STAGE-DISCHARGE RATINGS FOR NINE STREAMGAGES IN EL SALVADOR AND GUATEMALA

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INTRODUCTION

In 1998, streamgage networks in Central America suffered heavy damage as a result of Hurricane Mitch. The networks required much repair to be operative for use in river forecast systems and in planning for disaster preparedness and mitigation. To address this need, the U.S. Geological Survey (USGS) installed or retrofitted nearly 40 streamflow gaging stations in the countries of El Salvador, Guatemala, Honduras, and Nicaragua. An integral part of each gaging station is the stage-discharge rating curve, which is critical for the successful implementation of river forecast systems. In 2001, the USGS developed stage-discharge ratings for nine selected streamgages in El Salvador and Guatemala. This work was done as part of the Hurricane Mitch Program of the USGS in cooperation with the U.S. Agency for International Development (USAID).

Hurricane Mitch became a Category 5 (Saffir-Simpson scale) storm in the southern Caribbean Sea on October 26, 1998, with sustained winds of 180 mph. The hurricane stalled off the coast of Honduras before moving inland. Because of this, much of the ground along the storm's path was already saturated before the most intensive rain fell. The flooding and landslides caused by Hurricane Mitch resulted in 9,000 deaths in Honduras, Nicaragua, Guatemala, and El Salvador. This disaster punctuated the need for real-time streamflow monitoring in the region.

From 1999 to 2001, existing streamgage networks in Central America were augmented by the USGS to establish a real-time river forecast system. Existing gages were repaired, nearly 40 new streamflow and rainfall gages were established, and satellite telemetry was installed at each gage. The network includes nine streamgages in El Salvador and four in Guatemala. Stage-discharge ratings were developed in 2001 by the USGS for nine streamgages in Central America, including six in El Salvador and three in Guatemala (fig.1). Ratings were developed for gages located on the Rio Lempa (sites 1-3), Rio Sumpul (site 4), and Rio Grande de San Miguel (sites 5-6) in El Salvador, and the Rio Ostua (sites 7-8) and Rio Coyolate (site 9) in Guatemala.

METHODS

A rating curve defines the stage-discharge relation at a specific location along a stream. Where a stream is not affected by backwater or tides, the stage-discharge relation typically is a simple curve; each specific stage, or water-surface elevation, corresponds to a specific discharge. Rating curves are computed at gaging stations to convert measured stages to discharges. Rating curves are best defined by obtaining discharge measurements by current meter through a wide range of stages. However, it is rarely safe, and is sometimes impossible, to measure discharge during floods. Therefore, rating curves are often developed by using computations based on hydraulic theory, and assuming uniform, non-varied flow.

One method used to establish a stage-discharge relation is the step-backwater method. The step-backwater method uses channel and valley geometry, water-surface profiles, and roughness coefficients together with Bernoulli's energy equation (Chow 1959) to account for energy lost as water flows from an upstream section to a downstream section. Water-surface profiles can be computed with this method, beginning with a given water-surface elevation at the downstream section. Profiles computed over a reach of several sections and initiated at different downstream water-surface elevations usually converge toward normal depth (Davidian 1984) as they proceed upstream (fig. 2). Therefore, more reliable upstream water-surface elevations usually result from longer stream reaches. A stage-discharge rating can be developed for the section at the upstream end of the stream reach by computing water-surface profiles for a wide range of stages and discharges. For example, at section 4 of the stream reach shown in figure 2, the stage is about 1.7 meters for a discharge of 10 cubic meters per second.

Field data required to perform the hydraulic analyses include channel and floodplain cross sections, roughness coefficients (Manning's “n”), and water-surface or channel-bed slopes. Personnel of the USGS and host-country agencies visited the sites in April 2001. Two to four cross sections were surveyed at each site. Roughness coefficients were selected for the channel and overbank portions of each cross section based on engineering judgment. Reference marks were surveyed at each site so that all surveyed elevations were to gage datum.

The stage-discharge rating for each site (figs. 3-5) was developed using the step-backwater method. Water-surface profiles were computed by using WSPRO, a one-dimensional hydraulic model developed by the USGS for the U.S. Federal Highway Administration (Shearman 1990). Computed water-surface profiles were initiated at the downstream section based on slope-conveyance computations where the water-surface slope was governed by channel characteristics. Profiles were initiated using critical depth at the downstream section where hydraulics were governed by section control. Slope-conveyance computations were based on surveyed water-surface or channel-bed slopes or channel slopes obtained from topographic maps. Discharge measurements obtained by the host-country agencies were used to calibrate WSPRO; however, most of the discharge measurements were limited to the lower portions of the rating curves. Where sufficient discharge measurements were available, water-surface profiles were initiated based on discharge-conveyance ratios. Table 1 summarizes the data used to develop the stage-discharge rating for each site.

RESULTS

The USGS developed stage-discharge ratings for nine selected streamgages in El Salvador and Guatemala. The streamgages are part of a real-time river forecast network in Central America. The stage-discharge ratings were developed with the step-backwater method and available discharge measurements. Step-backwater computations were based on two to four cross sections surveyed at each site. The computed stage-discharge rating curves have been used by the host-country agencies to compute instantaneous discharge from recorded river stages at these nine streamgages. Real-time stage and discharge data for these sites are available on the internet at:
http:// pr.water.usgs.gov/.

REFERENCES

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Davidian, Jacob. 1984. Computation of water-surface profiles in open channels. U.S. Geological Survey Techniques of Water-Resources Investigations, Book 3, Chapter A15.

Shearman, J.O. 1990. User's manual for WSPROA computer model for water surface profile computations: U.S. Department of Transportation Publication No. FHWA-IP-89-027.

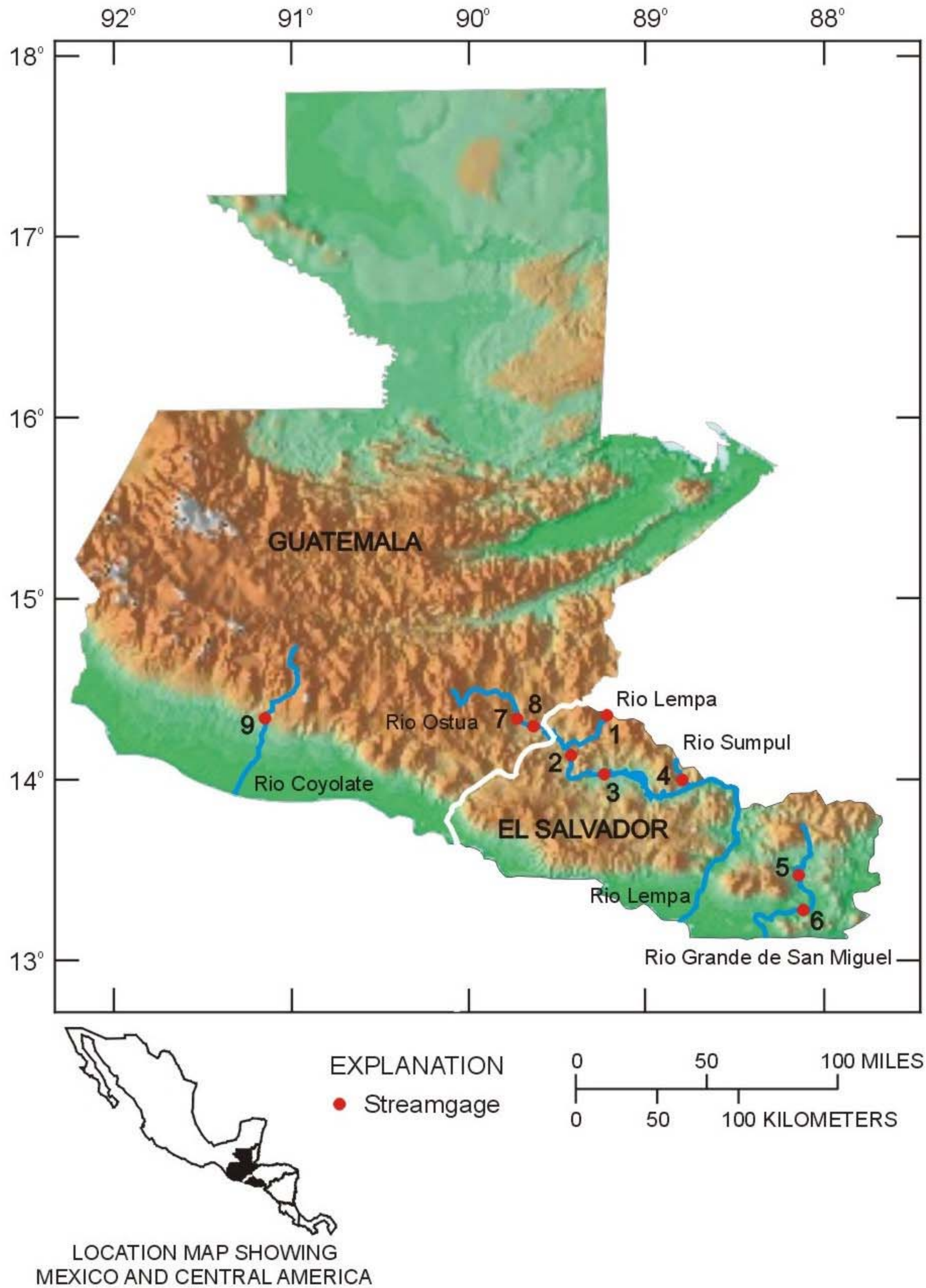

Figure 1. Locations of nine streamgages in El Salvador and Guatemala.

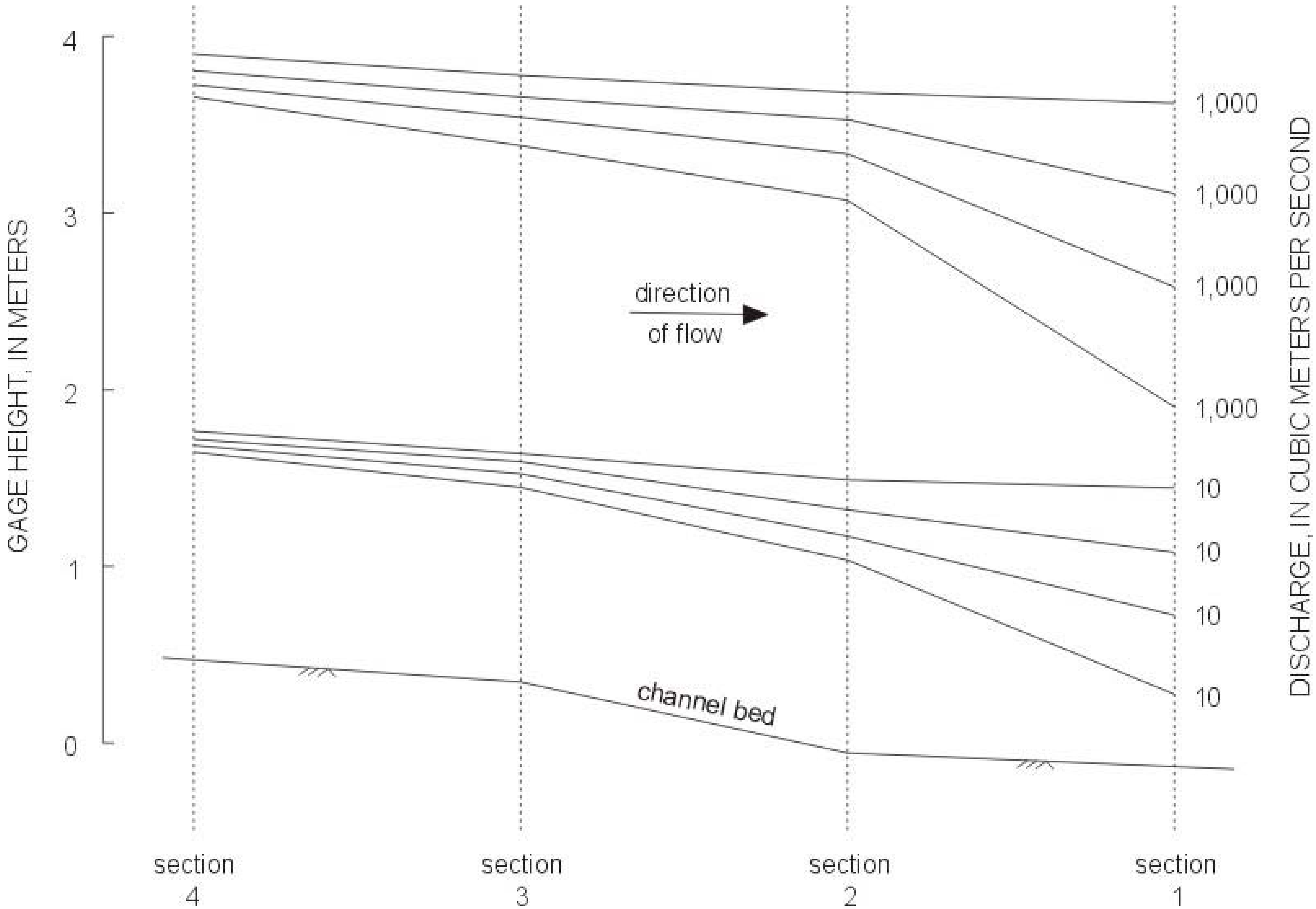

Figure 2. Typical water-surface profiles computed by step-backwater methods.

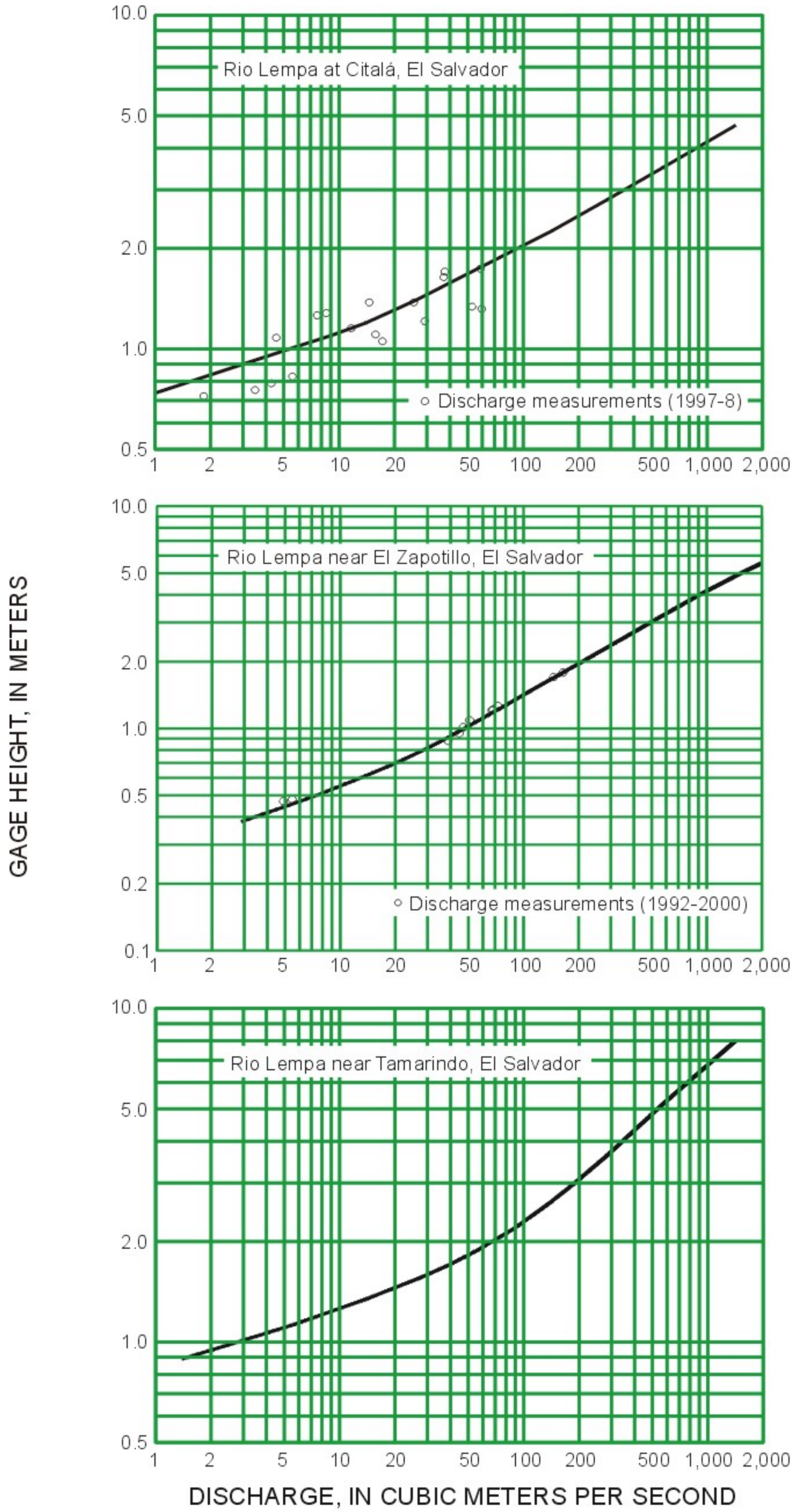

Figure 3. Stage-discharge ratings.

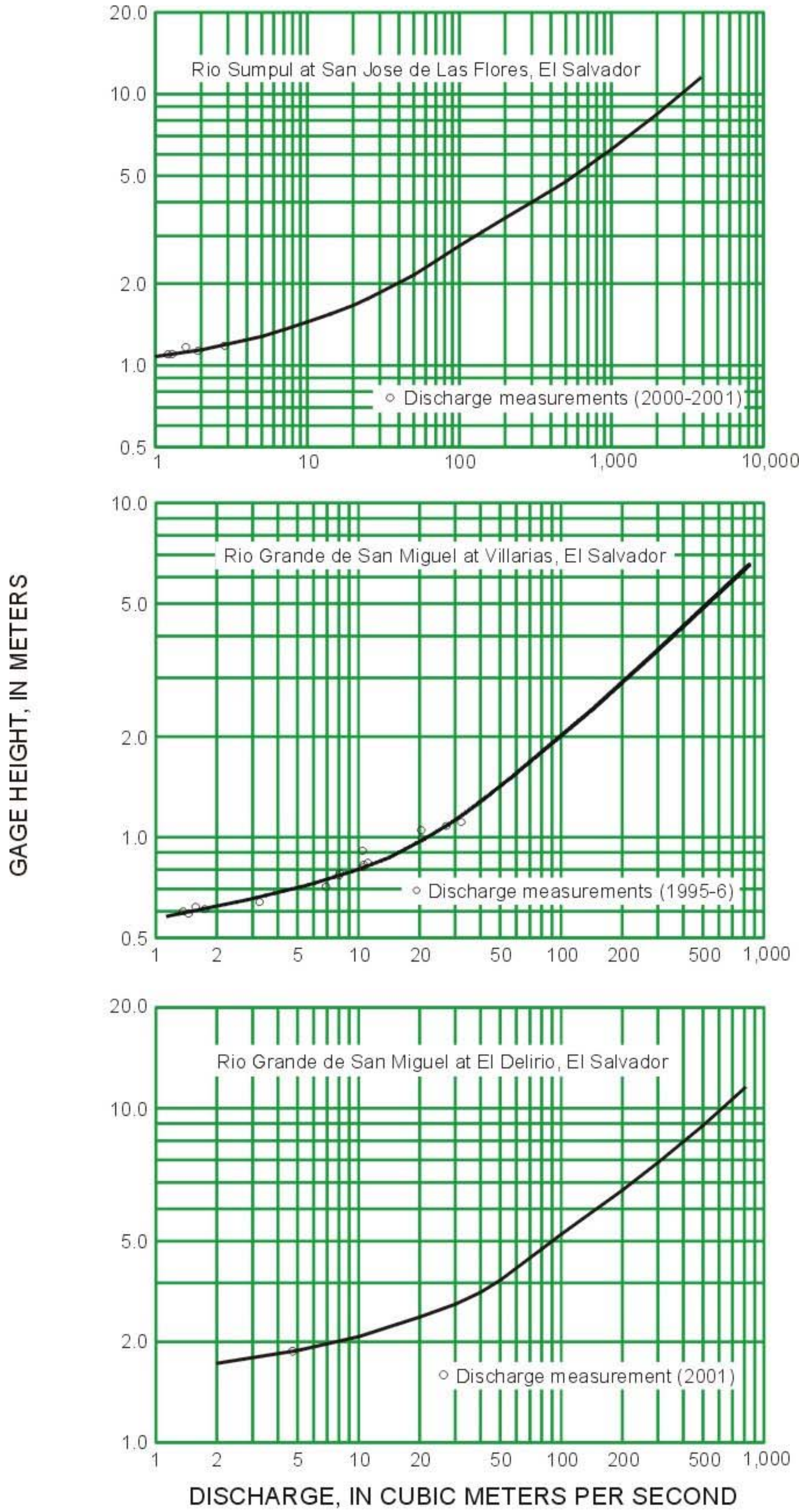

Figure 4. Stage-discharge ratings.

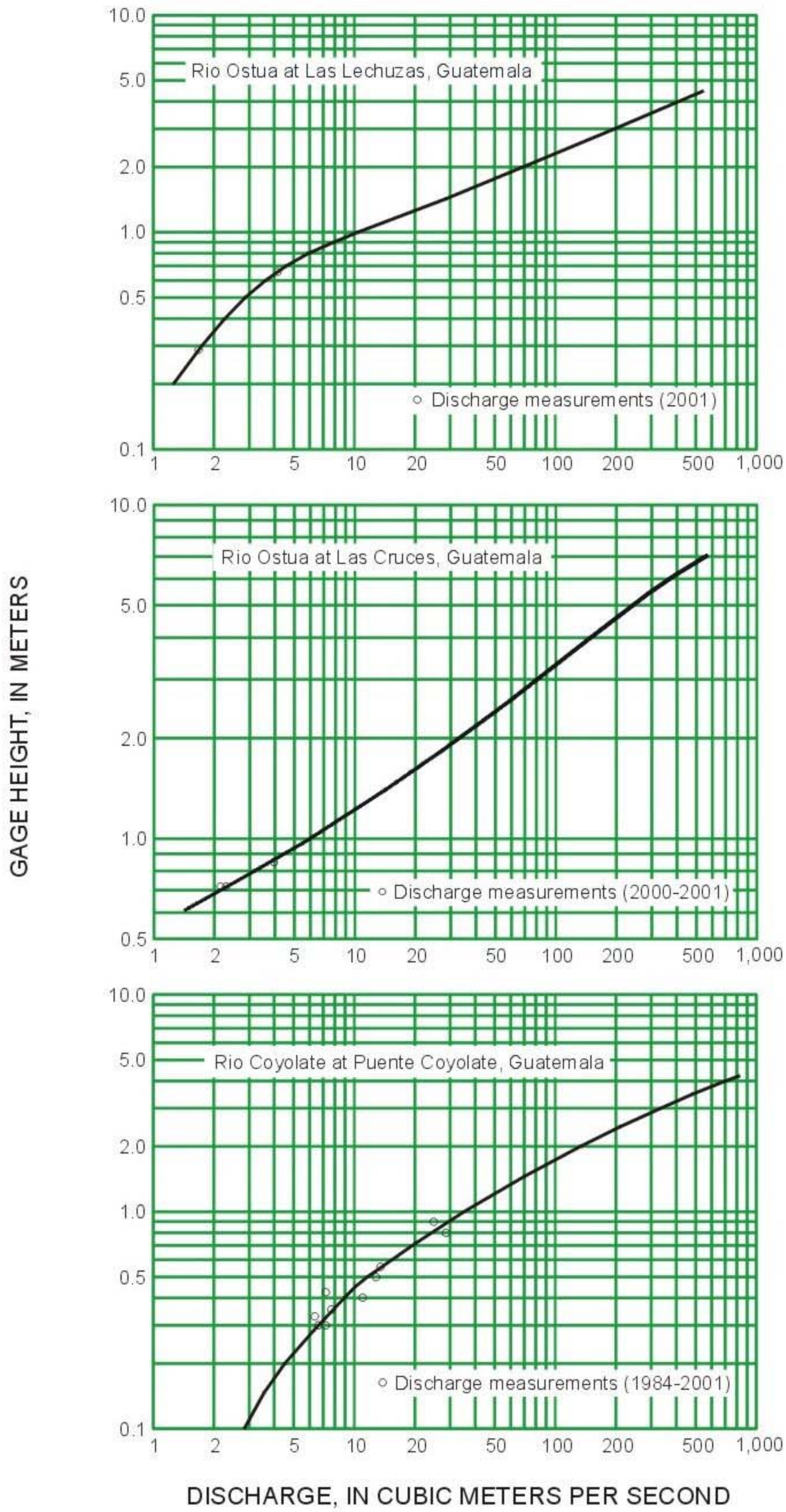

Figure 5. Stage-discharge ratings.

Table 1. Site descriptions and data used to develop stage-discharge ratings for nine streamgages

Site Description				How the rating curve was developed		
ID	Site	Latitude	Longitude	Discharge Measurements Used	Step-backwater computations were initialized with…	Cross sections
1	Rio Lempa at Citala, El Salvador	14°22'09"	89°12'46"	18	slope from topographic map	4
2	Rio Lempa near El Zapotillo, El Salvador	14°10'35"	89°24'48"	11	discharge-conveyance ratios	3
3	Rio Lempa near Tamarindo, El Salvador	14°02'49"	89°15'08"	0	water-surface and channel bed slope	4
4	Rio Sumpul near San Jose de las Flores, El Salvador	14°02'38"	88°48'33"	5	channel bed slope	4
5	Rio Grande de San Miguel at Villarias, El Salvador	13°31'05"	88°10'27"	16	slope from topographic map	4
6	Rio Grande de San Miguel at El Delirio, El Salvador	13°19'43"	88°09'01"	1	channel bed slope	4
7	Rio Ostua at Las Lechuzas, Guatemala	14°21'15"	89°42'45"	2	critical depth	4
8	Rio Ostua at Las Cruces, Guatemala	14°19'06"	89°37'20"	3	average slope from water-surface and topographic map	4
9	Rio Coyolate at Puente Coyolate, Guatemala	14°22'37"	91°08'12"	10	critical depth	2

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