The Municipality of Pereira, capital of the Department of Risaralda in West Central Colombia has experienced a long and destructive history of earthquakes. During the 20th century, the municipality and its region experienced at least seven major seismic events. In 1906, an earthquake of 8.5 magnitude caused the dome of the then-recently built cathedral to collapse. The 1938 earthquake caused major damages on 19th Street. In 1961, a 6.7 magnitude earthquake damaged 15 percent of the houses and 20 percent of other buildings and infrastructure. The neighborhoods of Cuba and Providencia were deeply impacted. A year later, the 1962 earthquake impacted once again the neighborhood of Cuba, and caused a number of structures to completely collapse. The 1979 earthquake, with epicenter in Santa Rosa de Cabal, destroyed buildings and caused the deaths of 37 people. Pereira lost electricity for four hours and telephone service for three days. In 1995 and 1999, earthquakes further destroyed and damaged private homes, public buildings, roads, hospitals and other structures.

Pereira’s high seismicity is the result of a large number of both deep and surface seismic sources. The high magnitude earthquakes are directly related to the actions of the Nazca Plate, a tectonic plate off the South American coast, pushing under the South American continent through a process called subduction. The surface, or cortical, earthquakes are caused by faults not too far from the city. The response of the soil to earthquakes is determined mainly by the material at the surface or near the surface, such as ash fall and pyroclastic material of variable size deposited over the years by the nearby volcanoes.

Pereira and Its Vulnerability

With a population of over 500,000, Pereira is the economic and population center of the Department of Risaralda. As many cities in South America, Pereira has participated in the region’s dynamic demographic and economic growth. Its location in Colombia’s coffee growing area near the major cities of Bogota, Cali, and Medellin enhances its strategic importance as a regional logistics hub. Among the most important causes of hazard risk is inadequate land-use planning—in other words, where people and assets are located. Pereira’s recent unplanned growth, for example, has increased the population’s exposure to probable natural hazards. Some streams have been channeled and used

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as sewage and rainwater collectors, and after some time, many of them have been filled to level the ground without the recommended technical specifications. Thus, one of the main seismic vulnerability problems is the possible amplification of the seismic waves in these areas. Additionally, one of the major problems with critical infrastructure systems is the low structural capacity of the Egoya wastewater collector due to its deteriorating condition.

**Colombia and Disaster Risk Management**

In response to this historical record of disruption and casualties, Colombia decided to become a recognized leader in hazard assessment and disaster risk management. The government has made important investments in monitoring seismic events, volcanic eruptions, and rainfall. Colombia has improved the monitoring of natural hazards and enforcement of building codes. These efforts have reduced the number of lives lost. Colombia has also been working to improve its response and mitigation efforts at the local level. In Risaralda, the Seismic Risk Mitigation Project for Pereira, Dosquebradas and Santa Rosa de Cabal (1996-2001) used tectonic studies to identify important seismic sources, including active faults, and analyze the local and regional seismic hazard. This project accounted for estimations of maximum probable magnitudes and analyzed the soil response based on geotechnical explorations and five newly installed accelerographs that measure the movement of the soil, which are managed by the Autonomous Regional Corporation of Risaralda (Corporación Autónoma Regional de Risaralda, CARDER). With a solid knowledge base of disaster risk information, Pereira decided to include a disaster risk management component in its 2008-2011 Development Plan, with the goals of consolidating an early warning system and integrating information on technological, natural, and man-made hazards in the development and land-use planning processes. Moreover, the new Colombian Standard for Seismic-Resistant Construction NSR-10 (Reglamento Colombiano de Construcción Sismo Resistente) establishes strict recommendations for microzoning studies. Unfortunately, despite these important achievements, disasters continue to cause destruction with no discrimination. Authorities found their decisions on static hazard assessment models rather than on modern dynamic risk assessment, which account for the stochastic nature of natural events. Probabilistic models and more sophisticated computational techniques for the assessment of seismic hazard, as well as the existence of a larger record of seismic events, will enhance disaster risk management.

**Supporting the Change**

The objective of the Technical Assistance Project (TAP) in Pereira is to strengthen local institutional capacity in disaster risk assessment and decision making for risk reduction. The municipal government is using the Probabilistic Risk Assessment (CAPRA) Platform as a tool to strengthen its ability to manage the seismic risk of the Downtown area (Zona Centro, CEZ 1), which stretches along the Otun River. The CAPRA Platform is a modular and open-source tool that integrates specific software for modeling hazards, building exposure databases, and determining the physical vulnerability of assets. The software includes hazard mapping, risk assessment, and cost-benefit analysis tools to support decision making. The CAPRA Platform evaluates disaster risk in terms of physical damage (buildings and infrastructure), estimating economic losses and losses of...
human life. The software was developed under the CAPRA Program, which started as an initiative to assist Central American governments to assess their disaster risk from natural events (e.g., earthquakes, floods, volcanic activity), and to use this information to adopt standards to reduce disaster risk. Since its inception in 2008, CAPRA Program activities have expanded to South America and South Asia using a TAP approach. Through a TAP, government institutions enter into a partnership with The World Bank and receive hands-on training and target technical advisory services in disaster risk assessment, including:

- Identification of hazards, historical review, and probabilistic analysis,
- Inventory and categorization of exposed and vulnerable buildings,
- Evaluation of disaster risk by natural events, and
- Creation of hazard and risk maps and examples of disaster risk management applications.

The TAP in Pereira is (i) providing hands-on training, (ii) updating the municipality’s microzoning database, and (iii) improving information on more than 100 buildings belonging to the Education and Health Departments. Using the disaster risk information generated, TAP participants will develop strategies and guidelines to improve land-use planning and reduce the vulnerability of schools, hospitals, and other public buildings. The TAP of the CAPRA Program is sponsored by Colombia’s National Planning Department (Departamento Nacional de Planeación, DNP) and the National Unit for Disaster Risk Management (Unidad Nacional para la Gestión del Riesgo, UNGR). The Pereira municipal government is the TAP implementing agency. Participating agencies include CARDER, the Secretariats of Municipal Planning, Education and Health, the water company, the telephone company, the Engineering Association of Risaralda (Asociación de Ingenieros de Risalda, AIR), the Colombian Geological Service (Servicio Geológico Colombiano, SGC), the Colombian Geology and Mining Institute (Instituto Colombiano de Geología y Minas, INGEOMINAS), the Free University of Pereira, and the University of Quindio. The consortium Evaluación de Riesgos Naturales (ERN) is providing the training and technical assistance, and The World Bank is providing the financing.

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The goal is to increase regional capacity in risk modeling in order to support disaster risk management processes that inform development programs.”

—Fernando Ramírez, World Bank Senior Disaster Risk Management Specialist
The TAP began in March 2011 with a workshop to introduce participants to the software, tools, applications and methodology. Participants discussed the CRISIS 2007 component on seismic hazard and the Colombian disaster risk model. During the second half of the workshop, participants focused on the geographical information system (GIS) component, which introduced hazard, exposure, vulnerability, and seismic risk assessment, among other topics. During the second workshop, in August 2011, participants reviewed the region’s seismicity, the microzoning model, seismic sources, attenuation laws, site effects, and exposure levels. An important focus of the two-day presentation was the methodology to define vulnerability functions. Participants completed this work during the third workshop in November 2011, reviewing the final seismic hazard levels, exposure, vulnerability, and site effects.

**Results**

The TAP’s main output for the city government is the increased capacity in disaster risk management and the use of the CAPRA Platform. The hands-on training improved the participants’ understanding of the software’s potential to aid in decision making and their daily work assignments. The TAP’s focus on microzoning provided a detailed understanding of the region’s topography and of surface and underlying soil materials. The study area’s seismic response (measurement of how a structure reacts to an earthquake) is mainly characterized by the presence or absence of surface volcanic ash fall, alluvial deposits, or man-made fill, all of which make up the soft soil surface deposits. Given their dynamic characteristics, seismic response is largely a function of surface soils and not of the rigid underlying layers. The risk assessment combines the geological and geophysical characteristics of seismic micro zones (e.g., ground shaking, liquefaction susceptibility, landslides) with a database of private properties, hospitals, and schools data – currently being collected by the municipality and participating universities, and vulnerability data to assess risk. The process of seismic microzoning estimates the response of soil layers to an earthquake. The results of the risk assessment will provide updated information for a new Disaster Prevention and Mitigation Plan (Plan Indicativo para la Prevención y Atención de Desastres).

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