Pilot Project to Investigate the Feasibility of Using HAZUS To Estimate the Number and Location of Manufactured Housing Units in the Northeast United States and the Nation

Fire damage from severed gas lines at the Napa California Valley Mobile Home Park which was struck by a 6.0 earthquake on August 24. 2014.
FEMA PHOTO

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A. Background

Earthquake hazard mitigation strategies and emergency management activities require information about building vulnerability, which is directly related to the type of building construction.

There is an abundance of consistent and conclusive evidence from past earthquakes that Manufactured Housing Units (MHU's) also known as a mobile homes, have not performed well.

Manufactured Housing Units (MHU's) are defined as follows:

Manufactured Housing Unites (MHU's) are prefabricated housing units that are trucked to a site and then placed on isolated piers, jack stands, or masonry block foundations (usually without any positive anchorage). Floors and roofs of MHU's homes are typically constructed with plywood and outside surfaces are covered with sheet metal. MHU's may not perform well and result in the potential for increased damage, fire and potential injury and loss of life in the event of an earthquake.

For example, the 1994 Northridge California Earthquake (M 6.7) reportedly caused damage to 9,000 MHU's. Damage was mainly due to homes sliding off their support systems and fires, some of which were fueled by broken gas lines. [1]

More recently, the Napa California Earthquake (M 6.0) which struck on August 24, 2014, caused significant damage to MHU's resulting in injuries, and 10 deaths (See Figure 1). Most of this damage was due to failed anchoring systems which can also lead to severed gas lines causing significant fires (See Figure 2). This magnitude event (M 6.0) is considered a credible size event that has occurred historically in the Northeast United States (1755 Cape Ann Earthquake (M 6.0) and 1638 Central New Hampshire Earthquake (M 6.5)[2] and could occur again. This raises concern that MHU's in the Northeast could be susceptible to the same level of damage experienced in Napa if a similar size event were to occur. This concern is justified due to the fact that many MHU's in the Northeast, especially older ones, may not have adequate seismic strengthening.

A report prepared for the California Seismic Safety Commission by the Pacific Earthquake Engineering Research Center (PEER) found that the significant damage to manufactured housing in the 2014 South Napa earthquake was almost exclusively associated with support systems rather than the homes themselves.[3]

[1] U.S. Department of Housing and Urban Development, Office of Policy Development and Research, Minimizing Damage and Repair Costs to Manufactured Homes During an Earthquake, 1995

[2] Earthquakes In and Near the Northeastern United States, 1638-1998, U.S. Geological Survey Fact Sheet 0006-01,Version 1.0

[3] CSSC Publication 16-03, PEER Report No. 2016/04, June 2016

This type of damage, caused by inadequate or missing seismic support systems, can be prevented or reduced. FEMA P-85 Protecting Manufactured Homes from Floods and Other Hazards reflects the requirements of the most current codes and standards and provides a best practices approach in reducing damages to MHU's from natural hazards including earthquakes.

While these requirements do increase the cost of home installation, they can if implemented properly, provide significant savings by reducing or eliminating the cost of repairing the damage to the home after an earthquake. More importantly, they can save lives and reduce injuries.

Figure 1. Damage to Manufactured Housing Unit following the 2014 Napa California Earthquake Likely Due to an Inadequate Support System

In addition, the Federal Emergency Management Agency (FEMA) and the Applied Technology Council (ATC) have developed training titled "Improving Earthquake Performance of Manufactured Homes" which contains recommendations for improved earthquake performance of manufactured housing consistent with FEMA P-85.

We understand the problem that inadequately anchored MHU's do not perform well during an earthquake and we know how to improve their performance. It is therefore essential to identify and inventory MHU's in the Northeast and elsewhere in order to better understand the scope of the problem and establish a baseline from which progress to mitigate the potential impact of these potentially

hazardous housing units can be measured. Traditional land survey methods for assessing MHU's are expensive, labor intensive and time consuming. Public safety officials in areas of low to moderate seismic risk, like the Northeast, simply do not have the resources or the inclination to undertake such expensive studies.

NESEC's goal was to investigate the feasibility of using FEMA's HAZUS Loss Analysis Software[4] and other low or no-cost methodologies to help quickly and inexpensively identify and quantify the number and location of MHU's in the Northeast.

Figure 2. Fire damage from broken gas lines at the Napa Valley Mobile Home Park which was struck by a 6.0 earthquake on August 24, 2014

B. Objectives

The objectives of this project were as follows:

1.) Investigate the feasibility and accuracy and ease of using FEMA's HAZUS methodology to estimate the number and spatial location of MHU's in the Northeast.
2.) Identify a pilot region of known MHU's for testing and validation of the methodology.
3.) Determine the feasibility of using the HAZUS methodology and GIS spatial analysis to identify MHU's in the pilot region and its potential for expansion in the northeast and nationally.

[4] HAZUS Version 4.0 MHU Data was used for this project.

C. Methodology and Results

The count and spatial distribution or MHU's was identified for the eight NESEC states and nationally utilizing the HAZUS methodology. HAZUS is a nationally applicable standardized methodology that contains models for estimating potential impact and losses from earthquakes, floods, and hurricanes. HAZUS uses Geographic Information Systems (GIS) technology to estimate physical, economic, and social impacts of disasters. The Federal Emergency Management Agency (FEMA) developed HAZUS under contract with the National Institute of Building Sciences and it is widely accepted as a leading earthquake loss assessment software platform.

The first step in our project was to identify the estimated number of MHU's by census tract (the basic geographic unit in HAZUS) in the NESEC States (CT, MA, ME, NH, NJ, NY, RI, VT) and nationally for comparison, using the default building inventory contained in HAZUS. This was accomplished by creating a new earthquake region using HAZUS. (See HAZUS–MH User Manual for detailed instructions on how to create a new region). Once the region was created, we selected Inventory > General Building Stock > Building Count > By Building Type > MH > Map. This process results in a map of the estimated number of MHU's by census tract for the study region (See Figure 3).

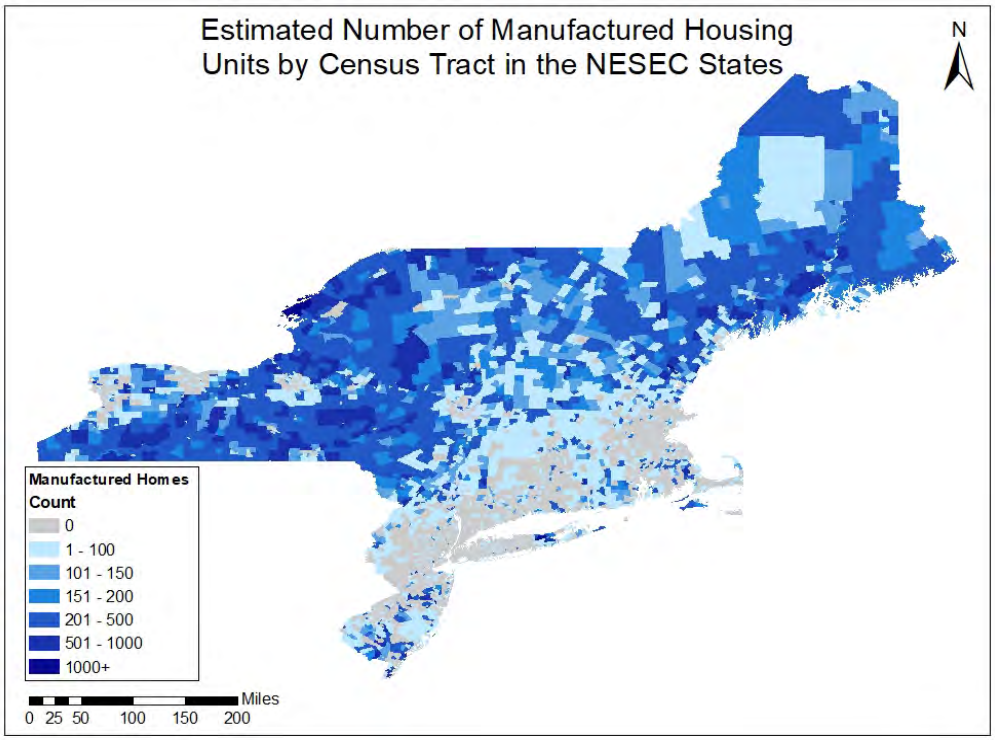

Figure 3. HAZUS Estimated Number of MHU's by Census Tract in the NESEC States

As Figure 3 illustrates, the estimated number of MHU's per census tract can become spatially skewed and visually distorted due to the varied size of census tracts. Some are very large while others are very small.

For example, there are single census tracts in northern Maine that are larger than the entire state of Rhode Island. These large census tracts tend to dominate the map visually at this scale based on their size, while smaller tracts are invisible at this scale. This makes visual comparison and analysis at a regional scale very difficult.

To control for this size variation, NESEC used the HAZUS data and ArcGIS to develop a map of MHU density, depicting the number of units per square mile (See Figure 4).

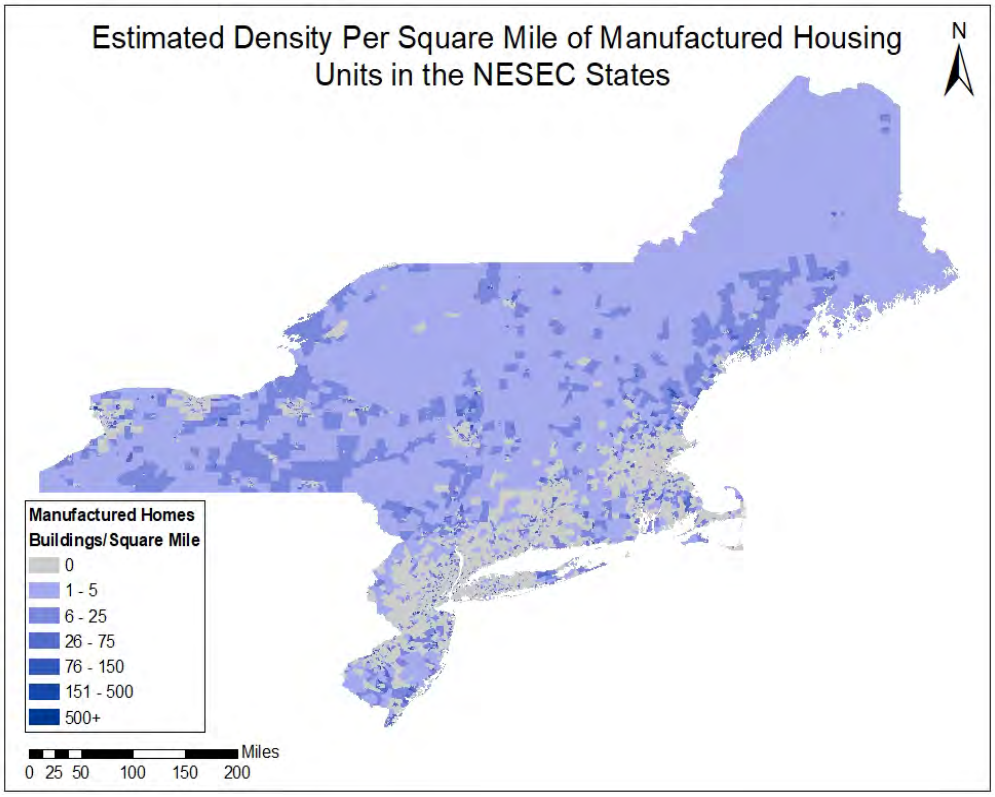

Figure 4. Estimated Density per Square Mile of MHU's in the NESEC States

Figure 4 represents a more accurate regional representation of where we suspect there to be large the largest concentrations of MHU's in the Northeast.

If we look closer and zoom in on the New York City to Boston Corridor, HAZUS accurately represents the known low concentration of MHU's in Boston and New York City (See Figure 5).

Using the HAZUS building count data, NESEC was able to estimate the total number of MHU's in the Northeast NESEC States at 405,890. The Breakdown per state is illustrated in Figure 6.

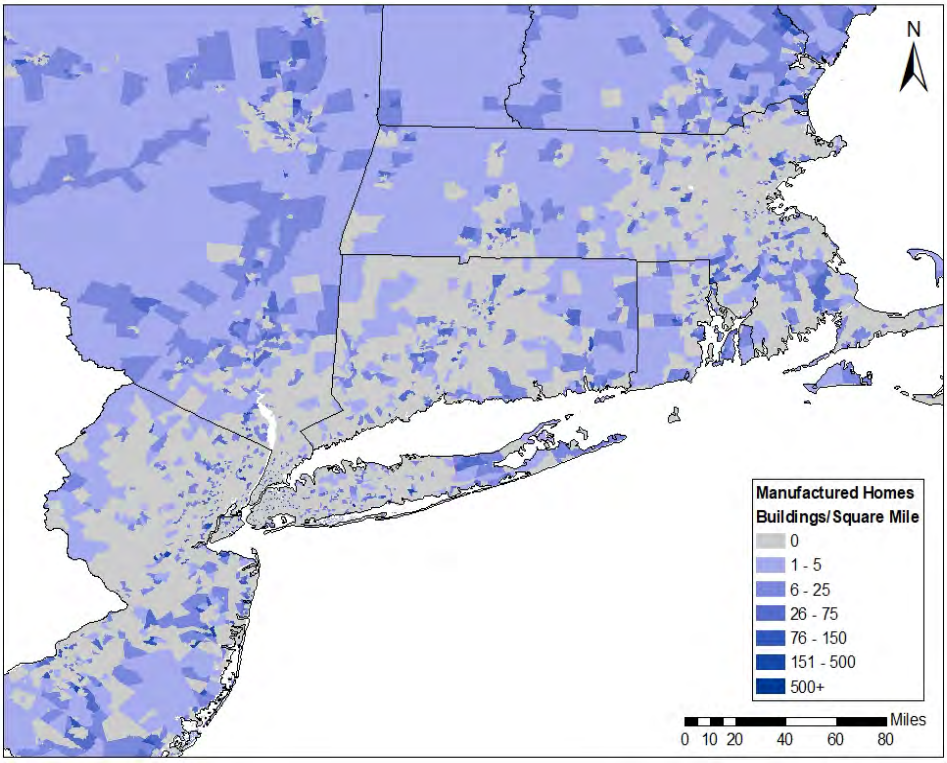

Figure 5. Estimated Low Density of MHU's in the New York City and Boston Areas

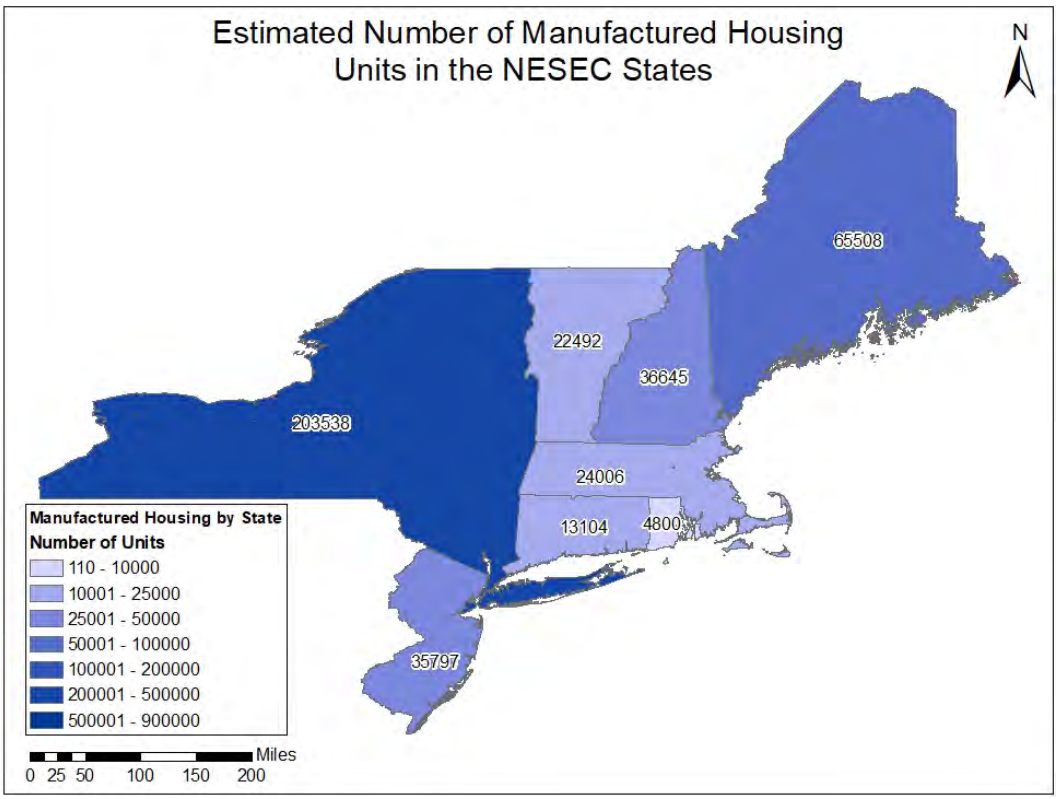

Figure 6. Estimated Number of MHU's in the NESEC States

While regional data does not currently exist to validate the HAZUS estimated number of MHU's in the Northeast, data was available to validate the number and spatial distribution of MHU's in the State of Vermont. This data was available from the statewide E 911 Inventory compiled by Vermont Cities and Towns.

Using the E 911 data, NESEC identified 22,492 MHU's in the State of Vermont. HAZUS data estimated 23,308 MHU's statewide. HAZUS data represent a very slight (3.6 percent) overestimate of these units. Based on these results, at least for the State of Vermont, HAZUS provides a very reasonable estimate of the total number (count) of MHU's statewide at a very low cost and minimal level of effort.

For comparison purposes, we also calculated the number of MHU's by state for the Nation (See Figure 7). According to HAZUS there are 8,853,443 MHU's in the United States. We then calculated and mapped the number of MHU's nationally by census tract (See Figure 8). To control for the size variation of states and their corresponding census tracts, NESEC used the HAZUS data and ArcGIS to develop a map of MHU density, depicting the number of units per square mile (See Figure 9). As Figure 9 illustrates, the densest concentration of MHU's is in the southeastern United States.

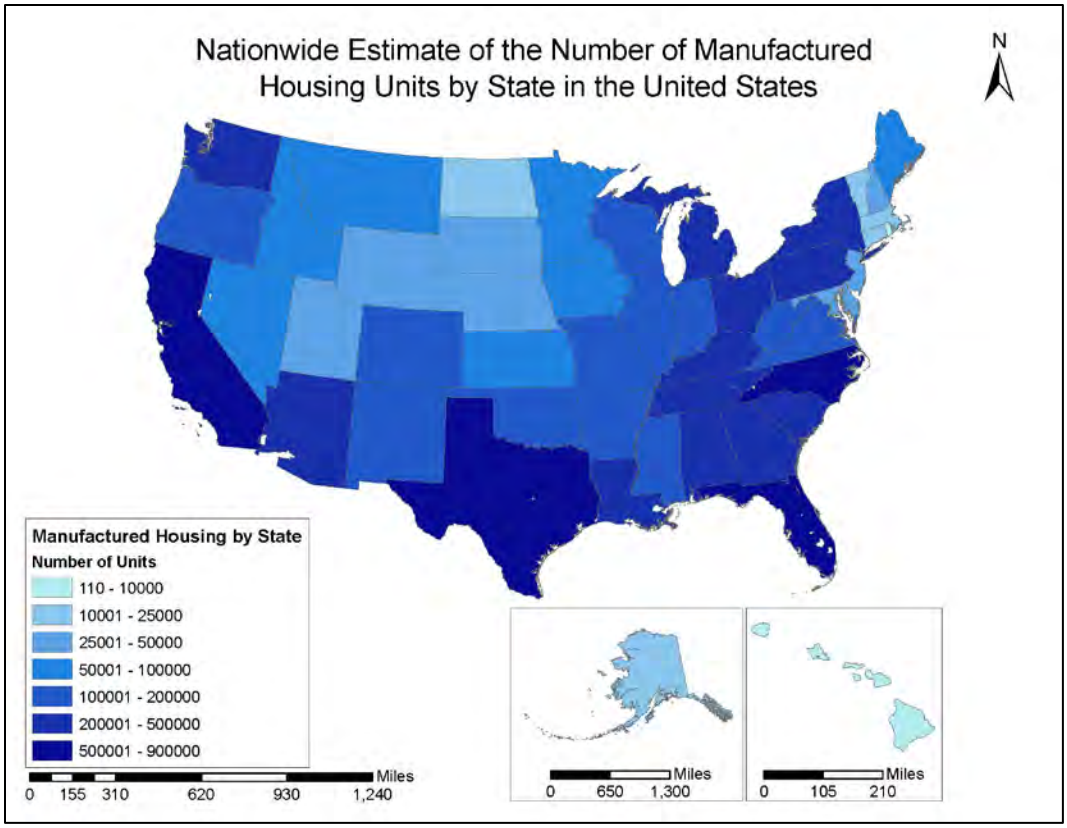

Figure 7: Nationwide Estimate of the Number of MHU's by State

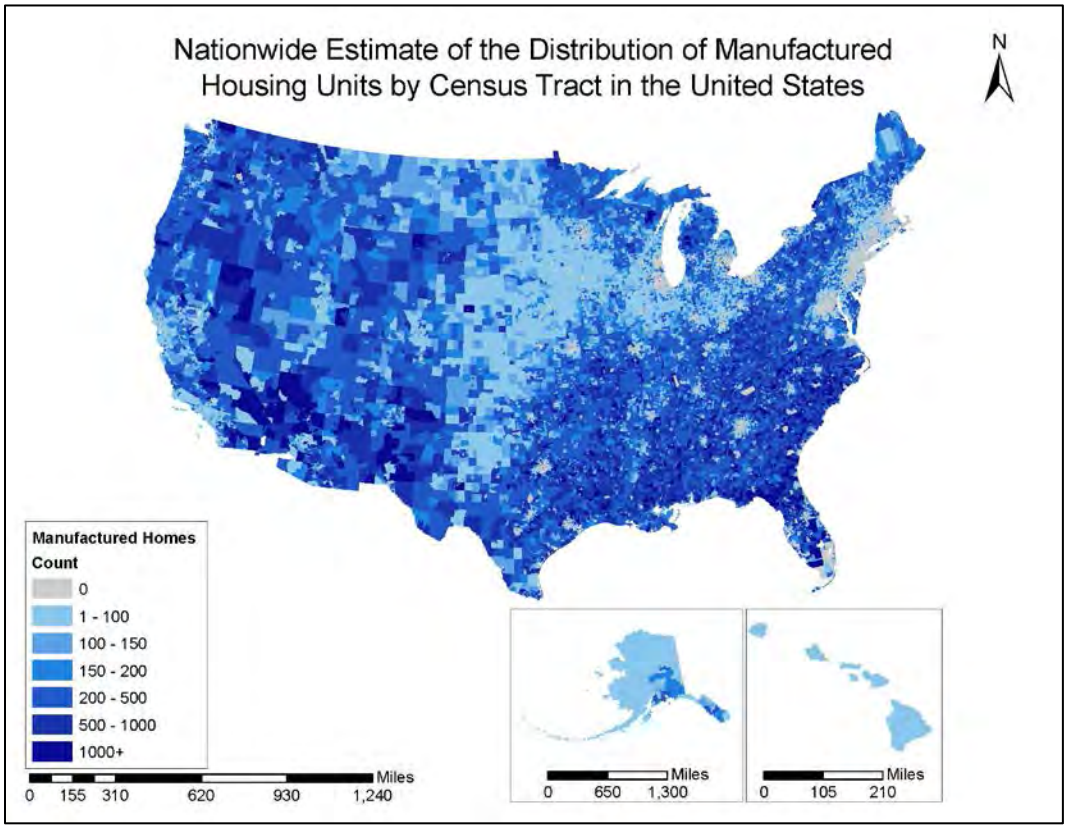

Figure 8: Nationwide Estimate of the Distribution of MHU's by Census Tract

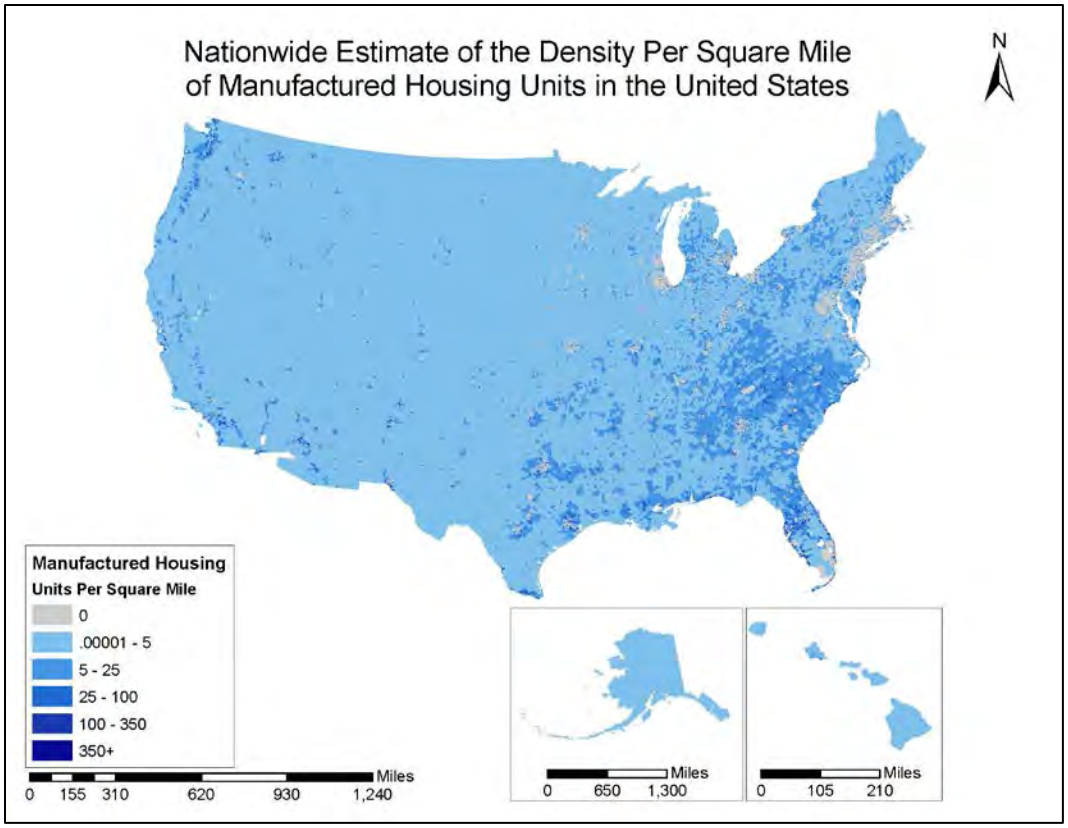

Figure 9: Nationwide Estimate of the Density Per Square Mile of MHU's

While HAZUS reasonably estimates the total number of MHU's at the state level, and presumably at the national level, we wanted to see how well it estimated at the local city and town level. To do this, we established a sample size of 5 percent of Vermont Communities (15) and ran HAZUS Flood for those communities. The building inventory results using the HAZUS Flood Model provided a count of MHU's for each community by census block, rather than tract. Analysis by block allows for a more accurate assessment at the local level. This is not available in the HAZUS earthquake Model that only estimates MHU's at the census tract level.

We then compared the HAZUS estimate MHU's with the actual numbers obtained from the Vermont 911 data base. A comparison of the HAZUS estimates and the 911 data are shown in Table 1.

Town	E911 Count	Hazus Count	Percent Difference	Total Difference
Newark	53	74	0.28	21.00
Hyde Park	280	235	-0.16	-45.00
Orange	91	74	-0.19	-17.00
Burlington	120	156	0.23	36.00
Norwich	31	57	0.46	26.00
Poultney	117	80	-0.32	-37.00
Tunbridge	85	83	-0.02	-2.00
Wardsboro	52	28	-0.46	-24.00
Tinmouth	43	22	-0.49	-21.00
Wilmington	94	69	-0.27	-25.00
Jamaica	100	118	0.15	18.00
Shoreham	57	93	0.39	36.00
Averill	2	13	0.85	11.00
Killington	15	26	0.42	11.00
East Montpelier	117	122	0.04	5.00
Totals	**1257**	**1250**		**-7.00**

Table 1. Comparison of HAZUS Estimated Count of MHU's and Actual 911 Count for sampled Vermont Communities.

As Table 1 illustrates, HAZUS estimates the total number of MHU's for the sample 14 communities at 1,250, while the actual count is 1,257. This estimate is incredibly accurate with HAZUS estimating 99.4 of the actual number of MHU's. However, when we look at the estimates for the individual communities the numbers, HAZUS underestimates MHU's at a range of 2% to 49% and overestimates from 4% to 85% and sometimes it is remarkably accurate like in East Montpelier Vermont where HAZUS estimates 122 MHU's and the E911 data confirms 117. Figure 10 is a map comparing the locations of HAZUS and E911 MHU's.

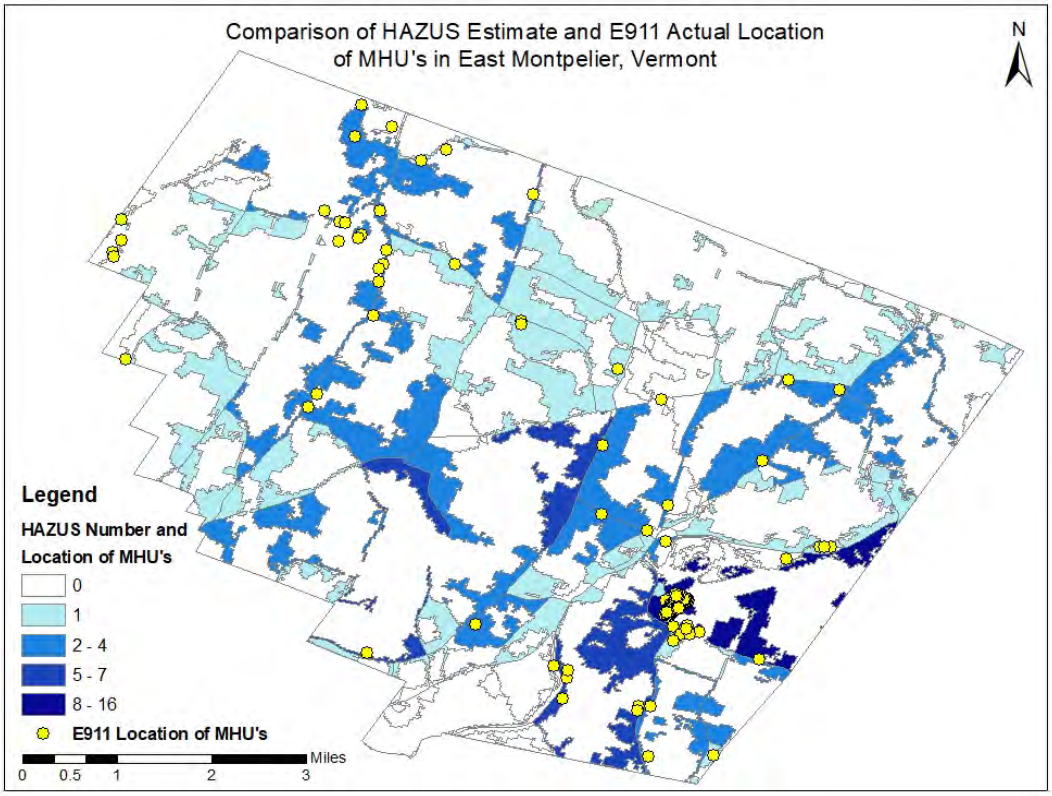

Figure 10. Comparison of HAZUS estimates and E911 Actual Location of MHU's in East Montpelier, Vermont

So while HAZUS estimates of MHU's are extremely accurate at the regional and state levels, they are not always accurate at the local community level.

D. Visualizing Manufactured Housing Data in Google Earth

In addition to the spatial assessment and mapping of the distribution of MHU's, we wanted to visualize MHU's using high resolution satellite imagery. We felt that to make the case for mitigation of MHU's, it was essential to be able to show an image of the suspected units so that policy makers could better understand the nature of the problem and how it could potentially impact their community. To accomplish this we used the Vermont E 911 MHU data layer and Google Maps.

Figure 11 illustrates known and suspected MHU's in a section of Hyde Park, Vermont using E911 data and Google Earth.

Figure 11. Google Map Image of Known and Suspected Manufactured Housing Units in an Area of Hyde Park, Vermont

This neighborhood has a dense concentration of known and suspected MHU's, which are shown in Figure 11 using Google Maps.

Figure 12 zooms in further using Google Street View to identify specific MHU's in the neighborhood.

Figure 12. A Closer Look at the Hyde Park, Vermont Neighborhood and the Manufactured Housing Units

E. Manufactured Housing Unit Regulation in the NESEC States

Damage to MHU's in past seismic events has been due primarily to support system failure and secondarily to fire caused by broken gas lines directly related to failed support systems.

Regulation of the installation of manufactured housing, including adequate support systems, varies in the NESEC States as well as the Nation. Connecticut, Massachusetts, New Jersey, Rhode Island and Vermont are U. S. Department of Housing and Urban Development (HUD) Administered Manufactured Housing Installation States. In these states HUD administers the Manufactured Home Installation Program. There are a total of 14 states in the nation that are HUD Administered Manufactured Housing Installation States (See Figure 13).

The HUD installation standards are derived from the Electronic Code of Federal Regulations Title 24: Housing and Urban Development PART 3285—MODEL MANUFACTURED HOME INSTALLATION STANDARDS https://www.ecfr.gov/cgi-bin/text-idx?SID=a2c5655a37054c584f7dd6a0ed240fb8&node=pt24.5.3285&rgn=div5%20-

It is important to point out that the HUD Regulations do not directly consider flood or seismic loads and are not intended for use in flood or seismic hazard areas. In those areas, the foundation and anchorage support systems are to be designed by a professional engineer or architect.

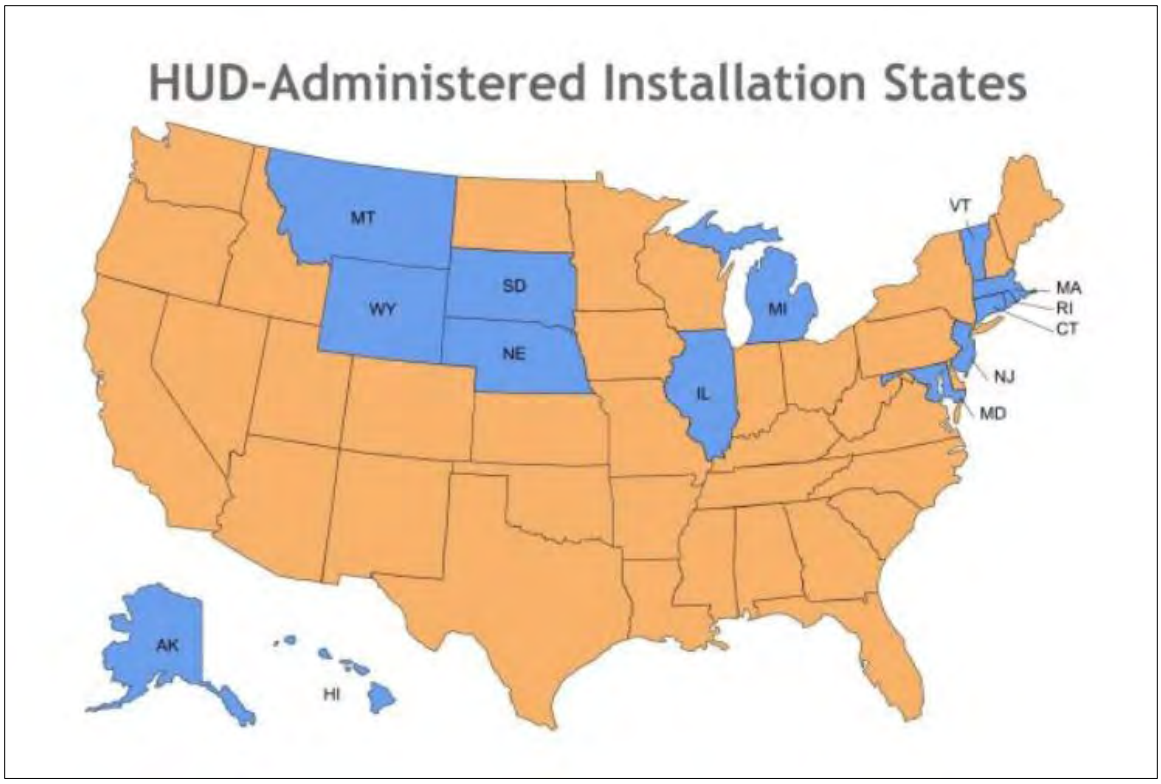

Figure 13. HUD Administered Installation States

The other NESEC States, Maine New Hampshire and New York administer their own laws and regulations regarding manufactured home installation, etc.

In New Hampshire it is the Manufactured Housing Installation Standards Board https://www.oplc.nh.gov/housing-installers/index.htm .

The New Hampshire Regulations are derived from TITLE XVII, HOUSING AND REDEVELOPMENT, CHAPTER 205-D, MANUFACTURED HOUSING INSTALLATION STANDARDS Section 205-D:1
http://www.gencourt.state.nh.us/rsa/html/XVII/205-D/205-D-mrg.htm

In Maine it is the Professional and Financial Regulation Manufactured Housing Board that determines manufactured housing regulations.
https://www.maine.gov/pfr/professionallicensing/professions/manufactured_housing/index.html

In the State of New York, the Department of State, Division of Building Standards and Codes, Manufactured Housing Program, determines manufactured housing regulations https://www.dos.ny.gov/dcea/manuf.htm . Their regulations are derived from Article 21-B of the Executive Law which is to implement the provisions of the Federal Manufactured Housing Improvement Act of 2000.

F. Conclusion

Data contained in HAZUS provide a remarkably accurate and reasonable regional estimate of the number of MHU's in the Northeast US and the Nation. When mapped using GIS, visually, the number of units per tract can be spatially skewed depending on the variation of the sizes of the tracts in the region studied. For example, there are single census tracts in northern Maine that are larger than the State of Rhode Island. These large census tracts tend to dominate the map visually. This makes visual comparison very difficult.

To control for this size variation, we used the HAZUS data to prepare a map of estimated MHU's density, noting the number of units per square mile. This corrects the visual skewing and presents a reasonable distribution of MHU's in the Northeast United States.

While HAZUS estimates of MHU's are remarkably accurate at the regional and state levels, our validation study in the state of Vermont at the municipal level indicates that the results have a wide range of accuracy. HAZUS underestimates MHU's at a range of 2% to 49% and overestimates from 4% to 85%. These estimates do not provide a reasonable basis for estimating the number of MHU's at the local city and town levels.

However, the number and location of MHU's in the Northeast US at the regional and state levels can be rapidly, efficiently and cost effectively estimated using HAZUS, and precisely validated at the local level using E911 structure data. Satellite imagery and Street View available in Google Earth are also effective tools for illustrating this information for potential users. While parcel data was not evaluated in this project it too along with assessors data can provide the number and location of MHU's.

This method can be similarly employed in other regions of the country as well as nationally. Our national assessment provides an accurate estimate of the number of MHU's in the United States (8,853,443) as well as their location and spatial distribution. This national assessment is essential to identify and inventory MHU's in order to establish a baseline from which progress to mitigate the impact of these potentially hazardous units can be measured.

To that end, free viewing platforms like Google Earth can provide viewing access to this data for many more cities and towns than would be possible otherwise. Easily transferable KML files can be viewed and utilized by anyone wishing to assess their area's potential risks and prepare most efficiently for them.

Finally, each of the NESEC States has a Federal or State Agency responsible for Manufactured Housing Regulation that can address seismic, flood and other hazard related issues especially as they relate to support system failure and secondarily to fire caused by broken gas lines directly related to failed support systems.

G. Disclaimer

The regional inventory of MHU's in this report was developed using HAZUS loss estimation methodology software which is based on current scientific and engineering knowledge. MHU default inventories contained in HAZUS were estimated using census and other data specific to each state.

This approach was tested in a pilot region comprised of the NESEC States (Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island and Vermont) and validated in an area of likely known MHU's in the State of Vermont. The actual number of MHU's in randomly selected cities and towns in Vermont based on E 911 data was compared with those estimated using HAZUS to validate the feasibility and accuracy of this approach the local level. This methodology would be easily transferrable to any location in the US and potentially elsewhere.

Nevertheless, there are uncertainties inherent in any loss estimation models software and default data. Therefore, there may be significant differences between the estimates contained in this report and the actual number of MHU's at the local, state, regional and national levels.