STABILITY ASSESSMENT OF A HURRICANE MITCH-INDUCED LANDSLIDE DAM ON THE RÍO LA LIMA, SIERRA DE LAS MINAS, EASTERN GUATEMALA

by

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Introduction

As a direct result of Hurricane Mitch in early November 1998, two large landslides occurred along the Río La Lima upstream from the town of Jones (Fig. 1). Both of these slope failures were dip-slope rock and debris slides on steep slopes in granitic gneiss of the Lower Paleozoic or older San Augustin Formation (Newcomb, 1978) along the west wall of the canyon of the Río La Lima. The lower of the two slides (area: ~16 ha; toe location: ~4 km north of the town of Jones) dammed the Río La Lima (Figs. 2-4). The upper of the two slides (area: ~25 ha; toe location ~5.5 km north of Jones) initiated at the head of the Río La Lima on November 1, 1998, and preceded the lower slide by a day (Jorge Mario Aldana Ramirez, personal commun., January 2000). Subsequent erosion of the debris flow deposits mobilized from the upper slide contributed much of the sediment that fills the impoundment behind the landslide dam. This report is based on a visit by Robert Bucknam, Manuel Mota, and Robert Schuster on 18 September 2000 to the lower landslide and the natural dam it formed.

Characteristics of the Landslide Dam

The landslide dam formed by the lower rock slide has a crest height of about 50 m above the former stream level, an estimated volume of 500,000m^3, and a downstream face slope of about 30º. An estimated 200,000 m^3 of additional sediment and water has been impounded by this barrier. The geologic materials comprising the slide and the natural dam were derived from the granite gneiss and schist that forms the western wall of canyon. These materials range in particle size from clays to boulders. The surface of the slide is irregular, is broken by many tension and shear cracks, and in September 2000 was covered by a thick growth of grass as much as 2 m high. Crossing the slide on foot was difficult because of the cracks, the very thick grass, and the slippery and irregular mixture of clay and rocks that make up the surface.

Shortly after the dam formed, the retention basin behind the dam partially filled by sediment eroded from the debris flow deposits that originated from the upstream slide. By the time of our visit, this basin had been almost filled by deposition of sediment from both slides. The only surface indications of impoundment of water by the dam were shallow ponds immediately behind the dam. Thus, the landslide dam functions much like a mine-tailings dam, retaining a mixture of about 200,000 m^3 of water and sediment.

At the time of our visit, there was no flow of water over the crest of the dam. Instead, the Río La Lima flowed through continuous voids in the dam, exiting the dam about half way down its face as a large spring at the contact between the dam and the valley-wall left abutment. Although we were did not reach the point of discharge through the dam, it appeared from a distance that there was no evidence of active internal erosion (i.e., the exiting water appeared to be clear).

Downstream Hazard Posed by the Río La Lima Landslide Dam and Its Impoundment

The gradient of the Río La Lima from the downstream toe of the landslide dam to the nearest downstream habitation averages 8 1/2º. The total volume of the dam and its impounded sediment and water is about 700,000 m^3. Thus, if the dam were to fail catastrophically, the river has a sufficiently steep gradient, and there is sufficient water and sediment/debris in the impoundment, to cause a major debris flow that could reach the populated

outskirts of the town of Jones, about 4 km downstream. However, after undertaking this field visit, we feel that the chance of catastrophic failure of the dam is very small because:

- The materials that make up the dam consists primarily of cobbles and boulders of granitic gneiss. These erosion-resistant rocks will inhibit both surface and internal erosion.

- If either surface or internal erosion were to begin, we feel that it would stop short of catastrophic failure because of the process known as "self armoring," in which fine materials would be eroded away leaving an erosion-resistant surface consisting of coarse cobbles and boulders.

- The downstream face of the dam (slope: ~30º) is not steep enough to be subject to slope failure in these coarse materials. We have seen no evidence of failure of these slopes thus far, and expect none in the future.

However, in spite of the above conclusion that the dam and its retained water and sediment/debris pose only a minimal hazard to the people of Jones and vicinity, we can envision three possible scenarios in which the hazard could increase substantially:

- A severe rainstorm, such as that which accompanied Hurricane Mitch in 1998, could cause a flood or debris flow from upstream that would overwhelm the present landslide dam, causing its failure by rapid surface erosion.

- A strong earthquake in the area could cause catastrophic failure of the dam by liquefaction of the mass or by slope failure on the downstream face of the dam.

- A simultaneous occurrence of heavy rain and an earthquake would increase the chance of failure. This scenario is the worst possible, but has only a very small chance of occurrence.

Recommendations

Two factors negate the need for installation of physical mitigation measures at the dam: (1) the very small likelihood of catastrophic failure of the dam, and (2) the extreme difficulty and expense of installing such measures in this very rugged canyon.

In addition, we feel that installation of an early-warning system at the dam would be of little value because of the short time required for an outburst flood/debris caused by catastrophic dam failure to reach Jones. At an assumed velocity of 20 km/hr, an such an outburst flood/debris flow would reach Jones in less than 15 minutes, probably an inadequate time for evacuation. A more practical precaution than an early-warning system would be evacuation of low-lying areas that border the Río La Lima and Río Jones in the event of prolonged heavy rain similar to that during Hurricane Mitch.

However, we do recommend that the condition of the dam, its impoundment, and the outlet of the river through the dam be observed on a regular basis. This can be done by means of binoculars from the trail on the west side of the canyon at a location about one kilometer downstream from the dam and at a site where the trail intersects the landslide above the dam. If additional landslides occur in the vicinity of the landslide dam or elsewhere in the Río La Lima drainage above the landslide dam the stability of the dam should be reevaluated.

Acknowledgements

We thank Prof. Francisco Morales Sagastume for his on-going interest in flood and landslide hazard issues in the Río Jones basin and for his assistance in collecting information from residents of the area on the sequence of events during Hurricane Mitch. We also thank Sr. Jorge Mario Aldana Ramirez of Jones, whose knowledge of the area and help in the field made a previous reconnaissance visit to the area by Bucknam, Mota, and James Vallance feasible.

Reference Cited

Newcomb, W.E., 1978, Geologic map of Guatemala, Río Hondo sheet: Guatemala, Instituto Geogràfico Nacional, Hoja 2261 II G, scale 1:50,000.

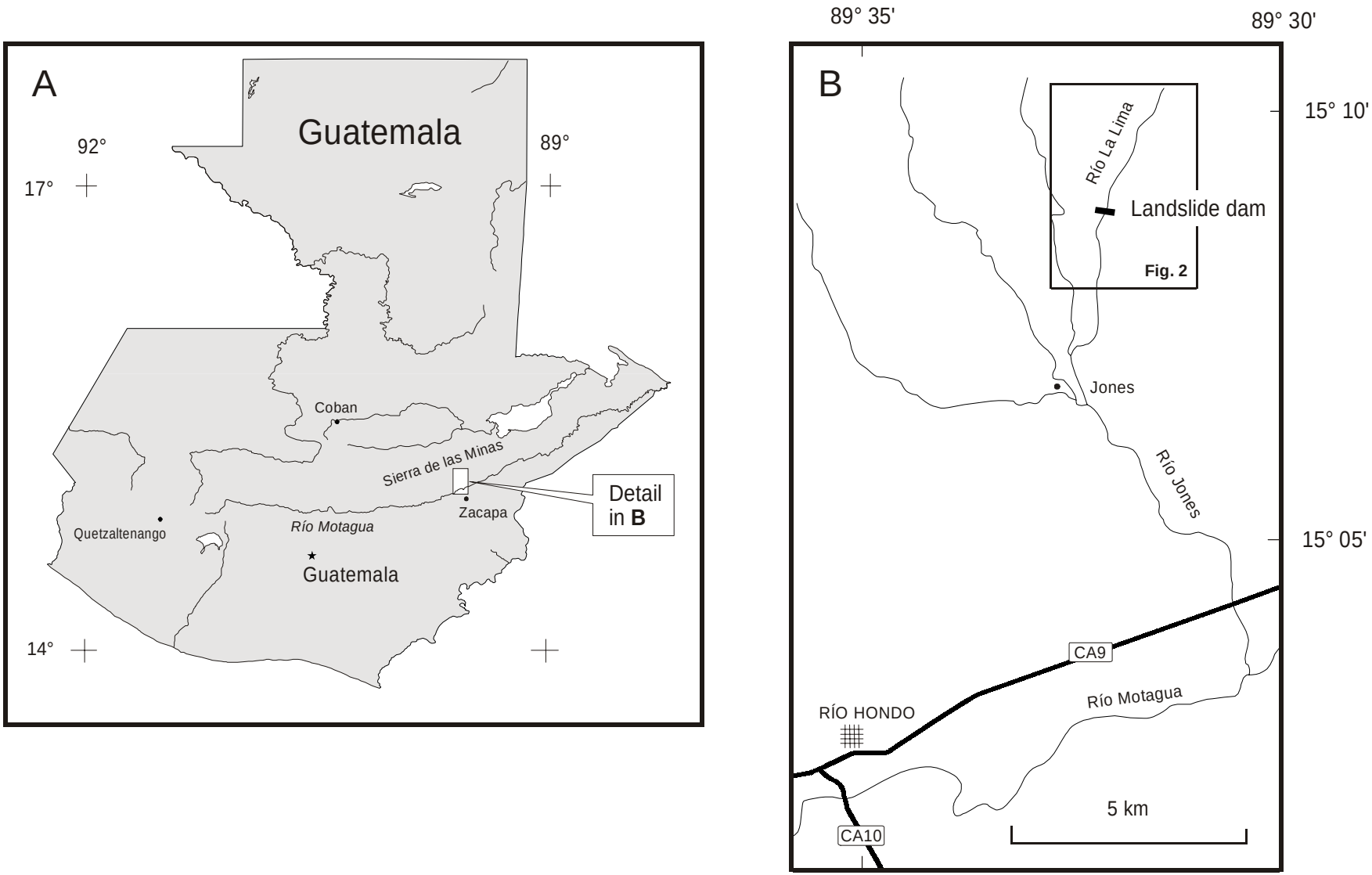

Fig. 1. Index maps. (A) Regional setting. (B) Area of landslide dam on the Río La Lima.

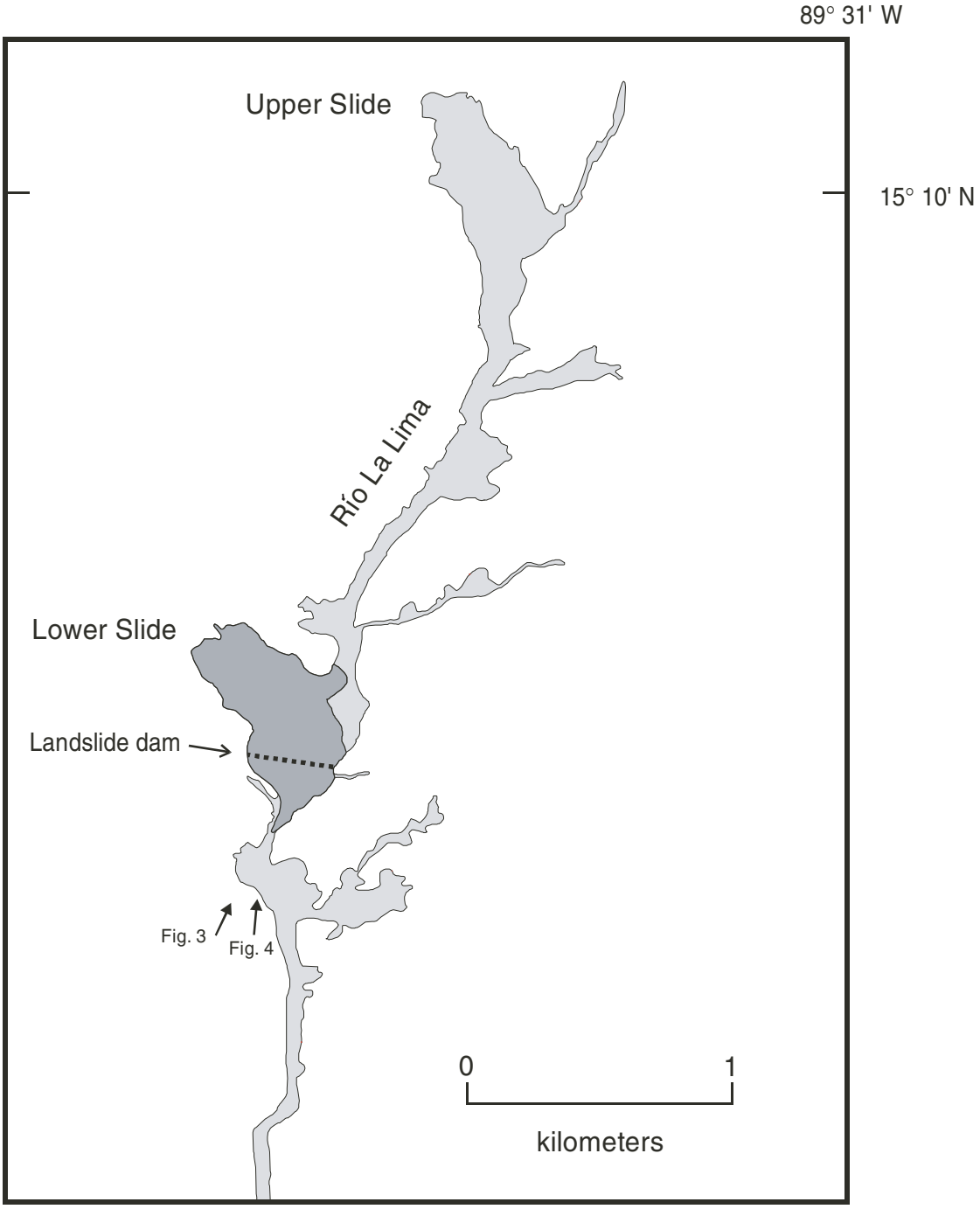

Fig. 2. Map showing areas (shaded) affected by landslides, debris flows, and flooding in the upper Río La Lima drainage. Dark shading shows the landslide complex that produced the landslide dam. Arrows show the approximate photo points and directions of view of Figs. 3 and 4.

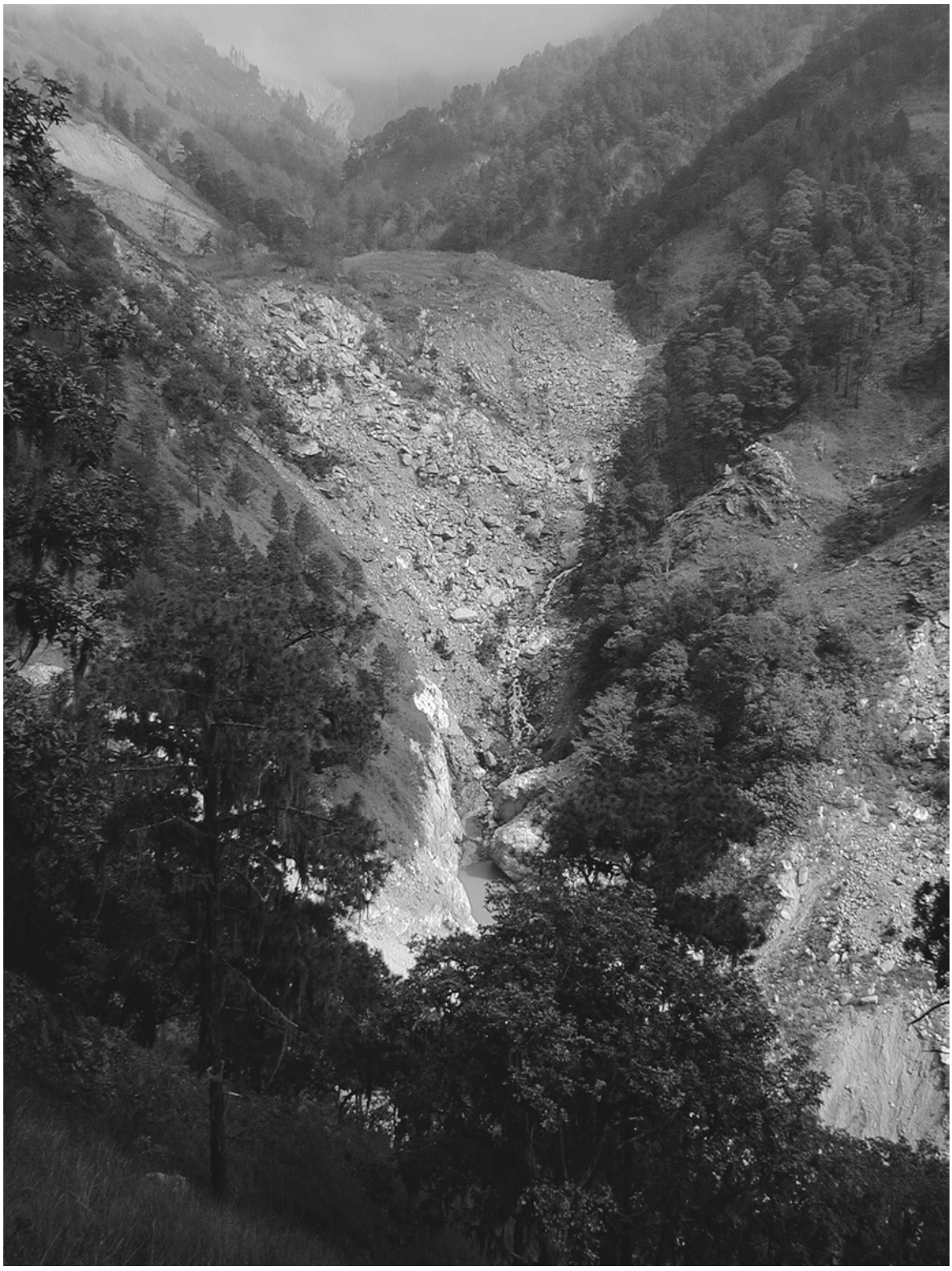

Figure 3. Landslide dam on the Río La Lima, looking upstream (north) from a point 4 km north of Jones; photograph taken 25 January 2000. The landslide originated on the steep slope in the upper left corner of the photograph (see figure 4). The point of discharge of the river from the debris that forms the dam is at the point where the water is first visible at the middle right part of the photograph.

Figure 4. Oblique aerial view to north of the landslide that produced the dam on the Río La Lima, photograph by Jeffrey Coe taken 12 January 2001. Smooth even-toned surface crossed by Río La Lima at the toe of the landslide is the sediment fill behind the landslide dam.