Chapter 8


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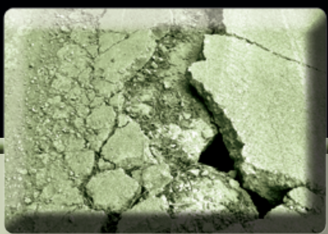


Chapter 8

Challenge Theme 6.
Natural Hazard Risks in the Borderlands

By William R. Page, Jean W. Parcher, and Jim Stefanov

Introduction

Natural hazards such as earthquakes, landslides and debris flows, wildfires, hurricanes, and intense storm-induced flash floods threaten communities to varying degrees all along the United States–Mexican border. The U.S. Geological Survey (USGS) collaborates with Federal, State, and local agencies to minimize the effects of natural hazards by providing timely, unbiased science information to emergency response officials, resource managers, and the public to help reduce property damage, injury, and loss of life. The USGS often mobilizes response efforts during and after a natural hazard event to provide technical and scientific counsel on recovery and response, and it has a long history of deploying emergency response teams to major disasters in both domestic and international locations. This chapter describes the challenges of natural hazards in the United States–Mexican border region and the capabilities of the USGS in the fields of hazard research, monitoring, and assessment, as well as preventative mitigation and post-disaster response.

(Facing page) La Conchita landslide, Ventura County, California, 2005

Earthquake Hazards

Earthquakes can occur at any time without warning and can have dire consequences, including damage to buildings and infrastructure, economic disruption (both locally and regionally), and loss of life. Earthquake damage to infrastructure—such as pipelines, wastewater treatment plants, power plants, and chemical storage facilities—can release contaminants that can cause long-term negative effects on ecosystems and natural resources.

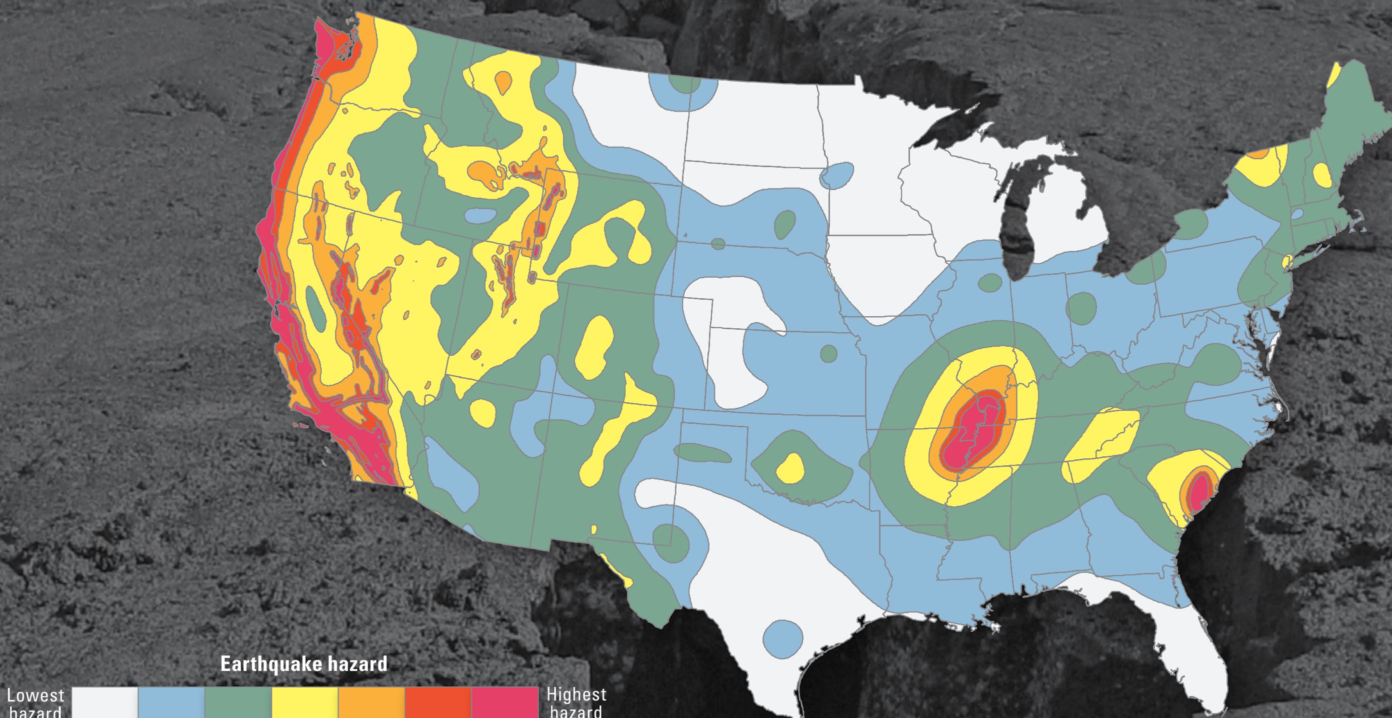
The area along the border most susceptible to earthquakes and associated hazards (ground shaking, liquefaction, landslides, etc.) is southern California and northern Baja California (fig. 8–1). Earthquakes in this region have occurred along several northwest-striking fault zones including the Imperial, Laguna Salada, and Cerro Prieto fault zones (fig. 8–2), which are part of the San Andreas transform fault system. A magnitude 7.1 earthquake along the Imperial fault zone in 1940 bent rail lines, severely damaged irrigation canals, and killed nine people in what was then a very sparsely populated Imperial Valley; a similar event today would be far more costly in loss of property and loss of life. Because earthquakes affect populations on both sides of the border, as illustrated by the magnitude 7.2 El Mayor–Cucapah earthquake in 2010 that caused major damage in northern Baja California, the need for coordinated and cooperative efforts between United States and Mexican agencies is imperative.

1940

Damage to shops and telephone lines in Imperial, California, caused by the 1940 earthquake

1979

Furrows in a plowed field offset by the 1979 Imperial Valley, California, earthquake



earthquakes

Figure 8–1. U.S. Geological Survey National Seismic Hazard Map showing expected levels of strong earthquake shaking likely to occur within the next 50 years. Pink colors define areas where ground shaking is expected to be strongest, while white colors are areas where ground shaking is likely to be minimal. Note that the border region along southern California ranks among the areas with the highest hazard expectations in the continental United States. (Map as of 2008 update.)

1979

Partial collapse of four columns of the Imperial County Services building in El Centro, California, during the 1979 Imperial Valley, California, earthquake

1992

Damage to a bowling alley in Yucca Lake, California, caused by the 1992 Landers earthquake

2010

Surface rupture from the 2010 El Mayor-Cucapah earthquake, Baja California

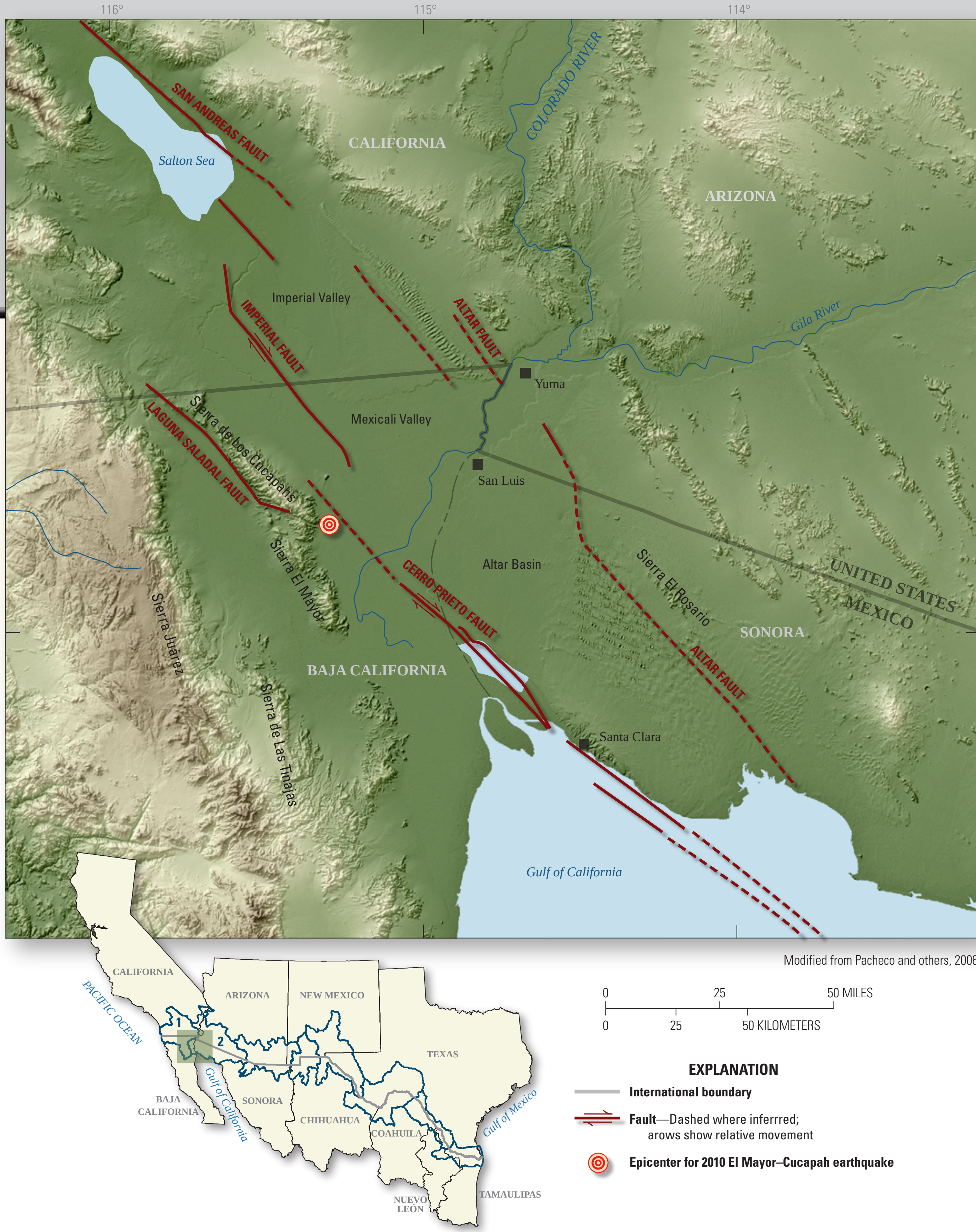
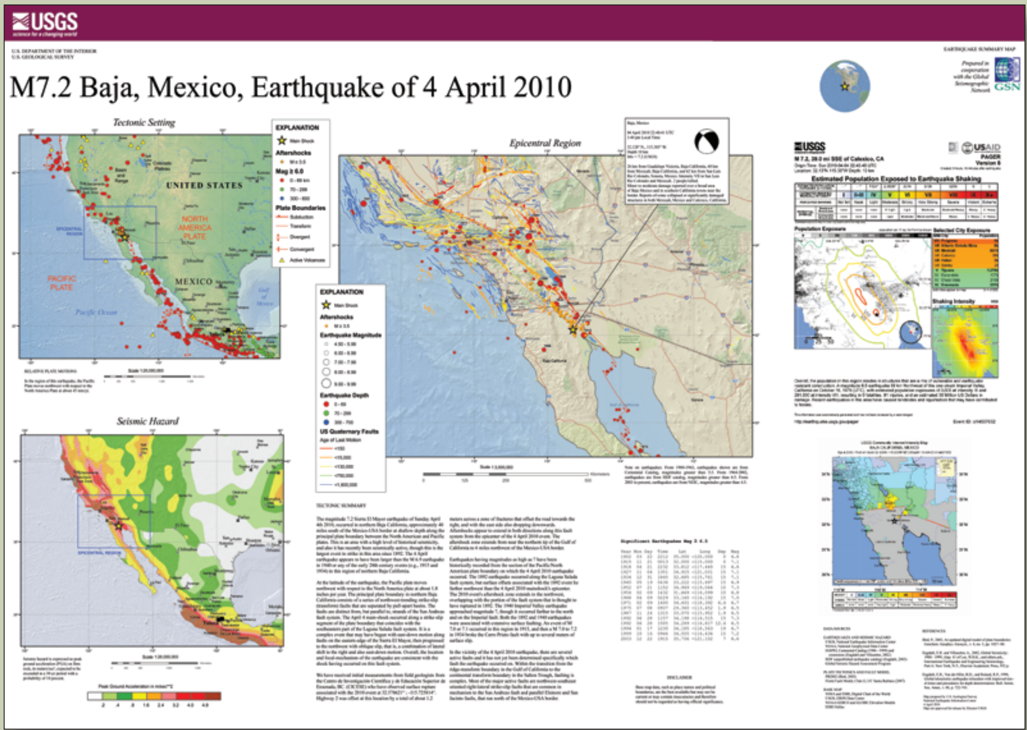


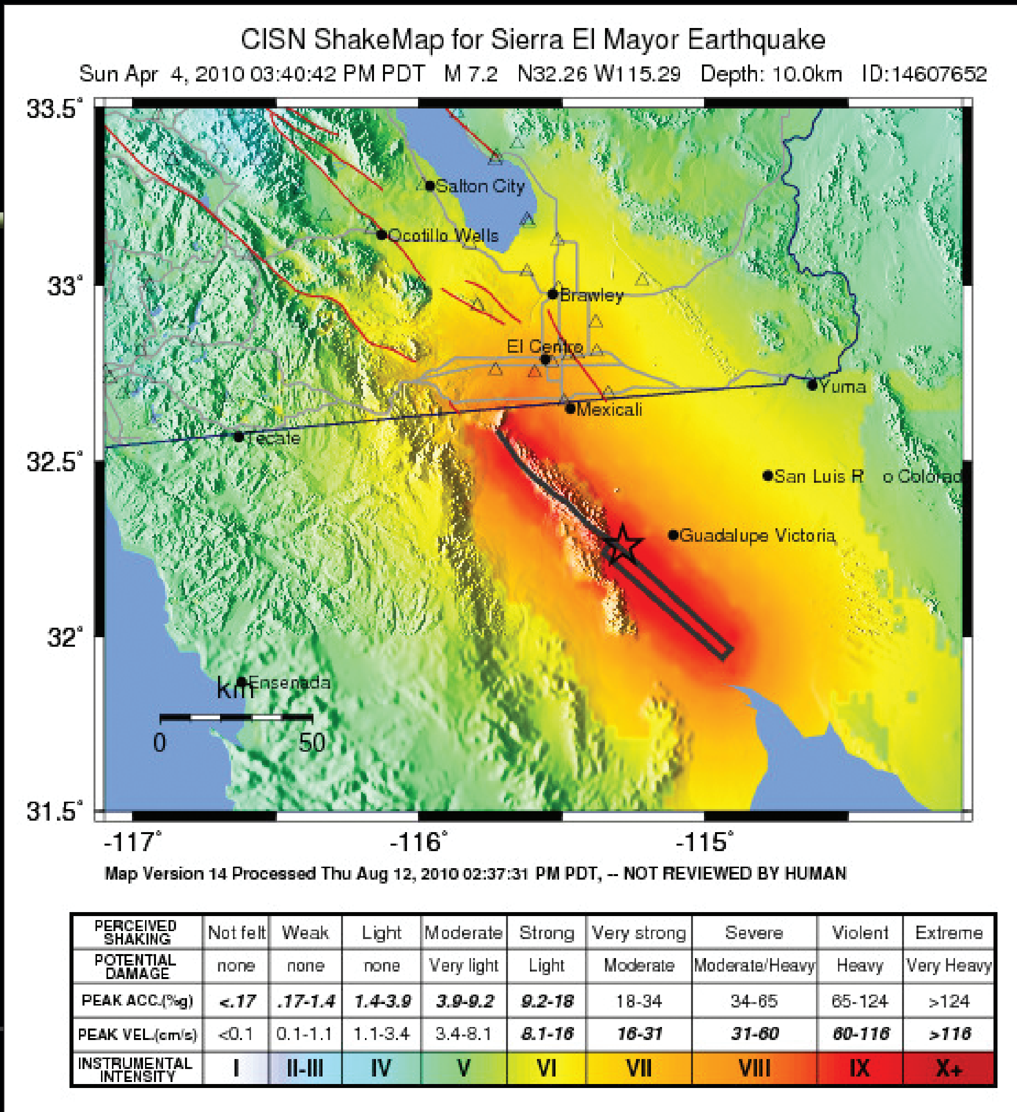
Figure 8–2. Major active faults along the United States–Mexican border in California and Baja California and the location of the 2010 El Mayor–Cucapah earthquake. Modified from Pacheco and others (2006).

2010 El Mayor–Cucapah Earthquake, Baja California, Mexico

On the afternoon of April 4, 2010, a magnitude 7.2 earthquake struck in northern Baja California approximately 60 kilometers (37 miles) south of the United States–Mexican border. The El Mayor–Cucapah earthquake occurred on the Laguna Salada fault (fig. 8–2) in an area of historical seismicity, though this was the largest event to strike in the area for over a hundred years. Because the energy release was shallow and extended over several tens of kilometers, the earthquake produced complex surface ruptures and severe damage was sustained in nearby populated areas, including Mexicali in Baja California. Earthquakes can disrupt transportation and critical lifeline infrastructure, as well as fuel and gas lines, high-tension power lines, and fiber optic communication lines. Because of the severity of damage and frequency of aftershocks, many inhabitants from Mexico were fleeing to the United States border at Calexico, Calif., for perceived sanctuary, while at the same time inhabitants from the United States were attempting to cross the border into Mexico to support relatives to the south. This flood of people on foot at the border eventually forced the closure of the crossing.



For more information on the earthquake and to download this poster, see *http://earthquake.usgs.gov/earthquakes/eqarchives/poster/2010/20100202.php*.



U.S. Geological Survey ShakeMap for 2010 El Mayor–Cucapah earthquake. For more information on ShakeMaps, see *http://earthquake.usgs.gov/earthquakes/shakemap*.

The area is traversed by a series of northwest-trending strike-slip faults parallel to the southern extent of the San Andreas fault, and field geologists from Mexico and the United States have subsequently been able to map a pronounced and complex rupture at the earth's surface with displacements in excess of a meter (Rymer and others, 2011). Working with regional seismic network partners, the USGS was able to transmit automated information on the El Mayor–Cucapah earthquake within 10 minutes of the mainshock through its National Earthquake Information Center and ShakeMap program.

(Continued on page 188)

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Surface fault ruptures from the 2010 El Mayor–Cucapah earthquake breaking through an abandoned highway west of Mexicali, Baja California, Mexico

landslides

Landslides and Debris Flows

Landslides cause billions of dollars in damage and dozens of fatalities each year in the United States. Often the loss of life and property is due to the fact that our homes, businesses, and transportation routes are frequently located in areas that are geologically prone to slope instability. A combination of natural and manmade events in series can greatly increase slope instability, and because much of the Borderlands are located in an arid to semiarid climate zone with sparse vegetation and shallow soils, the region is especially at risk for landslide and debris flow events. Heavy precipitation following other natural phenomena, such as an earthquake, wildfire, or flood, might trigger landslides and debris flows. For example, extreme convective thunderstorms in July 2006 caused 250 hillslope failures and debris flows in the Santa Catalina Mountains north of Tucson, Arizona (Magril and others, 2007). In Sabino Canyon, a heavily used recreation area managed by the U.S. Forest Service, debris flows destroyed roads and removed structures, necessitating the closure of the area for several months (fig. 8–3) (Magril and others, 2007). These same storms also caused debris flows in Coronado National Memorial, Ariz., where flows buried sections of Montezuma Canyon Road, the memorial's major road, and debris and mud filled picnic areas (fig. 8–4).

Figure 8–3. Debris flows in Sabino Canyon in the Santa Catalina Mountains, Arizona, caused by record flooding after extreme convective thunderstorms, July 2006.

Laguna Beach landslide, California, 2005

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Real-Time Monitoring of Landslides

Mark E. Reid, Richard G. LaHusen, Rex L. Baum, Jason W. Kean, William H. Schulz, and Lynn M. Highland

Landslides cause fatalities and property damage throughout the Nation. To reduce the impact from hazardous landslides, the U.S. Geological Survey develops and uses real-time and near-real-time landslide monitoring systems. Monitoring can detect when hillslopes are primed for sliding and can provide early indications of rapid, catastrophic movement. Continuous information from up-to-the-minute or real-time monitoring provides prompt notification of landslide activity, advances our understanding of landslide behavior, and enables more effective engineering and planning efforts.

During the exceptionally wet spring of 2006, thousands of tons of rock crashed onto one of the main highways leading into Yosemite National Park in the mountainous Sierra Nevada of California (fig. 1). These rocks, emanating from the massive Ferguson rockslide perched upslope, buried the highway and encroached into the Merced River. After 92 days, the highway was temporarily rerouted to the opposite side of the river. Nevertheless, geologists and land managers remained concerned—if the entire rock mass slid rapidly and blocked the river, it could cause upstream inundation and, potentially, downstream flooding.

To help reduce the threat posed by this rockslide, the U.S. Geological Survey (USGS), in cooperation with other agencies, acted quickly to provide continuous near-real-time monitoring of rockslide activity. Spider units, developed for remote monitoring of active volcanoes, were airlifted by helicopter and positioned on the active slide (fig. 1, inset). These spider units contain high-precision Global Positioning System (GPS) units capable of detecting small movements of the rockslide. Data from these remote spider units are transmitted by radio to USGS computers (fig. 2). Graphs of slide movement, available over the Internet, display current activity to geologists, geotechnical engineers, and emergency managers at the U.S. Forest Service, the National Park Service, and the California Department of Transportation.

Figure 1. Massive rockslide that buried California State Route 140 leading into Yosem[…] National Park, California, in 2006. Red dots are locations of spider monitoring units. Inset—Spider monitoring unit, containing Global Positioning System (GPS) receiver a[…] radio telemetry, installed via helicopter to detect continuing movement of the rockslid[…] (Photos: Mark Reid, U.S. Geological Survey)

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Fact Sheet 2012–3008
February 2012

Figure 8–4. Heavy equipment was used to clear debris flows on Montezuma Canyon Road in Coronado National Memorial, Arizona, July 2006.

Wildfires

Wildfires are an escalating natural hazard in all parts of the United States (fig. 8–5) and are significant threats to life and property, particularly where the urban fringe encroaches on native ecosystems. Wildfires are prevalent and dangerous phenomena in the Borderlands, where they are enhanced by frequent strong winds, arid conditions, and dry vegetation. The primary effects of wildfire are the destruction of community infrastructure and cultural and economic resources and the loss of life; the destruction of timber, forage, wildlife habitats, scenic vistas, and watersheds; and the release of hazardous material and the pollution of air, water, and soil. In the Borderlands, secondary effects include an increased potential for flooding, debris flows, and landslides; increased erosion; introduction of invasive species; changes in water quality; and reduced access to recreational areas.

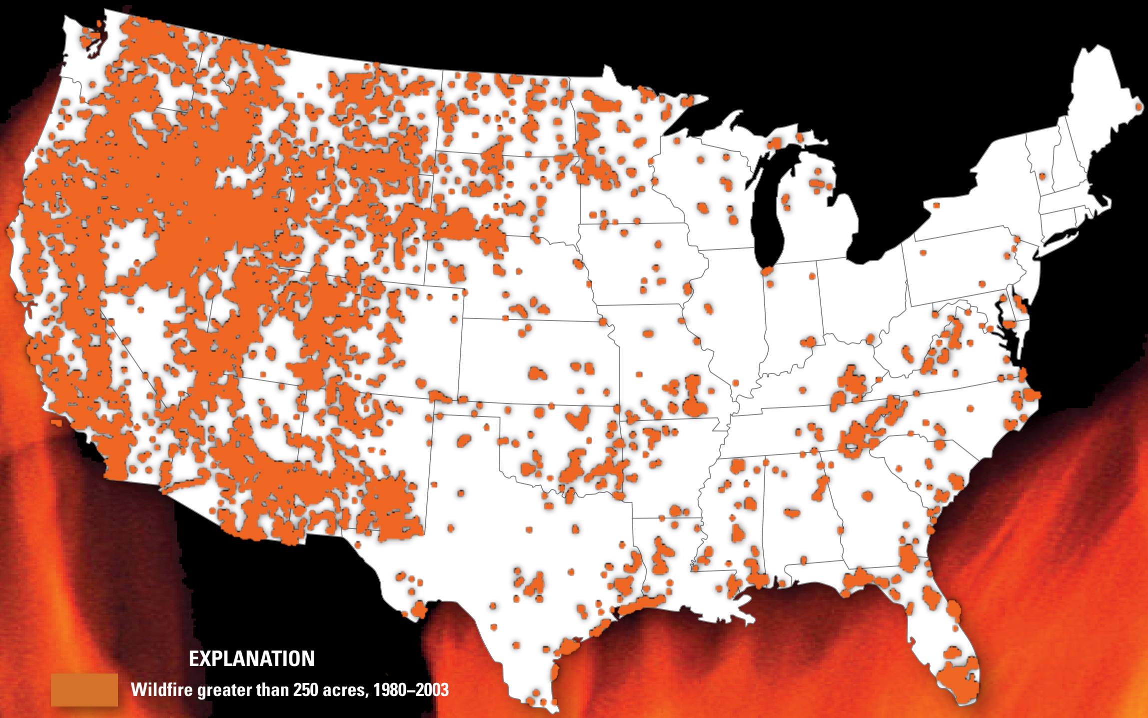

Figure 8–5. Locations of wildfires covering 250 acres or greater that occurred in the United States between 1980 and 2003. Information from the U.S. Geological Survey, Bureau of Land Management, U.S. Forest Service, U.S. Fish and Wildlife Service, Bureau of Indian Affairs, and National Park Service. Modified from U.S. Geological Survey (2006).

The United States–Mexican border region has experienced several catastrophic fires in recent years. In October 2003, wildfires burned hundreds of thousands of acres of land in the San Diego, Calif., area and spread rapidly because of dry conditions and active Santa Ana winds. Fifteen people were killed in the fire, and costs related to property loss and other destruction totaled about $27 million. In August 2007, devastating wildfires again ravaged southern California; they burned more than 202,000 hectares (over 500,000 acres), caused 9 deaths and 85 injuries, destroyed at least 1,500 homes, and resulted in about $1 billion in damage in the San Diego area (Flaccus, 2007). Wildfires have also burned national forest and grassland areas in southern Arizona and New Mexico and along the border of northern Sonora and Chihuahua.

wildfires

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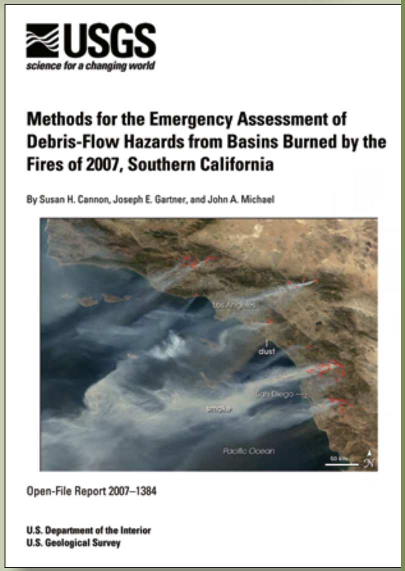
U.S. Geological Survey Support Activities Related to the 2007 Southern California Wildfires

After the 2007 southern California wildfires, the USGS Multi-Hazards Demonstration Project immediately began to assess the potential risk for secondary hazards of the fires, such as debris flows, increased flood risk, water quality degradation, and ecosystem damage affecting human health. Researchers collected and analyzed ash and burned soil to assess the effect of ash and burn products on ecosystems and water supplies. Preliminary geochemical analyses of selected samples (Plumlee and others, 2007; Wolf and others, 2008) showed some elevated concentrations of metals and alkalinity in ash, which could be of concern to human health. The project also conducted aerial surveys and collected spectral imaging data on key burn areas and compiled hazard maps for debris-flow warning systems (Cannon and others, 2007). The expertise of the USGS in using integrated geochemical and remote sensing techniques and in collecting and analyzing LIDAR, ASTER, and Landsat[1] imagery in vulnerable areas is crucial in the monitoring of wildfire effects on erosion, sedimentation, and ecosystems.

After the smoke has cleared, a U.S. Geological Survey geologist collects ash and soil samples following the 2007 southern California wildfires.

[1] LIDAR, light detection and ranging; ASTER, the Advanced Spaceborne Thermal Emission and Reflection Radiometer; Landsat, a satellite that collects images of earth from space. Each is a method of remotely collecting data on the earth's surface from aircraft (LIDAR) or space (ASTER and Landsat).

Satellite image of fires burning in southern California on October 24, 2007. For more information on this image, see *http://earthobservatory.nasa.gov/NaturalHazards/view.php?id=19225*. Modified from National Aeronautics and Space Administration (2007).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Methods for the Emergency Assessment of Debris-Flow Hazards from Basins Burned by the Fires of 2007, Southern California

By Susan H. Cannon, Joseph E. Gartner, and John A. Michael

Open-File Report 2007–1384

U.S. Department of the Interior
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Hurricanes and Floods

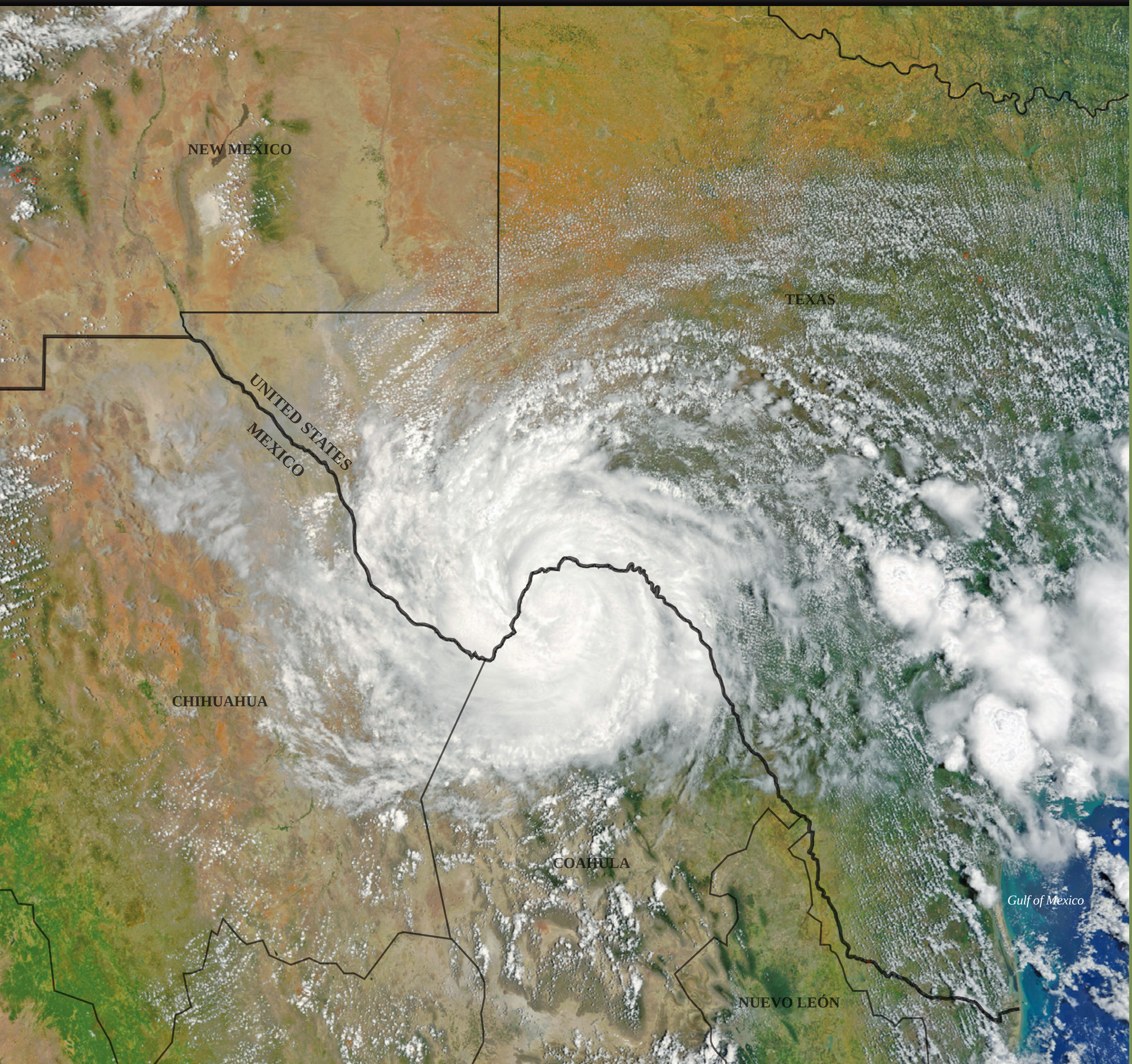
Hurricanes affect the Borderlands primarily in Texas and Tamaulipas along the Gulf of Mexico. One of the most devastating hurricanes that occurred in the Borderlands was Hurricane Beulah (fig. 8–6), which came ashore in the sister city area of Brownsville-Matamoros (Texas-Tamaulipas) in 1967 as a category 3 storm with winds at 219 kilometers (136 miles) per hour. As much as 69 centimeters (cm) (27 inches [in]) of rain fell in the Rio Grande watershed during Hurricane Beulah. Related flooding caused serious damage at Harlingen and McAllen, Texas, and inundated thousands of acres of agricultural lands along the Rio Grande in parts of Tamaulipas and Texas.

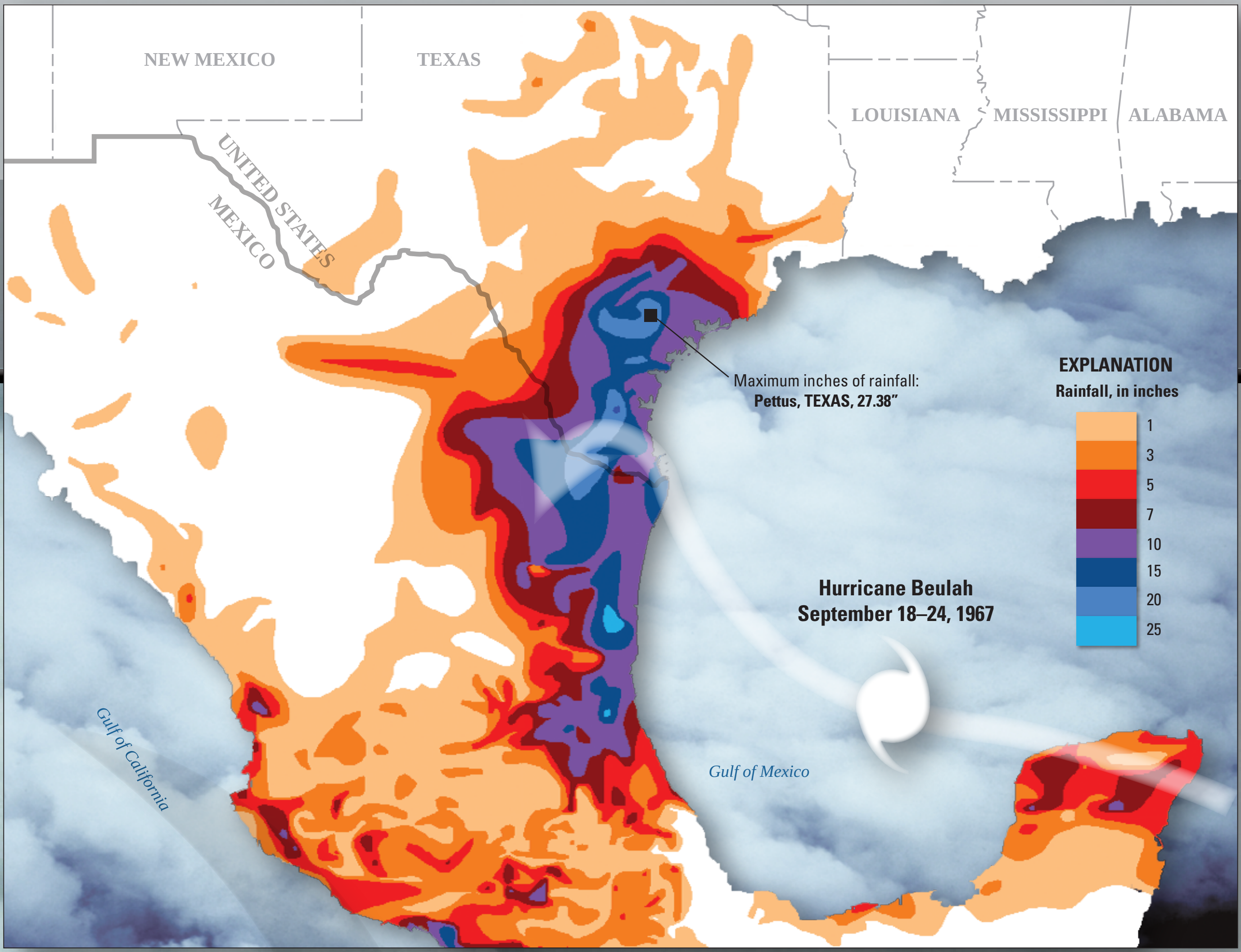
floods

(Left) Flooding along the Rio Grande below Presidio, Texas, after monsoon rains in northern Mexico, 2008

(Facing page) Satellite image of Hurricane Claudette in 2003 centered over southern Texas and northern Coahuila. For more information on this image, see *http://earthobservatory.nasa.gov/NaturalHazards/view.php?id=11746*.

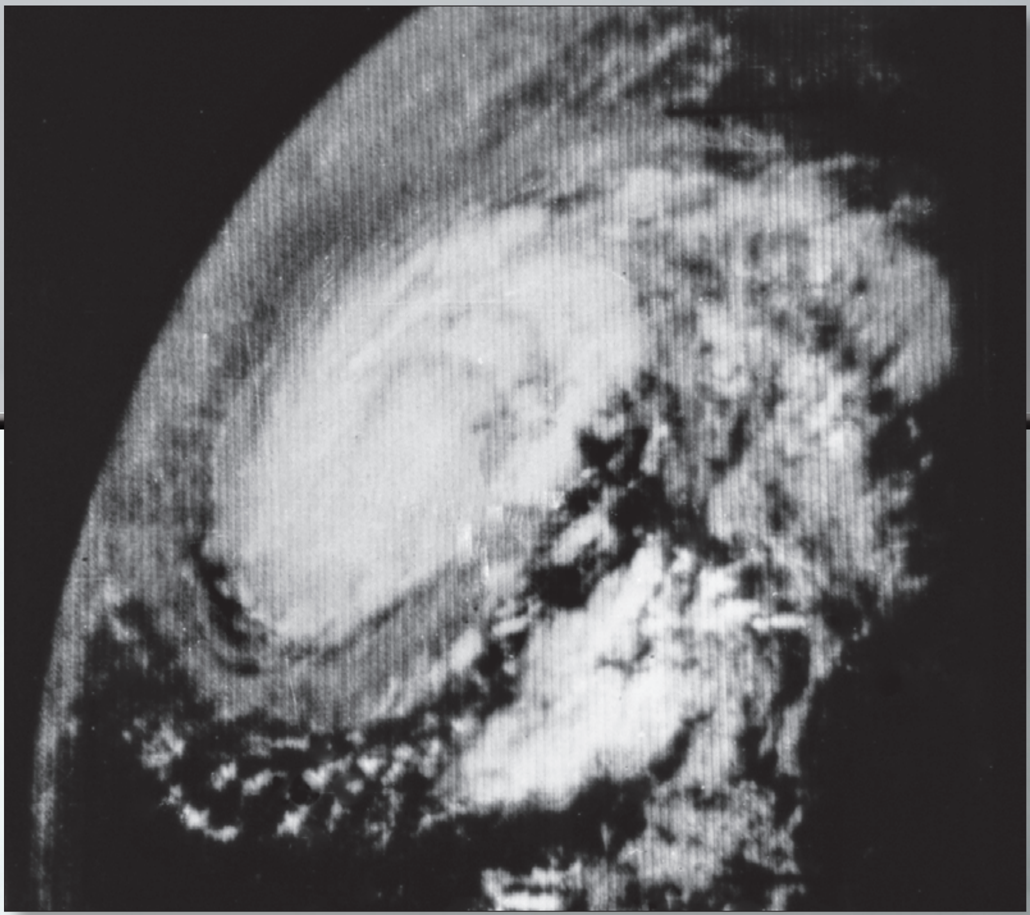
Although much of the Borderlands is desert, devastating flash floods from severe thunderstorms can occur. Major effects of flash floods include inundation of urban infrastructure and farmland, destruction of property, contamination of water supplies, and loss of life. Effects of flooding can also contribute to human health risks, such as bacterial contamination of water supplies and recreational waters. The 2006 floods in the sister city area of El Paso–Ciudad Juárez (Texas-Chihuahua) were caused by a series of heavy summer thunderstorms from July 27 through August 6 with a total rainfall of about 38 cm (15 in). Early research of the flooding caused by these storms indicates that accelerated urban growth in high-risk areas such as arroyos and a series of unusually severe storms combined to produce the damage experienced in the region (C. Brown, New Mexico State University, written commun., 2008).





hurricanes

Figure 8–6. Total rainfall in inches for Hurricane Beulah during landfall on the Gulf Coast in 1967 (above), and satellite image of Hurricane Beulah taken by TIROS VII on August 22, 1967 (top right). Areas along the Texas coast experienced flooding in the days after the hurricane (bottom right). Data for landfall figure from the National Climatic Data Center and the Comisión Nacional del Agua [National Water Commission]; modified from National Oceanic and Atmospheric Administration (2012).



August 22, 1967

September 1967

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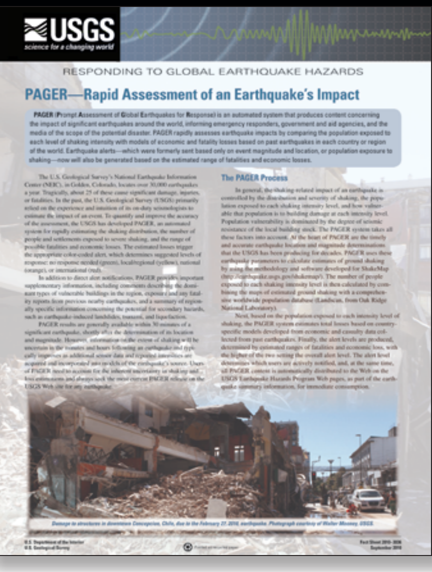
Vulnerability and Risk Analysis for Sister City Areas along the United States–Mexican Border

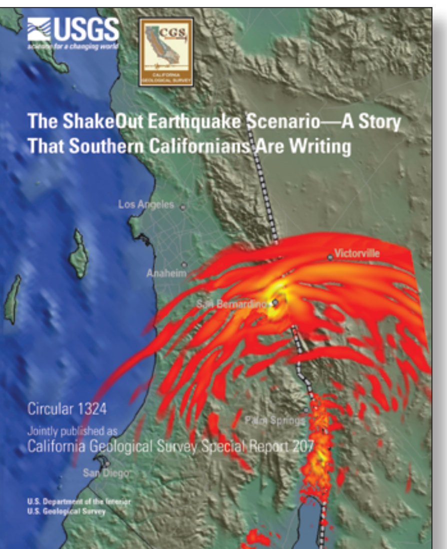
Intense urbanization in sister city areas along the United States–Mexican border coupled with extreme precipitation events increase the risk and vulnerability of these areas to natural disasters, especially those cities in the lowest economic tier. The differences in urban structure between Mexican and United States cities—dense population areas with a proliferation of substandard housing in low-income areas in Mexico (Chardon, 1999; Lopez and others, 2001) and urban sprawl in low-density developments in the United States (Johnson, 2001)—provide a unique research environment to study differences in urban vulnerability to natural disasters. The vulnerability of a community to a natural hazard is a function of the risk of the hazard and the development patterns of the built-up environment, such as business enterprises, community social structure and services, and natural resources related to natural hazards (Wood, 2006). Therefore, the policies, regulations, and decisions made before, during, and after the event greatly affect the hazard risk.

Urban development in the upper reach of an arroyo near El Paso, Texas, increases flood risks for residents in the lower reach.

From an engineering framework, flood risk models incorporate physical environmental datasets such as elevation and slope, soil infiltration capacity, evapotranspiration rates, surface runoff rates based on land-cover types, and structural conveyance facilities. Land-use modifications to the manmade environment are only considered in reference to changes in surface runoff rates (impervious cover, flood drainage conveyances, and so on), yet they play a critical role in assessing the vulnerability of the community to a natural hazard such as flooding.

Geographers with the USGS have refined processes based on geographic information systems (GIS), such as the Community Vulnerability Assessment Tool (CVAT; Flax and others, 2002), to assess the intersection of hazards and community resources. Tsunami vulnerability research along the Pacific Coast performed by Wood and Good (2004) incorporates readily available GIS layers such as the National Land Cover Dataset, U.S. census population and business economic data, major infrastructure data including essential facilities, and tax parcel values. Applying this similar CVAT process to assess the vulnerability of the population for sister city areas along the United States–Mexican border can assist Mexican and United States land-use planners and emergency response staff in reducing potential economic losses from flood hazards. Additional data, such as for hazardous waste and agricultural activities, provide information necessary for the community to address preparedness issues such as debris removal. Using the CVAT process, composite maps can be created to help community stakeholders set priorities, identify community vulnerability “hotspots,” and discuss new zoning regulations.





USGS Capabilities

The USGS possesses advanced capabilities for monitoring natural hazards, analyzing levels of risk and vulnerability for disaster prone areas, providing damage assessment data after extreme events, and providing timely, unbiased science information to emergency response officials, resource managers, and the public, helping to reduce property damage, injury, and loss of life.

The USGS Multi-Hazards Demonstration Project (*http://urbanearth.usgs.gov/*) helps communities in southern California reduce their vulnerability to catastrophic loss from earthquakes, wildfires, landslides, tsunamis, and coastal erosion. Long-term project objectives are to establish open communication between scientists and disaster managers and planners, plan USGS research with collaborators to further the goal of improved resiliency to natural hazards, initiate or expand real-time monitoring and warning systems, and provide easy access to new and existing hazards data, information, assessments, and models to facilitate integration and use by decisionmakers and researchers.

The USGS Global Seismographic Network monitors earthquake data and can relay that information to governments and the public during major earthquake events in real time. The USGS also developed PAGER, Prompt Assessment of Global Earthquakes for Response, an automated system that uses shaking hazard maps to rapidly estimate the number of people and communities exposed to severe shaking during earthquakes anywhere in the world. Federal, State, and local agencies also use shaking hazard maps to create and update seismic design provisions in building codes.

The USGS Landslides Hazards Program monitors landslides in real time and conducts research on precipitation-induced landslides and debris flows. The resulting information is shared with decisionmakers and the public to assist in developing landslide mitigation and loss reduction strategies and predicting where and when these hazards are likely to occur.

For wildfire preparedness, the USGS collaborates with other Federal, State, and local agencies to prepare maps of vegetation, fuels, and past burn areas. It also provides information to the public to identify wildfire risks, reduce fire hazards, develop emergency response plans, and assess wildfire damage and its aftermath.

To address major hurricane disasters, the USGS collects coastal impact data through remote sensing techniques to map the extent of flooding. Activation of current remote sensing data can be implemented through the International Charter on Space and Major Disasters, of which the USGS is both a participating member and an authorized user. Through the member agencies, the International Charter provides a unified system of space data acquisition and delivery to those affected by natural or man-made disasters.

The USGS assists in flood warning and emergency management activities by collecting streamflow data and displaying real-time streamflow maps for use by Federal, State, and local agencies. For the 2006 El Paso flood post-assessment, the USGS collaborated with the U.S. Army Corps of Engineers (2007) to collect field data at arroyo channels and precipitation monitoring sites.

References cited in this chapter are listed in chapter 12.