THE NATIONAL ACADEMIES
REPORT IN BRIEF

Mapping the Zone
Improving Flood Map Accuracy

Flooding is a leading cause of natural disaster in the United States. High-quality, digital mapping is essential to communicating flood hazards to those at risk, setting appropriate insurance rates, and regulating development in flood-prone areas. The Federal Emergency Management Agency (FEMA) recently generated digital flood maps for most of the U.S. population. However, FEMA has a long way to go to generate high-quality flood maps for those populations most at risk of flooding. Although this effort will require significant investments, the benefits of improving the accuracy of flood maps outweigh the costs, even when the most expensive aspects of map improvement are taken into account.

Watching as floodwaters inundate one's house seems like a homeowner's worst nightmare. But being caught unprepared—and uninsured—is worse. Flooding caused approximately $50 billion in property damage in the 1990s alone and accounts for more than two-thirds of federal natural disasters.

The key to anticipating, preparing for, and insuring against flooding is summed up in one word—maps. Flood maps use topography (information about the three-dimensional properties of land surfaces) and hydrology (information about the behavior and properties of water) to predict where water is likely to flow in a flood. Until just a few years ago, the available flood maps in most areas of the United States were outdated and printed on paper. From 2003-2008, FEMA engaged in a large-scale effort to collect new flood data in unmapped areas, update existing data, and digitize flood maps. The federal government invested about $1 billion in the Map Modernization Program; considerable funds were also provided by state governments and local community partners.


In 2008, flooding in downtown Cedar Rapids, Iowa inundated about 100 city blocks. SOURCE: Stephen Mally, used with permission.

But making accurate flood maps is complex and expensive. Although 92 percent of the continental U.S. population now has digital flood maps, only 21 percent has maps that fully meet FEMA's data quality standards. At the request of FEMA and the National Oceanic and Atmospheric Administration, the National Research Council convened a committee to examine the factors that affect the quality and accuracy of flood maps, assess the costs and benefits of map improvement efforts, and recommend ways to improve flood mapping, communication, and management of flood-related data. The resulting report concludes that even the most expensive aspect of making more accurate maps—collecting high-accuracy, high-resolution topographic data—yields more benefits than costs, and that, to complete the goals of its Map Modernization Program, FEMA should invest in updating and improving its flood maps.

Good Maps Are Essential

Flood maps are used for many purposes. FEMA's Flood Insurance Rate Maps—the primary type of flood maps in the United States—influence flood insurance rates, development regulations, and flood preparation for those at risk. Government

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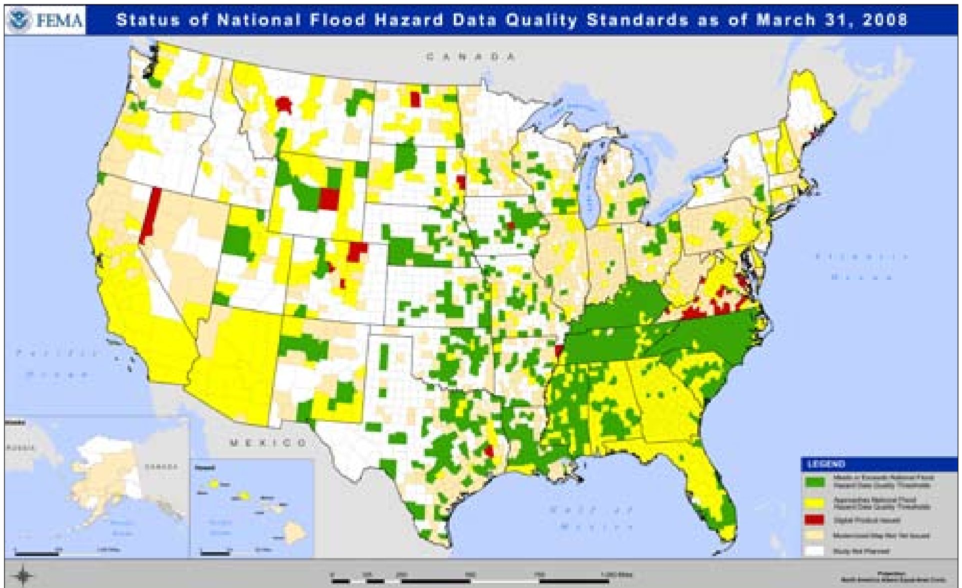
officials use them to establish zoning and building standards, to support infrastructure and transportation planning, and to prepare for and respond to floods. Insurance companies, lenders, realtors, and property owners depend on these maps to determine flood insurance needs.

Major outcomes of FEMA's Map Modernization Program included digital flood maps to replace paper flood maps, and new high quality maps for many areas. These accomplishments have improved the quality of flood hazard information available to the public. However, the job is not done. In some cases, paper maps have merely been converted to digital representations, adding only minimal value. Furthermore, even when floodplains are mapped with higher accuracy, maps must be continually maintained and updated to reflect natural and development-related changes.



Despite a large-scale effort that produced digitized flood maps for most of the United States, maps in most areas fall short of FEMA's data quality standards. On this map, only the green counties have maps that meet or exceed national flood hazard data quality thresholds. SOURCE: Paul Rooney, FEMA.

Current Maps Have Significant Uncertainties

Many flood maps are plagued with uncertainty. A study of sampling uncertainties in North Carolina and Florida found that base flood elevations (the elevation floodwater is expected to reach or exceed during a 100-year flood) cannot be estimated more accurately than about one foot. A one-foot difference in flood elevation was shown to correspond to a horizontal uncertainty in the floodplain boundary of 8 feet in the mountains, 10 feet in the rolling hills, and 40 feet in the coastal plain of North Carolina.

The United States Geological Survey's (USGS) National Elevation Dataset—a primary data source FEMA uses to produce flood maps—has a level of uncertainty about 10 times larger than what FEMA defines as acceptable for floodplain mapping. Alternative sources of topographic data exist, but they are not available nationwide. One alternative that meets FEMA's data standards is lidar, a remote sensing method that collects high-resolution data. A comparison of lidar data and the National Elevation Dataset around three North Carolina streams revealed computed elevation differences of about 12 feet, greatly exceeding FEMA's stated error tolerances. A discrepancy of 21 feet was found at one stream, in part because one method located the stream using digital orthophotography, which is being updated nationally more rapidly than the underlying elevation data, causing misalignment between these two basic data sources.

Floodplains are low-lying, relatively flat areas adjoining inland and coastal waters. Generally, two levels of flood hazard are designated when mapping floodplains: 1-percent-annual-chance flood (also known as the 100-year flood) areas and 0.2-percent-annual-chance flood (also known as the 500-year flood) areas. Areas in which flood hazards are minimal but still possible may also be mapped.

The Path Toward Improved Flood Maps

New technologies offer the opportunity to vastly improve the accuracy of digital flood maps. The report concludes that improving flood maps is economically and socially justified. Below are some key considerations for development of more accurate flood maps.

High-Quality Topographic Data Is Key

Topographic data is the most important factor in determining the accuracy of flood maps. High-quality topographic data offer insights on water surface elevations, the expected extent of flooding, and base flood elevation. The report recommends that FEMA expand its coordination and collaboration with USGS and state and local government agencies to acquire high-resolution, high-accuracy topographic data around the country. High-resolution lidar data can be used to calculate more accurate base flood elevations and delineate floodplain boundaries to reduce future flood losses, benefitting taxpayers throughout the nation. FEMA has recently begun to support collection of lidar data along the Gulf Coast, but lidar data coverage over most inland areas is still sparse.

Base Flood Elevations Are Worth the Cost

A cost-benefit analysis reveals that flood maps with base flood elevations yield greater net benefits than flood maps without. All of FEMA's flood study methods yield a floodplain boundary, but only the more expensive also yield a reliable base flood elevation. Producing an accurate base flood elevation yields the greatest increment of benefits because it enables insurance premiums and building restrictions to be set based on a more realistic profile of where water will flow in the event of a flood.

A comparison of study methods in different areas in North Carolina revealed that generating base flood elevations results in net benefits to the state. In contrast, approximate study methods, which do not yield base flood elevations, results in net costs. Even though the lidar surveys used to generate base flood elevations were expensive, the costs were outweighed by the benefits of more accurate maps. Because accurate flood maps should deter development in flood-prone areas, there are additional long-term benefits from preventing damage to future development that might otherwise spread into floodplain areas.

Unique Needs for Coastal Flood Mapping

The science of flood mapping for rivers and other inland waterways is well established, and the technology is available to improve these maps. Flooding in coastal areas, on the other hand, is influenced by many complex dynamics, some of which are not yet well understood. Coastal floods present hazards beyond inundation—for example, buildings can be damaged by wave action and by erosion of their foundations.

Coastal flood models are evolving rapidly, and continued refinement of these models can significantly improve coastal flood mapping. The report concludes that a comparison of available models, conducted by an independent external advisory group, would help quantify uncertainties and indicate which models should be incorporated into mapping practice. A goal is to replace one-dimensional models with two-dimensional models of waves, storm surge, and erosion and other processes. Improvements in bathymetric (underwater topographic data) and post-storm topographic data would also improve coastal flood map accuracy.

Guidelines Needed for Ponded Landscapes

Ponded areas are unique in the ways water flows from pond to pond through shallow flooding, and methods to map flooding in ponded landscapes are still being developed. The primary hurdle to progress is the lack of scientific studies and models on the interactions between ponds, the volume of water that is temporarily stored in depressions, and the rate at which water percolates out of these depressions. FEMA should commission a scientific review of the hydrology and hydraulics needed to produce guidelines for flood mapping in ponded landscapes.

Database Linkage Needs

FEMA's Map Modernization Program produced a large amount of geospatial data and models that represent the most comprehensive digital description of the nation's streams and rivers ever undertaken. However, these data are stored on a county by county basis and there is no requirement that map information be consistent from one county to the next. Another enormous data collection is the USGS National Hydrography Dataset, a seamless, connected map of the nation's streams, rivers, and coastlines. It is feasible to link FEMA's data with the National Hydrography

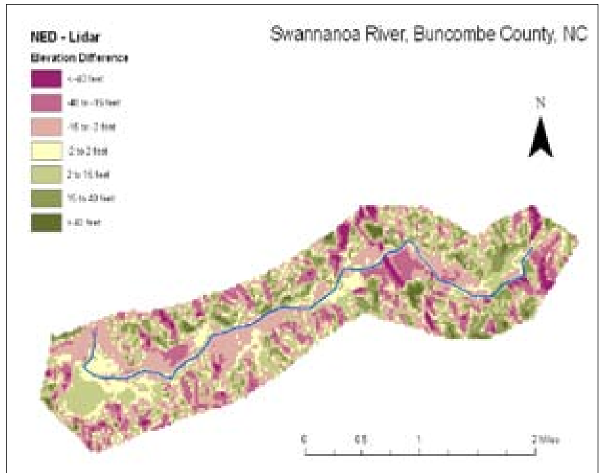
Color coded map of flood water surface elevation using lidar in Iowa City, Iowa. High-resolution lidar data can be used to calculate more accurate base flood elevations and delineate floodplain boundaries to reduce future flood losses. Ellipsoid height is a measure of elevation. SOURCE: Courtesy of Ramesh Shrestha, University of Florida, and Witold Krajewski, IIHR-Hydroscience and Engineering, used with permission.

Dataset using a technique called linear referencing. This linkage would enable FEMA flood data to be accessed as an integral part of the nation's hydrologic information infrastructure.

Communication of Flood Risk

Flood hazard is not the same as flood risk. Most flood maps express only flood hazard—that is, the places where flooding is possible. Many do not currently reflect flood risk—the probability that a flood will actually occur in a given area, that flood prevention systems will perform as designed, and the consequences of flooding. FEMA is moving from simply portraying flood hazard and flood insurance rate zones to communicating and assessing risk, an ambitious goal that could greatly improve the utility of FEMA's flood maps for governments, business, and the public.

To communicate risk, maps must show not only where flood hazard areas are located, but also the likely consequences of flooding (e.g., damage to houses, coastal erosion). Maps that show only floodplain boundaries imply that every building in a flood zone may flood and that every building outside the zone is safe. Providing the elevation of structures relative to the expected height of flood waters offers a better way to discriminate true risk. Where data are available, a geographic information system could be used to personalize flood risk to individual addresses. The variety of map products that can be produced and the availability of Web tools to provide personalized information to floodplain occupants can help inform decisions that ultimately reduce national flood risk.



Elevation differences between the USGS National Elevation Dataset and lidar data, Swannanoa River, North Carolina. Areas in red and pink are lower than appear on FEMA flood maps and suggest that the floodplain extends further than expected. SOURCE: Courtesy of T. Langan, North Carolina Floodplain Mapping Program, used with permission.

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The National Academies appointed the above committee of experts to address the specific task requested by the Federal Emergency Management Agency's Risk Analysis Division and the National Oceanic and Atmospheric Administration's Coastal Services Center. The members volunteered their time for this activity; their report is peer-reviewed and the final product signed off by both the committee members and the National Academies. This report brief was prepared by the National Research Council based on the committee's report.

For more information or copies, contact the Board on Earth Sciences and Resources at (202) 334-2744 or visit http://nationalacademies.org/besr, or see the Water Science and Technology Board at http://nationalacademies.org/wstb. Copies of *Mapping the Zone: Improving Flood Map Accuracy* are available from the National Academies Press, 500 Fifth Street, NW, Washington, D.C. 20001; (800) 624-6242; www.nap.edu.