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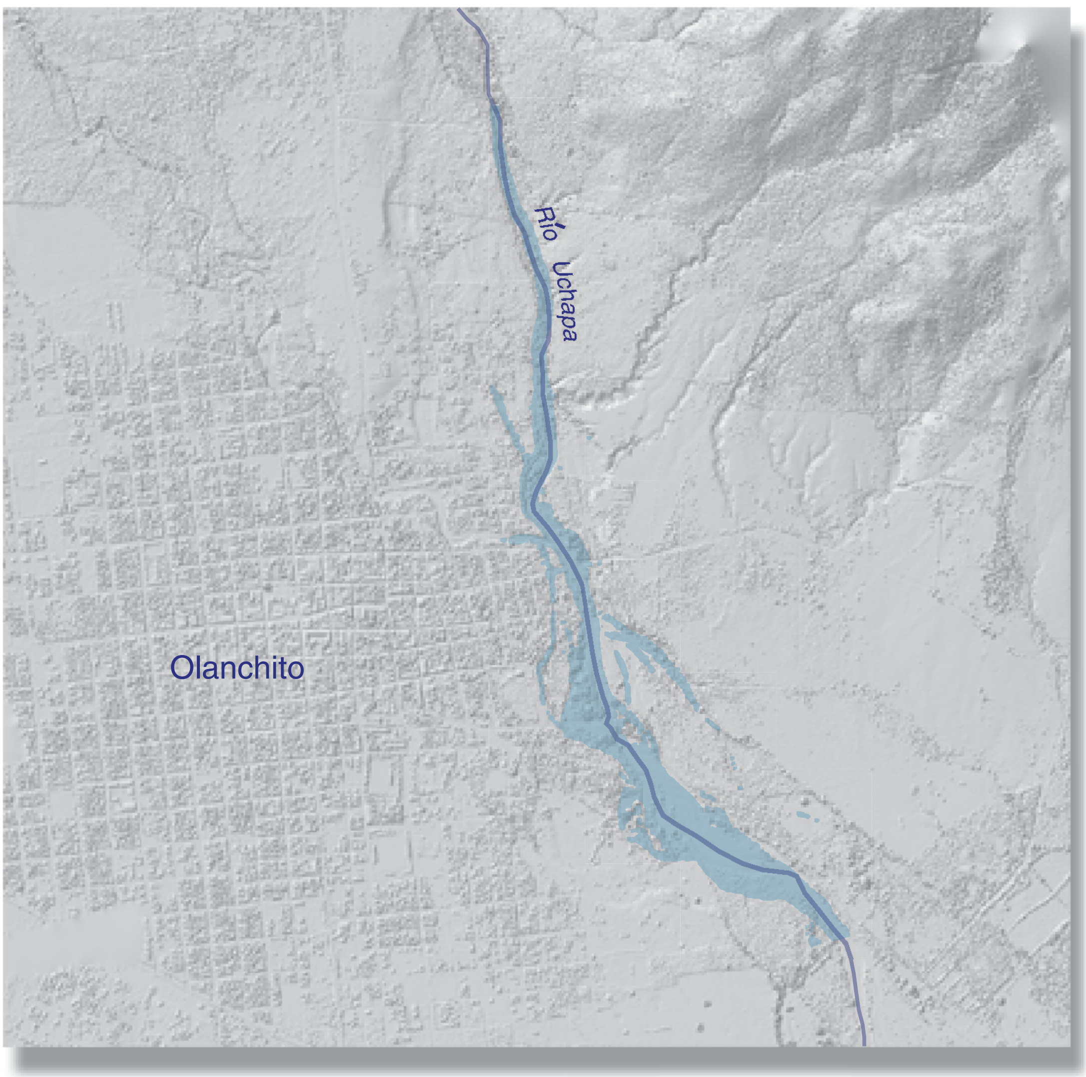
Fifty-Year Flood-Inundation Maps for Olanchito, Honduras

U.S. Geological Survey Open-File Report 02-257



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By David L. Kresch, Mark C. Mastin, and Theresa D. Olsen

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Tacoma, Washington
2002

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CONVERSION FACTORS

Multiply	By	To obtain
cubic meter per second (m^3/s)	35.31	cubic foot per second
kilometer (km)	0.6214	mile
meter (m)	3.281	foot
millimeter (mm)	0.03937	inch
square kilometer (km^2)	0.3861	square mile

VERTICAL DATUM

Elevation: In this report "elevation" refers to the height, in meters, above the ellipsoid defined by the World Geodetic System of 1984 (WGS 84).

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ABSTRACT

After the devastating floods caused by Hurricane Mitch in 1998, maps of the areas and depths of the 50-year-flood inundation at 15 municipalities in Honduras were prepared as a tool for agencies involved in reconstruction and planning. This report, which is one in a series of 15, presents maps of areas in the municipality of Olanchito that would be inundated by a 50-year-flood of Río Uchapa. Geographic Information System (GIS) coverages of the flood inundation are available on a computer in the municipality of Olanchito as part of the Municipal GIS project and on the Internet at the Flood Hazard Mapping Web page (http://mitchnts1.cr.usgs.gov/projects/floodhazard.html). These coverages allow users to view the flood inundation in much more detail than is possible using the maps in this report.

Water-surface elevations for a 50-year-flood discharge of 243 cubic meters per second on Río Uchapa at Olanchito were estimated using HEC-RAS, a one-dimensional, steady-flow, step-backwater computer program. The channel and floodplain cross sections used in HEC-RAS were developed from an airborne light-detection-and-ranging (LIDAR) topographic survey of the area. There are no nearby long-term stream-gaging stations on Río Uchapa; therefore, the 50-year-flood discharge for Río Uchapa was estimated using a regression equation that relates the 50-year-flood discharge to drainage area and mean annual precipitation. The drainage area and mean annual precipitation estimated for Río Uchapa at Olanchito are 97.1 square kilometers and 1,178 millimeters, respectively.

INTRODUCTION

In late October 1998, Hurricane Mitch struck the mainland of Honduras, triggering destructive landslides, flooding, and other associated disasters that overwhelmed the country's resources and ability to quickly rebuild itself. The hurricane produced more than 450 millimeters of rain in 24 hours in parts of Honduras and caused significant flooding along most rivers in the country. A hurricane of this intensity is a rare event, and Hurricane Mitch is listed as the most deadly hurricane in the Western Hemisphere since the "Great Hurricane" of 1780. However, other destructive hurricanes have hit Honduras in recent history. For example, Hurricane Fifi hit Honduras in September 1974, causing 8,000 deaths (Rappaport and Fernandez-Partagas, 1997).

As part of a relief effort in Central America, the U.S. Agency for International Development (USAID), with help from the U.S. Geological Survey (USGS), developed a program to aid Central America in rebuilding itself. A top priority identified by USAID was the need for reliable flood-hazard maps of Honduras to help plan the rebuilding of housing and infrastructure. The Water Resources Division of the USGS in Washington State, in coordination with the International Water Resources Branch of the USGS, was given the task to develop flood-hazard maps for 15 municipalities in Honduras: Catacamas, Choloma, Choluteca, Comayagua, El Progreso, Juticalpa, La Ceiba, La Lima, Nacaome, Olanchito, Santa Rosa de Aguán, Siguatepeque, Sonaguera, Tegucigalpa, and Tocoa. This report presents and describes the determination of the area and depth of inundation in the municipality of Olanchito that would be caused by a 50-year flood of Río Uchapa.

The 50-year flood was used as the target flood in this study because discussions with the USAID and the Honduran Public Works and Transportation Ministry indicated that it was the most common design flood used by planners and engineers working in Honduras. The 50-year flood is one that has a 2-percent chance of being equaled or exceeded in any one year and on average would be equalled or exceeded once every 50 years.

Purpose, Scope, and Methods

This report provides (1) results and summary of the hydrologic analysis to estimate the 50-year-flood used as input to the hydraulic model, (2) results of the hydraulic analysis to estimate the water-surface elevations of the 50-year-flood discharge at cross-sections along the stream profile, and (3) 50-year-flood inundation maps for Río Uchapa at Olanchito showing area and depth of inundation.

The analytical methods used to estimate the 50-year-flood discharge, to calculate the water-surface elevations, and to create the flood-inundation maps are described in a companion report by Mastin (2002). Water-surface elevations along Río Uchapa were calculated using HEC-RAS, a one-dimensional, steady-flow, step-backwater computer model; and maps of the area and depths of inundation were generated from the water-surface elevations and topographic information.

The channel and floodplain cross sections used in HEC-RAS were developed from an airborne light-detection-and-ranging (LIDAR) topographic survey of Olanchito. Because of the high cost of obtaining the LIDAR elevation data, the extent of mapping was limited to areas of high population density where flooding is expected to cause the most damage. The findings in this report are based on the condition of the river channel and floodplains on March 9, 2000, when the LIDAR data were collected.

Acknowledgments

We acknowledge USAID for funding this project; Jeff Phillips of the USGS for providing data and field support while we were in-country; and Roger Bendeck, a Honduran interpreter, for being an indispensable guide, translator, and instrument man during our field trips.

DESCRIPTION OF STUDY AREA

Río Uchapa flows along the eastern boundary of Olanchito. The study area includes the river channel and floodplains of Río Uchapa from approximately 1.3 kilometer (km) upstream from Olanchito to approximately 1.0 km downstream (figure 1).

The headwaters of Río Uchapa are in the Montañas del Charro, de Cavieles, La Gloria, and La Dante, all of which are located north of the study site. The streambed material in the study area ranges from sand and gravel to cobbles and small to medium boulders. The main channel banks and floodplains are generally covered with dense vegetation.

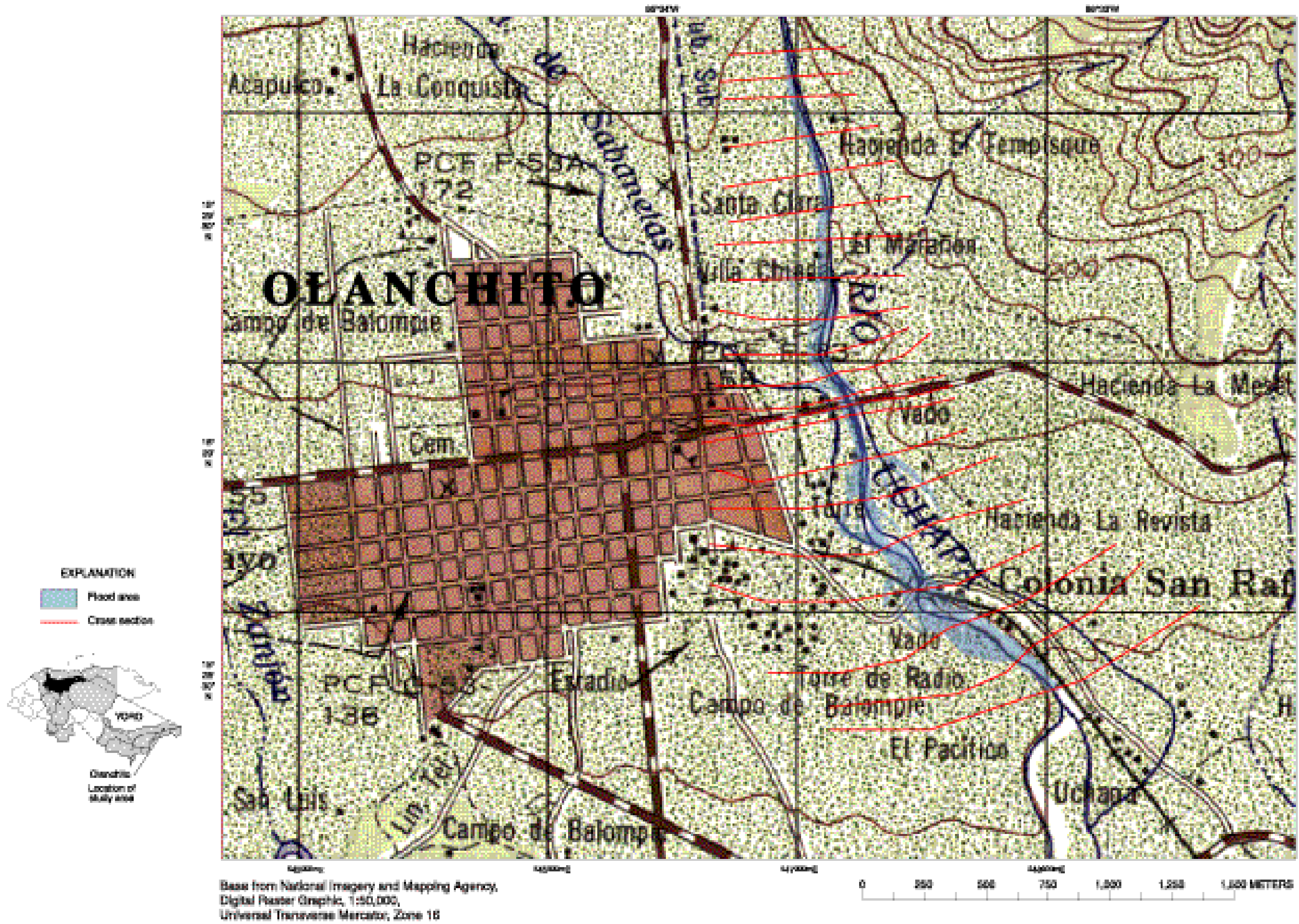

Figure 1. Location of study area and cross sections, and the area of inundation for the 50-year flood on Río Uchapa at Olanchito, Honduras.

FIFTY-YEAR FLOOD DISCHARGE

A value for the 50-year-flood discharge on Río Uchapa at Olanchito is required as input to the computer model. There are no long-term streamflow records on Río Uchapa; therefore, the 50-year-flood discharge was estimated using the following regression equation, which was developed using data from 34 streamflow stations throughout Honduras with more than 10 years of annual peak flow record, that relates the 50-year peak flow with drainage basin area and mean annual precipitation (Mastin, 2002).

$$Q_{50} = 0.0788(DA)^{0.5664}(P)^{0.7693}\ , \qquad (1)$$

where

Q_{50} is the 50-year-flood discharge, in cubic meters per second (m^3/s),

DA is drainage area, in square kilometers (km^2), and

P is mean annual precipitation over the basin, in mm.

The standard error of estimate of equation 1, which is a measure of the scatter of data about the regression equation, is 0.260 log unit, or 65.6 percent. The standard error of prediction, which is a measure of how well the regression equation predicts the 50-year-flood discharge and includes the scatter of the data about the equation plus the error in the regression equation, equals 0.278 log unit, or 71.3 percent

The drainage area of Río Uchapa at Olanchito was determined to be 97.1 km^2 using a geographic information system (GIS) program to analyze a digital elevation model (DEM) with a 93-meter cell resolution from the U.S. National Imagery and Mapping Agency (David Stewart, USGS, written commun., 1999). The mean annual precipitation over the Río Uchapa drainage basin was determined to be 1,178 mm using a GIS program to analyze a digitized map of mean annual precipitation at a scale of 1:2,500,000 (Morales-Canales, 1997-1998, p. 15).

The 50-year-flood discharge estimated from regression equation 1 for Río Uchapa at Olanchito is 243 m^3/s.

WATER-SURFACE PROFILE OF THE 50-YEAR FLOOD

Once a 50-year flood discharge has been estimated, a profile of water-surface elevations along the course of the river can be estimated for the 50-year flood with a step-backwater model, and later used to generate the flood-inundation maps. The U.S. Army Corps of Engineers HEC-RAS modeling system was used for step-backwater modeling. HEC-RAS is a one-dimensional, steady-flow model for computing water-surface profiles in open channels, through bridge openings, and over roads. The basic required inputs to the model are stream discharge, cross sections (geometry) of the river channels and floodplains perpendicular to the direction of flow, bridge geometry, Manning's roughness coefficients (*n* values) for each cross section, and boundary conditions (U.S. Army Corps of Engineers, 1998).

Cross-section geometry was obtained from a high-resolution DEM created from an airborne LIDAR survey. The LIDAR survey was conducted by personnel from the University of Texas. A fixed-wing aircraft with the LIDAR instrumentation and a precise global positioning system (GPS) flew over the study area on March 9, 2000. The relative accuracy of the LIDAR data was determined by comparing LIDAR elevations with GPS ground-surveyed elevations at numerous points at two easily detectable ground features in the Olanchito study area. The mean difference between the two sets of elevations at 1,708 points at one feature is -0.318 meters, and the standard deviation of the differences is 0.098 meters. The mean difference and standard deviation of the differences for the 903 points at the other feature are -0.304 meters and 0.066 meters, respectively. The LIDAR data were filtered to remove vegetation while retaining the buildings to create a "bare earth" elevation representation of the flood plain. The LIDAR data were processed into a GIS (Arc/Info™) GRID raster coverage of elevations at a 1.5-meter cell resolution. The coverage was then processed into a triangular irregular network (TIN) GIS coverage. Cross sections of elevation data oriented across the floodplain perpendicular to the expected flow direction of the 50-year-flood discharge (figure 1) were obtained from the TIN using HEC-GeoRAS, a pre- and post-processing GIS program designed for HEC-RAS (U.S. Army Corps of Engineers, 2000). The underwater portions of the cross sections cannot be seen by the LIDAR system.

However, because the LIDAR surveys were conducted during a period of extremely low flows, the underwater portions were assumed to be insignificant in comparison with the cross-sectional areas of flow during a 50-year flood; therefore, they were not included in the model.

The study area was visited on January 15, 2001, to determine whether any bridges over Río Uchapa needed to be surveyed for inclusion in the HEC-RAS model. The only bridges found were a low-water crossing (vado) at cross section 1.570, which was still under construction, and a few remnants from a washed out railroad bridge crossing just upstream from cross section 0.753. Visual inspections of the two bridges indicated that neither would be likely to cause any contraction of flow during a 50-year flood. Therefore, the bridge geometry for these bridges was not surveyed for inclusion in the HEC-RAS model.

Most hydraulic calculations of flow in channels and overbank areas require an estimate of flow resistance, which is generally expressed as Manning's roughness coefficient, *n*. The effect that roughness coefficients have on water-surface profiles is that as the *n* value is increased, the resistance to flow increases also, which results in higher water-surface elevations. Roughness coefficients (Manning's *n*) for Río Uchapa were estimated from digital photographs taken by a hydrologist during a field visit to the study area on January 15, 2001, and from computer displays of shaded-relief images of the LIDAR-derived DEM before the vegetation removal filter was applied. The *n* value estimated for the main channel is 0.038 and the *n* values estimated for the floodplain areas range from 0.045 to 0.060.

Step-backwater computations require a water-surface elevation as a boundary condition at either the downstream end of the stream reach for flows in the subcritical flow regime or at the upstream end of the reach for flows in the supercritical flow regime. Initial HEC-RAS simulations indicated that the flow in Río Uchapa would be in the subcritical flow regime. Therefore, the boundary condition used was a water-surface elevation at cross section 0.014, the farthest downstream cross section in the Río Uchapa step-backwater model. This elevation, 131.48 meters, was estimated by a slope-conveyance computation assuming an energy gradient of 0.01, which was estimated to be equal to the slope of the main channel bed. The computed water-surface elevations at the first few cross sections upstream may differ from the true elevations if the estimated boundary condition elevation is incorrect. However, if the error in the estimated boundary condition is not large, the computed profile asymptotically approaches the true profile within a few cross sections.

The step-backwater model provided estimates of water-surface elevations at all cross sections for the 50-year-flood discharge (table 1 and figure 2).

Table 1. Estimated water-surface elevations for the 50-year flood on Río Uchapa at Olanchito, Honduras

[Peak flow for the 50-year flood is 243 cubic meters per second. **Cross-section stationing**: distance upstream from an arbitrary point near the model boundary; **Minimum channel elevation**, **Water-surface elevation**: elevations are referenced to the World Geodetic System Datum of 1984; **Abbreviations**: km, kilometers; m, meters; m/s, meters per second]

Cross-section stationing (km)	Minimum channel elevation (m)	Average velocity of flow (m/s)	Water-surface elevation (m)
3.102	164.67	4.56	167.54
2.997	163.16	4.43	165.87
2.915	162.21	4.48	164.86
2.744	159.64	3.56	162.50
2.586	157.77	4.35	160.54
2.435	155.95	3.52	158.50
2.304	154.77	4.04	156.96
2.148	152.64	4.16	154.84
1.979	150.54	3.52	152.92
1.821	148.36	4.01	150.79
1.711	146.76	2.80	149.51
1.606	146.58	3.16	148.43
1.570	146.20	2.99	147.75
1.525	144.69	3.45	146.79
1.336	142.63	2.65	145.01
1.177	140.56	3.95	143.32
0.960	138.04	2.42	140.45
0.753	136.35	3.28	138.60
0.532	134.35	2.46	136.31
0.200	130.94	2.76	133.29
0.014	129.11	3.33	131.48

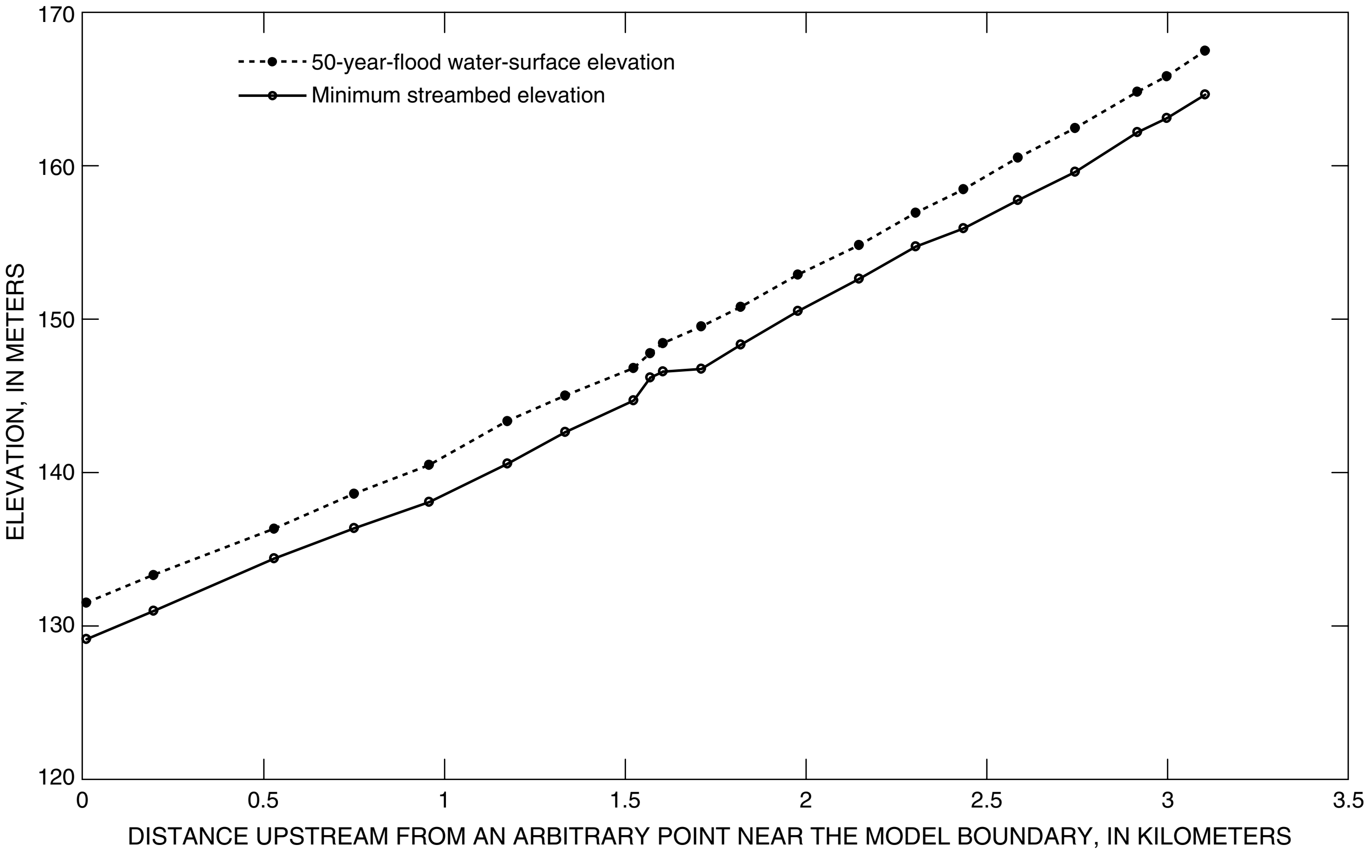

Figure 2. Water-surface profile, estimated using the step-backwater model HEC-RAS, for the 50-year flood on Río Uchapa at Olanchito, Honduras.

FIFTY-YEAR FLOOD-INUNDATION MAPS

The results from the step-backwater hydraulic model were processed by the computer program HEC-GeoRAS to create GIS coverages of the area and depth of inundation for the study area. The GIS coverage of area of inundation was created by intersecting the computed water-surface elevations with the topographic TIN that was produced from the LIDAR data. This coverage was then overlain on an existing 1:50,000 topographic digital raster graphics map (figure 1) produced by the U.S. National Imagery and Mapping Agency (Gary Fairgrieve, USGS, written commun., 1999). Depth of inundation at Olanchito for a 50-year-flood on Río Uchapa (figure 3) was computed by subtracting the topographic TIN from a computed water-surface elevation TIN to produce a grid with a cell size of 2 meters.

The blue line depicting the Rio Uchapa channel on the digital raster graphics map used as the base map for figure 1 lies outside the 50-year-flood boundaries at some locations. This probably results from changes in the river course as a result of flood flows that occurred after the map was created, especially those that resulted from Hurricane Mitch.

The flood-hazard maps are intended to provide a basic tool for planning or for engineering projects in or near the Río Uchapa floodplain. This tool can reasonably separate high-hazard areas from low-hazard areas in the floodplain to minimize future flood losses. However, significant introduced or natural changes in main-channel or floodplain geometry or location can affect the area and depth of inundation. Also, encroachment into the flood plain with structures or fill will reduce flood-carrying capacity and thereby increase the potential height of flood waters, and may also increase the area of inundation.

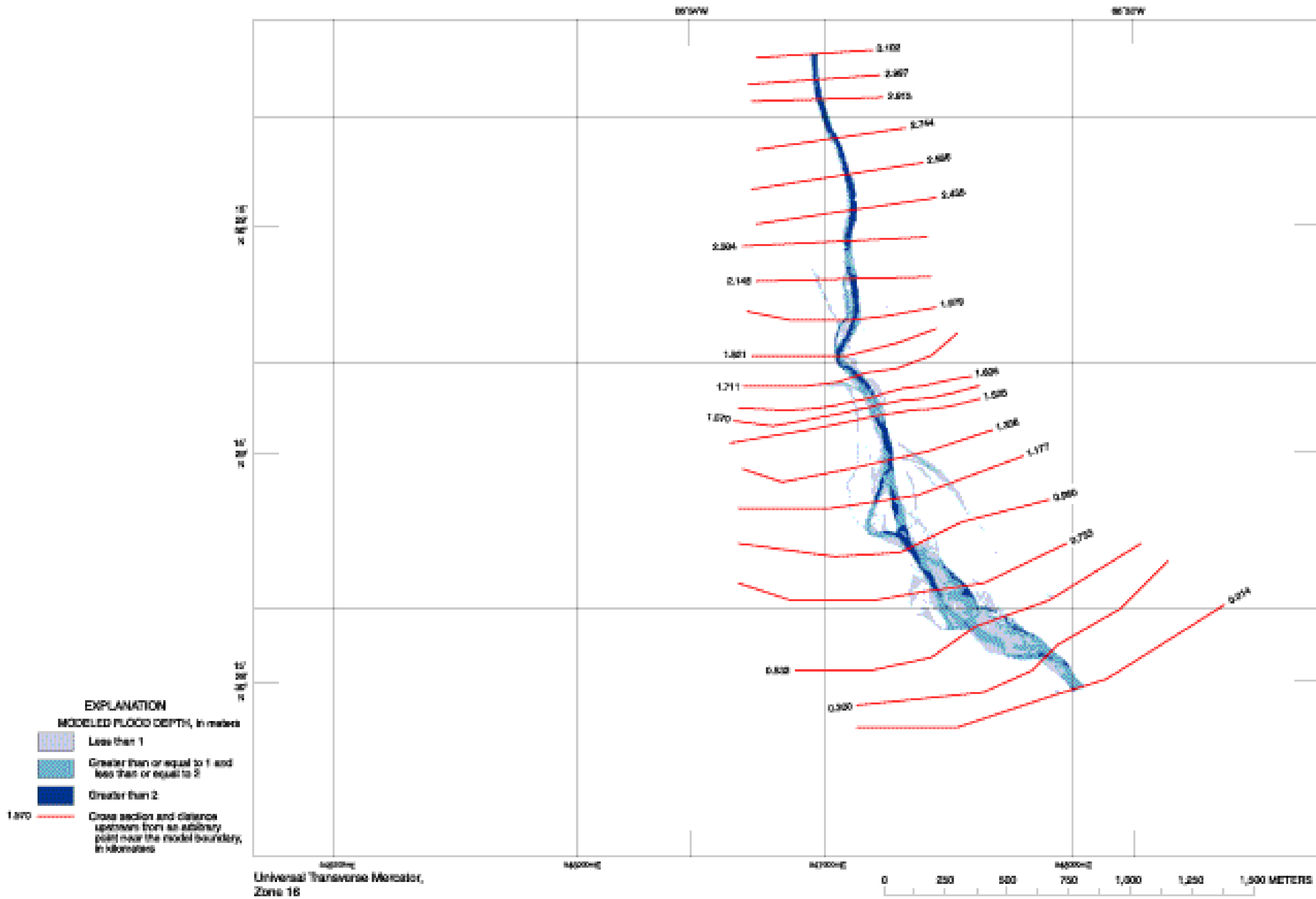

Figure 3. Depth of inundation for the 50-year flood and location of cross sections on Río Uchapa at Olanchito, Honduras.

DATA AVAILABILITY

GIS coverages of flood inundation and flood depths shown on the maps in figures 1 and 3 are available in the Municipal GIS project, a concurrent USAID-sponsored USGS project that will integrate maps, orthorectified aerial photography, and other available natural resource data for a particular municipality into a common geographic database. The GIS project, which is located on a computer in the Olanchito municipality office, allows users to view the GIS coverages in much more detail than shown on figures 1 and 3. The GIS project will also allow users to overlay other GIS coverages over the inundation and flood-depth boundaries to further facilitate planning and engineering. Additional information about the Municipal GIS project is available on the Internet at the GIS Products Web page (http://mitchnts1.cr.usgs.gov/projects/gis.html), a part of the USGS Hurricane Mitch Program Web site.

The GIS coverages and the HEC-RAS model files for this study are available on the Internet at the Flood Hazard Mapping Web page (http://mitchnts1.cr.usgs.gov/projects/floodhazard.html), which is also a part of the USGS Hurricane Mitch Program Web site.

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