

two kilometers on all lines. A slight decrease in middle and lower crustal seismic velocities trenchward probably indicates fracturing and possibly crustal hydration due to plate bending. Seismic velocities in the oceanic upper mantle systematically increase with plate age, though on corridor 2 they locally decrease trenchward, perhaps due to serpentinized mantle rocks [Ranero and Sallares, 2004].

In conclusion, the lithospheric structures of both incoming and overlying plates appear relatively homogeneous along the Chile margin, despite the strong difference in age. Moreover, homogeneity also appears in the distribution of the incoming sediments (trench fill ~2 kilometers in the TIPTEQ area). One may speculate that the reason for the 1960 great Chile earthquake to rupture right through all age segments was because the structures in this region are so remarkably similar.

The information gained through the TIPTEQ project will help to further characterize the earthquake hazard for this area, and will provide a framework to study other subduction zone areas. More information about TIPTEQ can be found at: <http://www.gfz-potsdam.de/pb3/pb31/tipteq>

### Acknowledgments

We gratefully acknowledge Captains Martin Kull and Lutz Mallon and the officers and crew of R/V *Sonne* for a successful data acquisition. The University of Hamburg, Germany, provided part of the ocean bottom instrumentation. This is publication GEOTECH-210 of the Research and Development Programme GEOTECHNOLOGIEN funded by the German Ministry of Education and Research and German Research Foundation, grants 03G0594E and 03G0181A. TIPTEQ Scientific Party leaders on cruise SO181 were E. Flueh (IFM-GEOMAR, Kiel, Germany), I. Grevemeyer (IFM-GEOMAR), J. Behrmann (University of Freiburg, now at IFM-GEOMAR), H. Brasse (Free University of Berlin, Germany), T. Dahm (University of Hamburg, Germany), A. Kopf (RCOM, Bremen, Germany), E. Vera (Universidad de Chile, Santiago), and H. Villinger (University of Bremen, Germany).

### References

Bourgeois, J., C. Guivel, Y. Lagabrielle, T. Calmus, J. Boulègue, and V. Daux (2000), Glacial-interglacial trench supply variation, spreading-ridge subduction, and feedback controls on the Andean margin

development at the Chile triple junction area (45°–48°S), *J. Geophys. Res.*, 105(B4), 8355–8386.  
 Krawczyk, C., et al. (2003), Amphibious seismic survey images plate interface at 1960 Chile earthquake, *Eos Trans. AGU*, 84(32), 301, 304–305.  
 Ranero, C. R., and V. Sallares (2004), Geophysical evidence for hydration of the crust and mantle of the Nazca plate during bending at the north Chile trench, *Geology*, 32(7), 549–552.  
 Rietbrock, A., C. Haberland, K. Bataille, T. Dahm, and O. Oncken (2005), Studying the seismogenic coupling zone with a passive seismic array, *Eos Trans. AGU*, 86(32), 293, 297.  
 Tebbens, S. F., S. C. Cande, L. Kovacs, J. C. Parra, J. L. LaBrecque, and H. Vergara (1997), The Chile ridge: A tectonic framework, *J. Geophys. Res.*, 102(B6), 12,035–12,059.

### Author information

Martin Scherwath, Ernst Flueh, and Ingo Grevemeyer, Leibniz-Institute of Marine Sciences, IFM-GEOMAR, Kiel, Germany; Frederik Tilmann, Bullard Laboratories, Department of Earth Sciences, University of Cambridge, Cambridge, U.K.; and Eduardo Contreras-Reyes and Wilhelm Weinrebe, Leibniz-Institute of Marine Sciences, IFM-GEOMAR; E-mail: [mscherwath@ifm-geomar.de](mailto:mscherwath@ifm-geomar.de)

## Creating Effective Flood Mitigation Policies

PAGES 265, 270

Hurricane Katrina in 2005 increased awareness of the vulnerability of people and property in flood-prone areas of the United States, particularly repetitively flooded properties. Prior to Katrina, repetitive loss properties cost the United States over \$200 million annually [General Accounting Office (GAO), 2004].

The U.S. Congress passed the Bunning-Bereuter-Blumenauer Flood Insurance Reform Act of 2004 (FIRA) to maintain the fiscal soundness of the National Flood Insurance Program (NFIP) and ease the burden of repetitive loss properties on NFIP. Federal calculations indicate that every dollar spent on mitigation activities creates a \$3.65 savings in future disaster recovery costs, and the U.S. Federal Emergency Management Agency (FEMA) estimates that over \$1 billion are spared annually through flood mitigation and floodplain management programs [GAO, 2005a].

Despite the availability of existing flood mitigation programs, many property owners decline mitigation offers, increasing potential future costs and their own personal vulnerability.

Since the success of flood mitigation programs such as FIRA depend on large-scale voluntary participation, it is important to understand the drivers of human decision-

making at the household level, and embed this analysis in an examination of the realities of actual mitigation policy implementation. An ongoing study being conducted by the University of North Carolina has been focusing on this issue of why some repetitive loss property owners accept offers of mitigation while others make the decision to decline such offers. Results to date show that individual participation in mitigation activities hinges in part on the availability of nonfederal matching funds, building local

capacity to sustain mitigation programs, creating an efficient and effective project application and review process, and the development of effective relationships between mitigation officials and local communities. While program adjustments may be made at each level of government, an overall conclusion from the study is that a community-based approach toward program implementation is needed to develop sustainable mitigation initiatives across the United States.

### Flood Mitigation Programs and Repetitive Loss Properties

Of all natural hazards, flooding causes the greatest economic losses and loss of life within the United States, and 90% of all natural disasters in the United States include flood events

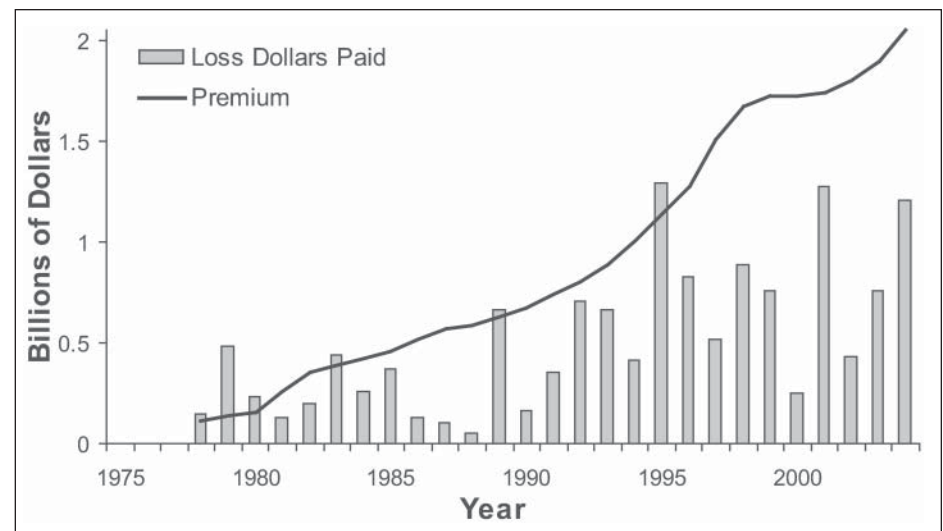


Fig. 1. Annual National Flood Insurance Program dollars paid and annual NFIP premiums. Source: FEMA [2004b].

[GAO, 2005a]. Current figures prior to Hurricane Katrina indicate that flooding causes \$1 billion in property damage annually within the United States (Figure 1) [FEMA, 2004a; GAO, 2004]. Such damages are likely to increase due to elevated hurricane frequency and intensity related to climate change [Webster *et al.*, 2005]. FEMA statistics indicate the federal impact of Hurricane Katrina alone has been \$4.2 billion spent on financial and housing aid and \$8.3 billion paid out for NFIP claims. This is in addition to the tragic loss of approximately 1300 lives.

There are about 4.4 million NFIP policyholders located across 20,000 communities nationwide [GAO, 2004]. The NFIP typically provides the only flood insurance available, since private companies are unwilling to bear such risk. Approximately 49,000 NFIP properties are repetitive loss properties, i.e., have incurred two or more flood losses within a 10-year period and have received insurance payments of at least \$1000 for each claim [GAO, 2004]. These repetitive loss properties compose roughly 1% of NFIP-insured properties, but they result in 25–30% of claim losses. These properties have resulted in claim payments totaling \$4.6 billion from 1978 through 2004, and yet they only pay about 35–40% of the true actuarial cost of insurance due to government subsidies [GAO, 2005b]. Many of the heavily subsidized repetitive loss properties were built prior to floodplain maps delineating high-risk areas and are essentially the Achilles' heel of the NFIP.

Flood mitigation projects, such as elevating, flood-proofing, or property buyouts, present the primary mechanisms for ensuring the long-term fiscal sustainability of NFIP. Since the early 1990s, mitigation has become the preferred approach to reducing losses associated with flooding. Three federal grant programs support hazard mitigation: the Flood Mitigation Assistance Program, the Pre-Disaster Mitigation Program, and the Hazard Mitigation Grant Program (Table 1). For all three programs, the federal government funds 75% of project costs but requires a 25% nonfederal match. While some states provide the match, others require the homeowner to finance these costs. These mitigation programs are strongly driven by decisions made at state and local levels, and ultimately depend on the individual property owners' voluntary participation.

Despite the availability of federal mitigation assistance for property owners, many individuals and communities remain in harm's way. This prompted Congress to pass FIRA, which will provide mitigation funds to a targeted list of severe repetitive loss properties. Under FIRA, refusals of mitigation will result in higher flood insurance premiums for property owners, as an incentive to motivate participation in mitigation programs.

#### *Important Factors for Successful Mitigation*

In this study, household surveys were conducted in eight targeted repetitive loss sites, and interviews were conducted with property owners who were offered financial mitigation

<i>Federal Program</i>	<i>Created</i>	<i>Funding</i>	<i>Description</i>
Hazard Mitigation Grant Program (HMGP)	1988	\$1.7 billion from 1990 through 2000	Enable long-term reduction in the threat of all hazards; funds granted after a disaster to spur immediate recovery
Flood Mitigation Assistance (FMA) Program	1994	\$20 million per year <sup>b</sup>	Reduce losses to NFIP-insured properties by providing planning, projects, and technical assistance for flood-related projects
Pre-Disaster Mitigation Program (PDM)	2000	\$255 million from 2003 to 2005	Provide funds for all hazard mitigation projects, not only flood hazards
Flood Insurance Reform Act (FIRA)	2004	\$300 million from 2004 to 2009	Mitigate targeted repetitive loss properties

<sup>a</sup>Sources: *U.S. Congress* [2000]; *FEMA* [2006]; *FEMA* [2004a]; *Congressional Budget Office* [2004].

<sup>b</sup>The funding allocated for the FMA program has rarely, if ever, been totally utilized.

assistance through various federal grant programs (Felton Grove, Calif.; Sacramento, Calif.; Savannah, Ga.; Saint Tammany Parish, La.; Jefferson Parish, La.; Beaufort County, N.C.; Washington, N.C.; and Belhaven, N.C.; for details see *Fraser et al.* [2006]). These surveys were used in a logistic regression to identify factors influencing mitigation acceptance. In addition, 41 mitigation officials from local, state, and federal governments were interviewed during site visits to understand the policy context surrounding homeowner decisions.

Program funding was the most significant factor determining property owner participation in mitigation programs. When the local or state government provided the 25% non-federal match, repetitive loss households were 6.5 times more likely to accept an offer of mitigation. Further, when provided with matching funds, low-income (<\$20,000) and middle-income (\$20,000–60,000) property owners accepted mitigation offers 12.1 and 2.6 times more frequently than high-income (>\$60,000) property owners.

The ability of local mitigation officials to guide property owners through the mitigation process also affected program participation. Repetitive loss property owners were 5.2 times more likely to accept mitigation offers when they felt the mitigation official was helpful, which was related to the ability of the official to present offers through a consistent and efficient process. State and local officials expressed the need for a more flexible and streamlined application approval process. The complex and time-consuming review process removes autonomy from the local level, and it inhibits officials from designing site-specific solutions as new information becomes available or the situation changes.

Further, virtually all local/state mitigation officials stated that the current program structure favors using funds to contract with private consultants as administrators of mitigation projects rather than building local capacity (i.e., locally based personnel who conduct outreach and implementation of mitigation offers) to manage mitigation projects with those same funds. This increased reliance on private-sector consultants hinders the ability to create sustainable mitigation programs with institutional memory, commitment to the local community, and

accountability to citizens. Maintaining consistent policy interpretation and program continuity between flooding events requires institutional memory, which can be limited when external consultants are the primary program administrators.

Regardless of funding availability and programmatic structures, decisions regarding one's home can be emotionally driven. Property owners' sense of place was a significant variable that shaped the willingness to accept an offer of mitigation. As homeowner concern over leaving a neighborhood increased, the likelihood of accepting an offer of mitigation decreased substantially. Also, as homeowners' self-appraisal of property condition increased, the likelihood of accepting an offer of mitigation decreased. Therefore, personal attachment to both home and community influence the efficacy of federal mitigation policy implementation. These results imply that federal policies must acknowledge the importance of sense of place in mitigation implementation. Local officials noted that working with neighborhood and community-based organizations was one of the most effective strategies for building partnerships, notably by giving the mitigation official legitimacy within the community, and by providing the community with an outlet for their collective concerns. These officials suggested that FEMA could provide programmatic support for increased efforts at explicitly using a community-based approach toward mitigation efforts.

#### *Building a Stronger Mitigation Program*

For the implementation of the pilot program created by FIRA, FEMA will need to carefully consider which elements of mitigation programs effectively encourage property owner participation. First, the most substantial gains in terms of mitigating flooding will be achieved by alleviating some or all of the need for the 25% matching funds. This will be particularly true for low- and middle-income property owners; providing matching funds may not influence high-income property owner decisions. Second, FEMA should emphasize flexible and streamlined applications and project modification procedures to allow

time-sensitive and site-specific decisions. Third, FEMA should support incentives to build local capacity in flood hazard management whenever possible. Finally, FEMA should support and increase the role of community-based organizations in mitigation. This is crucial in the wake of Hurricane Katrina as FEMA attempts to play a role in conducting post-disaster mitigation activities in the disadvantaged neighborhoods of New Orleans, La.

The FIRA pilot program potentially will reduce the financial risk that repetitive loss properties impose on the NFIP, and partially reduce the vulnerability of people living in floodplains. Previous mitigation programs have been successful in reducing flood hazards; more than 29,000 properties were mitigated from October 1989 to July 2003, at a cost of approximately \$2 billion [GAO, 2004], creating substantial savings in future disaster recovery costs. However, because mitigation program success rests on individual property owners' decisions, administrators and policy makers increasingly must consider the factors that affect individuals' decisions of whether or not to accept a mitigation offer,

and how existing policies and practices can be structured and executed in ways that will maximize their efficacy.

#### Acknowledgments

This paper is based on research funded by FEMA through a contract with the URS Corporation.

#### References

- Congressional Budget Office (2004), Cost estimate: S. 2238 Flood Insurance Reform Act of 2004, Washington, D.C.
- Federal Emergency Management Agency (2004a), National Flood Insurance Program policy and claim statistics, Washington, D.C. (Available at <http://www.fema.gov/nfip/statscal.shtml>)
- Federal Emergency Management Agency (2004b), FY 2004 flood mitigation assistance guidance, Washington, D.C. (Available at [http://www.fema.gov/doc/fima/fy2004\\_fma\\_guidance.doc](http://www.fema.gov/doc/fima/fy2004_fma_guidance.doc))
- Federal Emergency Management Agency (2006), Pre-Disaster Mitigation (PDM) Grant Program, Washington, D.C. (Available at <http://www.fema.gov/fima/pdm.shtml#fy2006>)
- Fraser, J.C., D. DeVries, and H. Young (2006), Mitigating repetitive loss properties: Final report for Federal Emergency Management Agency, Washington, D.C.

- General Accounting Office (2004), National Flood Insurance Program: Actions to address repetitive loss properties, *GAO Rep. GAO-04-4017*, Washington, D.C.
- General Accounting Office (2005a), Challenges facing the National Flood Insurance Program, *GAO Rep. GAO-06-1747*, Washington, D.C.
- General Accounting Office (2005b), National Flood Insurance Program: Oversight of policy issuance and claim, *GAO Rep. GAO-05-532T*, Washington, D.C.
- U.S. Congress (2000), Hearings before the Subcommittee on Oversight, Investigations, and Emergency Management on the cost effectiveness of hazard mitigation spending, 106th Congress, 2nd Session, 20 July. (Available at <http://www.house.gov/transportation/pbed/hearing/07-20-00/07-20-00memo.html#EXHIBITS>)
- Webster, P.J., G. J. Holland, J. A. Curry, and H.-R. Chang (2005), Changes in tropical cyclone number, duration and intensity in a warming environment, *Science*, 309, 1844–1846.

#### Author information

James C. Fraser, Department of Geography and Center for Urban and Regional Studies, University of North Carolina at Chapel Hill, E-mail: [pavement@unc.edu](mailto:pavement@unc.edu); Martin W. Doyle, Department of Geography, University of North Carolina at Chapel Hill; and Hannah Young, Center for Urban and Regional Studies, University of North Carolina

# NEWS

## Climate Warmer Than in Past 400 Years, Panel Confirms

PAGE 266

The Earth's climate in the late twentieth century was the warmest in at least the last 400 years and likely the warmest in the last millennium, a U.S. National Research Council (NRC) panel confirmed in a 22 June report.

"The committee finds it plausible that the Northern Hemisphere was warmer during the last few decades of the twentieth century than during any comparable time during the previous millennium," said panel chair Gerald North, a geoscientist at Texas A&M University, College Station.

The U.S. Congress requested the report after controversy arose over a 1998 *Nature* article by Pennsylvania State University climatologist Michael Mann and colleagues that concluded

that the 1990s were the warmest decade and 1998 the warmest year in the Northern Hemisphere in the past 1000 years. The paper also presented the 'hockey-stick' curve that has since been widely used to illustrate rising temperatures.

The NRC panel assessed the instrumental evidence of temperature from the past 150 years, and proxy evidence of temperature—such as corals, ocean and lake sediments, ice cores, and cave deposits—over the past 2000 years. They found that the conclusions of the Mann study are "essentially valid" for the last 400 years, but the evidence from further in the past is more "murky," said panel member Kurt Cuffey, a professor of geography at the University of California, Berkeley.

The panel placed a high level of confidence in temperature reconstructions of the past 400 years but less confidence in the data from 1600 to 900 A.D., and very little confidence in the data beyond that. The panel's uncertainty in the data from further in the past was due to factors such as the scarcity of precisely dated proxy data for those time periods, the fact that proxies are influenced by factors other than temperature, and difficulties in calibration of the proxy data.

However, Cuffey said, "this information is certainly consistent with the prevailing view that our climate is warming due to human influence and will continue to do so in the future."

The panel recommended that future temperature reconstructions would benefit from updating of proxy records collected decades ago, new analytical methods, and large-scale reconstructions of complementary data, such as precipitation.

—SARAH ZIELINSKI, Staff Writer