

Natural Disaster Risk and Preparedness in Mexico

Executive Summary

Indiana University EAS E-490: Environmental and Energy Diplomacy

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Background and Context

Mexico's complex landscape, extensive coastline, and unique geological and climatic setting make it vulnerable to a variety of natural disasters, including earthquakes and tsunamis, flooding and landslides, volcanic eruptions, and meteorological hazards. Each of these primary hazards in turn is associated with a variety of secondary hazards (e.g., flooding from tropical cyclone precipitation or landslides triggered by an earthquake). The impact of a potential natural disaster represents a combination of its *hazard* (i.e., likelihood of occurrence of the natural process), *exposure* (i.e., population and infrastructure affected by the hazard) and *vulnerability* (i.e., susceptibility to damage). The presence and distribution of U.S. citizens is not static within Mexico, but for each hazard category, we focus on settings where large numbers of U.S. citizens are likely to be exposed to a given hazard. Aside from geographic proximity to a natural hazard, the most vulnerable segment of the population for any of the natural disasters evaluated are those who are socioeconomically disadvantaged (e.g., substandard dwelling structures and shortages of resources for evacuation). With a history of persistent and severe natural disasters, the Mexican government is constantly improving its preparedness and response to natural hazards by adopting evolving technologies and increasing cooperation with the U.S. government. While a comparison of recent case studies to those of the prior century demonstrates substantial improvements in Mexico's ability to manage the threats from natural hazards, we examine remaining shortcomings and identify potential solutions for improved preparation and response. Specifically, we analyze the U.S. Embassy's preparedness and response in protecting U.S. citizens in Mexico in relation to (1) earthquakes and tsunamis, (2) volcanic eruptions, (3) meteorological hazards, and (4) landslides and flooding. We provide a suite of curated resources summarized below that can be used internally and externally by the U.S. Embassy to prepare for and respond to the four groups of natural hazards in Mexico.

Project Deliverables - Natural Hazards Geodatabase

The principal deliverables from our project include a series of resources for each identified group of natural hazards that threaten Mexico. Individualized reports for each set of natural disasters provide a comprehensive overview of the impacts of the natural hazard, including a plain language scientific background on the source of each of the phenomena, a review of case studies, an annotated list of resources, and policy recommendations. We also provide a comprehensive suite of spatial data relevant to all four natural hazard subgroups. These project deliverables were created using ESRI *ArcMap* and *ArcCatalog* 10.6.1 software, as well as spatial data files compatible with *Google Earth* software. Static maps illustrate high risk areas (e.g., flood vulnerability indices, coastline storm surge risk), key infrastructure (e.g., monitoring stations, shelters), and other relevant data projected onto maps organized by topic, hazard type, region or city with. A guide is provided for user accessibility.

I. Earthquake and Tsunami Hazards

Mexico is impacted by earthquake primary and secondary effect hazards including ground shaking, tsunamis, liquefaction, landslide, and amplification. High concentrations of American citizens, residing in or visiting Mexico, are exposed to high or very high earthquake, landslide and liquefaction hazard in ten Mexican states; Baja California, Baja California Sur, Colima, Distrito Federal, Jalisco, Mexico, Michoacán, Morelos, Nayarit, and Sonora. Seven of the ten states are also exposed to local and distant tsunami hazards. In addition to high exposure, the cities of Tijuana, Mexicali, Morelia, Guadalajara, and Mexico City have added environmental, physical, and socioeconomic vulnerabilities that compound to increase their risk of an earthquake-related natural disaster. Case studies of the 1985 Mexico City and 2017 Puebla earthquakes indicate that Mexico greatly improved their mitigation and preparedness efforts in the last 30+ years. However, there still remain vulnerabilities due to poor building code enforcement and socioeconomic inequalities. Scenario analyses of earthquakes in San Diego-Tijuana and Morelia illuminate potential earthquake-related natural disasters that would require national or international response due to compounding secondary effect impacts in areas with high U.S. citizen population. The U.S. Embassy in Mexico provides timely, informative updates regarding natural disasters via their social media and the Smart Traveler Enrollment Program; however, earthquakes cannot be predicted and thus require periodic reminders about what to do in preparing for a future event.

II. Volcanic Hazards

Volcanoes pose a serious threat to Mexico, and in turn to U.S. citizens visiting or residing in Mexico. There are 42 actively monitored volcano sites in Mexico, with two volcanoes (Colima and Popocatepetl) experiencing recent bouts of activity. The key volcanic hazards include are volcanic ejecta (in the form of large fragments and ash, which pose a particular danger to air travel, ground transportation, and agriculture), pyroclastic flows (dense fast-moving clouds of superheated gas, ash, and rock fragments), and lahars (destructive mudflows triggered by the mixing of ash and rain or the destruction of mountaintop lakes or alpine glaciers). Case studies of the 1943 eruption of Parícutin and 1982 eruption of El Chichón suggest that local authorities play a critical role in the immediate response to an eruption and that use of monitoring and warning systems are essential to prevent fatalities during an eruption. The more recent 2013-2017 and 2019 eruptions of Colima and the 2020 activity of Popocatepetl demonstrate that Mexico has greatly improved coordination of monitoring systems and *Protección Civil* mitigation and warning efforts; however at the same time they show a gap in effective outreach to American citizens. A risk assessment of the potential eruptions of Colima and Popocatepetl highlight the present danger to growing urban centers in close proximity to the volcanoes (Mexico City, Colima, and Guadalajara), as well as damage to major roadways and airports, which will be essential in the evacuation of American citizens.

III. Meteorological Hazards

The heavily exposed coastline of Mexico is surrounded on both coasts by warm tropical waters favorable for tropical cyclone formation. Given the substantial population growth and development, especially in coastal areas with resorts on or near the coastline, tropical cyclones are the foremost meteorological hazard that continues to threaten vulnerable populations, including U.S. citizens. The deadly primary and secondary hazards reinforce the necessity to prioritize and optimize preparedness, mitigation, and response efforts addressing these seasonal storms. We describe the formation and climatology of tropical cyclones in Mexico. Our analysis indicates that major hurricanes (category 3+ storm) make landfall, on average, on the east and west coasts every 7 to 11 years, respectively. As case studies, we review the effects of hurricanes Dean (2007; Quintana Roo) and Odile (2014; Baja California Sur) in regions with vulnerable populations that U.S. visitors frequent.

We also provide an overview of tornado risks, as well as an annotated list of resources relevant to meteorological hazards.

IV. Landslides and Floods

Flooding and landslides have the potential to cause immense damage. Unfortunately, both events occur in Mexico every year. The former occurs predominantly as either flash floods triggered by short, intense rainfall events and lack of infiltration, or as riverine flooding when days of rainfall exceed the capacity of a stream and spill water into floodplains. Although less frequent, catastrophic flooding can occur when a collapse such as a landslide or dam failure releases large volumes of water downstream; these are often produced by an initial flooding event. Riverine and catastrophic flooding risks are highest in the low-lying areas surrounding rivers, whereas flash flooding is especially impactful in urban settings like Mexico City. Due to its unique coupling of geographic setting and water management history, the city is vulnerable to flood hazards which are predicted to be exacerbated by climate change. Whereas floods impact low elevations, landslides pose the greatest threat to civilians living on or beneath steep hillslopes with limited stability and are usually triggered by heavy rainfall from meteorological events. Their potential to cause sudden, tremendous damage is exemplified by a particularly catastrophic la Aurora landslide in Teziutlán, Puebla, which produced over one hundred casualties. There is currently only one landslide monitoring station in Mexico, and flood monitoring has its deficits as well. Although a network of dam and water quality stations are available for monitoring through the *Centro Nacional de Prevención de Desastres*, flash floods and landslides often occur before these methods can be used to notify victims. Therefore, it is especially important for the Embassy to have knowledge of the nature of flood and landslide hazards in Mexico, to educate American citizens and prepare their response. Based on our analysis of flood and landslide hazards we present recommendations for how the Embassy can better prepare for and mitigate the exposure of these hazards to American citizens in Mexico.

Highlighted Recommendations

Each individual report includes detailed recommendations described within the context of the specific hazard discussed. Below are highlighted recommendations for Embassy consideration to enhance prevention and mitigation of damages relevant to all hazard types.

- 1. Develop an Embassy disaster preparedness training program.** We recommend developing a disaster preparedness training program for the staff of the U.S. Embassy and consulates in Mexico. This training program, designed for both long-term and short-term visitors, would include both advance preparedness actions and how to respond in the event of an active disaster. Training materials could make use of our geographic resources that would help Embassy staff respond quickly and appropriately to emerging disasters in various parts of Mexico.
- 2. Improve Communication to American Citizens in Mexico**
 - a. Use STEP and/or social media for disaster education.** Many Americans visiting Mexico may be coming from areas where the hazards addressed in this report are uncommon. We recommend using the Smart Traveler Enrollment Program to provide a general overview of locations where hazards are present in Mexico and the basic steps of response to those hazards.
 - b. Improve hazard information on travel.state.gov website for Mexico.** The U.S. State Department website for Mexico provides minimal information regarding natural disasters. We recommend updating the links to provide access to specific web

sites regarding hazards and preparedness and adding information about earthquake, tsunami, and other early warning systems in Mexico. We recommend adding an “Emergency Preparedness” component to the “Additional Resources for U.S. Citizens” section on the U.S. Embassy’s website for Mexico. This page could also link to an American Citizen Services (ACS) website as Embassy Tokyo has on the travel.state.gov website for Japan.

- c. **Educating American Citizens.** We recommend the development of traditional educational tools, such as brochures, videos, flashcards, checklists, and quizzes about individual home preparedness and secondary hazards. These materials could be particularly useful for enhancing awareness about natural hazards and related impacts in areas frequented by short-stay American tourists.
- d. **Refine existing State Department apps to display for disaster preparedness.** ‘The Smart Traveler App’ provides a convenient way to access the State Department’s travel-related resources. A few key additions and modifications to the user interface would help increase the productivity of the app as a tool for disaster preparedness. A Disaster Preparedness section within the app could include background on the common natural hazards within the country and ways in which Americans can be prepared. The use of geo-technology and location tracking features within the app could be utilized for locating American citizens during or after a disaster.
- e. **Make use of the American Liaison Network and Citizen Liaison Volunteers.** The American Liaison Network (ALN) and Citizen Liaison Volunteers can act as a resource as well as a model for community engagement during crisis communications. This network can be used as an additional support mechanism to address health, safety, and security issues affecting U.S. citizens during an emergency. This community engagement can be particularly helpful in smaller cities and rural areas, which tend to be the hardest places to reach during a natural disaster.

- 3. **Enhance collaboration with US scientific agencies on hazard research and response.** Collaboration with U.S. scientific agencies and institutions, such as the U.S. Geological Survey, the Smithsonian Institution’s Global Volcanism Program, National Hurricane Center, and academic institutions with hazard-specific expertise will allow the Embassy to establish better connections to prepare for and respond to these disasters. These connections will make it easier to improve hazard assessment and mitigation, and to obtain reliable information before, during, and after an event.