Field Data and Satellite Imagery of Tsunami Effects in Banda Aceh

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The rapid response of researchers with the international tsunami survey team (1) to the Banda Aceh, Sumatra, region after the 26 December 2004 earthquake and tsunami led to the recovery of data on the characteristics of the tsunami inundation. These data were used in conjunction with satellite imagery to identify runup height (elevation above sea level), inundation distance, shoreline erosion, and coseismic subsidence. Working alone, the author collected field data consisting of cross-shore profiles and photographs (located by global positioning satellite) of watermarks suggestive of flow depths (elevation above ground level) and of flow directions. Wave arrival times and wave patterns were inferred through eyewitness interviews and video taken during the tsunami. Only a brief summary of the data is presented here.

Flow depths along the north-facing shoreline of Banda Aceh were in excess of 9 m and tapered landward to the extent of maximum inundation, 3 to 4 km inland. Eyewitnesses in Banda Aceh described a series of three waves, beginning with a leading depression N wave (one in which the trough reaches the shoreline first) (2). The second elevation wave was the most destructive. In Banda Aceh, the predominant flow direction was from the northwest (Fig. 1). Fifteen km to the southwest, at Lhoknga, bark stripped from trees suggested flow depths in excess of 15 m at the shoreline, with flows predominantly from the west. Runup heights here were estimated during the initial survey in excess of 25 m. This value was later confirmed by comparing the inundation line inferred in satellite images to digital elevation data on the coastal topography. Runup around a steep conical island, less than 50 m off the south end of Lhoknga, reached 31 m. The runup values around Lhoknga are consistent (within a factor of 1 or 2) with values for coseismic slip proposed for the faulting region offshore of this area. This supports Plafker’s rule, which suggests that the maximum runup is never larger than twice the maximum seafloor displacement (3).

In the lowlands between Banda Aceh and Lhoknga, eyewitnesses reported waves from both the north and southwest. A comparison of before and after imagery allowed assessment of coastal erosion and subsidence and confirmed that two tsunami wave fronts merged across the northwestern tip of Sumatra. Alterations in the shoreline are clearly visible (Fig. 1). Standing water over what was previously dry land suggests subsidence. Wave scour and subsidence permanently moved the shoreline of Banda Aceh inland by as much as 1.5 km, and 65 km² of land between Banda Aceh and Lhoknga were flooded.

In this study, field data and remote sensing imagery were employed together to describe tsunami inundation. In future events, satellites could be directed to image affected regions and guide emergency response, allowing for more focused damage assessment and field measurements. The extent of the catastrophe underscores the need for real-time tsunami forecasting (4).

References and Notes
4. V. V. Titov et al., Natural Hazards 35, 35 (2005).
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