention or not, they are writing this ending every day, through the decisions they make—or don't make—to get ready for earthquakes.

How Do We Write the Ending?

A major earthquake in southern California is inevitable, and it will be a regional disaster. Thousands of square miles will suffer heavy shaking, tens of thousands of people will be injured, hundreds of thousands of buildings will be damaged, and millions of lives and businesses will be disrupted. Whether or not the disaster becomes a catastrophe—an event that permanently changes the nature of life in southern California—will depend on the choices that every person makes between now and the day the earthquake occurs.

By examining the consequences of one hypothetical earthquake and the dynamic interactions among elements of our physical infrastructure and economic and social systems, the ShakeOut Scenario is helping to identify potential points of failure and places where relatively small efforts or investments *before* the next earthquake could yield tremendous benefit *after* the earthquake. Perhaps the biggest lesson of the ShakeOut Scenario is that our individual and collective decisions intertwine. The future vitality of southern California depends on the sum of personal decisions regarding earthquake preparedness and resiliency. The sum includes everyone—tenants and building owners, students and retirees, corporations and corner businesses, individuals and groups, neighborhoods, and governments. Some efforts can be made immediately, such as storing water and protecting families; some efforts will take time, such as increasing volunteer preparedness and collaborative planning; and some efforts will require money, such as retrofitting problem buildings or strengthening infrastructure.

DISTRIBUTION OF SHAKING INTENSITIES IN THE SHAKEOUT SCENARIO EARTHQUAKE



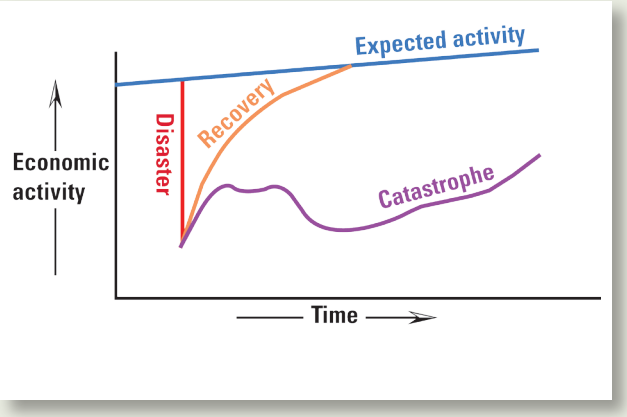
PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<.17	.17-1.4	1.4-3.9	3.9-9.2	9.2-18	18-34	34-65	65-124	>124
PEAK VEL.(cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	8.1-16	16-31	31-60	60-116	>116
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Although an earthquake has only one magnitude and epicenter, different locations will experience different shaking levels. The strongest shaking occurs very near the fault and dies off as seismic waves travel away. Away from the fault, natural basins filled with sediments trap some waves and create pockets of stronger shaking with longer durations. Not every basin traps waves in every earthquake. Consequently, in the ShakeOut earthquake, the San Fernando Valley experiences relatively low levels of shaking compared to the Coachella, San Bernardino, Antelope, and San Gabriel Valleys and the East Los Angeles area. The fault rupture modeled for the ShakeOut Scenario extends along 200 miles of the southern San Andreas Fault, so it would take this section of fault about 100 seconds to rupture. Ground shaking continues as the waves move out, and from the first fault motion near the Salton Sea to the last strong shaking in Ventura, the hypothetical magnitude 7.8 ShakeOut Scenario earthquake would shake southern California for more than 3 minutes. At most sites, strong shaking would last about 15 seconds, but in the basins strong shaking would continue for as much as a minute as the earthquake waves reverberate.

These and many more steps can be taken, starting now, to protect all southern Californians from the earthquake disasters that are certain to come.

The USGS developed the ShakeOut Scenario at the request of community leaders and emergency responders who said that this was the kind of science they needed to improve southern California's earthquake resiliency. Through this and upcoming projects, the USGS and its partners are continuing to evolve the way that hazard science is done, to help protect all of us from natural disasters.

DISASTER OR CATASTROPHE?



Under normal conditions (blue line), the economic activity in a region will gradually grow with time. When a disaster strikes (red line), assets are lost and many businesses shut down. As power and water service are restored, some businesses reopen, and an influx of insurance payouts and government assistance is used to hire contractors. This can lead to a rapid regeneration of economic activity and a return to economic health within a couple of years (orange line). To an economist, a disaster becomes a catastrophe (purple line) when the regional economy suffers a breakdown in resiliency and sinks into a depression that could last decades. To a sociologist, a disaster becomes a catastrophe when social, economic, and political systems suffer severe disruptions.

Additional Information

The ShakeOut Scenario (U.S. Geological Survey Open-File Report 2008-1150; http://pubs.usgs.gov/of/2008/1150/)

Forecasting California's Earthquakes—What Can We Expect in the Next 30 Years? (U.S. Geological Survey Fact Sheet 2008-3027; http://pubs.usgs.gov/fs/2008/3027/)

http://urbanearth.usgs.gov/

http://www.daretoprepare.org/

Photographs in The ShakeOut Scenario Narrative (in order of appearance)— *Trucks on freeway*: courtesy Port of Long Beach; *Los Angeles cityscape*: copyright by and courtesy of Erik Arnesen; *Back to school after Hurricane Katrina*: courtesy FEMA; *Loma Prieta quake damage Salinas*: USGS by J.C. Tinsley; *Crushed bikes Loma Prieta quake*: USGS by C.E. Meyer; *Kitchen damage Northridge quake*: USGS; *Broken gas meter, Watsonville, Loma Prieta quake*: USGS by H.G. Wilshire; *Damaged apartment, Northridge quake*: courtesy FEMA; *2007 Peru quake victims*: copyright and by Michael Mullady; *LA Structure fire*: courtesy Los Angeles County Fire Department by Capt. Larry Collins; *LA firefighter being interviewed*: copyright and by Troy Case, courtesy of Los Angeles County Fire Department; *Nighttime fire*: courtesy Los Angeles County Fire Department by Capt. Larry Collins; *Helicopter, Northridge quake*: courtesy FEMA; *Northridge quake victims with tent*: courtesy FEMA; *Firefighter with chainsaw*: courtesy Los Angeles County Fire Department by Capt. Larry Collins; *Red Cross trucks*: courtesy FEMA; *Loma Prieta quake damage*: USGS by C.E. Meyer; *Red-tag sign Loma Prieta quake*: USGS by John Nakata; *Bank-owned sign*: USGS by Dale Cox.

Prepare Now to Ensure a Better Outcome!!!

All Californians live in earthquake country and should therefore be prepared. Information in English and Spanish on earthquakes in southern California and how to prepare for them can be found in *Putting Down Roots in Earthquake Country* (*Echando Raíces en Tierra de Terremotos*), available at http://www.earthquakecountry.info/roots/.

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SCEC an NSF+USGS center

U.S. Department of Homeland Security

FEMA

State of California Seismic Safety Commission

OES California Governor's Office of Emergency Services

Governor's Office of Homeland Security State of California

USGS

Perry and others—The ShakeOut Earthquake Scenario—A Story That Southern Californians Are Writing—Circular 1324 / CGS Special Report 207

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