Risk Analysis for Greene County and Wright Patterson Air Force Base, Ohio: Simulation of Riverine Flooding Using HAZUS-MH

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ABSTRACT

Greene County in Dayton, OH houses Wright Patterson Air Force Base (WPAFB), whose estimated 2009 economic impact within its Metropolitan Statistical Area (MSA) is $5.17 million. Despite its military/strategic importance as the largest base in the U.S. Air Force, literature search did not uncover a published comprehensive risk analysis for WPAFB, or even Greene County, across the entire spectrum of hazards from natural to technological to man-made (including terrorism). This paper presents a summary report on risk determination and economic impact data for Greene County and WPAFB (within Greene County) in the context of riverine flooding, using FEMA's HAZUS-MH tool. It is hoped that the results will further the regional compilation of data and thus prove of use to the local disaster management community while generally growing the overall body of work in risk analysis. Future work aims to expand regional risk determination to other natural disasters and terrorism scenarios.

Keywords

Risk Analysis, Greene County, OH, Wright Patterson Air Force Base, Riverine Flooding.

INTRODUCTION

Risk analysis involves (1) quantifying the probabilities of potential consequences in various hazardous scenarios (risk determination) and (2) evaluating that information to decide how to act under conditions of uncertainty (risk management) (Bedford & Cooke, 2001; Haimes, 2004). Risk determination involves an assessment of uncertainties associated with the likelihood of occurrence and intensity of the potential disaster at the location/site of interest. The vulnerability analysis/risk management stage involves uncertainties regarding the correlation among various parameters that link the natural hazard with the consequent damages and losses. Risk determination approaches are summarized in, for instance, Pate-Cornell (1996) & Haimes (2004), and range from simplistic to sophisticated. The best method for a particular situation depends on a number of factors including the magnitude and likelihood of the hazard, the importance of the decisions that will be made on the basis of risk determination, decision-making constraints, and the availability (or lack thereof) of data (Venkateswaran & Trivedi, 2008). A particular level of risk may be judged acceptable, or, alternately, management may decide to take measures to reduce the level of risk**.** Such risk assessment provides vital input for risk management, which helps to identify and prioritize appropriate mitigation actions to reduce losses from the identified hazards. A strategically developed and informed disaster plan, including a coordinated communications effort, helps protect people and assets and saves money in the long run.

Greene County, OH includes both Wilberforce University and Wright Patterson Air Force Base (WPAFB), a large air base of strategic military significance. In a terrorism scenario WPAFB is a more likely target than Greene County. However, from the perspective of tornadoes, the city of Xenia within Greene County has historically proven to be a much more likely target (State of Ohio Hazard Mitigation Plan, 2007, p.94). The

Reviewing Statement: This short paper has been fully double-blind peer reviewed for clarity, relevance and significance.

present work focuses on the impact of one such common natural disaster - floods, using HAZUS-MH, open-source US government software, to simulate probabilistic damages over different flood return periods. Although restricted to Greene County, the approach is general and can be extended to any other region. Published reports of anticipated damages at the local/county level are somewhat sparse. The Ohio EMA, Ohio Department of Natural Resources (ODNR) and the US Army Corp of Engineers, completed HAZUS-MH Level 1 flood analysis for 49 Ohio counties. However, at the time (Dec. 2007), Greene County was not included among them (State of Ohio Hazard Mitigation Plan, 2007, p.87). Hence this work undertook to conduct a HAZUS riverine flood analysis for Greene County and for the portion of WPAFB within Greene County. Subsequent research aims to estimate the probabilistic impact of earthquakes, tornadoes, fires, and select terrorism scenarios. Such 'outputs' will serve as 'inputs' for a disaster plan system being developed by team members. A key goal of that system (WILBER) is to supply a potential user with the frequency and estimated impact of the most common disasters for a specific region, along with a recommended disaster plan for each specific disaster.

METHODOLOGY AND CHOICE OF RISK ASSESSMENT TOOL:

Secondary research involved broad literature review of government and industry websites and reports, academic journal and conference publications and books to obtain information (to the extent possible) on the probabilities, vulnerabilities and impact associated with a specific natural hazard striking the particular locality (Greene County). Subsequently, loss estimates were obtained for a selected scenario - floods, by running FEMA's HAZUS multi-hazard (MH) model, at the basic level, probabilistically, for different return periods.

The rationale for the use of HAZUS-MH, a GIS-based modeling tool is that: (a) it allows for probabilistic risk modeling and (b) enhances a unified approach to the assessment and evaluation of risks from different natural hazards. Furthermore, it is open source software that has been tested over the years by a variety of government, commercial and academic users, comparing the simulated results with actual disasters and their known damages. While the default probabilistic scenarios are used in the present work, to obtain quick estimates over a range of disasters, HAZUS-MH has provisions that allow for user–modifications of several default parameters, as well as capabilities to run user-specified deterministic scenarios instead of stochastic ones.

Various datasets on hazards, demographics and inventory databases feed into HAZUS-MH (HAZUS-MH User Manual, Chapter 3). Default inventory databases include demographics; general building stock; essential, high potential loss, and hazmat facilities; and transportation and utility lifelines. The building stock information is collected from the US Census of population & housing, Dun & Bradstreet, and the Dept. of Energy (Meyer, 2004). The HAZUS riverine flood model performs two inter-related analyses: flood hazard analysis and flood loss estimation. The flood hazard analysis characterizes the flood and must be completed before the flood loss estimation. In this work, stochastic scenarios for riverine flooding were run using associated inventory data sets from January 2005. Two study regions were described– Greene County and Census Tract 2002 (the portion of WPAFB within Greene County). Losses were obtained and compiled for each of the two study regions.

RISK ANALYSIS FOR NATURAL HAZARDS FOR GREENE COUNTY, OHIO:

The National Oceanic and Atmospheric Agency (NOAA)/National Climatic Data Center (NCDC) reported some 340 severe weather events in Greene County, Ohio between 01/01/1950 and 07/31/2010. Such events are variously categorized as Thunderstorms with Wind, Tornados, Hail, Winter Storm, Heavy Snow, Freezing Rain, Ice Storm, Extreme Cold, Flash Flood, Excessive Heat, Drought, Funnel Cloud, Fog, Extreme Cold/Windchill, and Winter Weather. For Greene County in particular, events were isolated from their webpage using the drop down-menu by county (http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwevent~storms). Further, a drop-down menu was used to isolate the events by event type. Extracted data was analyzed to determine the most frequently occurring disasters, as well as those with the greatest recorded economic impact. It was determined that Thunderstorm Winds & High Winds, Floods, Tornadoes, and Snow and Ice present the highest risks for Greene County. Since floods are furthermore reported to have the highest weighted average risk for Ohio (State of Ohio Hazard Mitigation Plan, 2007, p. 18), it was decided to focus initially on floods, using HAZUS-MH to run simulations of probabilistic risk and resultant damages. Further impetus was provided by the fact that the 2007 report (ibid.) did not provide data on economic losses from floods, for Greene County.

Asset Base/Inventory of Greene County and WPAFB:

Greene County comprises 415 square miles and contains 3,121 census blocks/33 census tracts. Per the 2000 Census, the region contains over 55,000 households and a total population of 147,886. There are an estimated 45,138 buildings in the county, with a total building replacement value of 8,958 million dollars (2002 constant

dollars). Of these, 98.77% of the buildings, and 85.92% of the building value are associated with residential housing (HAZUS output based on Census Bureau and valuation information).

Essential facilities in the region include hospitals (1, with 150 beds), schools (54), fire stations (14), police stations (11), and emergency operation facilities (0). High potential loss facilities (HPL) include 13 dams, of which 7 are classified as high hazard, and 25 hazmat sites (HAZUS-MH Probabilistic Earthquake Scenario run for Greene County, December 30, 2010). Results revealed, however, that these were not significantly damaged under the probabilistic scenario and the assumed flood parameters/variables used to run the simulations.

Within HAZUS-MH, the lifeline inventory is divided as transportation and utility lifeline systems. Transportation systems are highways, railways, light rail, bus, ports, ferry and airports. Of these, Greene County has only highways, railways and airports, with a total replacement value estimated at $ 1,762 million. The utility systems lifeline assets for Greene County include potable water, waste water, natural gas and communications facilities. The total replacement value of Greene's utility inventory is estimated as around $ 1,184 million.

Other inventory inputs in HAZUS-MH include agricultural crops and businesses. Key agricultural crops in Greene County include corn and soybean. The business listing inventory is too large to detail individually - suffice it to say that the commercial building exposure totals $852.4 million. This is dwarfed however by the total residential building value of Greene, estimated at roughly $7.7 billion (in 2002 constant dollars).

The Buildings Capital Asset Base of WPAFB includes Housing(~ 860,000 sq.ft.), R & D(~ 5 million sq.ft.), Hospital(~ 826,000 sq.ft.) , Utilities and Grounds Improvements (~243,000 sq.ft.), Other buildings, structures and facilities(~7.4 million sq.ft.); for a total building exposure of ~ 16.8 million square feet. The annual economic impact in it's 5 county Metropolitan Statistical Area (MSA) of Greene, Clark, Miami, Montgomery and Preble, is estimated at $5.17 million (Economic Impact Analysis, 2009).

HAZUS-MH RIVERINE FLOODING RESULTS FOR GREENE COUNTY:

The riverine flood hazard analysis (stage 1) was run for the two study regions - Greene County and WPAFB within Greene (Census Tract 2002). Greene County is subject to riverine flooding from bodies of water such as the Great Miami River, Mad River and Little Miami River, on both large basins as well as smaller tributary streams. A four square mile drainage area was assumed, for a variety of return periods, 10, 50, 100 and 500 years. Four square miles is the drainage area picked by the Ohio Emergency Management Agency, which allows for comparison of damage data with that reported for other counties by the Ohio EMA. While multiple return periods were run to evaluate comparative losses, the most representative period is the 100 year return, referred to as the base flood, which has a one percent or greater chance of being equaled or exceeded in any given year. The 100 yr. flood, used as a regulatory standard by Federal agencies, most states, and the National Flood Insurance Program (NFIP), actually has a 26% chance of occurring during a 30 year period - the length of the most popular fixed mortgage (http://www.fema.gov/media/fhm/firm/firm/ot_firm.htm). The agriculture crop damage depends not only on parameters such as the type of flood, drainage and intensity (return period) but also on the time of year. The main agricultural crops in Greene County are corn and soybean and the extent of damage will vary depending on whether the ground is fallow, just planted, or close to harvesting. A July date was picked to run the riverine flood simulations, to gauge the damage to a pretty full crop. Results for damages are briefly summarized below for Greene County:

- Agricultural crop damage: ~ $19 million(10 yr. return), ~$23 million(100 yr.), ~$24 million(500 yr. return)
- Shelter requirements: none for 10, 50 yr. flood; 1,747 and 2,181 for 100 yr. & 500 yr. flood, respectively.
- Losses due to vehicular damage (by night): $3.9 million (10 yr), $6.5 million (100 yr), $7.4 million (500 yr)
- Debris: 4,088 tons (10 year return), 8,889 tons (100 yr.), and 11,291 tons (500 year return). HAZUS-MH provides an estimate of the amount and type of debris generated, but not a specific dollar amount associated with debris removal. Tonnage was therefore converted to an estimated dollar figure using $40 per cubic yard to transport & dispose of debris in Ohio. This yielded an estimated $2.49 million to dispose of the 8,889 tons of debris generated in the 100 year flood.
- Utilities: Estimated damages to utilities in Greene County were $55.94 million (potable water facilities) and $140.94 million (waste water facilities), for a total of $196.89 million. This represents about 16.6% of the total replacement value of all the regions utilities. Damages did not change with return period.
- Economic losses for buildings: $107.7 million (10 yr. return), $199.5 million (100 yr. return) and $217.1 million for the 500 yr return. Losses for the 100 year flood amount to about 13.2% of the total replacement value of buildings (in constant 2002 dollars). Losses from Business Interruption are much higher than those

due to direct damage to buildings/contents and are about 73% of the total for the 100 year flood. As the return period increases, the percentage of total losses due to direct-building related damage increases.

WPAFB WITHIN GREENE COUNTY – HAZUS- MH SIMULATION RESULTS FOR RIVERINE FLOODING:

Much of WPAFB is situated within the Mad River Floodplain (EPA Superfund Record of Decision, 1994, p.5). The geographical size of WPAFB within Greene County is ~ 10 square miles and contains 16 Census Blocks comprising over 1000 households and 736 buildings with a total replacement value of $209 million (in 2002 dollars). HAZUS- MH riverine flood analysis was run for the WPAFB region in Greene County, using the same parameters - 4 square mile drainage area and 10, 50, 100 and 500 year return periods. Unlike in Greene County, there are no significant losses predicted for crops, shelter requirements and utilities. This is because of differences in overall size (and corresponding assets) of the geographic region, and the nature of the general terrain and the distribution of streams, rivers and other water sources and drainage areas in the WPAFB region versus Greene County. This would affect the extent and depth of riverine flooding, and consequently, the resultant losses. No significant damage to either the environment or to utilities within the WPAFB Census Tract 2002 is predicted by HAZUS MH for probabilistic riverine flooding, under the assumed conditions. The simulated impacts/losses for buildings, vehicles, and debris are summarized below:

- Buildings: Total losses are $39.9 million (10 yr. return), $64.8 million (100 year return), & $114.5 million for the 500 year return. As with Greene County, business interruption accounts for the majority.
- Debris: 86 tons (10 yr. return), 179 tons (100 year return), & 419 tons (500 yr. return). A rough estimate of debris losses was obtained by converting from tons to cubic yards, and using a figure of $40/cubic yard for debris disposal in Ohio. This yielded an estimate of $50,120 for debris disposal due to the 100 year riverine flooding at WPAFB.
- Vehicular Damage: For the 100 year flood, the maximum vehicular losses for WPAFB are about $282,000, compared to the estimated $6.5 million in losses for Greene County.

DISCUSSION AND CONCLUSIONS:

Effective management of risks associated with a spectrum of hazards requires reasonable assessment of the involved uncertainties coupled with a determination of their consequences. Thus, risk determination is vital to, and precedes, risk management. Usable historical data is often not available on a narrow site-selection basis, particularly at the local or county level. Therefore, data on economic losses for Greene County and WPAFB from riverine flooding was generated by HAZUS-MH simulations.

Adding the losses for the various categories for Greene County, the total estimate for the 100 year flood is ~$284 million, not counting Business Interruption losses of $145 million. The presence of WPAFB with its large economic impact likely skews the high business interruption loss figure for Greene County. The total losses for WPAFB within Greene County (Census Tract 2002) are estimated as $65.5 million of which ~$ 3.5 million are due to direct damages. It is important to keep in mind that these are only estimates based on HAZUS-MH probabilistic simulations, for the assumed flood parameters, and based on inventory datasets from 2005. They do not reflect the current census (2010) and current infrastructure valuation.

Regardless, the ultimate purpose of such risk assessment is to provide some underlying factual data to identify and prioritize appropriate mitigation actions to reduce losses from identified hazards (Hazard Mitigation Plan, City of Xenia, 2009). In the pre-disaster stage, risk management could involve reducing residual risk by decreasing vulnerability. Tactics include strengthening barriers to storm surges and flooding, enforcing stricter building codes in naturally hazard-prone areas, developing 'contra-flow' escape routes, and investing heavily in warning systems and disaster education programs (Venkateswaran and Trivedi, 2008). A strategically developed, informed disaster plan helps protect the general public and saves money in the long run. Future work aims to extend regional risk determination to other hazards such as earthquakes, tornadoes, fires and terrorism.

Lastly, in the context of large scale disaster management, the importance of coordinated communication cannot be overstressed. A Statewide Communications Interoperability Plan (March 2008) discusses strategy for developing and implementing communications interoperability within the State of Ohio and its 88 counties. Large, geographically diverse threats require a multi-jurisdictional response requiring broad communications interoperability. In keeping with the National Incidence Management System (NIMS), the Ohio Response System (ORS) is a multi-agency coordination regional system, charged with the following goals: (1) Expand Ohio's capability to respond to incidents that overwhelm local resources, (2) Develop multi-disciplinary

regional response capabilities as an integrated and standardized system, (3) Identify and develop a regional response capability, able to respond to any part of Ohio within 2 hours, and (4) Ensure an integrated and interoperable response from local to federal resources. A Technical Advisory Committee (TAC) is designated for each ORS goal, comprising key providers at the local and state levels (State of Ohio Statewide Communications Interoperability Plan, 2008). The Ohio Homeland Security Division provides leadership and coordination for the TACs related to prevention and protection and the Ohio Emergency Management Agency (OEMA) provides leadership for the TACs related to response and recovery (ibid.). The ORS includes Emergency Response Plans for Fire and Law Enforcement, which maintain an inventory of resources and allow an incident commander to activate and mobilize them with a single phone call. These Response Plans are successfully exercised and field-tested during actual incidents. For planning purposes and for conducting multi-agency exercises, Ohio is divided into eight (8) Homeland Security Planning Regions. All the counties over which WPAFB has an economic impact fall within a single region – No. 3, which facilitates mutual communication. Multi-jurisdictional and multi-disciplinary participation including utilities, transit agencies, hospitals and volunteer fire departments is encouraged at regular open meetings and through the sharing of ideas and lessons learned throughout the first responder community within Ohio (ibid.).

ACKNOWLEDGMENTS

Funding for this research effort was provided by the National Nuclear Security Administration under Grant No. DE-FG52-06NA27579 and is gratefully acknowledged.

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