

SPECIAL REPORT

After the flood

Academic experts say they were all too aware of the devastation that would claim New Orleans and its surroundings in the wake of a fierce hurricane. Could they have done any more to convince politicians of the need to protect the city?

Nothing about last week's hurricane and the subsequent flooding of New Orleans should have come as a surprise. Experts knew such a storm would come at some point. They knew the coast's natural defences were degraded; they knew the levees were not designed for anything stronger than a category-3 storm; and they knew that a significant proportion of the population — the poorest and weakest — would not evacuate.

The science was all there, but apparently the planning was not. As the United States reels from one of the worst disasters in its history, scientists are trying to work out why policy-makers were unable to cope when experts knew so much about what was bound to happen.

Public officials criticized for mishandling the emergency have claimed that Katrina was simply too powerful a force to resist. New Orleans hadn't been hit by such a large storm since Hurricane Betsy in 1965 — at category 5, Katrina was still on the highest possible level of the Saffir-Simpson scale mere hours before landfall on the morning of 29 August (see 'The power of Katrina'). Breaches in the city's levee system then turned a bad situation into a catastrophe, flooding an area of more than 400 square kilometres with water from Lake Pontchartrain and trapping tens of thousands of people in a swiftly escalating crisis (see 'Threat of disease').

But the dire consequences of a large hurricane striking New Orleans have been predicted



Hurricane Katrina pounded the Gulf coast with winds of more than 200 kilometres per hour.

for years, precisely because of the risk of flooding (see *Nature* 431, 388; 2004).

It is public knowledge that the sandy barrier islands and marshy bayous that used to protect the Louisiana coast from storms and hurricanes are eroding as dams and levees hold on to the silt that usually rebuilds them. The marshes are disappearing at a rate of more than 60 square kilometres a year. In 1998, a document called *Coast 2050* was drawn up by state officials calling for restoration of the wetlands. However, the full cost of the project is estimated as \$14 billion, and the state has made little progress in persuading

federal government to give it more than a tiny fraction of the request.

It has also long been known that the system of raised levees and floodwalls that keep New Orleans dry are only designed to withstand hurricanes up to category 3. A project looking at upgrading the system is in the works, but after five years it is still in the pre-study phase. To be ready for Katrina, "we would have had to start working on category-5 twenty years ago", says Alfred Naomi, a senior project manager for the Army Corps of Engineers, which maintains the levee system.

A hurricane strike at some point was inevitable, say researchers. And they argue that there was also no excuse for not realizing the potential scale of the disaster.

Rick Luettich of the University of North Carolina in Chapel Hill helped to develop the Advanced Circulation Model that is used by Louisiana State University (LSU) in Baton Rouge and the Army Corps of Engineers. The model has become increasingly accurate at predicting storm surge — a wind-driven rise in sea level — even at small scales. Luettich says

it got the effects of Katrina "about right". Days ahead of the storm's arrival, computer simulations of the expected surge showed that water would probably overflow levees, flooding the city, which lies below sea level.

"It's a valuable tool," Luettich says. "Where we've had less success is in getting people to take it seriously and modify their behaviour based on it."

"Academia tends to be discounted," agrees Ivor van Heerden, director of LSU's Center for the Study of the Public Health Impacts of Hurricanes. "But we called this 100% right."

Politicians were slow to act on warnings from the models and related casualty simulations (see 'Counting the dead'). New Orleans' mayor, Ray Nagin, did not issue a mandatory evacuation order until the day before the hurricane hit — too late for many. An estimated 80% of the city's 470,000 residents evacuated using extra highway lanes that had been opened for the emergency — one of the few parts of the disaster plan that worked well. But that still left roughly 100,000 people in the city.

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THE POWER OF KATRINA

Katrina was the third most intense storm ever to make landfall in the United States, with a central pressure of 918 millibars. The storm affected an area of about the size of Britain, and the maximum storm surge was 10 metres, recorded in Biloxi, Mississippi.

The intensity of the storm is due partly to this year's high sea surface temperatures — in early August the Gulf of Mexico was 2–3 °C warmer than usual for the time of year. That led to perfect conditions for the formation of Katrina, and provided the energy that caused such destruction when the storm hit land. Katrina sucked so much heat from the gulf that water temperatures dropped dramatically after it had passed,

in some regions from 30 °C to 26 °C.

Forecasts don't augur well for the rest of the season. The hurricane risk usually peaks in August and September, and this year has already been exceptional for the number and intensity of storms, according to London-based firm Risk Management Solutions, which models disaster risks for the insurance industry. Sea surface temperatures in the central Atlantic are likely to remain at least 1 °C above normal until October, according to forecasts by the US National Oceanic and Atmospheric Administration and Colorado State University, so the risk of hurricanes is likely to remain high until then.

Quirin Schiermeier



THE AFTERMATH OF HURRICANE KATRINA
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This came as no surprise to LSU sociologists Jeanne Hurlbert and John Beggs. In 2004, their analysis of survey data suggested that 21% of the population would stay in their homes during a hurricane, and that 32% would remain in the area. People in poor health were especially likely to stay, as were those suffering from depression, disabilities and other life stresses — Hurlbert characterizes them as “people who are already not coping”.

Based on these data, Devyani Kar of LSU's Coastal Studies Institute was in the process of mapping New Orleans with a Geographic Information System database that includes variables such as income level and access to transportation, to determine which neighbourhoods were likely to have the most flood victims. Her study was not yet finished by the time Katrina struck.

Even so, there should have been strategies in place to ensure that the most vulnerable populations were evacuated, says Ilan Kelman, an expert on disasters at the National Center for Atmospheric Research in Boulder, Colorado. Public officials should be “entirely proactive” he says, and not rely on news reports to convey

THREAT OF DISEASE

Most of the deaths from Hurricane Katrina will have been caused by drowning — but the danger to those in the area was soon followed by a lack of food, water, shelter and sanitation.

“The immediate need is to provide shelter for all the displaced people,” says Eric Weiss, professor of emergency medicine at Stanford University Medical Center in California. “New Orleans is like the biggest wilderness in the United States right now. We need to get people to adequate shelter so they're not baking in the sun, which predisposes them to dehydration. The second thing they need is drinking water. There's a saying in wilderness medicine that people can live three hours without shelter, three days without water and three weeks without food.”

Experts agree that if people are evacuated quickly, the threat of disease is low. “The most important thing is to get people out,” says Louisiana state epidemiologist Raoult Ratard, speaking from a temporary operations centre in Baton Rouge. “In developed countries, if you get the population into shelters with fairly safe

environmental conditions, they are going to be OK.”

But by the end of last week, conditions were looking less and less like those of a developed country. Up to 20,000 people were trapped in hellish surroundings at the Superdome in New Orleans for a full five days after the flood waters rose, before being evacuated to other shelters. Speaking on 2 September, Ratard said that there were no reports of major disease outbreaks, but added that no surveillance officials had yet entered the Superdome or the flooded city.

Dead bodies are not thought to pose a large disease risk. Typhoid and cholera are also unlikely to be major threats, because the organisms that cause them are not endemic in New Orleans water. But there will be a major risk from diarrhoeal diseases, respiratory-tract infections and mosquito-borne illnesses, especially West Nile virus. The hurricane has temporarily cleared away the birds and mosquitoes that carry the virus, but Ratard warns that the virus could surge back in the weeks to come.

Erika Check

COUNTING THE DEAD

As rescue operations continue in New Orleans, a grim question looms: how many lives will Hurricane Katrina ultimately claim?

When federal and state agencies conducted an exercise called Hurricane Pam in July 2004, IEM, the Baton Rouge contractor that developed the hurricane disaster plan for New Orleans, estimated that 60,000 people would die in southeastern Louisiana alone. The initial estimate was 80,000, but Louisiana State University researchers say this figure met with such scepticism from government emergency planners that it was reduced.

The similarities between Katrina and the Pam simulation are "eerie", says IEM president Madhu Beriwal. In both cases, water flows over

or through the protective levees, flooding parts of the city with up to 7 metres of water. In both cases, drowning is the leading cause of death, depending greatly on the depth of the water.

Ezra Boyd, who models such emergencies at Louisiana State University, used data from past hurricanes to estimate the number of deaths that would be caused by a category-3 storm with a 5-metre storm surge. He came up with a similar number: 72,000 deaths in the greater New Orleans area alone.

Neither estimate includes the more than 350,000 people who live in the coastal Mississippi counties. These areas were not inundated like New Orleans, but experienced higher winds than the city and greater storm

surges — more than 8 metres in places. If 30% of the population stayed behind, more than 100,000 people may have suffered Katrina's fury.

A general rule of thumb, according to Han Vrijling of Delft University of Technology in the Netherlands, is that fatalities from flooding can amount to 1% of the affected population. Even that conservative estimate could yield as many as 5,000 deaths from Katrina.

As *Nature* went to press, workers had no death-toll estimates. But the researchers caution that casualties are highly dependent on the individual circumstances. Besides, says Beriwal, "it hasn't finished happening. We are still trying to save lives." **Tony Reichhardt**

information. Warnings should be tailored to people of diverse backgrounds. "It means setting up a website, and it means talking one-on-one with a homeless person on the street," he says. And for those who remain to ride out a hurricane, emergency supplies should be pre-positioned, to speed up rescue operations after the storm passes.

State of unreadiness

David Ozonoff, an environmental epidemiologist at Boston University in Massachusetts, agrees that there is no excuse for New Orleans' refuges being so poorly set up for survivors. "This should have been anticipated," he says. "People moving is not an unknown and unsolved problem. It can be very difficult, but if you've thought it out ahead of time you should be prepared."

Ozonoff believes part of the problem is that after the terrorist attacks of 11 September 2001 a shift in federal priorities crippled the US public-health and disaster-response agencies. The US Federal Emergency Management Agency was taken under the umbrella of the Department of Homeland Security, which is supposed to coordinate local and national responses to all kinds of disasters. The hope was that efforts to prepare for terrorist attacks would improve preparations for natural disasters; Ozonoff argues that the response to Katrina proves the approach wrong. "If there was ever an episode — other than a bioterrorist attack — that should have demonstrated that money put into public-health preparedness

is effective, then this was it," he says.

He criticizes the Department of Homeland Security for focusing on expensive gear to deal with unlikely bioterrorist attacks instead of on the less dramatic but crucial task of coordinating responses to more realistic scenarios. "The whole bioterrorism prevention effort has brought nothing in the way of preparation, and has left public-health departments in much worse shape than before they got the money," he asserts.

Others say scientists should take part of the responsibility. "Folks have talked about this scenario for decades, yet I've watched George Bush senior and Bill Clinton both comment that no one could have anticipated this sort of event," says Roger Pielke, director of the Center for Science and Technology Policy Research at the University of Colorado, Boulder. "That raises some real questions for the academic and scholarly community. What does it mean if scholars are aware of something with practical importance, but it doesn't get to the people who can take action?"

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Studies predicted that 32% of residents would fail to leave New Orleans.

Pielke argues that scientists need to move away from a 'loading dock' approach where they simply put out raw information for anyone who wants to use it. Instead they should tailor their research to practical needs, he says. "There's a real challenge of making knowledge useful. It is not something that the academic community is engaged in as a matter of policy."

His plea is echoed by van Heerden: "Academia gives more credit for journal publications than for helping a hospital prepare for a crisis."

Getting hands on

"Universities aren't particularly well organized to support applied research," adds Pielke, "but events like Katrina and research that languishes in journals should motivate policy-makers to demand more from the scientific community." Pielke concedes that attitudes within the scientific community are beginning to change, with agencies such as the National Science Foundation supporting some practical work: "There's a trend in the right direction."

But for researchers already carrying out such applied projects, the mood is one of frustra-

tion. LSU's Nedra Korevec, for example, has studied the scenario of a category-4 storm striking New Orleans. She managed to convince many of her family and friends to move in with her in Baton Rouge before the hurricane hit, and is now housing ten people. "I knew from the models we ran and the work I'd done how bad it was going to be," she says. "We do the research and we try to make things happen, but then we have to hand the ball to delegations and lobbyists." ■

Tony Reichhardt, Erika Check and Emma Marris