THE MASTER OF DISASTER

by **ALEX PRUD'HOMME**

Bob Bea, the nation's foremost forensic engineer, is the guy to call when levees break or oil rigs explode — to sift through the wreckage, assign blame, and try to prevent the same mistakes again. (He's still working on that part.)

ROBERT BEA'S large, beige, seemingly bland office in the engineering building at the University of California at Berkeley is revealed, upon close inspection, to be a cabinet of wonders. Perched on top of neat filing cabinets and tucked into corners are mysterious artifacts from around the world: a massive drill bit, a chunk of rusted metal, a model of an oil platform, a cluster of giant barnacles, strands of Mardi Gras beads, a beer bottle, and other totems. Each of them has a story to tell. That drill bit? It came from an oil rig that sank off the coast of Australia, causing a $1 billion disaster. The rusted metal? It's a piece of an oil tanker that supposedly "could not rust." The clutch of barnacles? From the Arctic seabed, where the oil industry once claimed, "There is no life." Bea (pronounced "bee") keeps these mementos as teaching aids and to prompt discussion about the role of human fallibility in mishaps — a subject rarely discussed in engineering circles, yet one that he believes is just as important as mechanical failure or software glitches.

"Never let a good disaster go to waste" is Bea's mantra. "I'm in the prevention business," he says. "And you can't prevent what you don't understand."

Bea has compiled a database of more than 600 engineering failures — from perforated submarine hulls to crumpled airplanes, fallen bridges, exploded pipelines, and upended oil rigs. But he also studies why things go right and how high-reliability organizations — such as pediatric emergency teams and aircraft-carrier crews — work successfully under pressure.

A bald, saber-thin 76-year-old, with an erect bearing, a silver mustache, and a direct manner, Bea is co-founder of the Center for Catastrophic Risk Management, a nonprofit group based at Berkeley, and a pioneer in the emerging field of forensic engineering. When catastrophe strikes, it is usually Bea who is called in to make sense of the twisted wreckage and smoldering remains. Over the past few decades, he has appeared, Gump-like, at nearly every high-profile calamity — from the sinking of the Exxon Valdez in 1989 to the 2003 Columbia space-shuttle explosion to the sinking of the Deepwater Horizon in 2010.

Today, Bea's grim expertise is central to two of the biggest lawsuits in U.S. history: a class-action suit alleging that the federal government failed to protect New Orleans from Hurricane Katrina, which killed more than 1,800 people in 2005; and another suit charging that BP and its partners in the Deepwater Horizon were responsible for the explosion that sank the drill rig, killing 11 and causing the largest oil spill in U.S. history. In November, BP, at least in part because of Bea's pointed testimony, settled, admitting to criminal liability for the spill and agreeing to pay a penalty of $4.5 billion.

Bea's ability to explain complex data in layman's terms and his willingness to point out mistakes have made him a hero to disaster victims and a scourge to the targets of his criticism. He is unapologetic for his unvarnished opinions: "If we don't learn from our mistakes, then we are doomed to make them again and again," he says. "Unfortunately, that's what we've been doing."

The week after superstorm Sandy devastated New York, New Jersey, and the nation's most populous coastline, Bea has a ready example of lessons that have gone unlearned. "It's a sad tale of complacency," he says, "by all measures a true 'predictable surprise.'" He wonders what was done to prepare infrastructure or why hospitals weren't prepared with generator systems, particularly after what happened at New Orleans' Memorial Medical Center during Katrina, but he also sees our weakness as a product of good fortune. "I think a key part of our challenge is our generally bountiful blessings. Many of us have a lot of things that give us pleasure and comfort. Thinking about complex issues like global climate change and our out-of-date, decayed infrastructure systems is hard to do. It is much easier to 'hope' someone is taking care of us so that we can return to the enjoyments of our lives. Hope is no strategy for success."

IN 1967, ERIC BROWN, who taught failure analysis at Imperial College London, described structural engineering as "the art of molding materials we do not

really understand into shapes we cannot really analyze, so as to withstand forces we cannot really assess, in such a way that the public does not really suspect." His observation can be applied to many modern engineering marvels.

It is one of the ironies of our time that while new technologies allow us to go ever-faster, deeper, and higher, they are increasingly laden with a "catastrophic complexity," which can overwhelm our ability to operate them safely. As the gap between man and his machines narrows — as computers become an extension of our nervous systems — the distinction between engineering and human problems has shrunk.

The cause of most large-scale calamities, notes Bea, is "the human factor." Too often, designers fall in love with their ideas and lose sight of practical, quotidian concerns. "We engineers tend to believe in the myth of perfection," he says. "We understand the logic of systems and machines. What we don't understand is all of you illogical humans. We aren't trained to take into account things like hubris, greed, sloth, office politics, and the rest of it. It's not part of our skill set. But it needs to be. Dealing with the human factor is almost always more complicated than the technology."

Indeed, Bea's database reveals that 20 percent of engineering disasters are the result of "intrinsic uncertainties" — i.e., natural events such as floods, tornadoes, and dust storms — while 80 percent are rooted in "extrinsic uncertainties" — i.e., human error.

Consider the Challenger disaster in 1986, which was ostensibly a technical problem but was really caused by organizational dysfunction at NASA. The space shuttle blew up after launching, when an O-ring seal failed, killing its seven crew members. Investigating the crash, Bea found that NASA had known that O-rings could be compromised by cold weather: The January launch day was cool, yet NASA controllers did not wait for the temperature to rise — a decision driven by inflexible managers and their schedules. The result was "an avoidable tragedy," says Bea. Similarly, when the space shuttle Columbia was destroyed during atmospheric reentry in 2003, killing all seven crew members, the given cause was broken foam insulation, but the root cause was NASA's broken culture. "We look back and say these accidents could have been prevented," Bea sighs. "NASA delivered incredibly high levels of individual performance, but they struggled to manage groups of people."

Looming behind such behavioral concerns is an intractable engineering problem: Much of America's critical infrastructure is aging and on the verge of failure. (A case in point: the 2007 collapse of an outmoded and improperly maintained highway bridge in Minneapolis, which killed 13 people.) Once the envy of the world, our power grids, bridges, tunnels, highways, dams, airports, drinking water, and wastewater-treatment plants are in desperate need of investment and updating.

In 2009, the American Society of Civil Engineers (ASCE) gave U.S. infrastructure an average grade of D, meaning it is nearing failure, and estimated that the cost to repair and modernize these building blocks of society will be at least $2 trillion. But the cost of allowing them to fail is even greater, both in the short term (leading to expensive and inconvenient stopgap measures) and long term (limiting America's efficiency and global competitiveness). The longer we avoid the problem, the greater the risk. Or, as Bea puts it: "We wait, we're fucked."

IT TAKES A PERSON who thinks in a weird way to figure out how things fail," Bea admits cheerfully. His goal is to identify the many small mistakes that compound into large disasters, learn from them, try to predict them, and avoid repeating them. While the task of design, building, or maintenance engineers is self-explanatory, the work of a forensic engineer is more of a dark art, akin to being a detective. "You examine the dirt, the steel, the concrete, the water, to find out what really happened," Bea says. "And, crucially, you talk to the people. It's the only way to find out who did what, when. It's chillingly fascinating."

When Bea talks about risk, his eyes brighten. From the age of 14, when he worked construction jobs in Florida, he has been intimate with the subject. After training in the Army Corps of Engineers, where he built levees to drain the Okefenokee Swamp, Bea joined Shell Oil as a roughneck on an offshore rig. Months into the job, one of Bea's colleagues lost part of his face and another lost three fingers in accidents. When Bea was ordered to replace the man who had lost his fingers, he says, "They just sent me up the derrick, 100 feet in the air, and told me to keep my head out of my ass — or I'd probably lose it. Terror is a fine instructor."

Bea undertook his first forensic investigation in 1961, when Shell tasked him to investigate the sinking of Texas Tower 4 (TT4), a U.S. Navy radar platform that disappeared off New York with 28 crew members. Shell was moving its rigs deeper offshore in the Gulf of Mexico and wanted to know what had gone wrong. The answer: "TT4 was a terrible design," Bea recalls. "It had a big X-brace that caught both the wind and the waves. It was an accident waiting to happen." Bea's report was so thorough, he was asked to testify before Congress.

By the time Hurricane Betsy struck New Orleans in 1965, Bea had been promoted to manager of Shell's Offshore Technology Development Group, where he was in charge of the company's Gulf oil platforms. His rigs survived Betsy's 140 mph winds and tanker-size waves. But the levees ringing the city failed, and the nation suffered its first "billion-dollar hurricane." Bea's house in New Orleans, where he was then living, flooded, and he and his family "evacuated vertically" into his office building, before fleeing to Houston. It was a defining experience, one that seems to have instilled a righteous anger in him to "make damn sure this never happens again."

Bea stayed with Shell for 16 years, working from the Great Barrier Reef to Arctic ice floes and in executive suites from London to the Hague to Manhattan. In his spare time, he earned a master's degree in engineering from the University of Florida and an MBA from Harvard. Chafing in the corporate "velvet coffin," he quit Shell in 1976, founded and sold two engineering firms, and went to Tulane to learn how to construct buildings that could withstand a nuclear blast. In 1989, he applied to the engineering Ph.D. program at Berkeley on a whim. While Bea didn't have the required course work, the school was so impressed by his résumé that it hired him as a professor.

At Berkeley, Bea met Karlene Roberts, a research psychologist studying human factors and high-reliability organizations, essentially working on the same problems from different angles. By necessity, their work is interdisciplinary, combining engineering, business management, and social science. Ultimately, their goal is not only to improve the way airliners, oil refineries, nuclear plants, and other engineered structures are built and operated, but also to create a design process that takes human fallibility into account and allows us to safely operate complex systems over the long term. But they have encountered resistance from academics and engineers who prefer to maintain specialized "silos" rather than encourage cross-pollination among disciplines. "Learning to be multidisciplinary takes a long time and a lot of money," Roberts explains. "People from different specialties don't speak the same language at first. They have to be trained, and that's difficult."

In trying to nudge his conservative profession forward, Bea has helped to develop new risk-management strategies, particularly an interactive system that stresses the assessment and management of risk in real time. In studying the way pediatric emergency teams coordinate to keep babies alive, for example, they found that successful teams are fluid, shifting from highly structured to loosely structured groups during a crisis. Free-flowing communication is paramount. Hierarchies melt away, team members continually update their diagnoses, and everyone supports the people with the best skills for the task at hand. "They search for what answer is right, not who is right," Bea says admiringly.

RETIREMENT LOOMS on the horizon, vaguely, but first Bea has a few things to wrap up. Much on his mind is the potential flooding of his backyard.

The weakest point of American flood

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PREVIOUS SPREAD: BORDER: HAPPYFOTO/ISTOCKPHOTO.COM

defense now is not New Orleans or Miami, but the Sacramento-San Joaquin River Delta, just up the road from Berkeley. The delta is a vast estuary, through which fresh water for more than 25 million Californians flows. The delta is ringed by 1,100 miles of levees, but some are nearly 150 years old and leaking. The region is vulnerable to Pacific storms or, worse, an earthquake. Seismologists have predicted a 40 percent chance of a "catastrophic" quake there in the next 30 years. If the delta levees fail, the result could be a megaflood that would cripple the state, now the ninth-largest economy in the world. Yet Californians have been bitterly divided over a response for decades. Every solution is expensive and politically fraught. Bea is working on a task force, and calls the delta a "ticking bomb," warning that a breach there would prove worse even than Hurricane Katrina.

"The Deepwater Horizon was trying to tell us something was wrong in the Gulf," he says. "Now the levees are trying to tell us something is wrong in the delta. If those levees go, we're all going to be drinking saltwater coffee," he jokes tragically. "My sailboat is rigged and ready to go!"

Bob Bea is genial, unfailingly polite, and has an uncanny ability to synthesize complex information. He is widely admired in engineering circles. But he admits to being "ornery," and seems haunted by the memory of Hurricane Betsy. He is in perpetual motion — teaching, writing technical papers, attending conferences, consulting hither and yon. He has missed Christmas with his wife and two sons. He eats and sleeps little. It's as if he's racing to plug all the holes in a giant, leaky dike before it bursts.

When I asked why he pushes himself so hard at an age when most people are focused on their golf game, he replies, "Make a living. Have some fun. Leave the world a better place." He shrugs, searching for answers. "I'm an engineer, but much like the corps, I don't always communicate well. Sometimes I don't have the words to explain myself. All I can say is 'I'm Bob. I'm here to help.'"

Bea has a lucrative international consulting career. But the work is exhausting, and he's growing tired. In the Katrina case, he is facing a vengeful Corps of Engineers, some of New Orleans' toughest lawyers, the Department of Justice, and 30 experts determined to poke holes in his work. It keeps him up. But he recently popped awake at 3 AM with an insight: "I suddenly realized they can say what they want, but I've got the data. Bingo! That's where I find my solace."

Bea's role in the lawsuit will soon end. He will then testify about his investigation of the 2010 San Bruno blast — in which a Pacific Gas & Electric gas pipeline exploded, killing eight and devastating a San Francisco suburb. "Then I'll be done," he smiles. Pausing a beat, he adds, "Well, there is one more thing."

San Pedro, near the port of L.A., has bloomed into a major petrochemical complex. Residents, worried about a San Bruno-type explosion, have asked him to investigate.

"Worn-out, tired old bastards are the only ones with the time and patience to look at this thing seriously," said Bea.

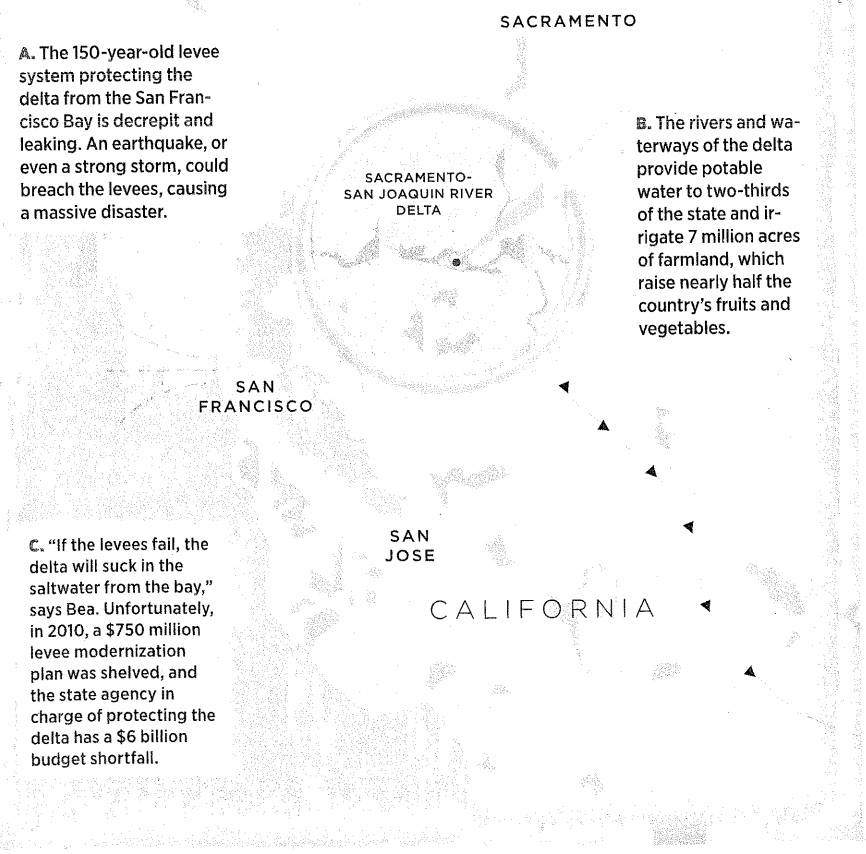
What does he see there? "It's risky. Very risky," he says, a gleam in his eye. "I'm going to have a look."

America's Most Vulnerable Places

THE SACRAMENTO-SAN JOAQUIN RIVER DELTA

Northern California

Bea believes the 1,100 miles of California's delta could be the next disaster waiting to happen. "In terms of damage, deaths and longer-term cost," he has said, "it would be far more destructive than what happened in Hurricane Katrina."



A. The 150-year-old levee system protecting the delta from the San Francisco Bay is decrepit and leaking. An earthquake, or even a strong storm, could breach the levees, causing a massive disaster.

B. The rivers and waterways of the delta provide potable water to two-thirds of the state and irrigate 7 million acres of farmland, which raise nearly half the country's fruits and vegetables.

C. "If the levees fail, the delta will suck in the saltwater from the bay," says Bea. Unfortunately, in 2010, a $750 million levee modernization plan was shelved, and the state agency in charge of protecting the delta has a $6 billion budget shortfall.

More Danger Zones

DIABLO CANYON POWER PLANT

Avila Beach, California

In 2008, an undersea fault line was discovered a half mile from this 18,000-gigawatt nuclear plant, which supplies electricity to more than 1.6 million homes. "They need tests to confirm the plant's ability to withstand earthquakes," Bea says. But seismic testing would displace marine mammals and kill fish larvae, and local agencies have so far blocked them. "There are diagnostic tests that are not environmentally invasive," Bea says. "Our one real option is not to ignore the problem."

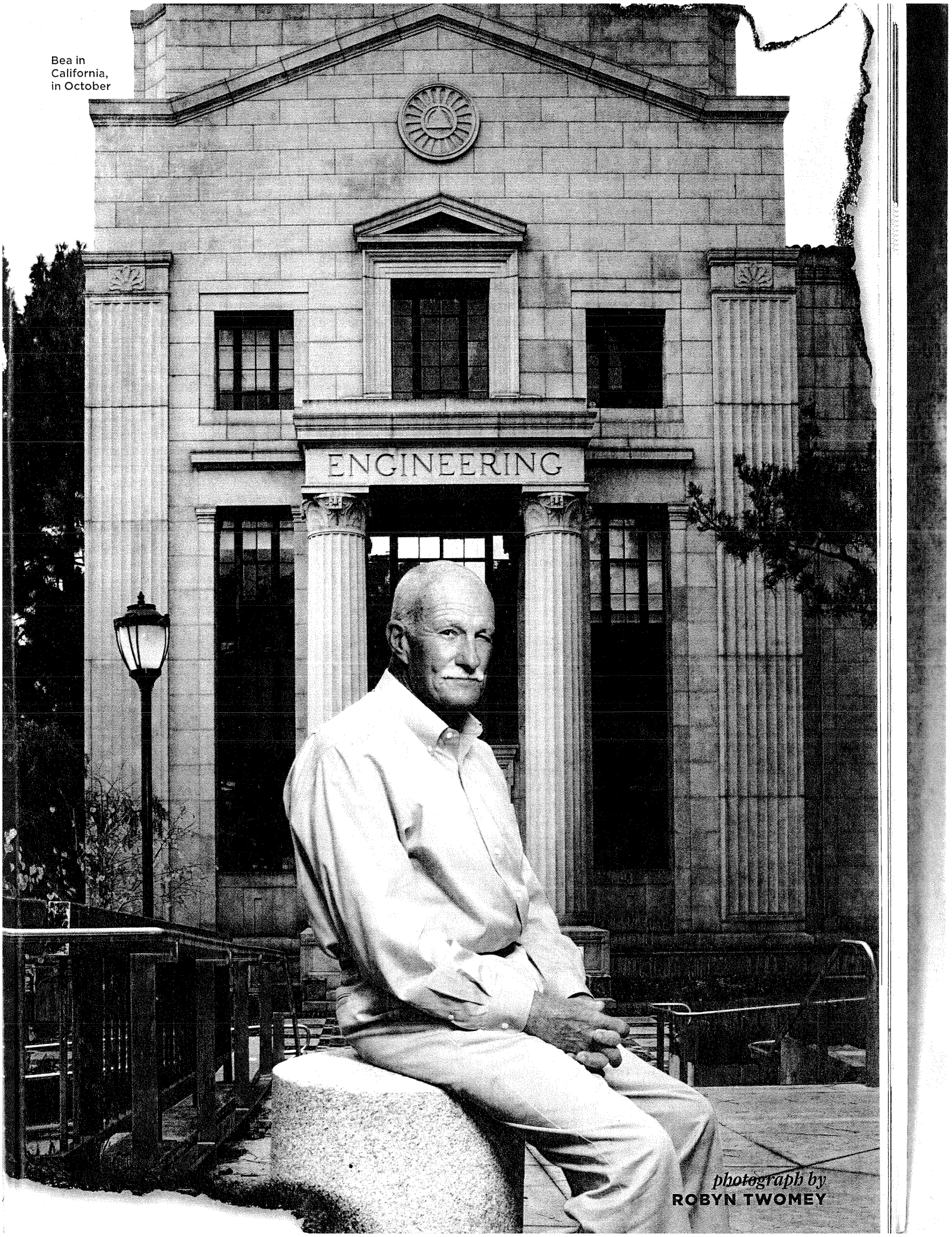
NEW YORK CITY

Bea has called for floodgates to regulate water levels at key sites along the East River and the Narrows tidal strait, where the Atlantic flows into Manhattan. He also recommends high-grade metal barriers — essentially mini-dams — to contain flooding on city streets and the subway. The cost for the floodgates is estimated at $17 billion, but, says Bea, "the greatest threat to New York is to not mobilize."

MIDWESTERN FLOODPLAINS

Mississippi River Basin

Extreme storms have nearly doubled in the basin's seven Midwestern states since 2001. Years of housing construction and other development in the floodplain mean that the barrier that once protected towns and millions of people is largely gone. Bea's solution? HiDro Barriers: five-foot inflatable plastic walls that can withstand a 100-year flood. Short of that, Bea says, head for higher ground. —DARREN REIDY



Bea in California, in October

photograph by
ROBYN TWOMEY