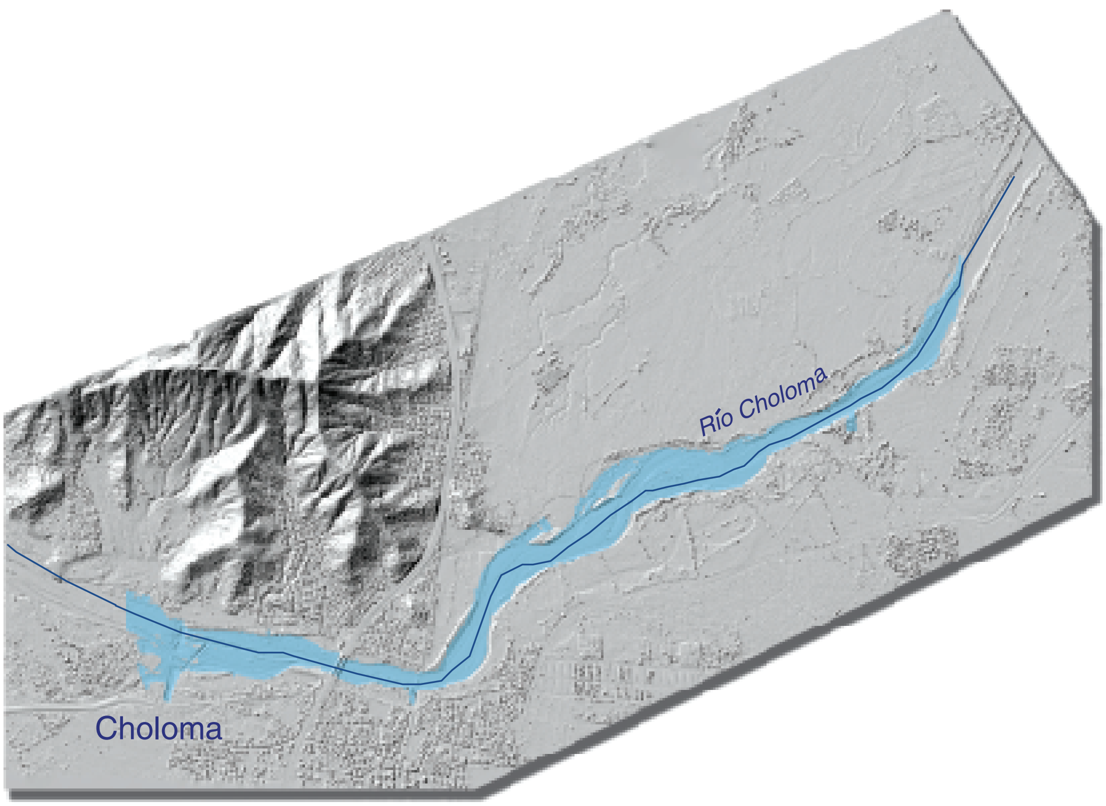
science for a changing world

Prepared in cooperation with the U.S Agency for International Development

Fifty-Year Flood-Inundation Maps for Choloma, Honduras

U.S. Geological Survey Open-File Report 02-249

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15



U.S. Department of the Interior
U.S. Geological Survey

Fifty-Year Flood-Inundation Maps for Choloma, Honduras

By Mark C. Mastin and Theresa D. Olsen

U.S. GEOLOGICAL SURVEY

Open-File Report 02-249

Prepared in cooperation with the
U.S. AGENCY FOR INTERNATIONAL DEVELOPMENT

Tacoma, Washington
2002

U.S. DEPARTMENT OF THE INTERIOR
GALE A. NORTON, Secretary

U.S. GEOLOGICAL SURVEY
Charles G. Groat, Director

For additional information write to:

District Chief
U.S. Geological Survey
1201 Pacific Avenue – Suite 600
Tacoma, Washington 98402

http://wa.water.usgs.gov

Copies of this report can be purchased from:

U.S. Geological Survey
Information Services
Building 810
Box 25286, Federal Center
Denver, CO 80225-0286

CONTENTS

Abstract 1
Introduction 1
    Purpose, Scope, and Methods 2
    Acknowledgments 2
Description of Study area 2
Fifty-Year Flood Discharge 4
Water-Surface Profile of the 50-Year Flood 4
Fifty-Year Flood-Inundation Maps 7
Data Availability 9
References Cited 9

FIGURES

Figure 1. Map showing location of study area and cross sections, and the area of inundation for the 50-year flood on Río Choloma at Choloma, Honduras 3
Figure 2. Graph showing water-surface profile, estimated using the step-backwater model HEC-RAS, for the 50-year flood and location of cross sections on Río Choloma at Choloma, Honduras 6
Figure 3. Map showing depth of inundation of the 50-year flood and location of cross sections on Río Choloma at Choloma, Honduras 8

TABLES

Table 1. Estimated water-surface elevations for the 50-year-flood on Río Choloma at Choloma, Honduras 6

CONVERSION FACTORS AND VERTICAL DATUM

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).

Fifty-Year Flood-Inundation Maps for Choloma, Honduras

By Mark C. Mastin and Theresa D. Olsen

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 Choloma that would be inundated by a 50-year flood of Río Choloma. Geographic Information System (GIS) coverages of the flood inundation are available on a computer in the municipality of Choloma as part of the in 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 on Río Choloma at Choloma were determined 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 Choloma; therefore, the 50-year-flood discharge for Río Choloma, 370 cubic meters per second, 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 Choloma at Choloma are 89.5 square kilometers and 2,164 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 (mm) 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 Choloma that would be caused by a 50-year flood of Río Choloma.

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 discharge 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 Choloma at Choloma 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 Choloma 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 Choloma. Because of the high cost of obtaining the LIDAR elevation data, the extent of mapping was limited to areas of high population where flooding is expected to cause the worst damage. The findings in this report are based on the condition of the river channel and floodplains on March 4, 2000, when the LIDAR data were collected, and May 1, 2001, when the bridges and the reconstructed area near the bridges were surveyed.

Acknowledgments

We acknowledge USAID for funding this project; Jeff Phillips of the USGS for providing data and field support while we were in-country; Roger Bendeck, a Honduran interpreter, for being an indispensable guide, translator, and instrument man during our field trips; and the representatives from the mayor's office for Choloma and Luis DaCosta from the Comision Ejecutiva Valle de Sula, who gave us important local insights into the hydrology of Río Choloma.

DESCRIPTION OF STUDY AREA

Río Choloma flows from the west to the east along the north side of Choloma (figure 1). The study area includes the river channel and floodplains of Río Choloma from approximately 1 kilometer (km) upstream from the main highway bridge just north of Choloma to approximately 4 km downstream of the bridge (figure 1). The headwaters of Río Choloma are located to the west in the heavily forested Cordillera del Merendon. Major reconstruction of the highway bridge, railroad bridge, and floodplain was occurring in the upper half of the study area during the topographic surveys.

During the reconnaissance visit in October 1999, the Japanese International Cooperation Agency (JICA) had begun work on constructing sediment traps upstream of the highway bridge. Major reconstruction of the floodplain in the vicinity of the highway and railroad bridge was already underway during a field visit in January 2001, and was near completion on May 1, 2001, when a ground survey was made of five cross sections in the floodplain in the reach between the railroad bridge and a point about 50 meters upstream of the highway bridge. The reconstructed area had three uniform levels consisting of a low- to medium-flow main channel sloping up to a wide, flat terrace and finally sloping up to a narrow upper terrace bordering residential lands. The banks of the reconstructed main channel are concrete and the wide flat terrace is smooth, compacted soil.

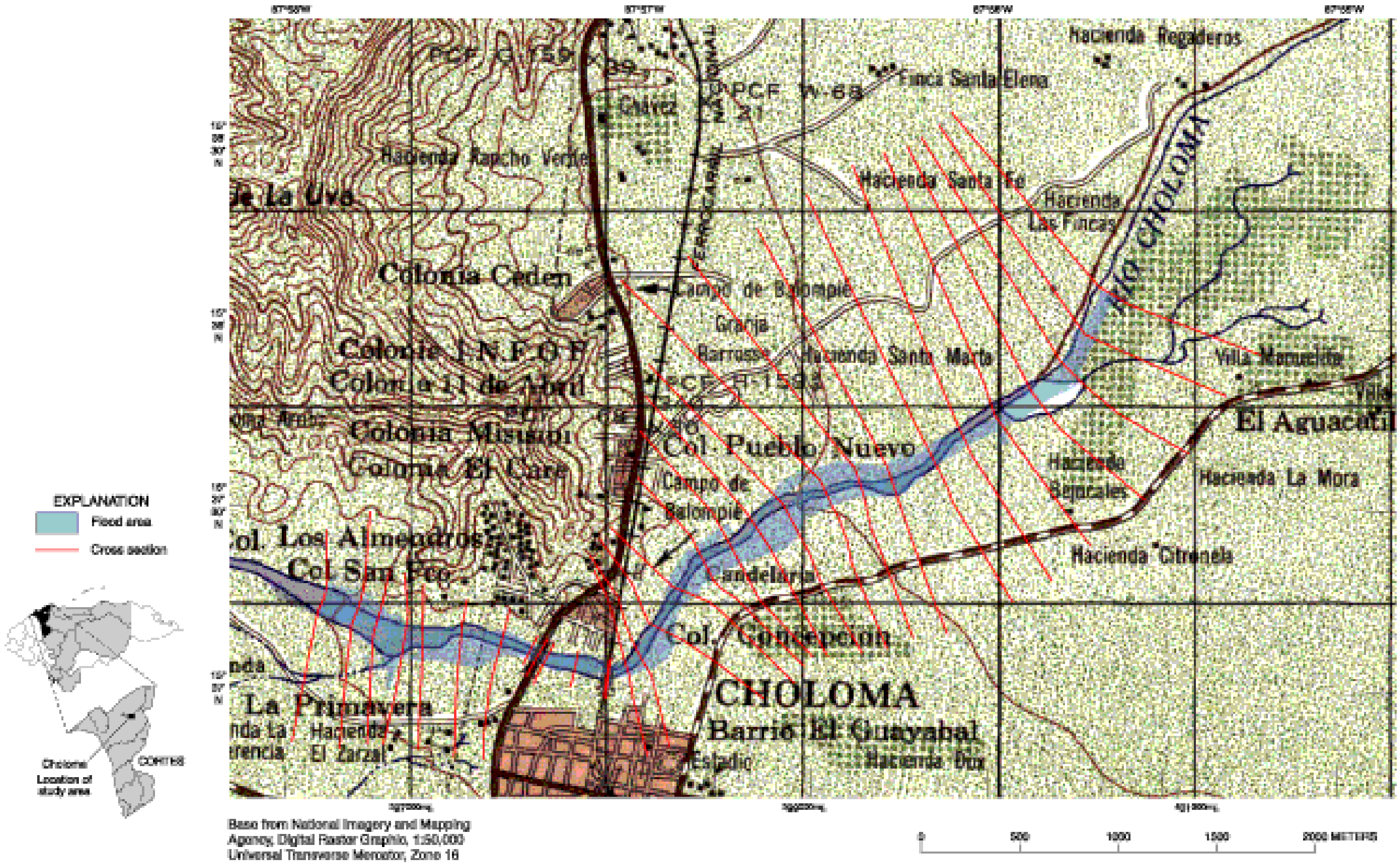


Figure 1. Location of study area and cross sections, and the area of inundation for the 50-year flood on Río Choloma at Choloma, Honduras.

The streambed material ranges from sand and gravel to cobbles and small boulders in the main channel in the area of the bridges--the only area closely observed. From aerial video that was acquired when the airborne topographic survey was acquired, the lower reaches in the study area showed braided channels and bare sediment deposits in the main channel, with agricultural land on the overbank areas. The slope of the channel decreases from a slope of 0.0065 in the upper end of the study area to about 0.003 in the lower end. In the lower end of the study area, the overbank areas slope down away for the channel banks.

FIFTY-YEAR FLOOD DISCHARGE

There are no long-term streamflow records for Río Choloma. 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 to 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 Choloma at Choloma was determined to be 89.5 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 (Dave Stewart, USGS, written commun., 1999). The mean annual precipitation over the Río Choloma drainage basin was estimated to be 2,164 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 equation 1 for Río Choloma at Choloma is 370 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 7, 2000. The relative accuracy of the LIDAR data was determined by comparing LIDAR elevations with GPS ground-surveyed elevations at 647 points in the Choloma study area. The mean difference between the two sets of elevations is 0.103 meter, and the standard deviation of the differences is 0.078 meter. The LIDAR data were filtered to remove vegetation while retaining the buildings to create a “bare earth” elevation representation of the floodplain. 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 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.

On May 1, 2001, the highway and railroad bridges on the north side of Choloma were surveyed.

Most hydraulic calculations of flow in channels and overbank areas require an evaluation 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 profiles. Roughness coefficients (Manning's *n*) for Río Choloma were estimated from field observations and digital photographs taken during the field visit to survey the geometry of the two bridges on May 1, 2001, and from computer displays of shaded-relief images of the LIDAR-derived DEM before the vegetation removal filter was applied. The *n* values estimated for the main channel of Río Choloma ranged from 0.034 to 0.036, and the *n* values estimated for the floodplain areas ranged from 0.050 to 0.070 except in the reconstructed areas near the bridges, where the *n* values of the overbank areas were estimated to vary from 0.028 to 0.030.

Step-backwater computations require a water-surface elevation 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 as a boundary condition. A water-surface elevation of 17.87 meters at cross section 0.181, the farthest downstream cross-section in the Río Choloma step-backwater model, was estimated by a slope-conveyance computation assuming an energy gradient of 0.0028. The energy gradient 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 Río Choloma 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 Choloma at Choloma, Honduras

[Peak flow for the 50-year flood is 370 cubic meters per second. **Cross-section stationing**: distance upstream from an arbitrary point near 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)
5.114	37.45	2.17	39.51
4.931	36.36	2.51	38.21
4.818	35.50	2.31	37.34
4.672	31.47	4.11	35.40
4.577	31.20	1.87	35.39
4.378	31.29	2.26	34.52
4.171	30.90	2.40	33.30
4.019	30.18	2.79	32.53
3.973	29.99	2.66	32.41
3.970 (bridge)			
3.933	29.69	2.72	32.17
3.771	29.24	2.79	31.61
3.603	28.55	3.06	30.89
3.600 (bridge)			
3.593	28.55	3.44	30.66
3.504	28.27	3.71	29.82
3.411	27.77	2.60	29.20
3.216	26.51	2.10	28.35
2.991	25.68	2.22	27.37
2.797	25.18	1.60	26.83
2.629	24.35	2.28	26.22
2.454	23.70	2.12	25.52
2.280	22.72	1.83	24.80
2.055	21.63	2.25	23.62
1.876	20.66	2.16	22.50
1.713	19.49	1.64	22.02
1.469	19.06	1.87	21.53
1.279	18.47	2.46	20.99
1.078	17.98	2.04	20.52
0.853	17.33	2.43	19.70
0.629	17.00	1.78	19.18
0.433	16.50	2.31	18.58
0.181	15.71	2.24	17.87

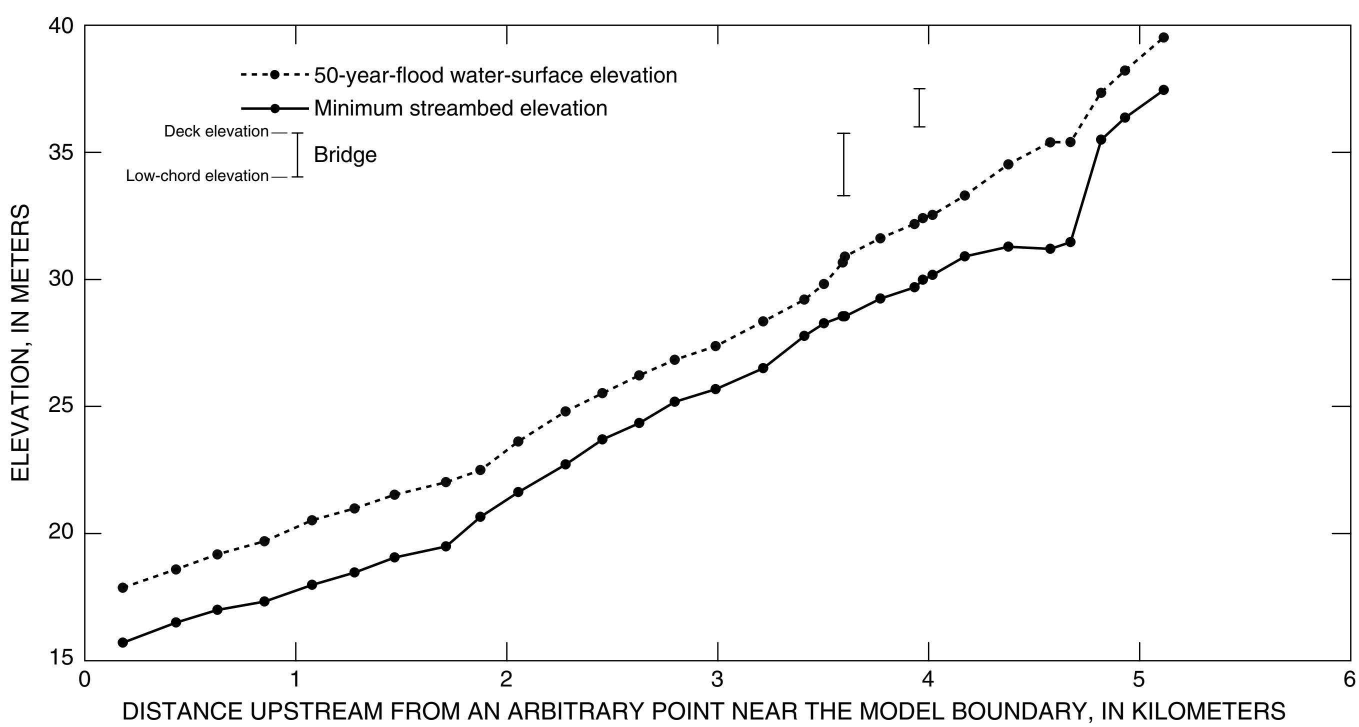


Figure 2. Water-surface profile, estimated using the step-backwater model HEC-RAS, for the 50-year flood and location of cross sections on Río Choloma at Choloma, Honduras.

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 overlain on an existing 1:50,000 topographic digital raster graphics map (figure 1) produced by the National Imagery and Mapping Agency (Gary Fairgrieve, USGS, written commun., 1999). Depth of inundation at Choloma for a 50-year-flood on Río Choloma (figure 3) was computed by subtracting the topographic TIN from the water-surface elevation TIN to produce a grid with a cell size of 2.0 meters. The area of inundation is for the most part contained within the main channel. In the vicinity of the bridges, the reconstructed floodplain easily contains the 50-year flood. The water surface of the 50-year flood is approximately at the height of the main channel banks, leaving most of the upper-terrace portion of the floodplain available to convey more discharge. In the downstream 2 km of the study area, the overbank areas slope down away from the channel banks. If river flows were to breach the natural channel banks, large areas of the floodplain would be susceptible to flooding. The 50-year flood, however, appears to be contained in the main channel banks.

The blue lines depicting the Río Choloma channel on the digital raster graphics map used as the base map for figure 1 lie outside the 50-year-flood boundaries at some locations. This is 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 Choloma floodplain. This tool can reasonably separate high-hazard from low-hazard areas in the floodplain, to minimize future flooding 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 floodplain with structures or fill will reduce the flood-carrying capacity of the channel and thereby increase the potential height of floodwaters, and may increase the area of inundation.

The area and depth of inundation maps in the vicinity of the two bridges may be in error because they are based on the topographic survey made in March 2000, which is known to have changed since that date due to the reconstruction of the channel. The water-surface elevations, however, are based on field surveys made in May 2001 when the construction was near completion and should represent current conditions if no further significant changes in the channel geometry and roughness have occurred. Within this area, however, the 50-year flood is contained within the lower main-channel portion of the reconstructed area.

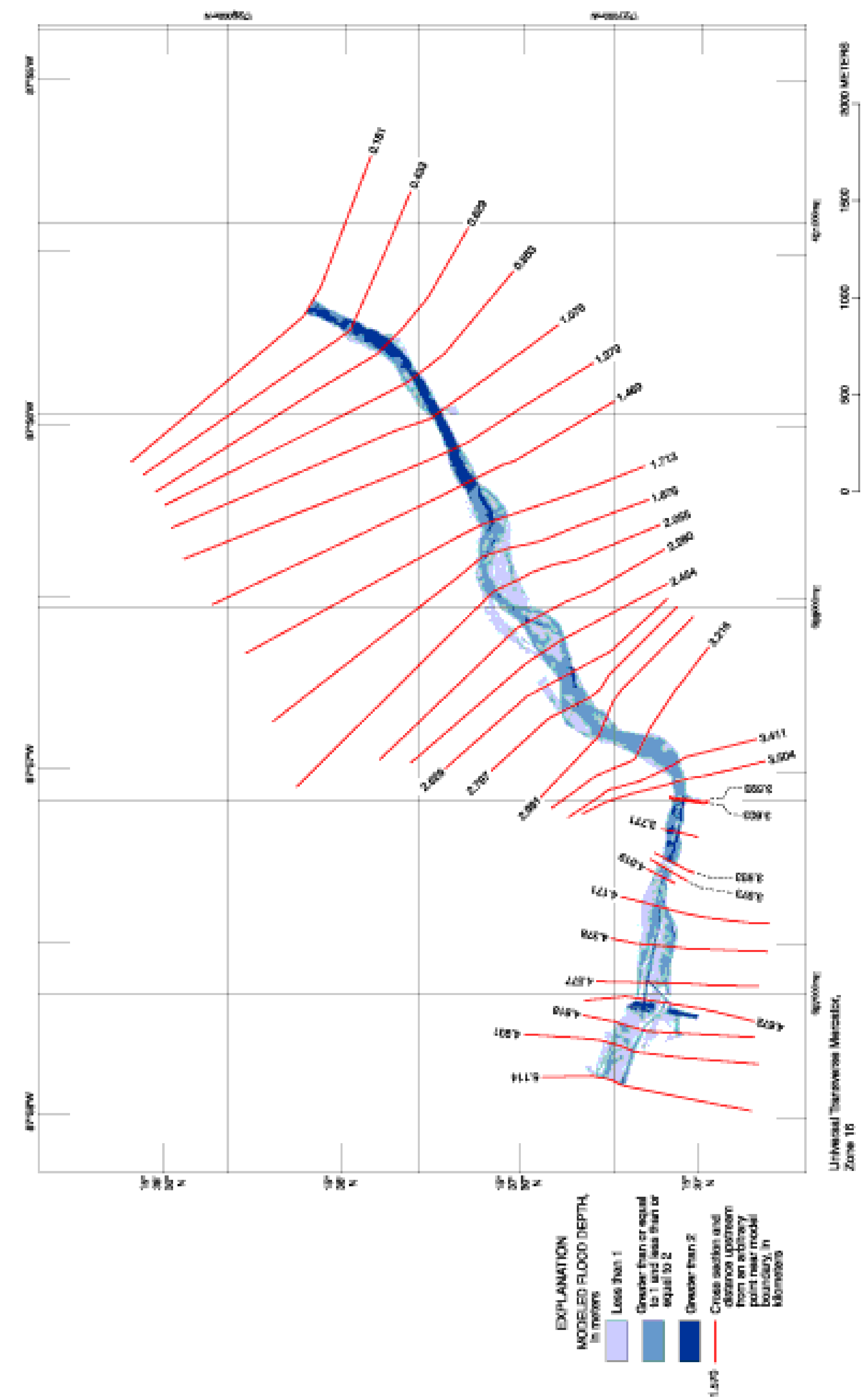


Figure 3. Depth of inundation of the 50-year flood and location of cross sections on Río Choloma at Choloma, Honduras.

DATA AVAILABILITY

GIS coverages of flood inundation and flood depths shown on the maps in figure 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 Choloma municipality office, allows users to view the GIS coverages in much more detail than shown on figure 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.

REFERENCES CITED

Mastin, M.C., 2002, Flood-hazard mapping in Honduras in response to Hurricane Mitch: U.S. Geological Survey Water-Resources Investigations Report 01-4277, 46 p.

Morales-Canales, José, ed., 1997-1998, Atlas geográfico de Honduras: Tegucigalpa, Honduras, Ediciones Ramsés, 48 p.

Rappaport, E.N., and Fernandez-Partagas, Jose, 1997, The Deadliest Atlantic Tropical Cyclones, 1492-Present: Miami, Florida, NOAA, National Hurricane Center, Tropical Prediction Center, technical memorandum, on-line on the World Wide Web from URL http://www.nhc.noaa.gov/pastdeadly.html, accessed September 21, 2001, HTML format.

U.S. Army Corps of Engineers, 1998, HEC-RAS, River Analysis System User’s Manual: Davis, California, Hydrologic Engineering Center, 320 p.

———2000, HEC-GeoRAS, An extension for support of HEC-RAS using ArcView user’s manual: Davis, California, Hydrologic Engineering Center, 96 p.

1

2

3

4

5

6

7

8

9

10

11

12

13

14

15

USGS
science for a changing world

Mastin and Olsen

Fifty-Year Flood-Inundation Maps for Choloma, Honduras

OFR 02-249