Undergraduate Research Program for Honor Students

Risk & Vulnerability Assessment on Water Treatment Infrastructure against Natural Hazards in Puerto Rico

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Abstract

This research focused on the use of FEMA's Hazus-Multi Hazard GIS modeling software for the performance of a risk and vulnerability assessment on drinking water treatment plants in Puerto Rico against natural hazards. Earthquake simulation by the software provided damage estimates for the water treatment plants closest to the epicenter. Based on the damage percentages provided by the software, an identification of the most vulnerable potable water treatment facility was accomplished. The limitation for the usage of only earthquake and tsunami hazards for the island of Puerto Rico, and the complex workings of the software, limits its potential usage for risk and vulnerability assessments in the future. With the proper development for the application of multiple hazards and the update to the default databases for Puerto Rico by the FEMA Hazus team, multiple risk and vulnerability assessments may be accomplished for different structures and for different natural hazards.

Introduction and Risk Analysis Software

Natural Hazards pose a significant threat yearly to various common and critical infrastructures. According to the (Department of Homeland Security, n.d.), critical infrastructures are systems, networks and assets that are so essential that their continued operation is required in order to ensure the security of a given nation, its economy, and the public's health and/or safety. Of all the critical infrastructure systems, the drinking water infrastructure is one of the most fundamental for our lives and is basically irreplaceable. Puerto Rico's drinking water infrastructure was rated a D by the ASCE 2019 Report Card (American Society of Civil Engineers (ASCE), 2019). The use of FEMA's Hazus-Multi Hazard software provides the simulation of different natural hazards such as earthquakes, tsunamis, floods, and hurricane winds, and their respective damages to different drinking water infrastructures on the island of Puerto Rico. Due to some constraints with the software in Puerto Rico, the analysis was only limited to the use of Earthquake & Tsunami Scenarios. The earthquake scenarios simulated were based on the January 2020 earthquakes that occurred on the southern part of Puerto Rico. A total of 3 Earthquake scenarios and 2 Tsunami scenarios were analyzed and documented on the report.

Objective

To establish a risk and vulnerability methodology for the proper evaluation of the possible damage that multiple natural hazards may have on different infrastructures, such as drinking water infrastructure, of a given study region. And use the methodology to identify the most vulnerable facilities, that may require special maintenance and/or retrofit to avoid failure due to extreme natural events.

Research Methodology

1) Study of Hazus-MH Software Functionality , ArcGIS, and their Integration and Compatibility
2) Installation of Software and Study of Hazus-MH Case Studies
3) Study and Collection of Drinking Water Infrastructure data for the Software
4) Description of the Hazards
5) Identification of Possible Assets at Risk
6) Hazus Simulation to Analyze Risks
7) Summarize Vulnerability
8) Evaluation of Mitigation Options

Common Hazus-MH Results

The software serves as an indicator of the possible locations of infrastructure failure on Puerto Rico based on data from the most recent census, the software's default databases, and the parameters provided to the software (soil data maps, landslide susceptibility maps, liquefaction map, among others). To show the effectiveness of the software, the results presented are based on a simulation of the 6.4 Earthquake that occurred January 7th, 2020 . Results that could be provided by Hazus-MH can be the amount of debris generated from a scenario and the amount of shelter requirements, Figure 1 and 2. Other results such as the estimate of economic impact and the damage to different critical infrastructure systems can also be provided by the software via reports.

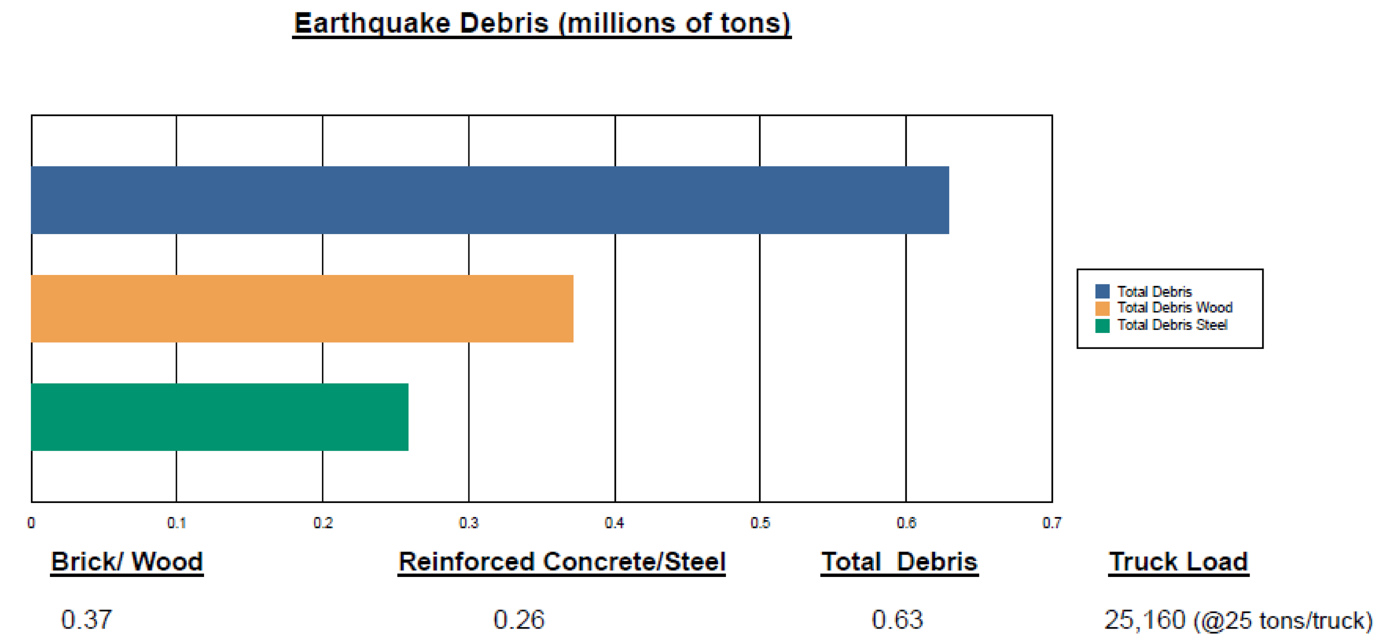

Figure 1: Debris Generation from 6.4 Magnitude Earthquake (Adapted from Hazus-MH Seismic Report)

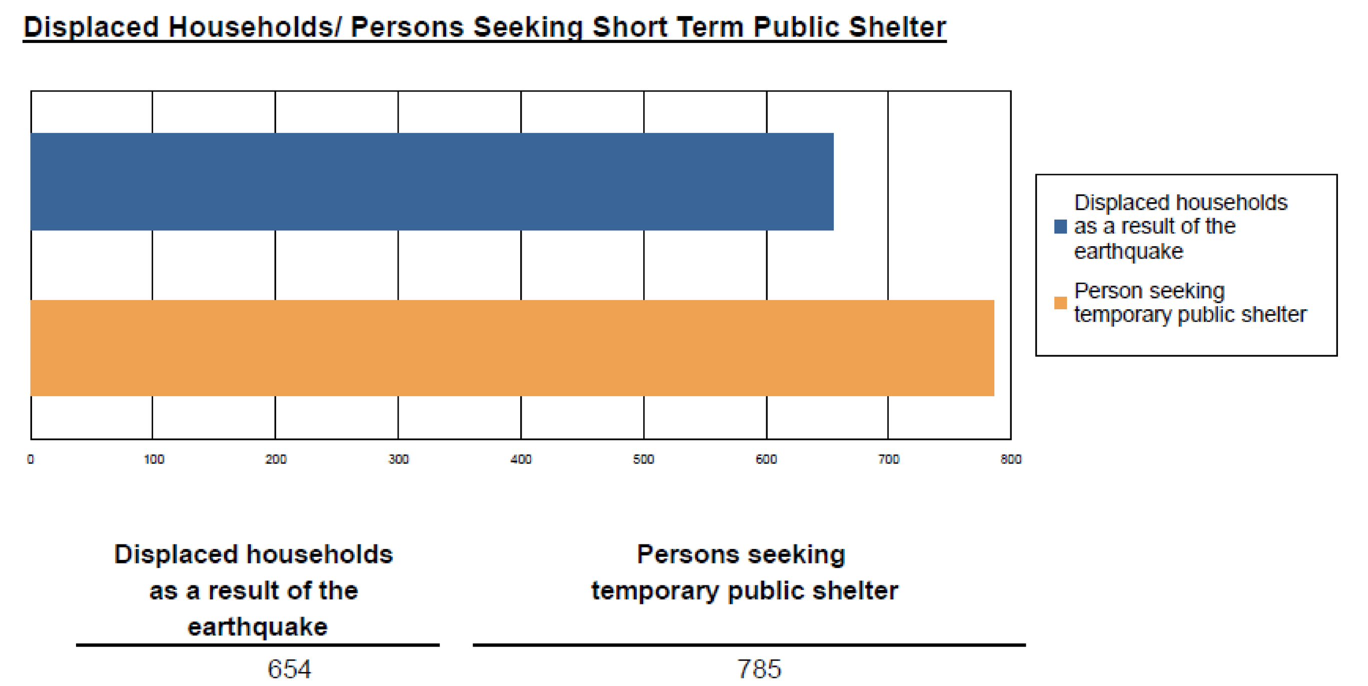

Figure 2: Population Displacement due to 6.4 Magnitude Earthquake (Adapted from Hazus-MH Seismic Report)

Additional to the Earthquake scenarios, Tsunami scenarios were also developed. These scenarios were developed for complementary purposes to show the effectiveness of the software. Said scenarios, don't provide damage estimates regarding the water treatment infrastructure, but it does provide damage data for coastal infrastructures, mortality rates, tsunami building related costs (Figure 3), and averages for travel time safety.

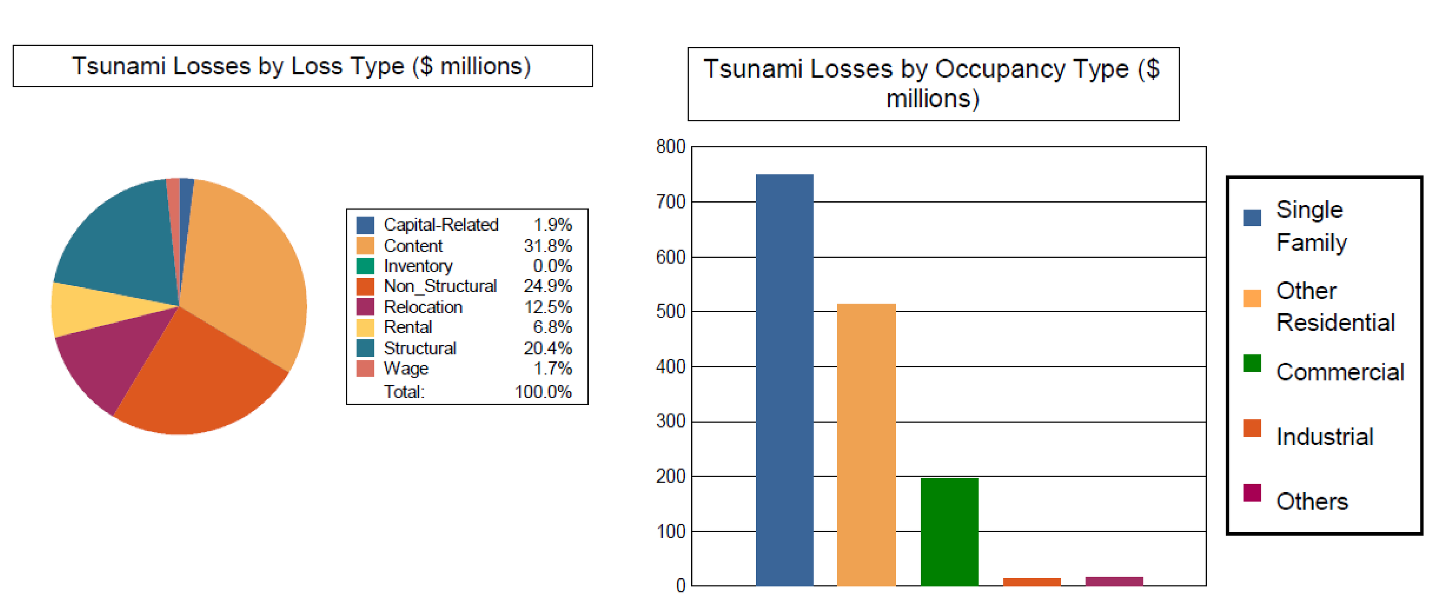

Figure 3: Tsunami Building related losses due to far-source Tsunami scenario (Adapted from Hazus-MH Tsunami Report)

Hazus–MH Results of Earthquake Scenario for the Potable Water Treatment Infrastructure

For the water treatment infrastructure aspect of the software. Figure 4 shows an example of the drinking water treatment plants mapping data added to the Hazus-MH software. Based on a simulation of the 6.4 Earthquake, we can see the effect that the seismic movement had on the water infrastructure near the epicenter area in terms of the Peak Ground Acceleration (PGA). This and many other seismic parameters can be measured on the Earthquake scenario.

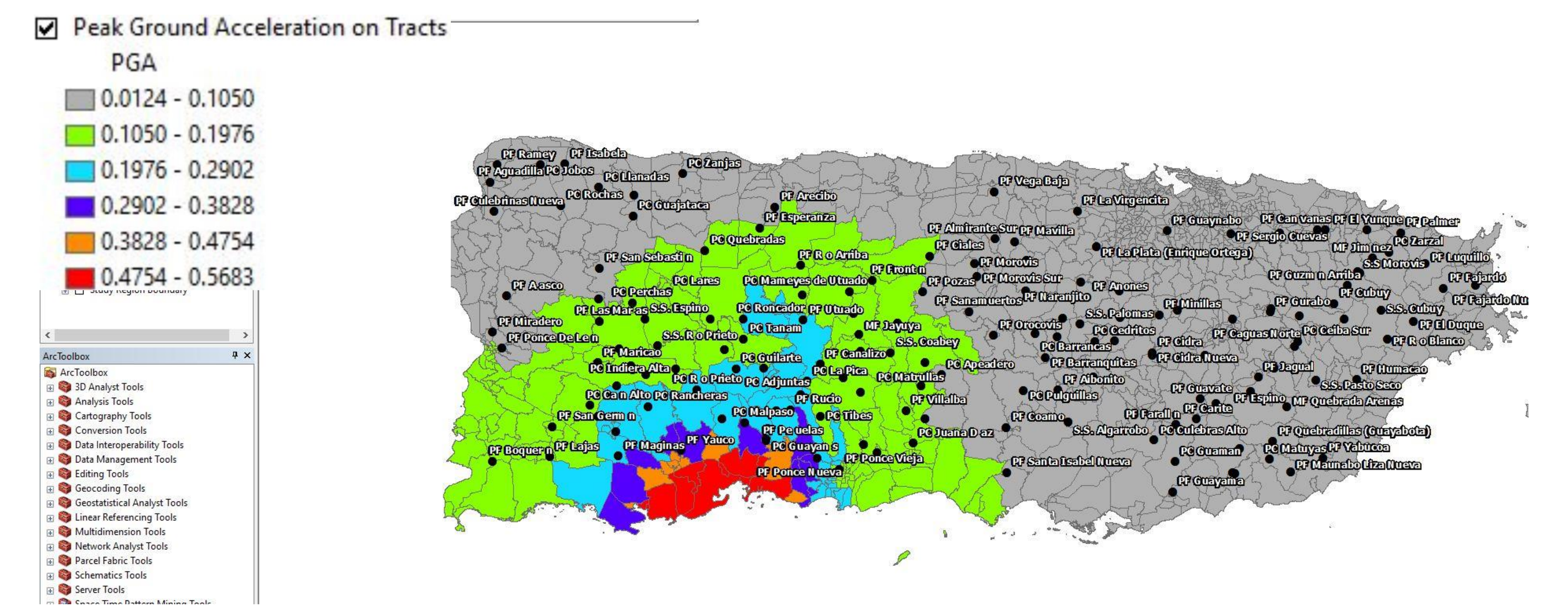

Figure 4: Hazus-MH Peak Ground Acceleration effects on WTP in PR for 6.4 mag. Earthquake on January 7, 2020

Vulnerability of the different drinking water treatment plants can be estimated based on the percentage of damage suffered by facilities near the area of the seismic movement. As shown on Figure 5, potential damage percentages are presented based on the categories of slight, moderate, extensive, and complete for facilities on the southern part of PR. Based on the graph presented, the PRASA drinking water treatment plant of Yauco is the water treatment infrastructure that may have the biggest amount of damage due to its proximity to the 6.4 magnitude seismic epicenter, which in turns leads it to have the higher percentage of complete potential damage. Based on the estimates by the software and complementary map data, the Yauco WTP was determined as to being vulnerable to earthquake stressors near the southern area.

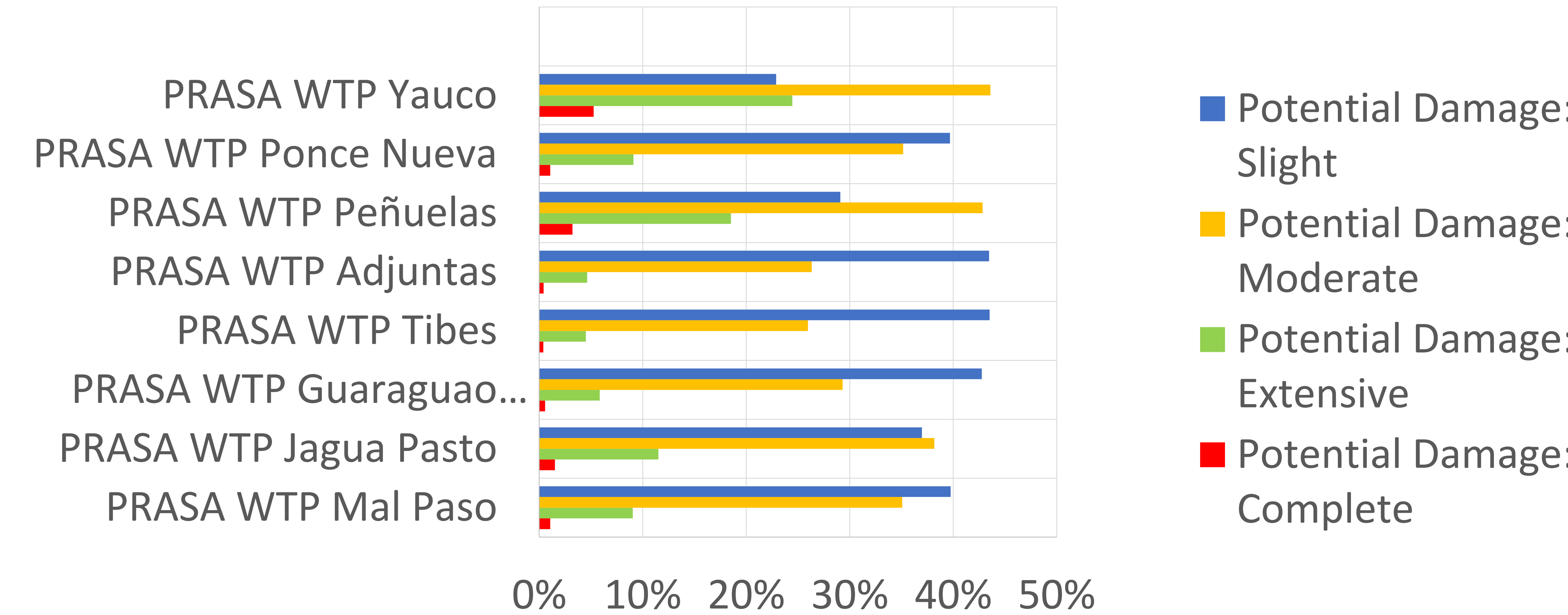

Figure 5: Potential Damage percentage to WTP near the southern part of PR for the 6.4 mag. Earthquake

Conclusions & Recommendations

The Hazus-MH software can serve as a valuable tool for the mitigation of possible damages on different infrastructures caused by Natural Hazards. Results for the potable water treatment plants show the software's effectiveness in estimating potential damages to seismic stressors. It's recommended that FEMA develops the complete software package for proper application on the island of PR and to be able to have the most up to date datasets for more accurate results. The hurricane model was not available for PR, and the flooding model was incompatible with the Hazus version for Earthquake and Tsunami, making the multiple hazard scenario analysis complicated and very time consuming. Further development of the software is required for its effective application in hazard mitigation practices in PR.

Acknowledgement

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For my family and their continuous support throughout this challenging journey.

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