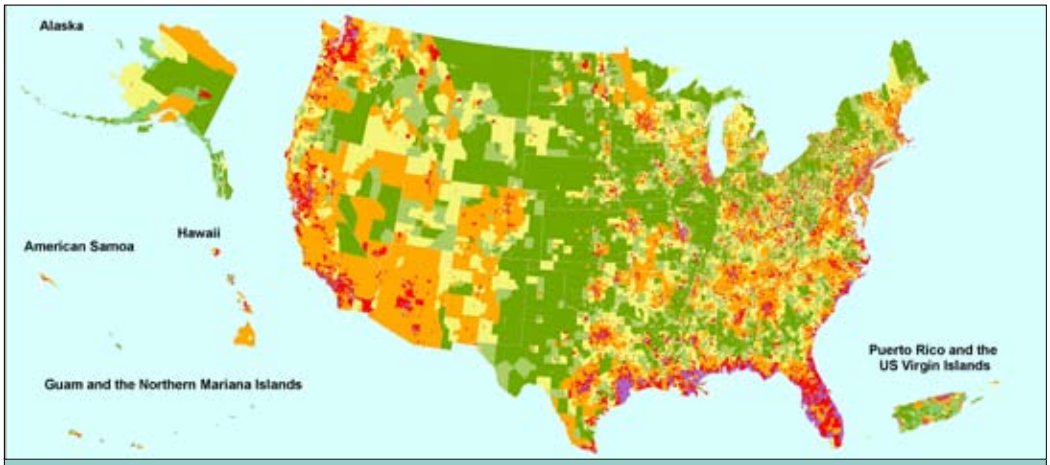
THE NATIONAL ACADEMIES
REPORT IN BRIEF

Elevation Data for Floodplain Mapping

Floodplain maps serve as the basis for determining whether homes or buildings require flood insurance under the National Flood Insurance Program run by the Federal Emergency Management Agency (FEMA). Under a funded mandate from Congress, FEMA is modernizing floodplain maps to better serve the program. To do so, however, FEMA needs land surface elevation data that are about ten times more accurate than data currently available for most of the nation. New, high-accuracy digital elevation data should be collected nationwide using laser measurements from aircraft (lidar technology). The new data should be input into the National Elevation Dataset that the U.S. Geological Survey maintains for use in support of flood map modernization and other applications.

The creation of floodplain maps is a fundamental part of FEMA's National Flood Insurance Program. Floodplain maps define flood hazard zones and determine whether flood insurance is required for homes or buildings located near streams and rivers. Approximately $650 billion in insured assets are now covered under the program. FEMA, in collaboration with state and local partners is undertaking an ambitious five-year program to replace existing paper Flood Insurance Rate Maps (FIRMs) with more accurate Digital Flood Insurance Rate Maps (DFIRMs). The effort is supported with Congressionally appropriated funds of more than $200 million per year. However, some concerns have been raised to Congress as to the adequacy of the map information available to support this task.

This report focuses on the adequacy of the two framework layers of floodplain maps: the "base map imagery" and the "elevation data." The report concludes that there is sufficient two-dimensional base map imagery available from digital "orthophotos,"—aerial and satellite photographs similar to those viewed on Google Earth—to meet FEMA's flood map modernization goals. However, elevation data are not adequate. Most state and local entities rely on the National Elevation Dataset that is maintained by the U.S. Geological Survey (USGS). Much of that dataset is more than 35 years old (and therefore out of



Flood risks affect much of the nation. FEMA calculates flood risks by looking at 10 parameters including population growth, population density, housing rates, and declared disasters. Purple areas are at highest risk followed by red, orange, yellow, and green at lowest risk. Source: FEMA

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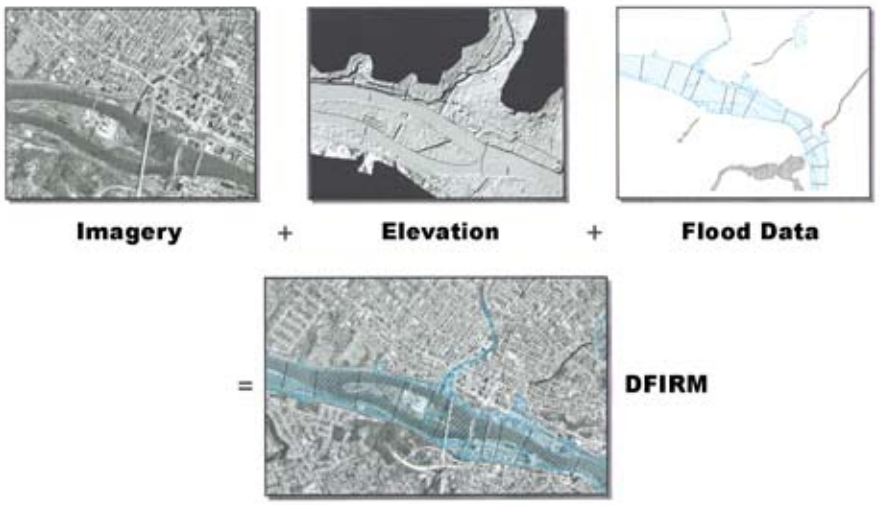


The three components of Digital Flood Insurance Rate Maps. Digital Flood Insurance Rate Maps comprise: 1) base map imagery, a digital orthophoto, that provides land surface information such as streams, roads, vegetation, and buildings; 2) base elevation data draped on top of the digital orthophoto to provide 3-dimensional information, and 3) engineering analysis such as data and models of stream and river flows. The first two components are addressed in this report.

date due to natural and human-induced changes in the land surface over time), and it was not collected at the level of accuracy now needed for the flood insurance program.

The report also reviews emerging technologies being used to generate elevation data to determine if they could or should be used to support flood map modernization. The report concludes that lidar technology, which is based on laser measurements collected from aircraft, should be used to update the nation's base elevation data.

The Importance of Accurate Maps to the Flood Insurance Program

The National Flood Insurance Program encourages communities to regulate the land development in their floodplains to avoid flood damages, and in return allows property owners located in flood hazard areas to purchase federal flood insurance. This insurance is designed to provide an alternative to federal disaster assistance to reduce the costs of repairing damage to buildings and their contents caused by floods. Federal flood insurance is required in order for property owners in flood plains to get federally-backed mortgages.

Map accuracy is very important to the program to ensure that property owners are not over- or under-insured. If property owners wish to protest the classification of their building for insurance purposes as being within the floodplain, they can file a Letter of Map Amendment (LOMA)—a laborious and expensive procedure for both them and the government. About 20,000 of these letters are currently being processed per year, and the work and expense involved probably prevent many more owners from pursuing them. Floodplain maps with more accurate base elevation data could potentially reduce the number of these disputes.

Two-dimensional "Base Map Imagery" Adequate to Meet FEMA Goals

Floodplain maps start with base map imagery that provide information about the land surface such as location of streams, roads, and buildings. The base map imagery being used as part of floodplain mapping has taken a giant step forward in recent years with the use digital orthophotos to replace older paper maps containing only vector data (points, lines, and polygons). The report finds that FEMA's base map image specification, which defines the required accuracy of digital aerial photographs, is satisfactory, and the nation has adequate image mapping to support flood map modernization through two federal programs: the National Digital Orthophoto Program (http://www.ndop.gov), and the National Agricultural Imagery Programs (http://165.221.201.14/NAIP.html). The report also endorses "Imagery for the Nation," a program proposed by a consortium of federal and state agencies that seeks to create and maintain better orthophoto products seamlessly across the United States.

National base map imaging capabilities are sufficient. Digital aerial photos like this one can be collected at the accuracy required to support Flood Map Modernization.

Flood Insurance Decisions Must Be Based on Three-Dimensional Criteria

Although the base map imagery standards are adequate, the elevation data component of mapping, which has a much greater effect on the overall accuracy of floodplain maps, needs much attention. Land surface elevation information is important in defining the direction, velocity and depth of flood flows. In the National Flood Insurance Program, flood insurance is required if any part of the footprint (or plan view) of the building outline lies over the spatial extent of the floodplain, based on a horizontal representation of data. However, the report concludes that a building's flood risk must be based on three-dimensional criteria, not as a two-dimensional analysis of a flat map.

In order to fully support the National Flood Insurance Program, updated floodplain maps should also show the Base Flood Elevation (BFE), defined as the water surface elevation that would result from a flood having a 1 percent chance of being equaled or exceeded in any year at the mapped location. The Base Flood Elevation is more commonly known as the "100-year flood level." So far, updated digital maps have been prepared for about 1 million of the nation's 4.2 million stream miles and, of those, only about one-quarter employed high-resolution elevation data that show the Base Flood Elevation. The remaining three-quarters (or 745,000 stream miles) were mapped with more approximate elevation data, and the resulting maps show the spatial extent of the floodplain but not its Base Flood Elevation.

Higher Accuracy Elevation Data Needed

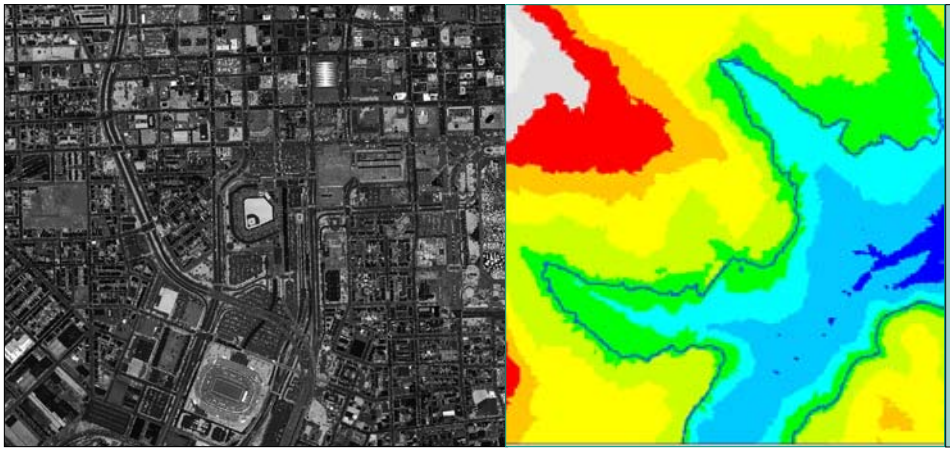
Accurately displaying the Base Flood Elevation requires high-accuracy base elevation data. The majority of communities rely on the National Elevation Dataset, maintained by the U.S. Geological Survey (USGS), for elevation data. Some communities undertaking flood map modernization already have available base elevation data of the required accuracy, or they pay to acquire such data as part of their contribution to the costs of floodplain mapping. Apart from exceptional circumstances, FEMA does not pay for the costs of elevation data acquisition in local communities.

Although the National Elevation Dataset is an excellent resource that has assembled all existing elevation data in a seamless way for the public, the report finds that the National Elevation Dataset does not, in general, contain data of sufficient accuracy to support flood map modernization requirements, except where new high-accuracy elevation data have been added from state or local sources. The data are mainly derived from elevation contours depicted in standard 1:24,000 scale topographic maps, which on average date back to 1970. Since then, a great deal of land development and urban expansion have occurred that has materially altered the shape of the land surface. In addition, about 17,000 square miles of land, much of it in California, Texas, Louisiana, and Florida is sinking at a rate of inches per year, rendering old elevation data obsolete.

Thus, while the report is supportive of the National Elevation Dataset continuing mission to achieve public access to the nation's elevation data, FEMA's floodplain mapping standards call for elevation data that are about ten times more accurate than the National Elevation Dataset can presently provide.

Lidar Should be Used to Collect High Accuracy Elevation Data

Elevation data have traditionally been collected by land surveyors. However, the several million miles of the nation's streams and shorelines covered by FEMA floodplain mapping make land surveying impractical for floodmap modernization goals.



Two representations of lidar data. The grayscale intensity image on the left shows first return lidar data of Baltimore, Maryland. (source: Fowler et al., 2007). The image on the right is a detailed elevation model of a river valley produced from lidar data. Because of the high accuracy of lidar elevation data, they can be used to redelineate floodplain boundaries for more appropriate insurance coverage.

An alternative to traditional data collection is the use of remote sensing techniques, which include laser- and/or radar-based measurements collected from aircraft or satellites. At the outset of the map modernization program, these technologies had not been widely adopted commercially and their costs were prohibitive. These technologies have since matured and costs for data collection have dropped.

This report concludes that light detection and ranging (lidar) is the preferred technology for digital elevation data collection at the accuracy specified by the map modernization program. Lidar is capable of producing a bare-earth elevation model with 2-foot equivalent contour accuracy in most terrain and land cover types and a 1-foot equivalent contour accuracy can be achieved in very flat coastal or inland floodplains. These flat areas account for about 11 percent of the U.S. land surface along the Gulf coast, Florida, the Eastern seaboard, and some interior locations. Data with a 4-foot equivalent contour accuracy, which may be more cost-effective to collect in mountainous terrain or in areas with very few people, is easily achieved with lidar.

Seamless National Elevation Dataset Needed

A number of states and local communities are acquiring new base elevation data on their own initiative and for various purposes, but these datasets frequently do not satisfy FEMA guidelines and specifications for 2- to 4-foot equivalent contour accuracy; some only satisfy a 10-foot equivalent contour accuracy. This ad hoc process of elevation data collection should not continue because it will not create consistent elevation data of the required accuracy to fully support floodplain mapping over the nation.

The report proposes creating a program called "*Elevation for the Nation*" to parallel the existing Imagery for the Nation concept. The program should employ lidar as the primary technology for digital elevation data acquisition. The program should first focus on remapping the elevation of the 65 percent of the nation that contains 92 percent of its population, where flood risk justifies the required data collection. The program can use newly acquired data or existing local and regional data if the existing data are reasonably up-to-date. The new data collected in *Elevation for the Nation* should be disseminated to the public by the USGS as part of an updated National Elevation Dataset.

Elevation for the Nation will involve significant expense, perhaps as large as the existing Flood Map Modernization program. It is for Congress and others to determine whether this expense is justified in the context of national spending priorities. The data arising from *Elevation for the Nation* would have many beneficial uses beyond floodplain mapping. In a paper published in 1998, the National Oceanic and Atmospheric Administration (NOAA) estimated the benefits of such a dataset to be worth about $2.5 billion for such diverse applications as precision farming, stormwater management, transportation planning, and disaster preparedness.

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This report brief was prepared by the National Research Council based on the committee's report. For more information, contact the Board on Earth Sciences and Resources at (202) 334-2744 or visit http://nationalacademies.org/besr. Copies of *Base Map Inputs for Floodplain Mapping* are available from the National Academies Press, 500 Fifth Street, NW, Washington, D.C. 20001; (800) 624-6242; www.nap.edu.