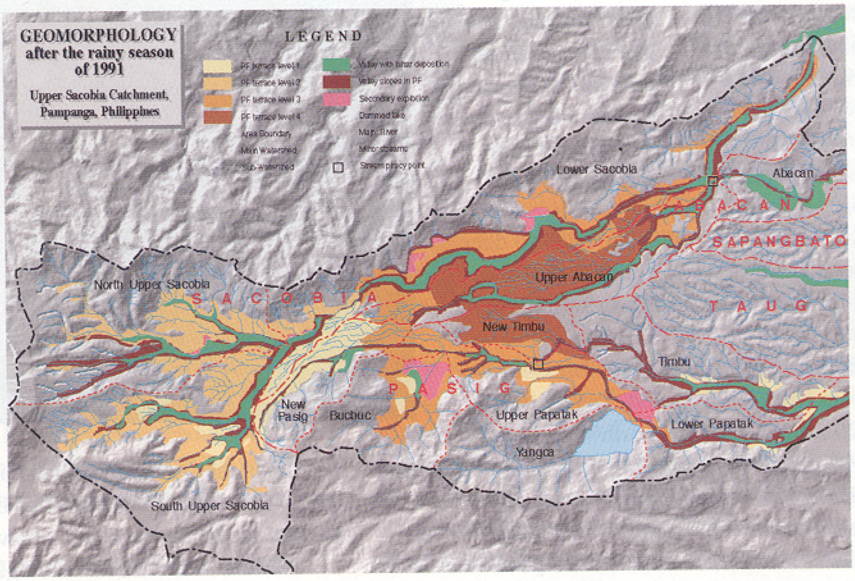
Estimating Erosion on Mount Pinatubo

DTM overlay technique provides life-saving information

By Dr. Cees J. van Westen and Art Daag



◀This Digital Terrain Model was made using the Map calculation in the ILWIS 2.1 geographic information system. It depicts the deposits resulting from the 1991 eruption.

The eruption of the Pinatubo Volcano in the Philippines, on June 15, 1991, deposited approximately 5 to 7 km³ of pyroclastic flows. These flow deposits affected eight major watersheds around the slopes of the volcano and radically altered the hydrological regimes, leading to unprecedented amounts of erosion and sediment delivery in the form of destructive lahars.

One of the eight watersheds, the Sacobia catchment was studied in detail. Situated on the eastern slope of the volcano, the Sacobia watershed drains two major rivers, the Sacobia and the Pasig. To quantify the volumes of pyroclastic flow material and the yearly erosion within the rapidly changing geomorphology of the Sacobia watershed, five Digital Terrain Models (DTM) were made and analyzed using the Map calculation module in the ILWIS 2.1 geographic information system (GIS).

Mount Pinatubo is located on the island of Luzon, about 80 kilometers northeast of Manila, the capital of the Philippines. Following the main eruption of Mount Pinatubo, rapid erosion and removal of the 1991 pyroclastic flow deposits created a major social and scientific concern due to the continued creation of these life-threatening lahars. The main objective of the study was to evaluate the decrease of volume in potential lahar source material in the Sacobia watershed during the three year period immediately following the eruption, and to make a sediment balance.

SUMMARY

With the use of Digital Terrain Models, scientists are able to monitor potential dangers associated with river drainage alterations caused by the 1991 eruption of Mount Pinatubo.

GeoTechnologies Discussed:

- DTMs
- GIS

Benefit:

DTMs and GIS data are providing life-saving information along the Sacobia Catchment.

To investigate this, maps for the pre- and post- eruption years until 1993, were made. This was done in order to evaluate the changes in the catchment areas and their importance in producing lahars. Digital Terrain Models for each year were also created, from which thickness of the pyroclastic flows and the yearly eroded volume were calculated. It was necessary to construct DTMs of several periods: i.e., the pre-eruption DTM; the post-plinian eruption DTM which rendered the undisturbed deposits of the 1991 pyroclastic flows; a post-lahar 1991 DTM; a post-lahar 1992 DTM; and a post-lahar 1993 DTM.

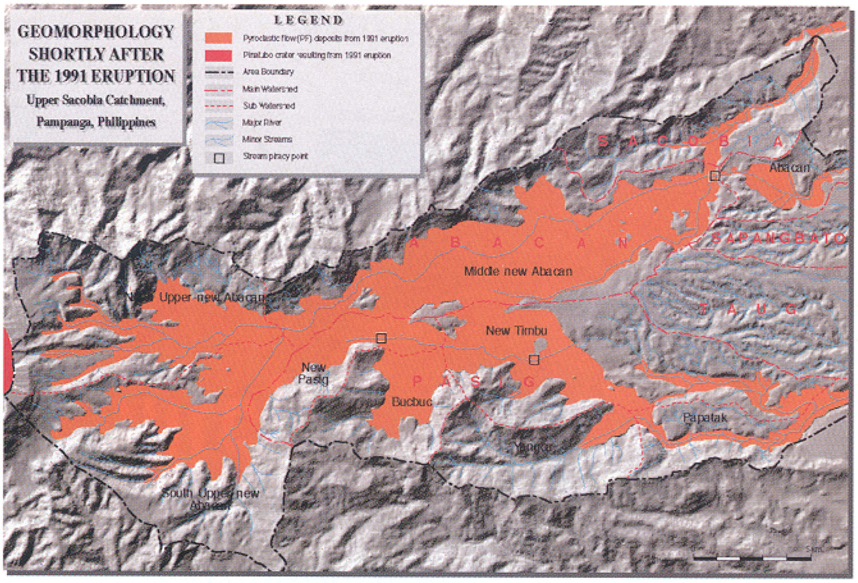
The pre-eruption DTM was generated by digitizing the contour lines, using a 20 meter interval, from the 1986 topographic base map prepared by the US Defense Mapping Agency. The DTM was converted to raster data using a pixel size of 20 meters.

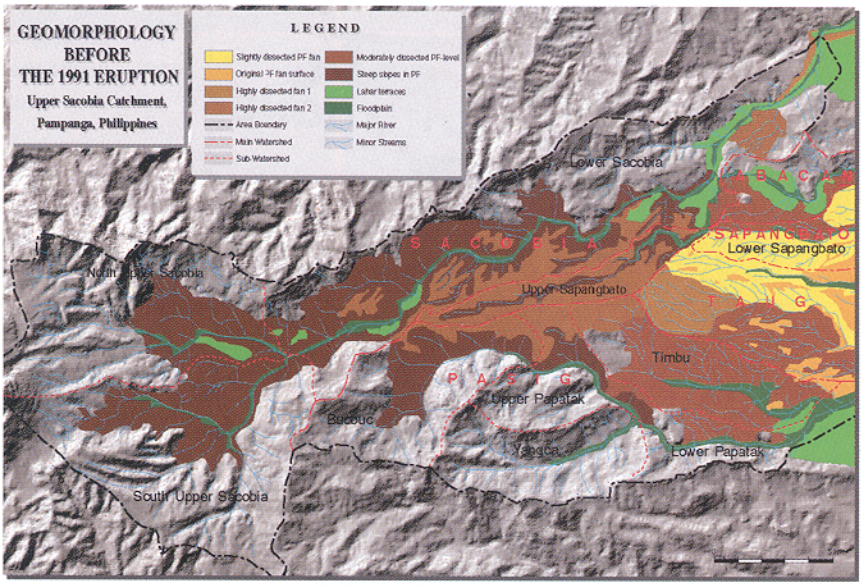
To calculate the volume of the 1991 pyroclastic flow deposit, a post-plinian eruption DTM was reconstructed to render the features of the original and undisturbed 1991 deposit. In constructing the post eruption DTM, oblique stereo photographs from July 1991 were used to show the original level of the new deposit. Contacts of the pyroclastic flows in relation to the surrounding topography were plotted on the enlarged topographic base map. Additional isolines were digitized across the deposit. Then the altitudes of the new pyroclastic flow level were masked into the pre-eruption DTM to fully reconstruct the post-1991 plinian DTM.

Calculating the volume of erosion for the three yearly post-lahar seasons required a DTM of each post-lahar season. These features were interpreted from the post-rainy season photographs. The vertical incision depth of valleys and gullies was estimated in the field for a limited number of sites. The depths at other inaccessible sites were measured with a parallax bar, which provided a minimum workable mapping depth for gullies of between 5-10 meters. Unfortunately, analytical photogrammetric work could not be conducted due to 1) the absence of precise ground control points in the study area; 2) the inaccessibility of the terrain, and 3) the fact that a precise GPS was not available.

In a GIS the boundaries of gullies were plotted over the 1991 pyroclastic flow deposits. The depth measurements made with the parallax reading were subtracted from the heights of the 1991 pyroclastic flow level to obtain the elevation along stream lines. The elevations of the remaining gully slopes were interpolated. Larger valleys were represented as polygons. The area of the polygons together with the measured valley depths were subtracted from the height of the post-eruption DTM. The sloping valley walls were masked separately, and their DTM values were calculated by interpolating the height value of the top and bottom of the valley. The same procedure was followed for the situations after the 1992 and 1993 rainy seasons, each time subtracting the newly eroded areas from the DTM of the previous year.

▶ Maps for the pre- and post eruption period through 1993 were created. These maps assist in the evaluation of changes in the catchment area.





DTM Overlaying Method

In order to calculate the yearly erosion and sedimentation volumes, ILWIS' new 2.1 version for Windows was used. This package contains a powerful Map Calculation tool. Using this, the volume of pyroclastic flow material covering the Sacobia watershed was calculated by subtracting the DTM after the eruption from the one before the eruption.

The positive values in the resulting map indicated the thickness of pyroclastic flow deposits, whereas the negative values represented the lowering of the terrain as a result of the formation of the crater. Volumes were obtained by multiplying the thickness in each pixel with the area of the pixel (the square of the pixel size). After that, the volumes were aggregated for the various subcatchments by crossing the subcatchment map with the volume map and summing up all positive values.

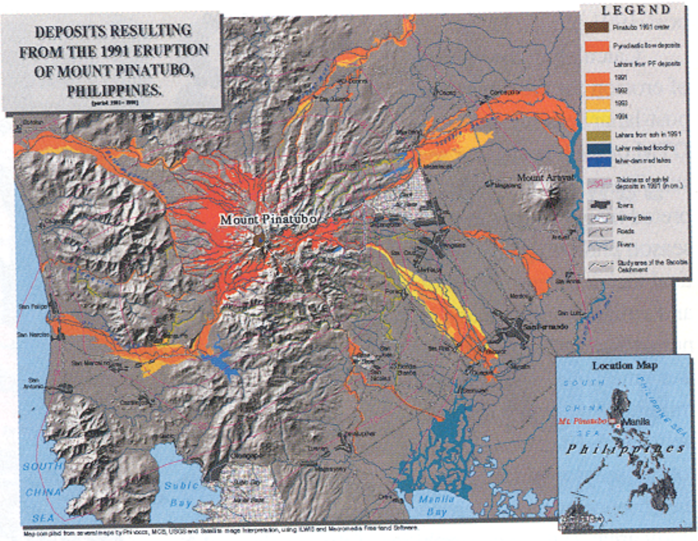
The next step was to calculate the amount of erosion and sedimentation that took place in the catchment during the first rainy season after the eruption. Three possible scenarios were considered:

- erosion in pyroclastic flow deposits
- erosion in other deposits
- sedimentation

The calculation of the erosion and sedimentation volumes which occurred during the second and third rainy season, in 1992, are slightly more complex since there may be further erosion in PF or other deposits, erosion in sedimentation material from the previous year, or sedimentation.

Results

The volume of pyroclastic flows and the subsequent erosion during the three year period was calculated for each catchment based on the five DTMs. These results were compared with calculations obtained in other studies. All the studies involved either estimated total volumes of pyroclastic flows using cross sections, photogrammetric techniques or an estimation of lahar volumes. Although there are differences, the order of the magnitude is the same. The erosion volumes calculated by comparing DTMs are slightly higher than the volumes of lahars. This can be attributed to the fact that a redeposit of pyroclastic material took place within the area and that not all materials were transported to the areas surrounding the volcano-as presumed in the lahar estimates. When the reoccurring sedimentation volumes are subtracted from the total erosion, the values match rather well.



▲ **Erosion of the 1991 pyroclastic flow deposit presents a major social and scientific concern. DTMs are currently used in an effort to calculate the movement of loose pyroclastic flow material and the life threatening and destructive lahar deposits this pyroclastic flow material creates.**

If the erosion values for the three years are compared it is clear that there is a large decrease in volume from 1991 to 1992, also expressed by a decrease in lahar volumes. Values for 1993, however, are not fitting into this exponential decay curve, since the erosion rate attributed to this year is higher than the previous year. This is mainly caused by the occurrence of the secondary explosion which resulted in the upper Sacobia catchment being influenced by the Pasig River which had dramatically increased erosion rates. Secondary explosions can still occur within the area for a number of years until the pyroclastic material has sufficiently cooled off.

Another factor which may prevent the exponential decay of erosion and lahar volumes is the break-out of lahar dammed lakes. In 1994 the break-out of the lake in the Yangca catchment caused a lahar in the lower Pasig area. This area covered a region which was larger than in previous years. Continued tracking and related understanding of these developments will require further applications of analytical photogrammetric techniques in order to obtain detailed and reliable results. ◆

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