RISK & INSURANCE®
TOP 10 RISKS

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SAN FRANCISCO residents look on as their city burns from fires ignited by ruptured gas mains and exploding stoves in the earthquake of 1906.

Today's 10 Greatest Risks

What are the greatest risks we face in the United States? *Risk & Insurance* posed this question to Risk Management Solutions, a leading risk modeling firm. The answers evolved into unique scenarios—fictional accounts of what may really happen.

It's been tough to avoid the question of risk in a post-Sept. 11 environment—or in any environment for that matter.

Recent headlines have been dominated by catastrophic events—earthquakes in Iran, devastating fires in the United States, floods in Europe, flu epidemics in Asia and attacks by computer viruses. And who can overlook the recent terrorist mayhem in Spain?

What are the greatest risks that we face as a nation? That's too broad a question to answer in one issue. We narrowed it down with the help of Risk Management Solutions, the nation's largest catastrophe modeling firm.

First we decided to look at only risks triggered by an event, natural or man-made. In retrospect, asbestos contamination has turned out to be among the most costly risks ever, but it's tough to identify an "asbestos event."

Second, the event had to have a reasonable chance of happening. We settled on an event with a probability of happening of once in a hundred years. It's not an asteroid destroying the entire East Coast. But it is a Category Four hurricane slamming into Miami.

For six months, a team of RMS researchers lead by Robert Muir-Wood, RMS's research director, looked at the panoply of risk and identified 10 events as the worst we face in the United States.

RMS created compelling and realistic scenarios to bring those events to life. All references in the narratives to names, places, loss of life and property damage are fictitious. Figures in the charts are estimates. Although all these events would have indirect economic costs, we decided it was too difficult to report accurate estimates.

This is part of our effort to find more imaginative ways to write and report on risk. As always, we welcome hearing what you think. You can e-mail us with you comments at riskletters@lrp.com. Many thanks to RMS who made this report possible.

—Jack Roberts, Editor-in-Chief

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AP PHOTO

HURRICANE ANDREW devastated Florida City and southern Florida in 1992 with state-wide damages estimated at more than $30 billion.

Gustav Bears Down On U.S. East Coast

The Hurricane Scenario: Gustav, an intense Cat 4 storm, wreaks supreme havoc upon the Eastern Seaboard, leaving a trail of losses from Key West to Cape Cod. BY AUGUSTE BOISSONNADE

The Hypothetical Scenario:
Early in the fall, the National Hurricane Center satellites identify a tropical depression in the middle of the Atlantic Ocean, moving west from the coast of West Africa. As the depression gains strength over warm water, it grows into a tropical storm. NHC calls the storm Gustav. It is the seventh tropical cyclone to emerge that year in the North Atlantic basin. NHC experts monitor it over a week as it develops into an intense hurricane that sends a glancing blow at Barbuda before heading toward the Bahamas.

Projections show that it is likely to make landfall along the east coast of Florida in Palm Beach County. With sustained winds of 145 mph, Gustav is a Saffir-Simpson Category Four storm. With landfall two days away, a hurricane warning is issued along the southeastern coast of Florida from north of Miami to Cape Canaveral. The tropical storm warning covers a broader area, from Key West to Jacksonville.

As the hurricane nears the coast, do-it-yourself and hardware stores sell out of materials and tools as residents and building owners install shutters or attempt to board-up windows. Tens of thousands of people evacuate coastal communities in the likely path of the hurricane and move inland.

As time passes, Palm Beach County and its surroundings are almost deserted. Only emergency personnel remain; a few stubborn residents and journalists are left behind. Risk managers and emergency officials are preparing for the worst. The Nuclear Regulatory Commission's Region II office in Atlanta implements its hurricane response procedure and shuts down a plant in St. Lucie. Other plants are on high alert. Utility companies activate their emergency plans.

Forecasters use reconnaissance planes, eyewitness accounts, satellite imagery and an ensemble of atmospheric models to forecast where the storm will make landfall. The latest forecasts suggest that the storm will move inland at approximately the same location as the "Great Lake Okeechobee" hurricane of September 1928, a Category Four hurricane that hit the coast near Palm Beach with sustained winds of 128 mph. At the time of Gustav's landfall, maximum gusts of 160 mph are observed in some coastal areas within the eye wall. Intense rain is reported and several tornadoes have been spotted. Gusts of 80 to 90 mph are reported in the Miami metropolitan area, about 60 miles south of where the hurricane came ashore. Heavy surf and surge affect the coastline over more than a hundred miles. Surge heights reach 15 feet over a 20-mile coastal stretch near Juno Beach, about 25 miles north of where Gustav made landfall. Florida's governor asks the President to declare Florida a major disaster area.

Once on land, Gustav weakens and begins to swing toward the north and northeast, ensuring that the highest winds remain over the heavily populated coastal communities. Gustav is quickly downgraded. Seven hours after landfall it is a tropical storm generating gusts of 80 to 90 mph at Cape Canaveral and 50 to 60 mph by the time it reaches Georgia, whereupon the storm moves back offshore. Its path is similar to the 1928 storm but as it remains closer to the coast, the high winds affect more of the coastal areas.

In the regular NHC forecasts, tropical warnings are now extended along the entire Eastern Seaboard, as the storm moves up the coast toward the Northeast.

With Gustav once again over water for about six hours, it strengthens and speeds up as it skims the coast before making landfall in South Carolina with sustained winds of 60 to 70 mph.

The storm moves north and becomes an "extra-tropical" storm as it moves along the Eastern sea-

board with gusts reaching 50 to 60 mph in coastal areas as far north as Massachusetts over the next two days.

The storm left an impact on much of Florida's eastern coast. The most damage took place along 100 miles of coastline, between Pompano Beach and Port St Lucie. The most severe damage is reported in coastal communities. In some areas the coastal landscape has changed completely. Beach houses have been uprooted from their foundations and debris is floating in the streets, swept in by heavy surf. Many older buildings that were not built in accordance with current state and local building codes are destroyed or heavily damaged. Resorts along the coast suffer extensive damage. Several lose their beach access.

Gustav affects more than seven million Florida residents. More than 1,000 coastal structures have lost 50 percent of their market value, victims of pounding surf. Thousands of other properties suffer minor to moderate damage. In all, about one million homes, condos and apartment buildings are affected by the storm, 400,000 of them severely. In addition, 200,000 commercial properties are damaged by the storm.

POWER FAILURES

Power outages are reported over large areas of Florida where high winds topple trees and branches knock out transmission and distribution lines. More than three million customers are without power for as long as three days. Some residents have to wait several weeks before power is restored. Businesses suffer the brunt of these power outages as inventory perishes or is simply destroyed. Fortunately, only a few hospitals and fire stations suffer extensive damage.

Despite heavy rains—more than 10 inches of rain over 24 hours—and high winds, the dikes built around Lake Okeechobee after the 1928 hurricane hold. There is no catastrophic inland flooding to speak of. States north of Florida suffer damage, mainly due to heavy rains and gusty winds, which knock down trees and inflict property damage. One million residents are affected in these states, including many in Rhode Island and Massachusetts where 300,000 buildings suffer mostly minor damage. While improved tree-clearance since 2003's Hurricane Isabel has reduced the impact of power outages in the Carolinas and the Mid-Atlantic states, several million people are without power in New England.

Building damage and flying debris from Gustav are directly responsible for 25 deaths, while another 60 fatalities are linked to the hurricane. The number of casualties is much lower than in the 1928 storm, in which more than 1,800 people died. Total U.S. economic losses reach an estimated $75 billion, with 95 percent of the losses occurring in Florida.

Total private insurance claims are reported to be about $48 billion, with insurance companies on the hook for about $45 billion of that $48 billion. Roughly two-thirds of those claims reflect residential losses; the large majority being wind-related. About $500 million in flood losses is paid out to businesses covered by flood insurance. Residential, coastal and inland flood losses are reported to be on the order of $1 billion, the majority of which are covered by the federal flood insurance program. Emergency and clean-up costs are estimated to be about $2 billion. Losses to agriculture are several billions of dollars, part of it covered by insurance.

Losses from Hypothetical Hurricane Gustav

Type of Loss	Total Loss	Insured Losses
Property and infrastructure damage	$57 billion	$37 billion
Workers' compensation, life and health costs	$100 million	$50 million
Direct costs of business interruption	$15.5 billion	$8 billion
Other costs (e.g. emergency response)	$2 billion	—
Total Direct Costs:	**$74.6 billion**	**$45.1 billion**
Total number of people killed:	**85**	
Total hospitalized with serious injuries:	**150**	
Total treated at outpatient clinics:	**500**	

Source: Risk Management Solutions

Mother Nature's Deadly Spins

Virtually every coastal area along the Gulf and eastern coasts of the United States, along with Hawaii, have the potential to be struck by a hurricane but some coastal areas are more at risk than others. The patterns of hurricane activity can be observed from history and explained by the physics and climatology of hurricane formation and motion. In an average year, three tropical storms hit the continental United States. About two of every three of these tropical storms come ashore with hurricane strength.

Loss reconstructions show that 80 percent of all historical hurricane losses resulted from just 65 hurricanes—a relatively small proportion of all hurricanes to hit the United States.

Since the devastating hurricane that battered Galveston in 1900 and claimed more than 8,000 lives, major investments have been made in better preparedness, and improved methods of tracking and forecasting hurricanes. As a result there are today far fewer deaths from hurricanes, despite a dramatic increase in the number of people living along the coasts. Between 1900 and 1960, 12 hurricanes caused more than 200 deaths each. Since the 1960s, the average number of people who die every year from hurricanes is 25.

Economic losses due to hurricanes, however, have increased steadily as more people choose to live by the shore.

The highest historical reconstructed losses (modeled with current exposures and values) in the past 100 years would come from a Category Four hurricane that hit Miami in 1926, causing $87 billion in damages and $47 billion in insured losses. The Category Three hurricane that hit New England in 1938 would cause $28 billion in damages and $17 billion in insured losses. The small but intense Category Five, Hurricane Andrew, in 1992 would cause $38 billion in damages and $23 billion in insured losses.

About 80 percent of U.S. coastal residents from Texas to Maine have not experienced a direct hit from a major hurricane since 1900. Risk Management Solutions first developed a catastrophe model for hurricane loss in 1993 and has revised this model over subsequent years. The model simulates tens of thousands of hurricanes that represent the frequency and severity of hurricanes likely to cause significant loss in the United States.

This model shows that there is a 1 percent annual probability that a direct economic loss of $75 billion or more could occur somewhere in the United States from the occurrence of an hurricane—i.e. a $75 billion economic loss has a 100-year "return period."

Results obtained with such a model show that there is a wide range of simulated hurricanes that could give such losses with 1 percent annual probability.

Gustav is a hypothetical scenario. This storm is similar to the "Great Lake Okeechobee" hurricane of September 1928. While the track and the impacts are different, Gustav illustrates the impacts of one of the many intense hurricanes that could strike this region.

Most of the economic losses resulting from Gustav are due to wind and wind-related perils. Surge and rainfall perils contributed to a relatively small portion of the total economic losses. This might not be true for other areas such as New York, for example, where the funneling coastline makes the region more vulnerable to coastal storm surge.

Gustav is by no means a worst-case hurricane scenario. Hurricanes with the same intensity could make a direct hit on a large metropolitan area, such as Miami, which would, in turn, have resulted in larger losses. Intense surge and flooding could have an impact on protective flood structures, such as in New Orleans, leading to widespread urban flooding. It would even be possible for Miami and New Orleans to be hit by the same hurricane in the space of two days. This almost happened in 1992.

—Auguste Boissonnade

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AP PHOTO

MISSISSIPPI RIVER floods inundated the area around the quad cities in Illinois in the spring of 2001.

Mississippi River Rages

The Flood Scenario: The Mississippi River system's flood protection plans and devices are overwhelmed. Thousands watch helplessly as their dreams drown in rising water levels. **BY ROBERT MUIR-WOOD**

The Hypothetical Scenario:

The end of the previous summer had been exceptionally wet across the upper Midwest, the north central states and as far east as Pennsylvania. Torrential rain fell day after day, as a high pressure system brought cool air from Canada to mix with moisture-laden tropical air moving up from the Gulf. Above-average rainfall continued through December, so that at the start of January, water levels were already at a record in the Ohio and upper Mississippi rivers. Following heavy snowfalls over the region in January, the rains returned in February falling onto ground saturated since the end of the previous summer. Average rainfall during February and March, throughout the lower Missouri, Mississippi and Ohio River basins was 200 to 300 percent of average.

The first flooding starts in the middle of February on the smaller rivers, affecting towns like Des Moines, Iowa; Springfield, Ill., and Indianapolis. Melting snow further to the west, combined with the heavy rainfall, means that levees fail all along the lower Missouri at Sioux City, Iowa and Omaha, Neb. And the rains continue.

Toward the end of March, with the arrival of warmer air from the Gulf, the storm systems strengthen into mesoconvective complexes which unleash intense thunderstorms bringing outbreaks of tornadoes and damaging hail.

By the end of March, levees begin to fail along the upper Mississippi, flooding Quincy, Ill., Hannibal, Mo., and vast areas of farmland. (By the time the flood is over, more than 60 percent of all the levees along the Mississippi and lower Missouri are ruined.) On April 4th, the combined flood waves of the Mississippi, Missouri and Illinois rivers arrive in St. Louis within days of one another, exceeding the 1993 record of 49.6 feet.

The flow of water approaches the previous record of 1844 — at least 25 percent more than in 1993. Finally, on April 7th, the levees north of the city can't hold back the river, now exceeding a height of 52 feet.

A day later, the southern side of the city is under water. Although the city founders had chosen their site carefully, and the downtown area remained dry, Riverview Drive and large adjacent industrial developments disappear under several feet of water.

Unlike the summer of 1993, when the flow of the Ohio River was low, the flood wave that now breaks through Mississippi levees south of St. Louis is destined to meet another flood wave pouring out of the Ohio River to the east. Defenses had already been breached at Evansville, Ind. and Paducah, Ky. Flood control procedures designed to regulate flow coming from the more mountainous southeast part of the Ohio River with reservoirs on the lower Cumberland and Tennessee Rivers are unable to cope.

In early 1997, the last significant Ohio River flood, flow was 250 percent above normal. This time it is closer to 350 percent, and the flood wave of 1.5 million cusecs arrives just a few days ahead of the flood wave advancing down the Mississippi. This is a recipe for disaster. Based on the Flood Control Act of 1928, the levees at Cairo, Ill., where the Ohio and Mississippi Rivers join, had been built to withstand the combined flood volume of 2.3 million cusecs. The previous record flow on the Ohio River had been 1.8 million cusecs in the spring of 1937. The combined flows on the two rivers is now perilously close to their design limit.

As the water level approaches the tops of the flanking levees, the U.S. Army Corps of Engineers begins using explosives to divert 550,000 cusecs of flow into a relief channel to surge over unpopulated farmland that had not been inundated since the Great Flood of 1937.

The water re-enters the main channel of the Mississippi River close to New Madrid, Mo., but intense rainfall over this section of the river at the beginning of April weakens the main downstream levees. After a night of frantic sandbagging, a section, 1,000-feet long, of the western levee fails.

Losses From The Hypothetical Greater Ohio and Mississippi River Floods

Type of Loss	Total Loss	Insured Losses
Property and infrastructure damage	$18 billion	$3 billion
Workers' compensation, life and health costs	$200 million	$100 million
Direct costs of business interruption	$12 billion	$1.6 billion
Other costs	$4 billion	—
Total Direct Costs:	**$34.2 billion**	**$4.7 billion**
Human Loss/Injuries		
Total number of people killed:	**66**	
Total hospitalized with serious injuries:	**70**	
Total treated at outpatient clinics:	**400**	

Source: Risk Management Solutions

Billions of gallons of water surge across the land carving a depression more than 100 feet deep and half a mile long. The water fans out into a flood of biblical proportions, 20 miles wide and tens of feet deep that submerges a number of towns including Caruthersville, Mo. and Blytheville, Ark.

The heavy rains over the upper Midwest are accompanied by near drought conditions over northern Texas, Oklahoma and Arkansas, so, unlike the situation in 1927, flow is not extreme along the Arkansas and White Rivers. However, to protect the City of New Orleans, the full flood management plan is put into action. Flows all down the lower Mississippi are already higher than the previous record set in 1997. Around 20 percent of the flow—some 500,000 cusecs — is diverted into the Atchafalaya River. A spillway 36 miles upstream of New Orleans is opened to divert 15 percent of the remaining flow into Lake Pontchartrain. At the end of April, the flood peak passes through New Orleans staying just below the crest of the floodwalls.

The impact of the floods is widely felt among residents living in the Mississippi, Illinois, lower Missouri and Ohio River basins.

Several major towns, including Peoria, Ill. and Des Moines, Iowa lose their water supply for more than 10 days as sewage and fuel oil clog inlets. Several blocks burn down in the center of one town after sparks ignite gasoline displaced from underground storage tanks.

In South St. Louis, Mo. three half-full liquefied propane tanks tear loose of their moorings, rupture connecting pipelines and explode—triggering further explosions in neighboring tanks. More than 800 businesses are affected in and around the City of St. Louis. Total damage in the St. Louis District is estimated at $6 billion.

The failure of the Monarch levee floods many industrial parks and the local airport. The largest losses, however, are in Illinois and Indiana. The agricultural sector is particularly hit hard, as all the spring plantings of corn and soy were ruined.

The number of buildings destroyed or damaged in the floods is 90,000 (compared with 56,000 in 1993). The flood displaces 150,000 people and leaves 21,000 square miles submerged, about 30 percent more than in 1993, but still significantly less than the 27,000 square miles inundated in 1927. Around 60 people, unable or unwilling to evacuate from their homes, or caught in their cars, die as the floodwaters rise.

From the beginning of February, navigation is closed on the upper Mississippi and Ohio rivers. Losses amount to around $4 million per day. From the middle of February the lower Mississippi is closed. At two large coal-fired power stations, power generation stops after floodwaters submerge a quay and ships can not supply the plants with coal for six weeks.

In early April, the rising waters set several barges free from their moorings. One of these, loaded with benzene and toluene, overturns in a bend in the river on the edge of Memphis, releasing toxic fumes. People living in neighborhoods along the river are forced to evacuate their homes. Another 40 barges in Louisiana drift through a 13-mile stretch in St. Charles Parish, home to 28 petrochemical plants. One barge collides with the intake valves of the Waterford Three nuclear power station, suspending operations. Other barges tear up wharves, intake facilities and loading platforms, rupturing a gasoline pipeline.

The spring rains trigger widespread debate about the impact of global warming. There is now evidence that average rainfall levels are rising across the United States and the Army Corps of Engineers is being challenged to re-evaluate all its flood defenses. In the state of Mississippi, lawyers serve papers in a mass-tort suit charging the principal greenhouse gas emitters—major oil companies, the steel industry and the coal-fired power generators—with recklessly endangering the livelihoods of all those living along the river.

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The Ebb and Flow—Of Life and Death

Flooding is the most common natural disaster in the United States.

As the biggest river system in North America, with a drainage basin of 1.25 million square miles, the 2,300-mile-long Mississippi River, fed by the Missouri and the Ohio tributaries, remains the nation's source of the biggest and most costly floods.

Floods afflicted the first settlements founded along the banks of the Mississippi and have recurred along the river throughout the past two hundred years. The most catastrophic Mississippi flood occurred in 1927. It claimed 246 lives, displaced 700,000 people, and destroyed or damaged 137,000 buildings. In all, a total of 27,000 square miles of the lower Mississippi flood plain was inundated. The loss in 1927 was assessed at $347 million at the time: inundating the same areas today would cause $28Bn in property damage alone.

The 1927 flood led to the 1928 Flood Control Act, which ushered the era of flood-protection projects: raised levees, diversionary channels and reservoirs. This was followed by the 1936 Flood Control Act authorizing the U.S. Army Corps of Engineers to construct flood control reservoirs along the Ohio River and its tributaries.

The belief that flooding had been contained—or at least could be controlled—drowned with the floods of the summer of 1993.

In St. Louis, the Mississippi surpassed flood stage for 144 days between April and September. Water levels surged beyond the previous record for more than three weeks. In all, 17,000 square miles and 56,000 homes in nine states were flooded. Thousands of miles of levees were damaged, and 400 counties were declared disaster areas. Economic loss estimates ranged from $10 billion to $20 billion. The flood submerged eight million acres of farmland. U.S. corn and soybean yields dropped by 5 percent to 9 percent.

Future Mississippi floods will continue to reflect the intersection between an extreme natural event, and the limitations of a river system managed by levees, spillways and reservoirs.

Every flood defense is built to provide protection, but only out to some flood return period such as 100 years—maybe even 250 years in a city. Beyond that level of probability, the defenses will be unable to hold the waters back.

The most catastrophic floods in the United States are likely to continue on the Mississippi River system. After all, about 80 percent of wetlands along the Mississippi, the natural storage for excess rainfall, have been drained since the 1940s.

The largest risk exposure on the river is in the City of St. Louis. Researchers at the Southern Illinois University of Carbondale, and Washington University in St. Louis, found that while an 1861 flow volume of 700,000 cusecs at St. Louis meant a flood stage of 31 feet, today the same flow volume would reach 41 feet.

Flow speeds have slowed dramatically as a result of the construction of wing dams to improve navigation at times of low flow. Constricting the river with flood defenses has simply raised the height of the floods.

Flood risk is widespread in the United States and the first job of a risk manager should be to determine the flood risk of a facility. However, being outside the designated flood zone does not make a facility immune to flood damage. It is important to consider what would happen in still more extreme events, including sheet flooding associated with persistent heavy rainfall, or blocked conduits.

Where floods can occur suddenly, it is important to rehearse and update a plan to protect facilities against flood damage. For buildings at significant risk of flooding it makes sense to elevate the most sensitive equipment.

—Robert Muir-Wood

AP PHOTO

WHEN A TANKER ruptured near Spain's coast in 2002, it spilled 22 million gallons of fuel oil.

Paradise Painted Black

The Oil Spill Scenario: A 15-million gallon slick drifted quickly because of strong tidal currents. Within a few days it reached all the coastal communities of the Puget Sound. BY ROBERT MUIR-WOOD

The Hypothetical Scenario:

Whether a simple navigational error was to blame or, as was later claimed, the second officer had left the wheelhouse, one fact is clear: The *SS Kodiak Star* ran aground at 2:26 a.m. PST on January 28th. With 80,000 tons of Alaska crude in its hold, the tanker was en route to a refinery in the Puget Sound.

It had strayed from its intended course by half a mile and was passing through the Rosario Strait in the San Juan Islands, the most hazardous part of its route, when it hit the shoals.

Such accidents were not unanticipated. The northern Puget Sound refineries at Cherry Point and Anacortes import 550,000 barrels of unrefined crude per day. As much as 15 billion gallons of oil and oil-related products move through the waters of the Sound each year. About 40 tankers, large commercial cargo ships and tanker barges pass through the straits each day.

Under normal circumstances, oil tankers are escorted by tugs, but that night the region was in the midst of the worst winter storm in several years, with 90 mph winds over the sea and a 25-foot swell surging through the Sound's Pacific gateway, the Juan de Fuca Strait.

Earlier in the evening, as the storm intensified, a Chinese cargo ship had lost power while passing Port Angeles, and the *Kodiak Star*'s escort tug had been diverted to tow the cargo vessel as it drifted dangerously toward the southern shore.

Immediately after the collision, the *Kodiak Star* grinds to a halt on the rocks. The tanker's hull begins to take a heavy beating from the storm swell and the rising eight-foot tide. Oil pours out of the ruptured tanks and through the gash in the single-hull vessel. At first light the next morning, just as the first tugs reach the site, the hull of the 24-year-old vessel breaks in two and the rear two-thirds of the vessel sinks in 120 feet of water. By then, an estimated 30,000 tons of crude has spilled out through the gash under the waterline. With the tanker now split in two, another 15,000 tons of crude spills into the sea. A lull in the winds later that day allows the first attempt to establish a boom around the wreck, but a second storm on January 30th splits the boom in several places. Containing the oil with booms is now hopeless. It is not until Feb. 2nd that calm weather allows an oil barge to be moored next to the sunken tanker in an effort to pump out the 12,000 tons of crude oil remaining in the two intact holds.

The 15-million gallon slick, 20 percent larger than that released from the *Exxon Valdez*, drifts quickly, carried by strong tidal currents. Within a few days it reaches all the coastal communities of the Puget Sound.

A number of towns and villages try to protect their harbors and inlets with booms. At first, they succeed. But bad weather in the second week of February severs the booms and oil washes ashore in nearly every community.

While the oil is mainly concentrated in an area within 40 miles of the wreck, contamination eventually spreads to more than 2,000 miles of coastline.

Southern and southeastern Vancouver Island is affected, as is the mainland coast up to the Fraser River delta close to Vancouver. Also affected are the beaches and rocky shorelines and inlets of the San Juan Islands and Juan de Fuca Strait. Oil makes its way as far south as Tacoma and as far west as Neah Bay. The harbors of Victoria and Seattle are also contaminated.

Following the disaster, there is no shortage of scapegoats. What if the tanker had been a modern double-hull vessel, built in the wake of the *Exxon Valdez* disaster? Some experts suggest that had that been the case, no more than 10,000 tons would have seeped into the sea. Some estimate the whole cargo might have been contained.

Other experts, however, note that in a collision the new, larger double-hull tankers are not immune to damage either and such vessels could leak as much as 37 million gallons, an amount 250 percent greater than that from the *Kodiak Star*.

The dispute soon moves beyond the bucolic shores of Puget Sound to the political arena as news reports note that after the 1989 *Exxon Valdez* disaster, Congress had outlawed the use of single-hull tankers in U.S. waters by 2015. Yet, because the Jones Act forbids any but U.S.-built vessels to trade between U.S. ports, only around one-third of the tankers on the Alaska route are operating with double-hull constructions, as compared with more than 50 percent worldwide.

U.S. shipyards are expensive, and the nation's big oil distributors, observing the declining production of Alaska crude, had postponed commissioning the construction of new tankers at $200 million apiece.

Many tanker owners also transferred their older ships to work in U.S. waters, following the European ban on older single-hull tankers after the 2002 sinking of the *Prestige* off the northwest coast of Spain. That accident released 70,000 tons of heavy fuel oil, equivalent to about 20 million gallons, and damaged hundreds of miles of coastline.

Meanwhile, back in the Puget Sound, the enormous cleanup operation gets underway. Thousands of fishermen are forced to remain ashore. The local fishing industry faces collapse.

Losses from a Hypothetical Oil Spill in the Rosario and Juan de Fuca Straits

Type of Loss	Total Loss	Insured Losses
Property and infrastructure damage	$1.2 billion	$100 million
Workers' compensation, life and health costs	minimal	minimal
Direct costs of business interruption	$12 billion	$3 billion
Other costs (e.g. emergency response)	$800 million	---
Liability claims	$4 billion	$500 million
Total Direct Costs:	**$18 billion**	**$3.6 billion**
Human Losses/Injuries		
Total number of people killed:	**5**	
Total hospitalized with hypothermia or ancillary accidents:	**8**	
Total treated at outpatient clinics:	**270**	

Source: Risk Management Solutions

That Seeping Feeling

Environmental catastrophes are notable for the way in which the impact of the event is not initially fully recognized, and consequently the way in which events become increasingly politicized. This politicization often leads to punitive liability payments, as well as forcing changes to industrial practice that can be far more costly than the original incident.

The most significant environmental incidents have had global consequences. Among the first such incidents was that at Minamata Bay, Japan, in 1952 when a chemical company dumped mercury into the sea, contaminating fish eaten by local villagers. A total of 397 people were poisoned, resulting in 68 deaths including 22 unborn children.

In the United States, one of the most notorious episodes of environmental damage occurred close to Niagara Falls, N.Y., in 1978. Hundreds of homes had been built on the abandoned "Love Canal," choked with 20,000 tons of waste including pesticides such as lindane and DDT. After 18 months of campaigning, with evidence of mounting health problems, including birth defects and miscarriages, around 850 families were eventually relocated. The Love Canal incident, some might argue, gave birth to the environmental risk management industry.

Arguably the world's largest environmental catastrophe was the 1986 Chernobyl reactor explosion and fire in the Ukraine, that released a plume of radioactivity contaminating thousands of square miles in the Ukraine and neighboring Belarus. The disaster led to the evacuation and resettlement of more than 325,000 people, and a 10-fold increase in the incidence of thyroid cancer among young children in the Ukraine. The disaster ended the building of nuclear power plants for a generation.

The United States, along with Russia, is no stranger to environmental pollution from nuclear weapons production and testing. At the Hanford, Wash., plutonium manufacturing and reprocessing facility there are 177 underground tanks containing 54 million gallons of radioactive waste. About one-third of those tanks have leaked more than one million gallons into the soil. The Columbia River, source of drinking water for more than 120,000 residents, is located just seven miles away.

The chemicals transported in the largest quantities are crude oil and its refined products. While there are many chemicals more toxic, there is little that combines the toxicity and volume in what can be released from a ruptured supertanker in a confined populated coastal setting. The 1989 *Exxon Valdez* grounding and oil spill in Prince William Sound, Alaska, was not the first major environmental spill on U.S. territory, and despite the work to reduce the risk of similar future accidents, will not be the last.

The 1 percent probability event here reflects the intersection of one of the principal oil transport routes in U.S. waters with the greatest concentration of hazard—the narrow Rosario Strait in the inner Puget Sound, where tankers pass daily to the oil refineries of northern Washington State.

The environmental impact of such a spill is exacerbated in the narrow channels and inlets of this region, far beyond what would be required to clean up an equivalent spill on the Gulf Coast of Texas, for example.

Much has been done to attempt to reduce the risk of such an accident in the Puget Sound region, in particular by stationing pilot tugs, but all it takes is a chain of interlinked coincidence, as presented here, to break all the precautions. Too often in risk analysis each element is considered independently. Many catastrophes reflect correlations of the kind presented here. The same storm which has forced the tug to help another stranded vessel, obscured visibility, made navigation more difficult and tired the ship's crew, is also responsible for ripping the ship apart in hours, rather than days as would have been more likely under normal weather conditions.

The modeling of the Rosario Strait oil spill is based on a study undertaken for assessing potential scenario oil spills by the British Columbia provincial government. Since the Exxon Valdez disaster, the tanker industry has made changes to how it operates in coastal U.S. waters: that includes having a tug stationed to escort vessels into the Juan de Fuca Strait. However, the tanker industry has been slow to adopt other practical safety measures such as switching all transport to double-hulled tankers.

—Robert Muir-Wood

Thousands of workers are recruited to shovel sand into bags and to begin pressure-cleaning the rocky shoreline. The cleanup continues into the summer, ruining the San Juan Islands tourist trade. Spurred by graphic images of thousands of dead sea otters and birds, activists begin demanding the closure of the four giant refineries along the northern coast of the state.

Finally, there is the question of cost, which will take several years to settle. Under the 'polluter pays' principle the responsible party, a large and well-capitalized oil company, faces massive costs. But the polluter's share price had fallen 26 percent in 24 hours.

Reparation payments cover the cost of protecting communities from oil slicks, removing oil throughout the affected sand and rocky coastlines, and rehabilitating wildlife. The federal and state agencies ensure that the cleanup meets the proper standards and that the environment and natural habitats are restored. The price is expected to be around double the $2.8 billion paid to clean up in the wake of the *Exxon Valdez* spill.

Hotels, restaurants, beach owners, fishermen and ferry owners submit property damage and personal claims. They also submit claims to recoup a portion of lost profits.

Residents living by the water in and around Seattle file medical claims and blame illnesses on the oil spill. In the Exxon Valdez disaster, only $300 million was awarded to third-party claimants, mostly fishermen. But another $5 billion in punitive damages was also assessed against the oil company.

In this case, with so many people making a living from the sea—in the form of tourism, recreation and fishing—the costs are expected to be far higher. Initial estimates run as high as $3 billion, raising the possibility of astronomical punitive damages.

Federal and state penalties are expected to cost the polluter another $200 million, in the form of new safety improvements and more money to the Marine Spill Response Corp.

A laundry list of other costs are also added to the final bill: loss of the ship, loss of earnings from the vessel and congressional requirements that all transport in U.S. waters must now be undertaken in double-hull vessels.

The final price of this disaster is expected to go as high as $18 billion, maybe more.

ROBERT MUIR-WOOD, PHD, *is chief research officer and heads the Research Group at RMS. He has published six books, 40 scientific papers, written more than 100 articles and reviews, lectured at many insurance seminars and run courses on Catastrophe Risk for Lloyd's of London.*

AP PHOTO

THE ALFRED P. MURRAH Federal Building in Oklahoma City was the last major domestic bombing prior to Sept. 11.

Echoes of Sept. 11

The Terror Scenario: Despite improvements in security since Sept. 11, terrorists take aim at Chicago's Loop, launching three highly coordinated truck bomb attacks. BY ANDREW COBURN

The Hypothetical Scenario:

Nobody noticed the white Ford Aerostar parked in front of the Federal Plaza in the center of Chicago's Loop. The minivan, disguised as a contractor's vehicle, arrives shortly after 11 a.m. on a Tuesday in June. It sits adjacent to a group of large skyscrapers in the downtown district only a few feet away from the LaSalle Street financial district. Five minutes after the van arrives on the plaza, a hoax bomb warning evacuates office workers from the landmark skyscraper to rally points in the plaza. More than 10,000 people mull about the plaza when the bomb, made from nearly two tons of ammonium nitrate mixture, explodes.

Another bomb detonates only a few minutes later in another part of the Loop near the regional headquarters of a large multinational American company. A delivery truck loaded with three tons of ammonium nitrate is driven unchallenged into the internal service bay of the 10-story historic building housing the company. The blast causes the partial collapse of the building and severe damage to surrounding buildings.

A third explosion occurs about 10 minutes later when a car crashes through protective barriers at the approach to the Navy Pier. That allows a large SUV to speed past the guards at a security checkpoint. The guards, already alerted by the distant explosions, open fire on the SUV. It explodes nearly a hundred yards short of its intended target—the crowds in the Crystal Gardens complex of restaurants and entertainment facilities.

DOWNTOWN CHICAGO DEVASTATED

All three targets are located within two miles of one another in downtown Chicago. The city center is badly damaged. Medical services are initially overwhelmed with the numbers of injuries. Doctors practice triage in the main plaza to treat those individuals who were badly injured by the explosions.

Search and rescue teams dig into the rubble of the collapsed building for survivors. A civil authority zone is declared, sealing off nearly 100 blocks with a ring of roadblocks. Emergency services try to keep the occupants of buildings within the zone indoors while they check for more bombs. Geiger counters are brought in to check that the bombs are not "dirty"—contaminated with radioactive sources. To their relief, radioactivity is not present. Finally, workers are released from their buildings and escorted out of the area. It will be many months before most of them return to their offices, and some will never come back.

The bomb in the plaza kills more than 3,000 people and severely injures 4,000. In the second bomb, 1,200 occupants are killed in the collapse of the 10-story building, and another 800 people are trapped in the rubble. Thousands of people suffer injuries from bomb debris and flying glass. Apart from six police officers and firemen attending the hoax evacuation, nearly all of the dead and injured are employees of companies in the target buildings or surrounding offices. The third bomb kills 400 people including security guards. Had the bomb reached its intended target, casualties and damage would have been much higher.

Buildings all around the plaza are severely damaged but remain standing. Damage to the façade of the famous skyscraper extends up to the 40th floor. Lower floors lose most of their protective cladding and the whole of the entrance to the building is destroyed. Buildings several streets away report minor damage, and windows are broken up to a half a mile away. Minor fires are soon extinguished in a few buildings.

The city center of Chicago is badly damaged and cordoned off for more than three weeks as a crime scene. Even when it reopens, people are reluctant to return for some time. The Chicago Board of Trade and stock exchanges are suspended for more than a week.

Several thousand companies with offices within the affected area relocate for several months, some to surrounding towns, some to other cities. A few decide to relocate permanently. The costs of emergency relocation are substantial: rental prices soar in surrounding areas; replacement office equipment is difficult to find and is in high demand. Stock markets plunge over the next several days but ultimately return to equilibrium. Companies worst affected in the attack see a big drop in the price of their stocks—billions of dollars in market value disappeared in a flash.

Losses to the skyscraper are estimated at $4.5 billion, with about 40 percent resulting from business interruption, 20 percent from property damage, and the remainder split between contents and workers' compensation losses.

Losses to the corporate headquarters building are estimated at approximately $3.2 billion, with 55 percent resulting from business interruption and 20 percent to property damage. The remainder is split between contents and workers' compensation.

Losses to Navy Pier are estimated at $500 million, with 40 percent due to business interruption and 15 percent due to workers' compensation. The overall direct cost resulting from this coordinated attack is about $24 billion.

ANDREW COBURN, PHD., *has many years of international experience in risk analysis and catastrophe modeling. He is a leading contributor to the development of the Risk Management Solutions' terrorism risk model, and was co-author of RMS' white paper on the World Trade Center disaster.*

Losses from Hypothetical Terrorist Attack

Type of Loss	Total Loss	Insured Losses
Property and infrastructure damage	$8 billion	$5 billion
Workers' compensation, life and health costs	$6 billion	$5 billion
Direct costs of business interruption	$10 billion	$4 billion
Other costs	$250 million	—
Total Direct Costs:	**$24 billion**	**$14 billion**
Human Losses/Injuries		
Total number of people killed:	**5,000**	
Total hospitalized with serious injuries:	**4,500**	
Total treated at outpatient clinics:	**70,000**	

Source: Risk Management Solutions

Conventional Attacks Pose The Most Danger

On Sept. 11, 2001 the multiple terrorist attacks on the symbols of American nationhood and commercial power caused property damage and business losses well in excess of $100 billion. Despite a major war on terrorism and massive expenditure on homeland security, the threat of extremist groups against the United States homeland remains palpable.

Prior to 2001, the United States had suffered only limited levels of foreign terrorism activity, certainly compared to other countries like Israel, the United Kingdom and Spain.

THE SEPT. 11 attacks on the World Trade Center and the Pentagon ushered in a new era in U.S. terrorism.

It had experienced the occasional massive attack, like the bombing of the Murrah Federal Building in Oklahoma City by right-wing extremists in 1995 and the World Trade Center bombing of 1993. But most terrorism incidents were relatively small scale—small yield bombs, assassinations, arson attacks and other acts that caused moderate loss.

Since Sept. 11 the specter of further large-scale terror attacks being perpetrated on American cities has been a major focus of internal and foreign policy. Despite the disruption of its Afghanistan base and the loss of many of its senior membership, Al Qaeda and its associated extremist groups have succeeded in carrying out major terror attacks in many other countries, including Saudi Arabia, Turkey, Indonesia and Kenya. The United States has been on Orange (high) Alert on average every four months.

COMPLEX ANALYSIS

Assessing the likelihood of a major terrorism attack is complex and requires an understanding of the motivation, psychology and capabilities of organizations that by their very nature are highly secretive. The chances of an attack are also affected by the security levels in place, counterterrorism actions taken by government agencies and protection levels in place at potential targets.

Risk Management Solutions has developed a U.S. Terrorism Risk Model that enables the frequencies and losses of potential terrorist attacks to be estimated. This model is in use by many leading insurance and reinsurance companies to manage their terrorism risk. RAND Corp., a leading think-tank, has independently audited the model and assisted in developing the model for public policy and strategy applications.

This model has been used to assess the 1 percent probability of loss from a terrorist attack in United States.

Estimates vary considerably around the probability and severity of a terrorist attack in any given year. RMS has derived estimates of the likelihood of a terrorist attack in the United States from data on historical attack frequencies and the opinions of some of the world's best experts on militant terrorist groups. These put the probabilities of a significant foreign terrorist attack in the year 2004 at less than 25 percent.

The magnitude of a potential attack is constrained by the capability of the terrorist organization in terms of its number of operatives and the kind of weapons they have.

Al Qaeda and its acolytes have been adept at using conventional weapons, such as bombs and aircraft hijackings. They have proven adept at scaling up their impact through multiple, synchronized attacks to cause mass casualties and economic disruption. Large-scale attacks using conventional weapons are complex to plan and require major resources including a sizeable team of skilled, disciplined operatives, lengthy reconnaissance and preparation time, and the ability to procure the equipment and material they need.

The chosen 1 percent probability event illustrates a triple truck bomb attack on the third largest U.S. city. This is at the upper end of the scale of an attack using bombs—it requires more than six tons of explosives, which is a considerable amount for a covert operation to amass without detection.

However it is not unprecedented. A thwarted Al Qaeda attack in Singapore in December 2001 reportedly revealed seven tons of explosives and a plan for up to six truck bombs to be used simultaneously. The attacks in Riyadh, Saudi Arabia in 2002 involved three vehicle bombs and more than four tons of explosives.

—Andrew Coburn

Matters of State at Stake

Terrorist attacks have increasingly focused on economic and civilian targets, making the central business districts of major cities likely locations for an attack. Other attacks elsewhere could cause other types of losses to commerce—attacks might take place using airplanes again, with severe consequences for the airline industry and on business travel. Ports and transportation infrastructure might be targeted, having an impact on travel and distribution networks for companies' goods. Industries could be targeted, like tourism, with attacks on hotels and leisure venues, or the energy industry, with attacks on oil and gas facilities.

Chicago was used to illustrate the effects of a terrorist attack on a major U.S. city. Other major cities would be similarly at risk—the terrorists' philosophy of striking at the economic engines of U.S. prosperity and symbols of U.S. nationhood means that attacks are more likely in the top-tier cities. In denser urban areas, such as Manhattan, the bombs could cause more damage and even larger losses. In lower-density cities, like Los Angeles, there aren't the same concentrations of buildings, so attacks would result in fewer buildings damaged by an attack of the same scale.

This scenario was also chosen to demonstrate the impact of a large but credible terrorist attack using conventional weapons. However, the 1 percent probability is on the borderline of the assessed likelihood of an organization like Al Qaeda being able to deploy weapons of mass destruction.

There has been a growing concern that the next attack could involve the use of chemical, biological, radiological or nuclear weapons. Few analysts doubt that terrorists would have any qualms about using such weapons if they achieved the capability. The State Department has stated that it views an attack in the United States using a CBRN weapon as "a high probability."

Any attack using a chemical, biological or radiological agent would cause huge property losses and lengthy business interruption while buildings and streets were decontaminated—effectively quarantining a major area of a city for many months or years.

The most severe scenarios of all involve terrorists attacking and sabotaging a nuclear power plant to cause a massive release of radioactive material, or a terrorist group obtaining and detonating a nuclear weapon. Losses from these scenarios could be in the hundreds of billions of dollars and cause hundreds of thousands of deaths. These scenarios are of low probability.

Small scale terrorism using conventional weapons, however, is a more imminent danger.

—Andrew Coburn

AP PHOTO

A MOTORIST ATTEMPTS to dodge fallen tree limbs and power lines following a massive ice storm Jan. 10, 1998 in Watertown, N.Y.

Cursing the Darkness

The Blackout Scenario: Incessant precipitation and freezing temperatures paralyze New York's complex power system, turning it into a winter wasteland. Essential services grind to a halt and many businesses in the Northeast are shut down for weeks. **BY GORDON WOO AND ROBERT MUIR-WOOD**

The Hypothetical Scenario:

It was a Monday morning in mid-January and heavy snow had fallen across the whole of New York State. Earlier in the month an extremely cold Arctic air mass had moved in from Canada with clear skies and daytime temperatures struggling to get above zero degrees Fahrenheit.

The cold and snow had lasted for five days. Now a warm front was arriving from the south, drawing warm moisture-laden air all the way from the Gulf up toward the Canadian border. Over the central region of New York State the precipitation had started as snow, then switched to rain. The rain froze on contact with the ground or anything else it touched. The warm front had now stalled overlying the cold Arctic air.

On the first day the freezing rain brings chaos to the roads of the state's capital, Albany, causing numerous accidents and blocking Interstate 87 and the New York State Thruway. The rain is not heavy but it persists. Within 24 hours, more than an inch falls, leading to heavy icing on roofs and trees, as well as on telephone and low-voltage electricity wires. Only on the main high-voltage transmission wires is the resistance heating sufficient to keep the wires free. However engineers note that the buildup of ice on the metal transmission towers is reaching critical levels, especially over higher ground.

On Tuesday, the rain is intermittent but the icing continues as rain resumes throughout the night. Collapsing branches laden with ice sever local power lines. It is on Wednesday morning, with ice as thick as two inches, that the first transmission tower collapses on the main power line from Fraser to Cooper's Corner. This is where the line receives the heaviest icing over the Catskill Mountains. The roads in this area are completely impassable. Helicopters are grounded because of low clouds and heavy freezing rain. Later that day the second parallel line over the Catskills collapses. One linesman venturing on a snowmobile reports 15 towers down.

By Wednesday evening, across a swath of land stretching from northern Pennsylvania through Binghamton, N.Y., and Albany, then into southern Vermont and Manchester N.H., the accumulation of ice has begun to sever the electricity distribution system. Branches crashing onto lines send thousands of poles tumbling under the load from the wires. The ice increases the load on the wires by a factor of four or five. In rural areas power is almost completely out. Farmers have no electricity to milk their cows, laid up in barns for the winter. Mobile phones no longer function because of icing on the radio masts. Without heat or power, tens of thousands of people move into shelters in schools and other public buildings.

The main power supplies into the New York City area from Hydro Quebec, Niagara and the nuclear stations at Oswego N.Y., are now all diverted along the three high-voltage transmission lines along the Hudson Valley. They are operating at maximum capacity.

On Wednesday night there is just enough power to maintain supply into the city, supplemented with supplies from the New Jersey and New England regions. As the rain continues, the icing is in excess of two inches on many structures. The first of the Hudson Valley power lines, from New Scotland to Leeds, fails at 5 a.m. on Thursday morning. The second transmission line at Gilboa goes down just ahead of the morning New York City rush hour.

In New York, the weather is mild with light rain. The New York Independent System Operator has been struggling with contingencies with only one of three transmission lines now functioning, but with demand far exceeding the available supply. The decision is made to separate the New York City region from the remainder of the network.

Subway trains grind to a halt, traffic lights fail, elevators stop. In the major city hospitals and at the N.Y. Stock Exchange and a number of major businesses in Lower Manhattan, emergency generators kick into action. Power to the city's five boroughs is brought down in a few seconds at close to 8 a.m. Thursday morning. Later Thursday morning the third and final Hudson Valley high-tension transmission line fails close to Leeds. When the weather clears, more than 800 transmission towers are found collapsed.

Losses from Hypothetical New York Ice Storm & Power Outage

Type of Loss	Total Loss	Insured Losses
Property and infrastructure damage	$1.2 billion	$600 million
Workers' compensation, life and health costs	$100 million	$50 million
Direct costs of business interruption	$15 billion	$2 billion
Other costs (e.g. emergency response)	$800 million	—
Total Direct Costs:	**$17.1 billion**	**$2.7 billion**
Any human loss or casualties:	**NA**	

Source: Risk Management Solutions

Commuters struggle to get to work. When they finally reach the office, they find blanked-out computer screens and darkened cubicles.

Most try to return home but confront the worst gridlock in New York City's history. Without power, all the main airports close. By midafternoon, only some trains and subways function again.

However, unable to obtain sufficient supplies to reconnect the whole city, the Independent System Operator reaches an agreement with New York's mayor to rotate the available power supplies. More than four million customers are reduced to alternating six-hour periods of electricity, followed by 12 hours of outages. On Friday morning, southern and central Manhattan have power while Brooklyn and Queens remain without. Most businesses, however, remain closed, while commuters stay at home.

Over mid-New York State, the rain finally stops falling in the early afternoon. The end of the freezing rain sees a rise in the winds that had, up to that moment, remained calm. By Friday evening winds of 40 to 50 mph blow over trees and poles still covered with ice.

On Saturday a thaw sets in, and as roads clear the main recovery operations can get under way. Linemen from six states and across the border in Ontario, with experience from the 1998 ice storm, work around the clock to remove the tangled debris of collapsed towers and repair the main transmission system. Two of the five lines bringing power down to New York City are repaired by the following Tuesday. Full power is restored to New York City later on Thursday, a week after the power outages had begun.

The restoration of the tens of thousands of downed distribution lines takes far longer. Only by late February had the final lines been repaired in the Bennington region of southern Vermont.

GORDON WOO, PHD., and **ROBERT MUIR-WOOD, PHD.,** *of RMS are experts in the field of natural hazard analysis. Woo is author of the book,* The Mathematics of Natural Catastrophes *and has published extensively on quantitative risk assessment. Muir-Wood has led research on the impact of catastrophic weather events on transmission and distribution systems in the United States and Europe.*

High-Voltage Gridlock

The North American electricity power grid represents more than $1 trillion in asset values, including 200,000 miles of high voltage (greater than 235,000 volts) transmission lines and 950,000 megawatts of power generation with nearly 3,500 utility organizations serving more than 100 million customers and 283 million people. The grid is also a quasi-stable dynamic system, prone to occasional failure causing local or regional blackouts.

These failures occur when power plants become disconnected from the grid, or when the flow of electricity through the transmission network suffers disruption. The grid system has limited redundancy, or backup, which causes regional utilities to protect their own equipment from damage. This, in turn, can give rise to anomalies in the flow of electricity, forcing a sequence of plants to go off-line and block transmission paths.

The eastern U.S. power grid has become so large and complex that control-room operators are sometimes unable to act fast enough to prevent events from cascading into blackouts. System instabilities may be triggered by an array of external factors. Natural hazards are a particularly significant factor. On Aug. 14, 2003, a brush fire under a transmission line in southwestern Ohio forced the disconnection of the line. When several other regional lines started to disconnect, the effectiveness of the transmission path from eastern Ohio to northern Ohio was impaired. A cascading blackout sequence then ensued, leaving a major portion of the eastern grid without power. The initial massive outage of 60,000 megawatts lasted four hours, but it took 24 hours before the majority of power had been restored.

One of the worst U.S. blackouts, on Nov. 9, 1965, affected 30 million people. It extended from Buffalo, south to New York City, as well as east into Maine and included a strip of Canada along the St. Lawrence River. The blackout was even blamed for a surge in births nine months later.

The natural hazard with the greatest potential to cause major damage to transmission and distribution systems over a broad region is a catastrophic ice storm. Ice storms occur when warm, moisture-laden air slides over a layer of extremely cold air, and rain falls onto freezing ground. The worst ice storm of the past 50 years happened in January 1998. That storm brought 80 hours of freezing rain, spread over six days, across Eastern Canada.

The resulting failures of more than 1,000 power transmission towers and 30,000 wooden utility poles caused a loss of power to more than a million homes in Quebec and Ontario provinces. That left more than four million people freezing in the dark, 100,000 of whom moved into shelters to find heat and light. New England reported over 500,000 customers without power including 80 percent of Maine's population. Most notable was how long it took to repair the networks—because the damage also affected the transmission system. Three weeks following the onset of the storm, more than 700,000 were still without electricity. Without power or heat, more than 2.6 million people, 19 percent of Canada's labor force, had difficulty getting to work or couldn't get to work at all.

Ice storms are not just restricted to the Northeast. In February 1994 a widespread ice storm in the Southeast caused month-long power outages in Mississippi. A storm that brought down 16 communication towers resulting in the cascading failures of hundreds of miles of transmission lines occurred in Iowa through the winter of 1990-1991.

Power outages can be characterized in terms of severity and duration. From the perspective of the utility company, a power blackout can simply be characterized in terms of megawatt hours lost. From the perspective of the small business or consumer the duration (and season) of the blackout can be critical in determining the level of pain and disruption. The August 2003 outage was notable for the significant amount of power (60,000 megawatts) that was lost, but restoration was fairly rapid, because there was no underlying physical damage to the network, and the total output lost was an estimated 920,000 megawatt hours.

By comparison, a month later, Hurricane Isabel, a large but relatively weak storm, created another record for the most customers to lose power in a hurricane (almost six million). This time the restoration was far slower, as it required repairing large sections of the distribution system, damaged by fallen trees.

Given the renewed investment now anticipated in transmission security following the August 2003 event, the 1 percent annual probability blackout event is most likely to be a result of physical damage to the network. The most vulnerable region for extended power outages remains the Northeast, because the transmission and distribution network coexists with trees and forests, but also because of the nature of the regional-scale catastrophic weather events that occur in this region. The 1 percent annual probability event selected here is an ice storm, comparable in magnitude to the January 1998 storm, but located further to the south, in the region affected by the comparable ice storm of 1929. The duration of the storm is modeled after the worst ice storm in the New England record in 1921.

—Gordon Woo and Robert Muir-Wood

AP PHOTO

THE CROWD watches helplessly as firefighters battle a blaze in Lakeside, Calif., on Oct. 27, 2003.

The Devil's Rampage

The Wildfire Scenario: A catastrophic fire holds an entire city hostage while residents and business owners run for their lives and firefighters risk theirs. BY AUGUSTE BOISSONNADE

The Hypothetical Scenario:

The California Department of Forestry and Fire Protection declared the fire season open slightly earlier than normal in early May as a result of the warm, dry weather and drought conditions during the previous winter. Emergency response dispatch levels increased, additional firefighters were hired and water tankers moved to strategic locations. A hot and dry summer led to more fires than usual across the state. In some areas, fire fighters work overtime and remain on alert ready to respond.

In mid-October, hot and dry Diablo winds start to blow across the San Francisco Bay area. The winds are expected to last for several days, increasing the fire hazard. Firefighters worry about the potential fire risk in the East Bay Hills. Because of the drought, there are a lot of dry materials in the dense underbrush that could spread the fire quickly to forested areas and to adjacent homes and businesses. These buildings are mostly built with wood and could easily catch fire. To make matters worse, there is generally little clearance between the buildings and the underbrush. The local roads are narrow and easily blocked by fire or abandoned vehicles. Firefighters remember a similar situation from the devastating 1991 Oakland fire. Fire danger notices around the hills are switched to "extreme" and access to forest areas is restricted to reduce the chances of a visitor starting a fire.

A small fire begins midday in a canyon behind the city of Piedmont. A neighbor spots the fire and calls 911. By the time firefighters arrive on the scene, several acres have already burned and the flames are approaching nearby buildings. Police immediately begin to evacuate about 100 nearby residents as the firefighters attempt to protect the buildings and homes threatened by the flames. Local radio stations broadcast a warning to residents near the fire site to be prepared to leave.

As firefighters battle, two other fires are spotted further along the hills. More help is called in as the first television news crews arrive on the scene. Local TV stations broadcast continuous coverage of what has become a very serious fire.

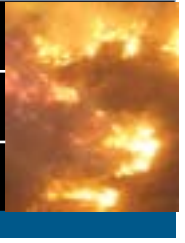
Winds pick up and the fire spreads rapidly and erratically. Despite heroic efforts from firefighters, several homes are already burning. More help is sought from neighboring counties but as the new fire crews arrive, they find the blaze spreading fast. Two fires combine into one rolling front. Stronger winds whip embers and burning debris into the air toward dry areas nearby. The fire front moves close to a four-lane freeway, which acts as a barrier between the burning woodlands and the major residential areas of Piedmont, a suburb of Oakland. The focus of the fire-fighting efforts aims at stopping the spread of the fire beyond the freeway. But by this time, more than 1,000 homes and businesses have already been consumed by flames and more than 5,000 people have been evacuated and relocated to temporary shelters. All through the night, the effort continues to contain the fire at the freeway firebreak. Trees are cleared along both sides of the freeway and firefighters hose down houses within 200 yards of the expressway.

By the next morning the fire has abated. It smolders all the way along the forested slopes facing the freeway but has not jumped across it. Firefighters begin to extinguish the remaining fires and push back the fire line away from the freeway. But weather forecasters radio a warning that wind speeds are increasing. Embers start to blow into the air as winds pick up. Fires burst back to life and fire chiefs order their men back. A rapidly circling wall of flame cuts off the retreat of one of the fire crews.

Embers whipped up by the wind have fallen

Hypothetical Wildfire Losses in Piedmont, California

Type of Loss	Total Loss	Insured Losses
Property and infrastructure damage	$6 billion	$4 billion
Workers' compensation, life and health costs	$60 million	$60 million
Direct costs of business interruption	$1.6 billion	$800 million
Other costs	$1 billion	—
Total Direct Costs:	**$8.7 billion**	**$4.9 billion**
Total number of people killed:	25	
Total hospitalized with serious injuries:	20	
Total treated at outpatient clinics:	200	



Source: Risk Management Solutions

across the freeway, igniting dozens of small fires that combine into a new front that begins to advance rapidly into the suburban neighborhood. Because of the dense vegetation, the fire spreads even more rapidly. Water pressure drops as hundreds and then thousands of homes collapse and burn, breaking the plumbing. In addition, electric power is lost in some areas, causing a failure of some water pumps. By now, the fire is spreading so rapidly that firefighters pull back to save their own lives. By midday, a full evacuation is underway and a perimeter is established around the city of Piedmont preventing traffic from entering. Only emergency vehicles are allowed in the streets. A cloud of smoke can be seen 30 miles away. Visibility throughout Oakland and nearby communities dwindles to less than 100 feet.

Businesses in Oakland, Berkeley and neighboring towns close. Managers send staff home and take critical documents and computer files with them. Business disaster plans are put into effect. Several commercial centers, containing grocery stores, restaurants and small businesses, are engulfed.

High winds persist during the daylight hours. The fire continues to advance, climbing the steep hills at the back of the city, and jumping from one wooden home and small business to the next. Entire neighborhoods are destroyed—interspersed by patches where a few homes have escaped untouched by flames. In most cases, these homes were set back from other neighboring structures and away from vegetation. Although most of the buildings in this area have wood shingles, several of the surviving homes have composite or tile roofs, preventing flying embers from igniting roof fires.

By late afternoon, nearly 10,000 buildings have burned and tens of thousands of people are displaced. Plans are developed to evacuate another 100,000 people.

As the fire spreads downhill through the city of Piedmont, the terrain flattens and the streets widen. The progress of the fire slows and allows hundreds of firefighters from throughout northern California to mount an aggressive counterattack. This has some success with fires beginning to be contained. Finally, the winds abate, and by the third morning, the winds shift to blow onshore, forcing the fire back. Light rain arrives with the new winds and the fire is declared under control.

The economic loss consequences from such a firestorm scenario are approximately $9 billion. About 60 percent of these reflect insured property losses while 40 percent are in other losses.

Insured losses are 80 percent residential—split between 70 percent for property losses and 30 percent for content losses, auto and health claims. Victims of the fire file hundreds of claims, the bulk of which are for the total loss of property. While claims for total fire loss dominate, there are dozens of smaller claims seeking compensation for damage from smoke. Commercial claims are split among property, contents and business interruption.

In the final tally, 10,000 buildings burned—mostly wooden structures. More than 95 percent of the homes in the area were wooden but only 25 percent of the commercial buildings were made of wood. About 30,000 residents were affected by the catastrophe and 17,000 fire victims were displaced. Few casualties were reported because residents were quick to evacuate, given their previous experience with catastrophic fire threats in the region.

AUGUSTE BOISSONADE, PH.D., *has more than 20 years of experience in risk assessment of natural hazards in the United States, Europe, Africa and Asia. Prior to joining Risk Management Solutions, he was with Lawrence Livermore National Laboratory developing seismic hazard guidelines for the U.S. Nuclear Regulatory Commission and guidelines on natural hazards for the U.S. Dept. of Energy.*

Flames Fan Through History

Major urban conflagrations occur repeatedly throughout history. One of the earliest, the Great Fire of Rome, dates back to July of 64 AD. The modern insurance industry was established to offer homeowners' fire insurance in England after the Great Fire of London in September 1666. High winds fanned a fire in a bakery shop in the city that then spread and destroyed 13,000 densely packed homes and businesses or about 80 percent of London.

Numerous large fires occurred in cities in more modern history including the Great 1871 Chicago fire that started in a stable and consumed more than 17,000 buildings, causing the deaths of 250 people during 18 hours. This fire occurred simultaneously with the Peshtigo, Wisconsin fire that burned 2,400 square miles and killed more than 1,200 people. Using present day values these losses cost between $4 and $10 billion.

More recently, the 1906 San Francisco fire following the earthquake led to 28,000 buildings destroyed over three days. Losses are estimated at more than $6 billion in present day values.

Fire suppression capabilities have improved within city areas since the 1950s. Most large urban fires have been the result of either earthquakes or wildfires that started close to urban areas. The U.S. cities most at risk to wild fires are those in the Western states, particularly California. Historically, significant urban losses happened in the San Francisco Bay Area and in Southern California around the Los Angeles and San Diego metropolitan areas.

Cities in the hills of San Francisco's East Bay are adjacent to wildfire areas. Fires that start in the forests of the hills can spread into the inhabited areas. This region has a Mediterranean climate and is subject to the "Diablo"—or Devil—winds, which are hot and dry.

This Oakland Hills fire was a result of extreme conditions created by a five-year drought and low humidity. The fire spread quickly, fanned by a fast Diablo wind, to buildings on the hillsides that were surrounded by dense vegetation. It moved on to the urban areas where most of the houses are made of wood and wood shingles and sit close to each other. It became a firestorm feeding on closely spaced homes, limiting the chances to effectively fight the fire. Losses resulting from the Oakland Hills fire exceeded $1.5 billion.

Climate and weather conditions similar to the East Bay Hills are present in Southern California. There the hot and dry Santa Ana winds blow off the mountains at speeds of up to 70 mph. This can create explosive conditions when combined with flammable brush. During these conditions, fires occur and can result in disaster. It has happened more than twelve times since 1970. The most notorious happened in 1993 in Los Angeles. It happened again last year in the Los Angeles and San Diego metropolitan areas, resulting in losses exceeding $3 billion. Both fires occurred in late October and early November and burned thousands of homes and businesses in a few days.

Although wildfires can occur everywhere in the United States, resulting catastrophic insured losses have historically been reported more frequently in the Western United States. The largest catastrophic loss wildfires since 1970 occurred in California because of the growing urbanization encroaching on wilderness areas and of ever-present fire weather conditions. Property development into the vulnerable areas has increased the risk of extensive property damage. Recent studies show that about one million housing units are within California's vulnerable areas with large concentrations of exposures in the metropolitan areas. Given the appropriate conditions, a 100-year wildfire loss event could occur in any region of California with large concentrations of properties.

—Auguste Boissonade

AP PHOTO

SMOKE BILLOWS from a fire at the Total Petroleum Refinery in Commerce City, Colo., in 1996. Seven fire brigades took more than an hour to bring the fire under control.

Hell on Rails

The Industrial Accident Scenario: Fires spread from a tanker car and jeopardize the facilities of Texas' largest city. "Houston, we have a problem," is the understatement of the day.

BY DAVID MILLER

The Hypothetical Scenario:

The fire begins in a rail tanker car loaded with gasoline in the railyards within the international port serving the petrochemical refineries along the shipping channel in Houston.

The yards are unusually crowded with a three-month backlog of tanker cars and other rolling stock following a labor dispute and above-average summer demand.

Fanned by strong onshore winds, the fire spreads from tanker to tanker, incinerating the power lines so that the emergency water systems fail and emergency responders are unable to contain the blaze. The railcar tankers are temporarily parked along sidings adjacent to a tank farm, and despite the best efforts of the firefighters, flames reach to first one and then several 10-million gallon oil-storage tanks.

The flames from these tanks reach 100 feet into the sky, and as the sides of one of the tanks ruptures, a river of burning oil gushes across into the neighboring liquefied natural gas facility, the site of a series of giant pressurized tanks.

The fierce heat causes the first tank to explode. The blast, equivalent to 100 tons of TNT, destroys buildings and equipment within a radius of half a mile. Windows break in buildings up to three miles away. Two other tanks explode before the fire is over.

However, alongside the gasoline tankers are two rail tankers containing 90 tons of liquid chlorine, destined for the water treatment plants of Houston.

The fire ruptures the first of these tankers, releasing a poisonous cloud of gas, killing three emergency workers and forcing firefighters back half a mile.

Fire captains order breathing equipment to be worn and order the evacuation of everyone within two miles of the rail yard. Choking chlorine gas billows out from the fire and envelops several streets and a hospice before the evacuation can get underway.

An estimated 180 people are killed in their homes, while several hundred are rescued and sent to the hospital with breathing difficulties and burning throats.

Concentrations of chlorine gas — as dense as 500 parts per million — form a lethal cloud that extends over an area of more than two square miles. Concentrations sufficient to cause breathing difficulties extend for several miles downwind. Police begin to evacuate populations in Galena Park and Jacinto City, close to the toxic cloud.

The next day, four million residents of Houston awake from the force and the noise of the explosions as dawn breaks over the threatened city. The smoke from the fire is visible as a pall rising in the distance.

Emergency services from five counties are attending the fire, and the sounds of their sirens, trucks and aircraft can be heard for several blocks. TV news channels provide uninterrupted coverage, and broadcast the pleas from Houston authorities for people to stay home.

Roads leading out of the city to the southwest become choked with cars as people try to leave. Emergency vehicles continue to move toward the fires as the acrid stench of yellowish chlorine descends over the stricken metropolis.

Many people are coughing. Some exhibit mild-to-serious breathing difficulties as they evacuate the area. Medical teams treat thousands of people with respiratory problems.

As the morning winds pick up, rescue teams become increasingly concerned about the possibility of the smoke and chlorine gas being blown across the city.

Air quality monitoring shows that chlorine levels are rising over a large area. Nearly a million people are already on the move. Roads are choked with traffic. The exodus proceeds slowly.

Air conditioning systems in cars provide no protection against the chlorine fumes. Officials move through the traffic jams encouraging people to pull their cars over and walk. By mid-afternoon, hundreds of thousands of people are walking out of the city to rally points where buses and volunteer drivers ferry people to shelters outside the city. Most of the chlorine gas is evaporating in the afternoon heat or dissipating in the breeze.

By evening, the fire is still burning but the levels of chlorine contamination, monitored within the urban areas, are falling as the chlorine becomes diluted in the breeze.

The fire at the port continues to burn throughout the night as firefighters bring the flames under control. It will continue to smolder for several days. City authorities finally declare an end to the emergency after three days. People begin to return to their homes but many complain of lingering chlorine smells and leave again to stay outside the city.

In the fire, explosion and toxic fumes, 600 people die — the most lethal industrial accident in United States in 100 years. Nearly 7,000 people are hospitalized, most of them suffering from chlorine gas or smoke inhalation. Paramedics and medical volunteers during the evacuation treat another 250,000 people. Because the fire occurs in the early hours of the morning, few injuries are caused to people at work keeping workers' comp claims relatively light.

Major parts of Houston's port

Losses from a Hypothetical Industrial Accident in Houston

Type of Loss	Total Loss	Insured Losses
Property and infrastructure damage	$5 billion	$3 billion
Workers' compensation, life and health costs	$1.5 billion	$1 billion
Direct costs of business interruption	$10-15 billion	$3-5 billion
Other costs (e.g. emergency response)	$500 billion	—
Total Direct Costs:	**$17-22 billion**	**$7-9 billion**
Estimated Human Losses/Injuries		
Total number of people killed:	**600**	
Total hospitalized with serious injuries:	**7,000**	
Total treated for light injuries:	**250,000**	

Source: Risk Management Solutions

and nearby refinery have been destroyed. Two ships in the channel are badly damaged and parts of the port remain closed for more than a month.

Operations resume, but only at reduced capacity. It takes more than a year before all the facilities are back in operation. Many businesses are disrupted by the damage to the port. Property loss is extensive: A commercial business center about half a mile from the port is badly damaged with most of its 300 commercial offices, hotels and retail buildings suffering severe structural damage from the blast of the LNG tank explosions.

Hundreds more buildings further away in Pasadena and South Houston suffer broken windows and other minor damage, requiring engineering inspections before they can be reoccupied.

Smoke densities overwhelm intake filters on air conditioning systems in many of the high-rise buildings in the eastern part of downtown Houston, resulting in minor smoke damage to interiors and spoiling of sensitive electronic equipment.

The evacuation of the city means that most businesses in the city are closed for at least three days, while some closest to the scene remain closed for a week or more, as damage assessments continue. Workers and managers are reluctant to return while the city's air quality remains poor. It takes more than 10 days to return to normal.

Dying plants in many areas show chlorine contamination in the soil and the water table. U.S. Environmental Protection Agency divisions have been monitoring contamination levels and cordoning off areas that remain above their safety guidelines. No one is allowed to return to live or work in the hardest-hit areas until the cleanup is completed. Property prices plummet as businesses and residents relocate out of the contaminated areas.

The costs to property and infrastructure are estimated at more than $5 billion. Workers' comp, life and health insurance payouts amount to around $1 billion. Business interruption losses are estimated at $10 billion to $15 billion. Only $3 billion to $5 billion is likely to be recovered from insurers. The longer-term economic impact of the disruption and consequential losses to other businesses is impossible to quantify, but is likely to exceed the direct loss costs.

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Industry's Killer Legacy

In the early morning of April 16, 1947, as the French Liberty ship the *SS Grandchamp*, was being loaded with Marshall Plan ammonium nitrate fertilizer, a small fire erupted in the hold.

The captain ordered the doors to be closed and the hold filled with steam, but at 8:45 a.m. the doors of the hold burst open and the billowing clouds of orange smoke brought crowds to gather and watch on the neighboring Texas City quayside. The 26 members of the local firehouse turned up to douse the vessel with water. Flames began to rise into the sky.

But then, at 9:12 a.m., the vessel and its 2,200 tons of fertilizer exploded. A steam turbine, weighing as much as one ton, was thrown three quarters of a mile. A mushroom cloud and shock waves pierced the sky and brought down two planes flying overhead. The explosion destroyed much of the port, created a 15-foot tidal wave and set fire to a neighboring Monsanto refinery. In neighboring Galveston, the explosion blew pedestrians off their feet and shattered windows. The blast was felt 75 miles away in Port Arthur. An adjacent Liberty Ship, the High Flyer, laden with a 1,000 tons of fertilizer, detonated 16 hours later, in another colossal explosion.

The disaster killed 576 people, injured several thousand, devastated 50 giant oil storage tanks by explosion and fire and destroyed one third of the 1,500 houses in Texas City.

The *SS Grandchamp* incident still counts as the most lethal industrial accident in the United States.

Worldwide, however, the most deadly industrial accident occurred in Bhopal, India, on December 2, 1984, when a toxic cloud of methyl isocyanate, was released from a Union Carbide plant and rolled into a highly populated shantytown in the valley below, killing more than 3,000 people.

An average of 5,000-6,000 work-related fatalities occur each year in the United States. While the occupational death toll for those aged 25-64 has declined by 57 percent since 1912, the rate of decline lags behind similar metrics in the areas of hurricane casualties or aircraft accidents.

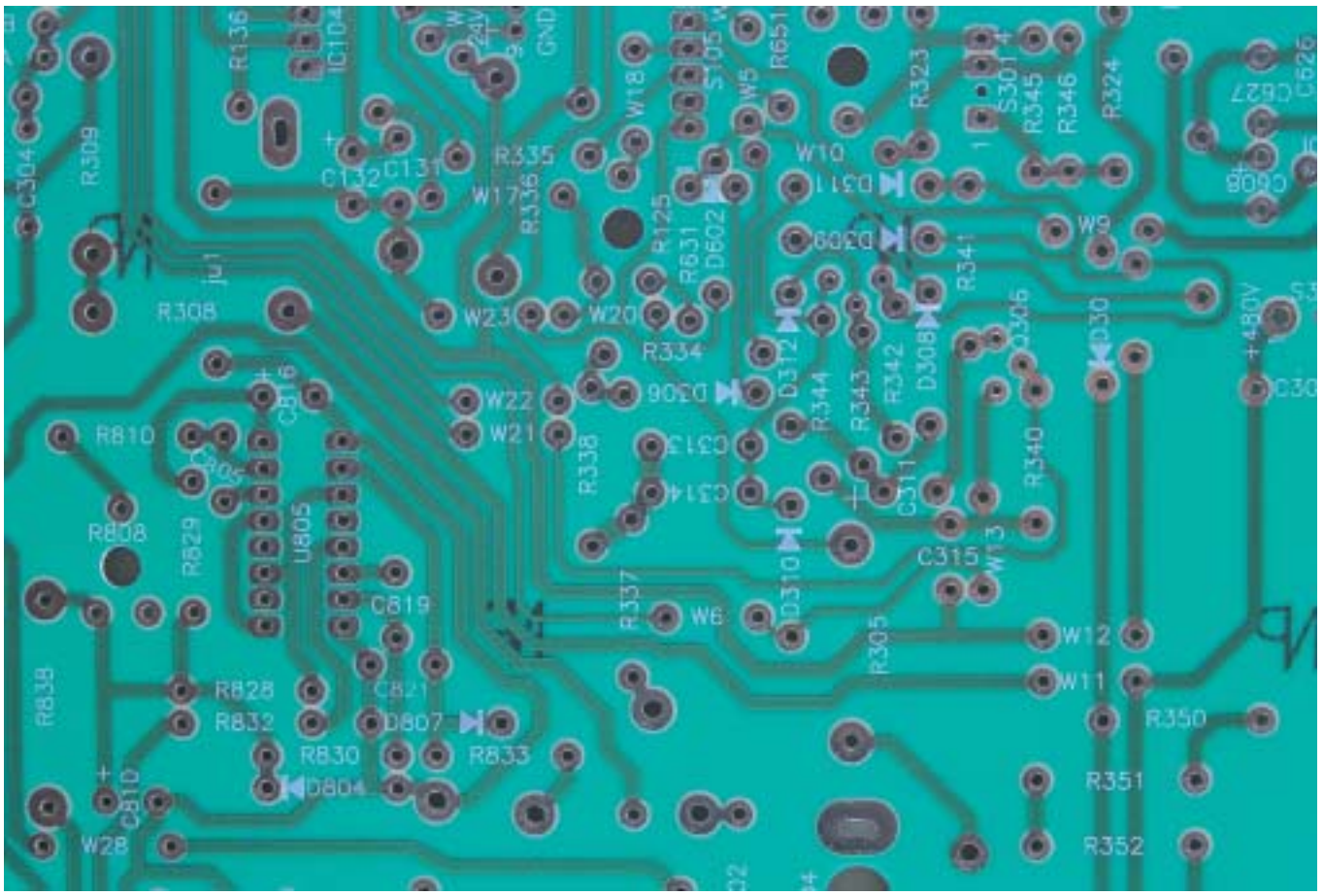
The most dangerous industries, those with the highest fatality rates per worker, are mining and oil and gas extraction. It is in these industries where there is the greatest potential for major incidents. A catastrophic industrial explosion affecting a city occurs somewhere in the world every few years, as at the Toulouse AZF fertilizer plant explosion in France in 2001 and the LNG compression plant explosion at Skikda, Algeria in January 2003.

The U.S. Environmental Protection Agency maintains a record of U.S. facilities containing hazardous materials. This so-called "HazMat" register contains thousands of dangerous locations, and 300 of these plants have a million or more people living within 10 miles of them, many located in the industrial belts fringed around the major cities.

This example used Houston to illustrate how an industrial accident event could cause losses on the scale that is likely to occur with a 1 percent annual probability somewhere in the United States.

Risk managers operating businesses in any of the major cities in the United States should be aware that this type of accident could occur. For any given city, the chances of an accident on this scale happening is far lower than 1 percent per annum—the 1 percent probability of loss is arrived at by considering the chances of an accident anywhere across all the cities of the United States.

—David Miller



Pentecost Worm Unleashed On Computer Networks

The Cyber Attack Scenario: Silent killers wreak havoc on the *Fortune* 1000. Databases are corrupted in the blink of an eye causing mayhem for corporate managers. BY ANDREW COBURN

The Hypothetical Scenario:
The computer network bug that comes to be known as the Pentecost worm is first publicized in a red alert on IT security Web sites Monday, May 31, 2004. The public first becomes aware of it through garbled e-mails between major companies and their customers, particularly those confirming automated transactions. But this virus has been alive for as long as three months, though few people recognized its seriousness.

A vulnerability in Apache Web software, run by more than 50 percent of network Web servers, was identified and publicized on IT security Web sites and mailing lists as early as mid-March. It was one of 30 vulnerabilities in a variety of operating systems and application software published that week.

To protect their systems, IT managers reminded themselves to download and install patches to protect their systems. The vulnerability looks relatively innocuous: validation routines for updating data can be bypassed in certain circumstances by the use of carefully crafted input data.

Unknown to the IT community, a powerful worm exploiting this weakness has been released somewhere in India in mid-April. It is slow to proliferate, using one of several techniques to penetrate servers. It takes days to spread through networks around the world.

Companies using the Apache Web server do not realize that their security measures can be bypassed and that the worm has access to intranet and secure internal networks hosting financial systems, search engine databases and other complex data.

In order to operate, the server must validate each transaction with the database, but the vulnerability allows this validation to be bypassed in certain circumstances.

The worm exploits this loophole by randomly changing alphanumeric characters in the transaction record, thereby corrupting the data. Because the software targeted can be used to provide access to a range of industry-standard databases, including those used by customer relationship management and transaction systems, all are vulnerable.

At first, the worm corrupts the data slowly—at a rate of one character in 10 billion—and this is difficult to detect. But the rate of data corruption increases by an order of magnitude every week.

Managers first notice small errors in reconciliation routines. Customer complaints about errors in account and billing statements increase.

Corruption rates reach one character in one million after almost a month, and several companies raise internal alarms about errors and inaccurate customer data.

When corruption rates reach one character in 100,000, managers know their companies have been infected. Because this worm was surreptitious, backup data systems are also infected.

Companies operating rotating backup systems find that many of the copies are also infected, though to a lesser extent. Live transaction systems and individual customer accounts are compromised, but in some companies the extent of data corruption is not easily verifiable.

Many companies discover that they have a problem in the weeks and days leading up to May 31st, but most of them have been working to contain the problem.

Late in May an IT security analyst realizes the potential impact of the Web server vulnerability and posts an alert including a demonstration version of how a potential worm might exploit it.

Shortly afterward this vulnerability is connected with the data corruption evidence that such a worm may already be in circulation. First the trade, and then mainstream media disseminate the story.

On Tuesday, June 1, corporate managers and customers return from their Memorial Day weekend to headlines about computers worldwide speaking in tongues.

A major savings-and-loan company is one of the first to admit publicly that the worm has infected it. Executives release a statement to shareholders, but it's too late. Its stock price falls 60 percent in the first hour of trading. The bank is forced to admit that it cannot be certain that its customer accounts are correct. Customers panic and begin

Losses To U.S. Companies from Computer Virus Attacks

Name	Date	Type	Threat Class	Machines affected	Cost
MyDoom/Novarg	Jan. 2004	worm	4	Over 600,000	$500 million
SoBig.F	Aug. 2003	worm	2	1 million PCs	$250 million
SQL Slammer	Jan. 2003	worm	4	100,000+ servers	$2 billion
Klez (versions e-k)	Feb. 2002	worm	3-4	750,000	$1.1 billion
DoS Internet	May 2002	virus	3	13 ISPs	$75 million
Nimda	Mar. 2002	virus	4	1.25 million	$100 million
Code Red	Jul. 2001	worm	5	10,000 servers	$2 billion
Anna Kournikova	2001	virus	3	5 million PCs	$750 million
I Love You	2000	virus	3	20 million PCs	$1 billion
Melissa	1999	virus	2	8 million PCs	$400 million

Source: Risk Management Solutions

withdrawing funds, causing the bank to suspend business by midafternoon. Other infected banks and trading companies, alarmed, freeze accounts and suspend business before making their announcements public.

Almost 10 percent of the companies in the *Fortune* 1000 are affected with at least one internal system suffering from corrupted data. Hundreds of thousands of smaller companies, with less secure IT systems, are also affected. Government and non-commercial systems also suffer high levels of infection.

Every company launches an internal audit to establish what parts of their computer systems have been affected by the breach. Data restitution is a priority. In extreme cases, some companies have to poll customers to rebuild data from scratch. IT departments scramble and senior managers attempt to minimize the impact on customers and business operations. Workers are consumed with the latest crisis; little else can be done before this is fixed.

Many companies reinstall software and data systems, reconfigure firewalls and look for new, expensive security measures. Lawyers, consultants and employees prepare to go to court against the perpetrators—if they can ever be found. Most companies suspend e-mail systems and routine use of their computer networks during the investigation and repair.

Electronic trading, financial services and communication systems are hardest hit. Some companies suspend part of their commercial activity, and several major corporations suspend it entirely for the rest of that week. Half of the affected companies are still closed by the end of the following week as well. Some companies are faced with losses of more than $100 million.

Companies absorb most of the costs themselves. Although more than 33 percent of major corporations have insurance policies protecting them against cybercrime, only 2 percent of midsize and small companies do.

The amount recovered through insurance is only 2 percent of the costs resulting from the attack.

ANDREW COBURN, PHD., *is vice president of catastrophe research at Risk Management Solutions. His research encompasses a range of catastrophe causes, ranging from bomb attacks to contagious diseases.*

The Far-Reaching Implications of Data Corruption

This is a fictional example. The Pentecost worm does not exist and this is not intended as a prediction, nor does it imply any knowledge of specific vulnerabilities of computer systems that could be exploited.

But this is an illustration of how a large economic loss could arise from widespread penetration of a virus or worm through the computer systems of companies across the United States and the rest of the world. Security consultants and IT business managers believe that data corruption is one of the most costly kinds of losses facing major businesses today.

If backup systems also suffer (as explained in this example), losses escalate exponentially.

Transaction systems, using electronic ordering and confirmation procedures, are also extremely vulnerable and would likely suffer sustained business losses for some time as a result of the loss of trust from a publicized breach of security.

Very large losses could also occur from an attack on online revenue systems, as companies with retail revenues increase the amount of business they generate through online channels.

E-commerce currently generates more than $50 billion a year in transaction volume, and now accounts for nearly 2 percent of all retail revenue, up tenfold from two years ago, according to a November 2003 estimate by the U.S. Department of Commerce.

Unless security increases proportionally, infected networks could mean a drop in transaction volume and cost businesses billions of dollars in sales and profits. Without a doubt, computer viruses are a serious threat to all forms of modern business activities.

Companies that increasingly rely on supply chain or procurement operations through online systems also face the potential for expensive business disruption from a cyberattack. The benefits, savings and business efficiencies that accrue from increasingly wired business activities need to be balanced against the vulnerabilities that these systems introduce, and the potential for disruption and losses that could be caused.

Events more extreme than the example cited here are possible. This example illustrates the damage done when a virus infects the Web servers of corporate America at a penetration rate of 10 percent. Higher penetration rates are certainly possible and costlier impacts per penetration could also result. Entire databases could be wiped out. The damage faced by the most unlucky of companies is, at worst, irreparable.

Targeted attacks could cause companies extreme losses and the most severe scenarios (of extremely low probability) envision the destabilization of entire business sectors.

This isn't so farfetched. The travel, tourism and entertainment sectors, which grow more reliant on computerization each year, have been targeted in the past. Hackers penetrating air traffic control systems, for example, could halt air travel or even cause airplanes to crash.

In the "worst-case" scenarios, cyberattacks cause physical damage or major and lengthy failures of the infrastructures considered vital to support business, government and daily life.

Security systems are now much harder to breach but the possibility exists for criminals, vandals or even terrorists to penetrate computer networks and control transportation networks, and power and water supply systems, according to researchers at the RAND think tank and academic researchers.

The possibility of a cyber attack causing massive physical damage and death is no longer the province of the unthinkable.

—Andrew Coburn

AP PHOTO

A THAI VETERINARIAN takes a sample of a dropping from a chicken at a Bangkok market in January to check for the avian flu virus.

The Deadly Plague Returns to America

The Pandemic Scenario: A mutated flu virus strain cripples the United States in a global pandemic. Employers struggle to function as a third of their personnel succumb to this virulent new bug. **BY GORDON WOO AND ANDREW COBURN**

The Hypothetical Scenario:
Over several years, clusters of cases of a deadly new strain of flu, designated A(H5N1), have been reported in Vietnam, Thailand and other parts of Southeast Asia. The flu strain is caught from chickens. It's particularly deadly—more than a third of its victims die—and most of the initial victims are children. There are no recorded cases of this strain of the flu being passed from one person to another—the only transmission path is from inhaling particles from birds, mainly chickens. Public health measures include the slaughter of infected flocks.

During the month of December four cases that appear different are identified in a hospital in Penang, Malaysia. These are traced back to an older man who died, apparently from a more common strain of flu, A(H1N1). Tests show that the man had both forms of flu and that he infected the other cases with a new strain: a combination of a rarer H-9 avian flu virus and genetic material of the human flu virus. This virus, designated A(H10N3), can be passed from person to person. Within days, other flu cases in Kuala Lumpur are found to be of this strain. It's clear that the virus is in the population.

The World Health Organization in Geneva issues a major alert in mid-December, and medical laboratories all over the world race to develop stocks of an appropriate vaccine. Newspaper headlines play up the genetic mutation—"Asian Killer Flu"—and predict massive numbers of deaths in Southeast Asia. A senior WHO official calls for quarantine zones and suspension of travel to and from Malaysia, Thailand and Singapore. The governments of these countries protest but several countries take unilateral action and close their borders to visitors from these countries. The United States does not ban travel but the U.S. Centers for Disease Control and Prevention issues an alert to primary health-care physicians detailing symptoms to watch for and guidelines for test referrals. CDC specialists are sent to Malaysia to help.

In Malaysia the number of flu cases increases rapidly. Doctors are asked to test flu victims and isolate those with the A(H10N3) strain. This severely overloads the clinics and health laboratories of Malaysia. By early January several thousands of cases of the A(H10N3) flu are identified, but the number of deaths are not as many as feared—there are 80 deaths from the 1,500 cases in the isolation wards of Malaysia. Epidemiologists establish that the lethality of the virus—the proportion of people who die from the infection—is close to the more usual strains of human flu at around 0.5 percent and certainly not as high as the 30 percent that was initially feared from experience of the avian strain A(H5N1).

The media reflects the relief felt by many health-care officials that the nightmare scenario of a human-transmitted flu that has the lethality of avian flu has not transpired—"Asian Flu Not a Killer" read the headlines, "Only as Bad as Regular Flu."

THE DOWNSIDE OF GOOD NEWS

Many health-care officials, fearing that it could undermine the strength of their efforts to combat the spread of the disease, view this reaction as a problem. The senior WHO official gives another news conference, at which he is quoted as saying, "You are all missing the point. The issue is not the lethality; it is the *infectiousness* of the disease and the fact that we do not yet have an effective vaccine that is the problem." He reiterates his call for the enforced quarantine of Malaysia and other affected countries. The prime minister of Malaysia lodges a formal complaint to the United Nations and the senior WHO official resigns.

In the United States, the first cases of Asian flu are reported in Los Angeles in mid-January from travelers returning from Southeast Asia. They are placed in isolation wards. Tests indicate that the A(H10N3) flu strain is resistant to the less expensive class of influenza anti-viral drugs.

This resistance is apparently the result of a change in just one of the many amino acids in the influenza virus itself. Several medical research laboratories in the WHO network, including Atlanta, Hong Kong and London, race to develop a human vaccine. New techniques are needed to prepare a seed virus for the vaccine, which is finally declared ready six weeks after the start of research, in late January. The seed vaccine is then used to prepare batches of vaccine for testing, which entails fast-track trials on animals and then on human volunteers. Finally, the new vaccine is ready for production and certified for administering to the general population of the United States in mid-April. Production of more than 100 million doses will be delivered in phases over the next eight months. Vaccination of the U.S. population against the Asian flu is at least assured for next year's flu season, but will not be possible for the remainder of this winter.

U.S. Losses from Hypothetical Flu Pandemic

Monetary Losses are not estimated	
Total number of people killed:	200,000
Total hospitalized with serious injuries:	750,000
Total treated at outpatient clinics:	40 million

Source: Risk Management Solutions

Isolation of Asian flu cases slows its initial spread in the U.S. population. Common flu cases run at their usual rate—about 10 percent of the population have common flu each year—and it is impossible to test every case to check which strain it is. But the rates of people exhibiting flu symptoms increase.

First this happens on the West Coast. But soon it is affecting urban populations across the country. Mass vaccinations of conventional flu vaccines are administered but this has little effect. The virus continues to spread.

WORKFORCE AFFECTED

Companies notice that employees with children are initially those calling in sick, but it quickly spreads to others in the workplace. Workers find themselves suffering from fever, tiredness, aches and nasal congestion. Most sufferers take three to four days off work, but some are off for two or more weeks. About 2 percent of sufferers develop complications like pneumonia, bronchitis and sinus and ear infections. Hospitals are quickly overloaded with cases of bronchial infections and other flu-exacerbated problems: many admitted to hospitals are older people and young children. Around one in every 200 flu victims develops fatal complications.

Overall, about 35 percent of the population of the United States is struck by the flu during this winter season. Many companies find they cannot operate once the number of sick rises past a certain threshold. Some companies close their offices temporarily, or encourage work-at-home policies, to try to prevent the spread of flu through workplace contact. Other companies suspend their operations for nearly three months. Some companies that don't take action are sued by the families of employees that died from flu-related complications.

The pandemic runs its course over nearly four months, with caseloads peaking in late February and March and gradually tapering off into April and May. By June, the number of flu cases has ebbed. The new vaccine becomes available and is provided to high-risk groups in late June. The crisis has prompted calls for more money for public health. The political fallout includes questions surrounding the ease of travel between countries with different standards of health care.

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A More Deadly Flu Is Overdue

The annual number of deaths in the United States from natural and accidental causes is about two and a half million. A notable source of variability in the mortality rate is influenza. The main complication of the influenza virus is that of pneumonia, which accounts for much of the morbidity and mortality. Secondary bacterial pneumonia associated with influenza is most common among the chronically ill, who are more susceptible to this complication. Occasionally flu rates can reach pandemic proportions across the population.

In between pandemics, influenza epidemics cause an annual average of 20,000 excess deaths in the United States, which is only about 10 percent of the number of deaths from all forms of respiratory disease. The death toll in pandemics is far greater. There have been three pandemics in the 20th century, in 1918, 1957 and 1968. Before that, there was a pandemic in 1889. Of these, the most disastrous was the global 1918 pandemic, which for America was more lethal than World War I. Around 700,000 Americans died in the 1918 pandemic. By comparison, the U.S. excess death tolls from the 1957 and 1968 pandemics were about 70,000 and 40,000.

The process by which an influenza virus mutates to evade immune systems is called antigenic variation. Every few years, there is an antigenic *drift,* which causes influenza epidemics. More rarely, about every 25 years on average, a more serious antigenic *shift* occurs involving an exchange of gene segments between human and avian influenza viruses. In a significant proportion of both adults and children, protective antibody levels are absent, and a global pandemic results.

The assumption that infectious diseases have been conquered by antibiotics and vaccines has been criticized by health-care professionals. Virus experts have warned that the growth of world population, rapid international travel and the development of drug-resistant microbes and pesticide-resistant insects make worldwide epidemics more likely.

The main reservoirs for antigenic variation are the vast flocks of birds in China, which are in close contact with large human populations. In June 2001, and again in May 2002, a total of four million chickens were destroyed in Hong Kong as a precaution against the global spread of a new strain of avian influenza. Beyond China, international surveillance is headed by the World Health Organization, which has developed an Internet application linking the global network of influenza centers (FluNet). A major objective of FluNet is the selection of strains included each year in influenza vaccines.

It is known that about 30 percent of the American population was affected by the 1918 pandemic—this is the highest severity index for any of the four pandemics since 1889. By ranking the four severity index values, the probability of the 1918 index being exceeded is approximately one-quarter. However, progressive immunity loss, a long elapsed time since the previous pandemic and its mildness may all be factors tending to exacerbate the severity of the next pandemic. With three decades having passed since the last pandemic, a chance of one-quarter should be ascribed to a severity index somewhat higher than that of 1918, say 35 percent. This would have an annual probability of one in 100. If 35 percent of Americans become clinically ill in the next major pandemic, CDC mortality modeling based on historical epidemic and pandemic data indicates that around 200,000 excess deaths would result, and three-quarters of a million people would be hospitalized. Some 40 million would require outpatient care.

This pandemic scenario would have enormous economic loss implications: direct health costs, indirect economic loss resulting from the loss of productivity of those who fall ill, and lost future earnings of those who die. Replacing the dead in the workforce might add another few billion dollars to the economic loss.

Most of the economic loss would not be covered by insurance, but insurers would foot some of the bill. There could be significant payments under workers' compensation insurance if employees were able to establish that they caught the flu in the workplace. Life insurers could be hard hit, although life policy losses might be hedged to some extent by gains on their annuity policies, especially if the pandemic takes a heavy toll on the elderly. As a fraction of average mortality, the annual increase in claims would be on the order of 8 percent. As a fraction of average hospitalization, the annual increase in health claims would be a few percent.

—Gordon Woo and Andrew Coburn

AP PHOTO

RESCUE WORKERS on the scene after the Northridge earthquake struck Los Angeles on Jan. 17, 1994. The 6.7 magnitude quake killed nearly two dozen people.

A Big One, Though Not *The* Big One

The Earthquake Scenario: Despite the high level of earthquake preparedness in many parts of California, losses—both human and property—are still breathtakingly high when nature decides to shake things up with a magnitude 7.0 quake.

BY FOUAD BENDIMERAD

The Hypothetical Scenario: Just after lunch on a summer Wednesday, more than 20 million people in Los Angeles feel the vibration underfoot. Immediately they know it is a major earthquake. Most people have felt distant or small tremors before. But this time they recognize the strong vibrations and the noise. The 30 seconds of shaking seems to last forever. This is no localized tremor.

High-rise office towers sway dangerously from side to side. Workers hold on to their computer equipment to prevent it from falling off their desks. Down below, drivers struggle to control swerving cars. After the shaking stops, there is a short silence. Outdoors, car alarms are going off across the city. To the south of downtown Los Angeles, a cloud of dust rises slowly into the Southern California sky. Office workers try to search the Internet for news but no sites are available. As they surf the Net, the power goes out. Many reach for their phones but the phone lines go dead. Cell phones show no networks are available. Managers walk through the offices telling everyone to go outside to their rally points.

News is coming through on car radios that the earthquake was a magnitude 7.0 centered in southern L.A. county, some 20 miles south of downtown Los Angeles. Some buildings have collapsed in the communities of Compton and Long Beach. Damage is being reported along stretches known as the Long Beach Freeway and the Harbor Freeway. Scientists from the United States Geological Survey have attributed the quake to a rupture of the northern segment of the Palos Verdes fault system. Emergency services rush to the area.

Coastal towns from Santa Monica in the north to Newport Beach in the south have suffered damage. The ground is deformed in many places and soil from steep slopes has slid into canyons.

EARTHQUAKE KILLS 400

Casualties are relatively light, given the amount of damage to buildings and infrastructure. A total of 400 people are feared dead and more than 3,000 people are injured. Many of them are employees injured in the workplace by falling equipment as well as collapsed partition walls and ceiling panels. Many people running out of buildings have been injured by falling debris. Ten people are reported to have been crushed in a shopping center by heavy building panels that came loose. Others are injured in car accidents. A few older structures have collapsed, including an eight-story office building occupied by a bottling company. Twelve people are pulled out alive, but another nine bodies are recovered. As many as 30 employees are missing. Search-and-rescue teams work into the night to cut through floors of pancaked concrete.

The high-rise buildings in downtown Los Angeles have escaped serious damage this time. But in the towns to the south and west, hundreds of thousands of buildings are damaged, including major commercial buildings. Tens of thousands more suffer lighter damage, but will require engineering surveys before they can be declared safe for occupancy. Repairs will take months. Many businesses face the challenge of trying to find suitable temporary office space.

PORT SINKS INTO ECONOMIC SLUMP

There has been extensive liquefaction and ground deformation around the port facilities. Areas around the Port of Los Angeles in particular are badly damaged. Container cranes, storage tanks and machinery rest at odd angles, as their foundations have slipped in the softened ground. Landings, berths and cargo terminals have also been damaged as their perimeter and retaining walls have moved and tilted. Bridges leading to Terminal Island are also closed pending detailed structural investigations. As all access to the port is impaired, non-essential workers are asked to go home.

The industrial areas of southwest Los Angeles County and Long Beach have suffered intense ground vibrations. The damage is heavy. Storage tanks and pipes have fractured. Emergency teams are dealing with hundreds of leaks. Minor fires are brought under control and extinguished. One fire in a tank farm takes two days to put out, even with dozens of firefighters. Some of the largest water treatment plants in the United States are badly damaged. There are reports of damage to power stations in Redondo Beach and Long Beach.

Los Angeles International Airport runways are cracked, and several terminal buildings have suffered damage. The crippled airport can only operate at very limited capacity.

With the exception of one section of the Harbor Freeway that slipped from its abutments, most of the major bridges appear to have remained in place, having been seismically retrofitted over the past decade. However, roadway cracks and differential settlement resulted in several arteries being closed to traffic in the southern part of the county. Faced with total gridlock, tens of thousands of drivers set out for the long walk home.

Electrical power is out across the whole city and is gradually restored to different parts over the next 72 hours. The Los Angeles central business district has power restored 24 hours after the earthquake. Managers attempting to restore business operations on Friday morning find, however, that they have no water services. Another day is lost.

Although engineers work over the weekend, water treatment facilities, pumping stations and pipelines are too badly damaged to restore supplies to large parts of the city.

The following Monday, some businesses are able to reopen with the help of bottled water and temporary toilets.

Losses from Hypothetical Los Angeles Earthquake

Type of Loss	Total Loss	Insured Losses
Property and infrastructure damage	$75 billion	$20 billion
Workers' compensation, life and health costs	$1 billion	$1 billion
Direct costs of business interruption	$23 billion	$6 billion
Other costs (e.g. emergency response)	$1 billion	—
Total Direct Costs:	**$100 billion**	**$27 billion**
Total number of people killed:	**400**	
Total hospitalized with serious injuries:	**1,200**	
Total treated at outpatient clinics:	**2,400**	

Source: Risk Management Solutions

Orders of Magnitude

Despite intensive preparations and contingency planning, risk managers typically list earthquakes among their concerns. Besides the obvious concern about the performance of their own facilities, risk managers understand that the recovery of their businesses is also highly dependent on the survival of the transportation network, the utilities and communication systems.

Risk Management Solutions first developed a catastrophe model for earthquake loss in 1988 and has updated and revised this model several times over subsequent years to reflect new research. The model simulates 42,000 earthquakes that represent the frequency and severity of earthquakes likely to cause significant loss across the United States. It incorporates the latest view of seismic hazards published by the United States Geological Survey and leading academic research institutions. This model has been used to assess the 1 percent probability of loss occurring from earthquakes in the United States.

We have chosen to illustrate the impact of a sizeable earthquake defined by a 100-year economic loss return period and occurring close to a major city.

The magnitude 7.0 Palos Verdes event—the one described here—has a major impact on business activity and is of direct relevance to risk managers in understanding how disruptive catastrophes can impact their businesses.

Southern California is home to more than 20 million people and is a vital region for the U.S. economy. Key manufacturing, defense, high technology and financial institutions are based in Southern California. To support its economy and trade, the region has built one of the most complex networks of transportation and lifeline systems in the world, including highways, bridges, ports and airports, power and water systems, and communication networks.

The magnitude 7.0 on the Palos Verdes fault is not "the big one" that Californians have heard about. The losses from this event would be relatively moderate compared with a magnitude 7.3 quake on the Newport-Inglewood fault (total losses around $175 billion) or a magnitude 7.0 on the Puente Hills fault that cuts through downtown Los Angeles and is expected to cause losses in excess of $210 billion.

However, the losses from the magnitude 7.0 Palos Verdes earthquake would still be more than twice those of the Northridge quake in 1994. Economic losses, including secondary losses such as business interruption and loss of income, would be around $100 billion—of which about $27 billion would be assumed by the insurance industry (compared with $15 billion in the Northridge quake).

Due to the complexity of business interruption coverage one should expect a difficult process for the settlement of business interruption claims. Many companies are expected to wake up to the reality that their business interruption coverage may not be adequate because they have not considered such external factors. At the same time, insurers may have difficulties tracking data and understanding their liabilities from such an event due to cumulative claims coming from coverages such as business interruption, fire, workers' comp and general liability.

Depending on the time of the earthquake, casualties can vary significantly. An occurrence in the middle of the day would cause the most casualties with about 400 people dead and 3,600 injured. There is uncertainty around the total number of casualties depending on the number of building collapses and industrial accidents, including fires and toxic releases, and the ability of the fire fighters to control such events.

Looking at the urban growth that has taken place in California since the 1933 Long Beach earthquake, one can start to comprehend the significant impact a larger and more destructive Palos Verdes event could cause to Southern California. Scientists have yet to develop reliable tools for predicting earthquakes, but have made remarkable progress in understanding their mechanisms and in quantifying their impacts. With this knowledge, risk managers and executives, insurers and the public can develop preparedness, contingency and mitigation plans to reduce their losses and speed up their response and recovery from major earthquakes.

While Southern California, especially the Los Angeles area, is considered one of the most prepared communities in the world, the powerful nature of earthquakes coupled with the complexity of urban systems and infrastructure require careful planning and constant attention.

—Fouad Bendimerad

However, most industrial operations cannot function without proper water supplies and sanitation. For those unlucky businesses, there is no chance of getting back to work for another two weeks at least. Water supplies are restored gradually over the next three weeks. Sanitation services take six weeks to get back to normal.

SLOW TO RECOVER

Los Angeles International Airport, ranked fifth in the world in the number of passengers and tonnage of air cargo, is forced to run on a partial schedule for several weeks while runways are repaired. The slowdown causes hardship to businesses and to the 400,000 employees dependent on the airport economy.

The port is badly damaged and takes months and tens of millions of dollars to repair. Limited access aggravates the quake's impact on trade and business. Replacement of special cranes and other damaged equipment will take more than a year. Before the earthquake, the port was the busiest port in the United States and the eighth busiest in the world. It generated tens of billions of dollars in sales every year in California, as well as thousands of local jobs. While it is repaired, rival West Coast ports siphon off much of the business. It will be a challenge for Los Angeles to regain its position.

Damage to residential real estate is significant. Nearly a million homes have been damaged. Fewer than one in 12 of the affected households have insurance with special additional earthquake coverage. Even those that have earthquake insurance find that the deductible levels on their policies leave them liable for a large portion of the repair bills. A political controversy ensues, and the governor demands that insurers settle claims promptly. The governor asks the legislature to create a new insurance structure for earthquakes.

Businesses recover only slowly, over the course of many months. The thousands of small businesses that need temporary office space find that rents in the unaffected parts of the city have gone up with the sudden demand. Some companies relocate business operations to their offices out of town, or even out of state.

Manufacturing and industrial facilities need to repair or replace damaged machinery, creating a surge in orders. The construction sector booms as contractors from all over California and nearby states pour into town to help rebuild.

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