Topography-based Analysis of Hurricane Katrina Inundation of New Orleans

By Dean Gesch

The ready availability of high-resolution, high-accuracy elevation data proved valuable for development of topography-based products to determine rough estimates of the inundation of New Orleans, La., from Hurricane Katrina. Because of its high level of spatial detail and vertical accuracy of elevation measurements, light detection and ranging (lidar) remote sensing is an excellent mapping technology for use in low-relief hurricane-prone coastal areas.

Background

Geospatial data are critical for hurricane response and recovery activities, and topographic data are a primary requirement. High-resolution, high-accuracy elevation data were used extensively during the first weeks of response to Katrina to provide rough estimates of inundation, and they continue to be useful for studies of the impacts of the storm.

Lidar is a relatively new remote-sensing technology that has advanced significantly over the last 10 years and is now a standard survey tool used by the mapping industry to collect very detailed, high-precision measurements of land-surface elevations. In an effort to improve the quality of the Nation's topographic data available for mapping and scientific applications, the U.S. Geological Survey (USGS) has been integrating recently collected lidar elevation data into the National Elevation Dataset (NED), its primary topographic database (*http://ned.usgs.gov/*). Fortunately, high-resolution lidar-derived elevation data for southeastern Louisiana, including the New Orleans area (fig. 1), were integrated into the NED in June 2005 and thus were readily available for response to Katrina.

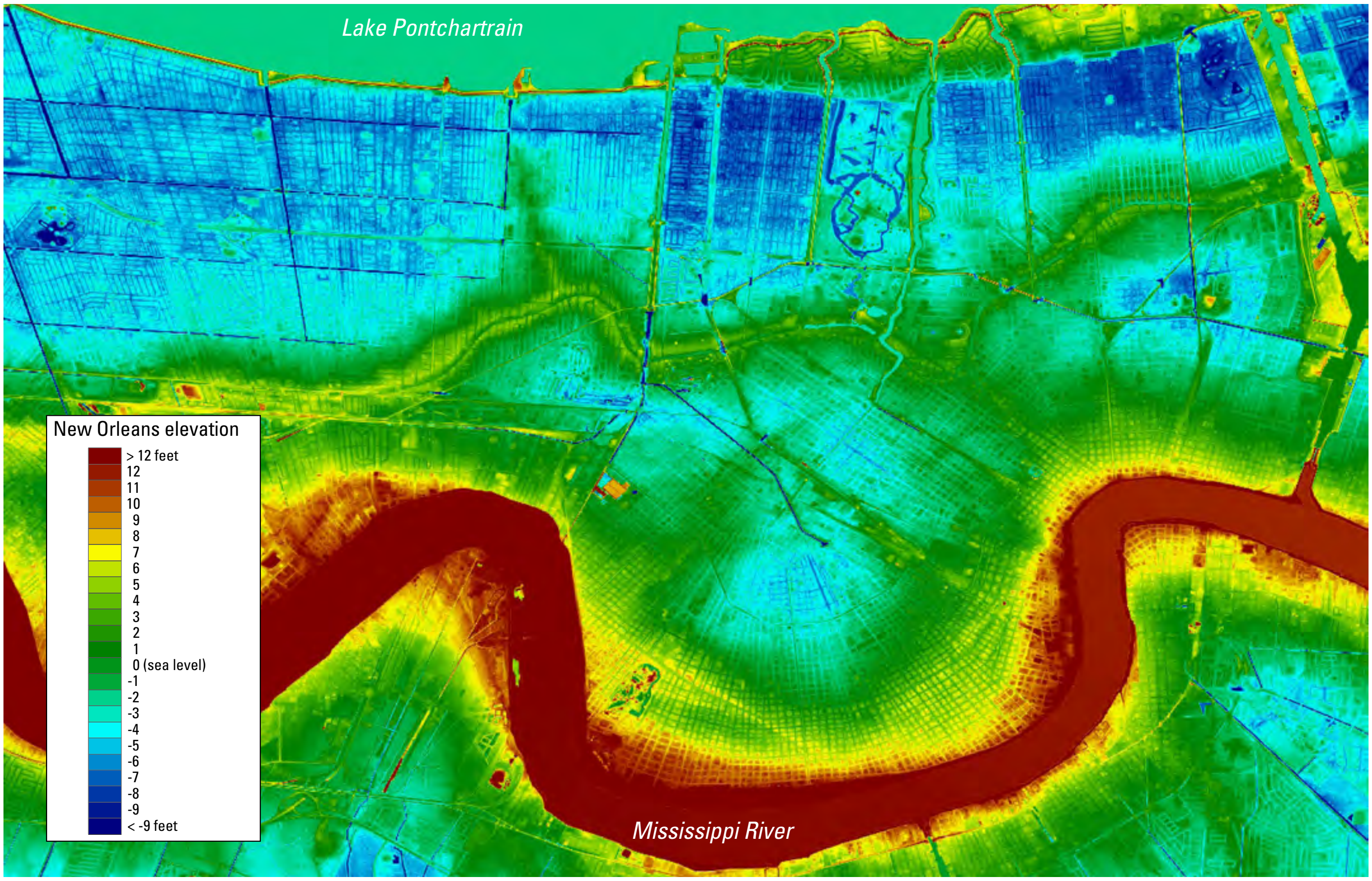

Figure 1. High-resolution elevation data of New Orleans, La., derived from light detection and ranging (lidar) data collected in 2002. Note that the land along Lake Pontchartrain and the Mississippi River is higher than the land in the center of the city, which is below sea level, resulting in what is often referred to as the bowl shape of New Orleans. Also note that on this map the level of Lake Pontchartrain has been set to a constant value. In reality, the level of the lake changes. In many cases, lidar measurements over water are inaccurate; therefore, elevation of the water surface is inferred from surrounding areas or other data sources.

Elevation Data

Lidar data were collected for southeastern Louisiana in 2002 under the auspices of the Louisiana Oil Spill Coordinator's Office. These data are publicly available through Atlas, the Louisiana statewide geographic information system Web site operated by Louisiana State University (*http://atlas.lsu.edu/*). The original 16.4-ft (5-m) resolution lidar elevation data were processed into a 32.8-ft (10-m) resolution data set for integration into the USGS NED. Products of the NED are available for free download through an interactive Web interface to a seamless data distribution system (*http://seamless.usgs.gov/*). This online availability of high-resolution elevation data for New Orleans proved to be a valuable asset for many geospatial data users responding to the aftermath of Katrina (fig. 2).

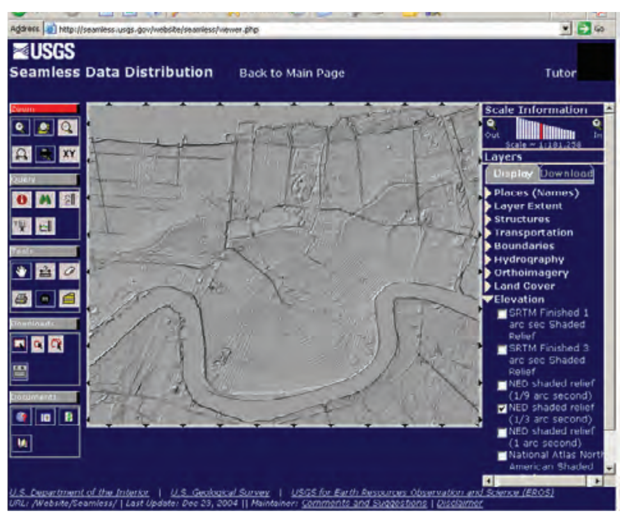

Figure 2. High-resolution elevation data of New Orleans, La., in the National Elevation Dataset. These data are available via the Web for viewing and downloading from a seamless data distribution system (*http://seamless.usgs.gov/*).

Estimates of Inundated Area and Water Volume

In the days immediately following the levee breaches in New Orleans, there was a demand for map products depicting the extent and magnitude of the flood waters within the city. The lidar-derived elevation data in the NED proved to be quite useful in providing a rough mapping of the extent and depth of the inundation (fig. 3). On Friday, September 2, 2005, an accurate delineation from aerial imagery of the inundated area was not yet available, so a topography-based approach was used. Temporary water-level gages were being installed within the city and were not yet operational, so the floodwater elevation was derived from a lake-level gage on the Lake Pontchartrain Causeway. The assumption in using the data from the Lake Pontchartrain gage was that the level of the lake and the flood waters within the city had equalized by the afternoon of September 2. Comparison with subsequent aerial and satellite imagery has shown the flood delineation to be a reasonable depiction.

The lidar-derived elevation data were also used to calculate rough estimates of floodwater volume. A flood capacity curve was produced at the request of the USGS Office of Surface Water in response to an inquiry from the U.S. Army Corps of Engineers to provide independent corroboration of their estimates. Accurate estimates of flood volume were needed to project the length of time required to remove the water from the city. Figure 4 displays the estimated volume and surface area of the flood waters at 1-ft (0.3-m) increments. Note that the volume and area estimates are only for the areas shown as inundated on figure 3. The depths are relative to the elevation of the water surface as recorded by one Lake Pontchartrain gage (no. 073802330) on the afternoon of Friday, September 2, 2005. Data for this gage are available at the National Water Information System Web site (*http://waterdata.usgs.gov/nwis/inventory/?site_no=073802330*).

The flood extent and volume estimates were based on hydrologic data from one Lake Pontchartrain gage, and even these data were provisional and subject to revision. The timeliness of these products was, however, critical for initial response efforts in the first few days of the flooding event. This application demonstrated the usefulness of highly detailed topographic data paired with real-time gage data for inundation mapping and analysis, especially when information is needed quickly.

In the future, by combining the precise elevation information from lidar with accurate ground-based water-level information and inundation delineations derived from remote sensing, a complete history of flooding and water removal can

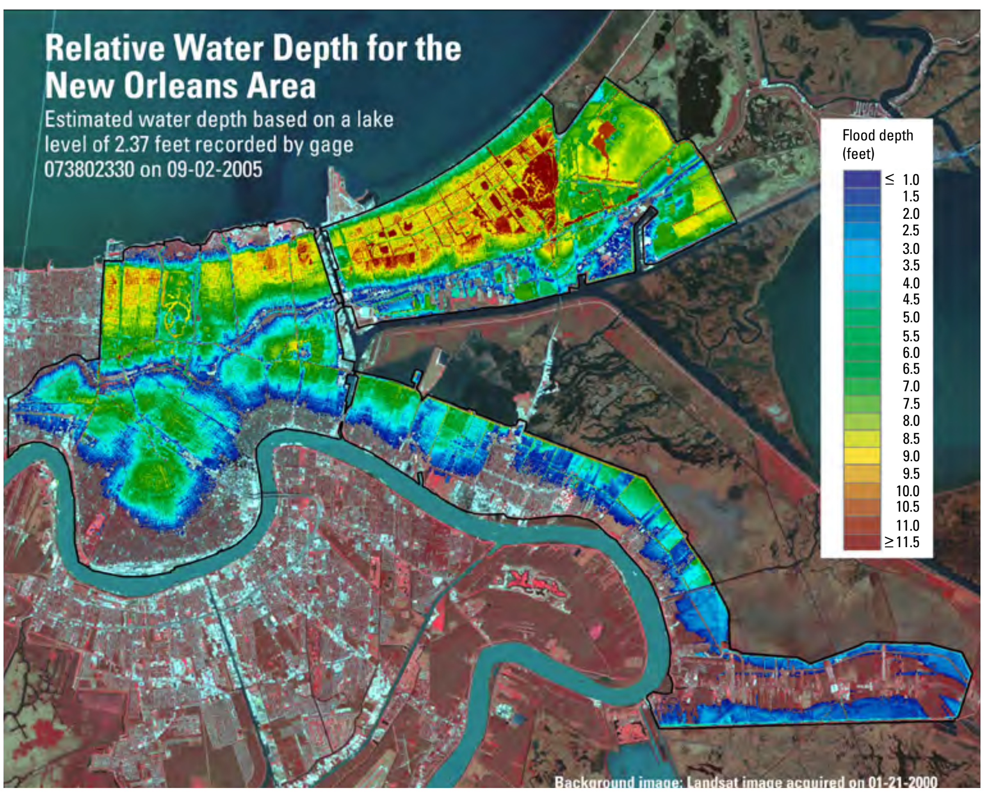

Figure 3. Map of relative water depth in New Orleans, La., on September 2, 2005. The estimated flood depth is based on lidar-derived elevation data and water level data from a Lake Pontchartrain gage. Note that the estimated depth of inundation was calculated only for the areas north and east of the Mississippi River enclosed within the heavy black lines.

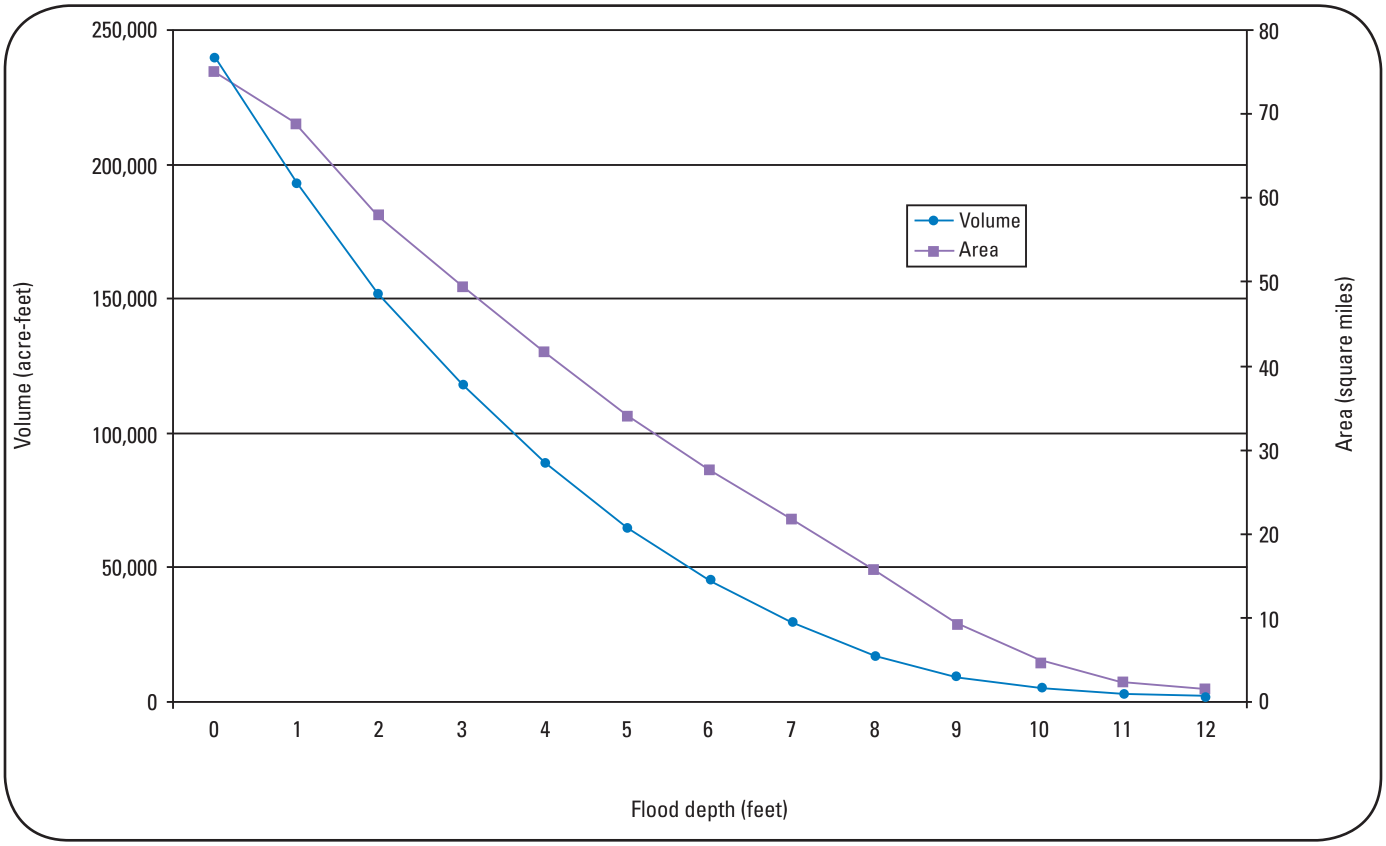

Figure 4. Estimated floodwater volume and area within New Orleans, La., on September 2, 2005. The flood depth is measured relative to the elevation of the water surface within the city as recorded by a Lake Pontchartrain water-level gage. The chart displays the contribution of each foot of flood water to the cumulative flood volume and area. For example, at elevations of 10–12 ft (3–3.7 m) below the elevation of the floodwater surface (as measured by the gage), only a relatively small area of less than 5 mi^2 (13 km^2) is inundated, but at the elevation of the water surface as measured on September 2, nearly 75 mi^2 (194 km^2) are inundated.

be reconstructed. Such a history is useful for assessing the effects of flooding on the urban landscape. For example, the effects of depth and length of inundation on different types of structures can be documented.

Understanding of the effects of inundation over time on the urban environment will also be useful in planning reconstruction of infrastructure. If a detailed hydrologic analysis shows specific inundation-duration patterns, then structures can be rebuilt in a way that mitigates impacts from future storms. The inundation history and conditions can also be used to test the accuracy of prestorm planning simulations and to make appropriate modifications to future modeling scenarios.

Conclusions

The ready availability of high-resolution, high-accuracy elevation data derived from lidar proved valuable for development of topography-based products to provide rough estimates of the inundation of New Orleans from Katrina in the immediate days following the storm. Because of its high level of spatial detail and vertical accuracy of elevation measurements, lidar is an excellent mapping technology for use in low-relief hurricane-prone coastal areas. When lidar elevation data have been processed and are available before a storm event, as was the case for New Orleans, then geospatial-based inundation maps and products can be quickly generated for response and recovery efforts immediately following the storm.

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