Using FEMA's HAZUS-MH to Estimate the Number and Potential Location of Unreinforced Masonry Buildings (URM) in Chittenden County Vermont

report available on-line at:
https://dec.vermont.gov/geological-survey/hazards/earthquakes

Howard Opera House Building Burlington, VT Circa 1878 Possible URM Building

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Background

Earthquake hazard mitigation strategies and emergency management activities typically 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 Unreinforced Masonry Buildings (URM's) do not perform well and result in the potential for increased loss of life and damage.[1]

For example, the May 12, 2011 earthquakes in Lorca Spain were only magnitude 4.4 and 5.1, yet there was incredible damage to URM buildings, significant injuries, and 10 deaths (See Figure 1).

Figure 1. Damage to URM buildings Following the 2011 Lorca Earthquake in Spain

The return period for this magnitude earthquake (4.4 - 5.0) striking somewhere in the Northeast, including the State of Vermont, is approximately once every 50 years and there is concern that older URM buildings in the Northeast could be susceptible to the same level of damage experienced in Spain. [2]

This concern is justified due to the fact that our URM buildings in the Northeast can date back to the 1700-1800's, as well into the 1930's and beyond. Older sections of

[1] Unreinforced Masonry Buildings and Earthquakes, Developing Successful Risk Reduction Strategies, FEMA P-774, October 2009
[2] John E. Ebel, 1984

downtown areas contain numerous historic, red brick buildings that are being used as businesses, homes, schools and critical facilities such as fire stations, police stations and hospitals. Many of these URM buildings are being renovated without adequate seismic strengthening.

Moreover, URM Buildings are not just vulnerable to earthquake. There is evidence that shows that these buildings can also be vulnerable to hurricane wind and fire.[3]

Winds from all categories of hurricanes have the potential to cause damage to URM buildings. Category 1 hurricanes can fall brick chimneys, which can lead to further collateral damage. Category 2 hurricanes can cause damage to masonry walls, which can compromise the integrity of the building. Categories 3 and above have the highest potential to cause collapses and failures to URM buildings.

For example, in New Orleans, winds from Hurricane Katrina caused significant damage and destruction to URM buildings (See Figure 2).

Figure 2. URM Building Damage New Orleans, LA Hurricane Katrina 2005

Fires following earthquakes are quite common and can also significantly affect URM buildings. Collapse of URM Buildings is more likely during a fire and the collapse is normally outward at a distance greater than the height of the exterior wall. [4]

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[3] Hurricane Charley in Florida, Mitigation Assessment Team Report, FEMA 488, 2005

[4] Reading a Building, Identifying Unreinforced Masonry Construction, Fire Engineering, June 2005.

Fires following earthquakes are quite common and can also significantly affect URM buildings. Collapse of URM buildings is more likely during a fire and is normally outward at a distance greater than the height of the exterior wall.[4] (See Figure 3)

Figure 3. Fire Causing Collapse of a URM Building

It is therefore essential to identify and inventory URM buildings in order to better understand the scope of the problem and establish a baseline from which progress to mitigate the potential impact of these hazardous buildings can be measured. While some cities, largely on the West Coast, have completed detailed URM inventories, we do not know for sure how many URM buildings exist in Vermont, the Northeast or across the United States. Traditional land survey methods for assessing URM buildings are expensive, labor intensive and time consuming. Public safety officials in areas of low - moderate seismic risk, like the Northeast, simply do not have the resources nor the inclination to undertake such expensive studies.

NESEC's goal for this project was to provide maps identifying the relationship between the estimated number of URM buildings in Chittenden County by census tract and their potential locations by developed land area.

Objectives

The objectives of this project were as follows:

a. Identify total estimated number of URM buildings in Chittenden County by census tract.

b. Determine potential locations of URM buildings.

c. Create a county map displaying the results along with supporting table.

These objectives were achieved using the Federal Emergency Management Agency (FEMA) HAZUS-MH Loss Estimation Software and ArcGIS.

Methodology

For this project, the count and spatial distribution or Unreinforced Masonry Buildings was estimated for Chittenden County Vermont utilizing the HAZUS-MH methodology. HAZUS-MH is FEMA's nationally applicable standardized loss estimation methodology that contains models for estimating potential impact and losses from earthquakes, floods, and hurricanes. HAZUS-MH uses Geographic Information Systems (GIS) technology to estimate physical, economic, and social impacts of disasters. The Federal Emergency Management Agency (FEMA) developed HAZUS-MH 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 was to identify the estimated number of URM buildings for each census tract in the county. This was accomplished by creating an earthquake region for Chittenden County using HAZUS-MH. (See HAZUS–MH User Manual for detailed instructions on how to create a new region). Once a region was created, we selected Inventory > General Building Stock > Building Count > By Building Type > URM > Map.

This process results in a map of the estimated number of URM buildings by census tract for the study region. Symbology was changed to display four sets of number ranges for the number of URM buildings by census tract. The total number of URM buildings in the county was then summarized from the attribute table.

The second step was to identify the potential locations of URM buildings. Because a HAZUS-MH earthquake region does not use dasymetric land cover data to distinguish between built and unbuilt areas, this was achieved by creating a new flood region for the county, which does. The dasymetric land cover data provides a more accurate and focused representation of potential building locations at the census block level. Once the region was created, we selected Inventory > General Building Stock > Building Count > By Building Type > Masonry > Map. This data was extracted as a shapefile and brought back into the county's earthquake region to overlay the land cover layer on the census tract layer.

Results

The results of this analysis and the estimated URM count is shown in Table 1 by town as aggregated up from the census tract count. Please note that some towns share a single census tract so estimates are for the entire tract and not any single town.

City/Town Name (Population, 2010)	**Estimated URM Count**	**Estimated Number of URM Buildings Per Square Mile (Density)**
Burlington (42,417)	977	63.07
Bolton (1,182) Underhill (3,016) Westford (2,029)	100	.75
Buels Gore (30) Huntington (1,938)	28	.65
Charlotte (3,754)	70	1.39
Colchester (17,067)	315	5.38
Essex (19,587)	353	8.98
Hinesburg (4,396) St. George (674)	76	1.75
Jericho (5,009)	81	2.28
Milton (10,352)	156	2.56
Richmond (4,081)	75	2.29
South Burlington (17,904)	376	12.71
Shelburne (7,144)	130	2.88
Williston (8,698)	176	5.75
Winooski (7,267)	175	115.89
TOTAL (156,545)	**3,088**	

Table 1. Estimated Number and Density of Chittenden County URM Buildings by City/Town

As Table 1 illustrates, Burlington, South Burlington, Essex, Colchester and Williston are the top five communities from highest to lowest in terms of total estimated number of URM's. When we look at the estimated number of URM's per square mile (density), the top five communities in order of highest to lowest are Winooski, Burlington, South Burlington, Essex and Williston.

Map 1 illustrates the estimated number of URM buildings by census tract and city/town. Map 2 is an inset map of the most densely populated areas and resulting URM buildings.

Map 3 overlays potential URM locations in red on the estimated number of URM buildings by the census tract layer and city/town. Shades of gray are used to estimate the total number of URM buildings. The red overlay indicates the likely areas where URM buildings are located. The size of the census tract does not directly influence the number and location of URM buildings because census tracts are defined by total population and are intended to be roughly the same size based on population, not land area. While not true in all cases, small census tract are typically part of a more densely populated area. This is important to note for this project because more urbanized areas hold the greatest chance for containing multiple URM buildings. For this reason, an inset map of the most densely populated areas is included as Map 4.

Conclusion and Recommendations

Default data contained in HAZUS-MH provide a reasonable regional estimate of the location and count of URM Buildings in Chittenden County.

When mapped using GIS, visually, the number of URM buildings can appear to be skewed because census tract and block boundary lines do not distinguish between built up and open space areas. This can be confusing and result in a misperceived number and distribution of buildings. To counter this, dasymetric land cover data was used to identify developed areas where URM buildings are likely located, and the census tract data was used to estimate the number of URM buildings.

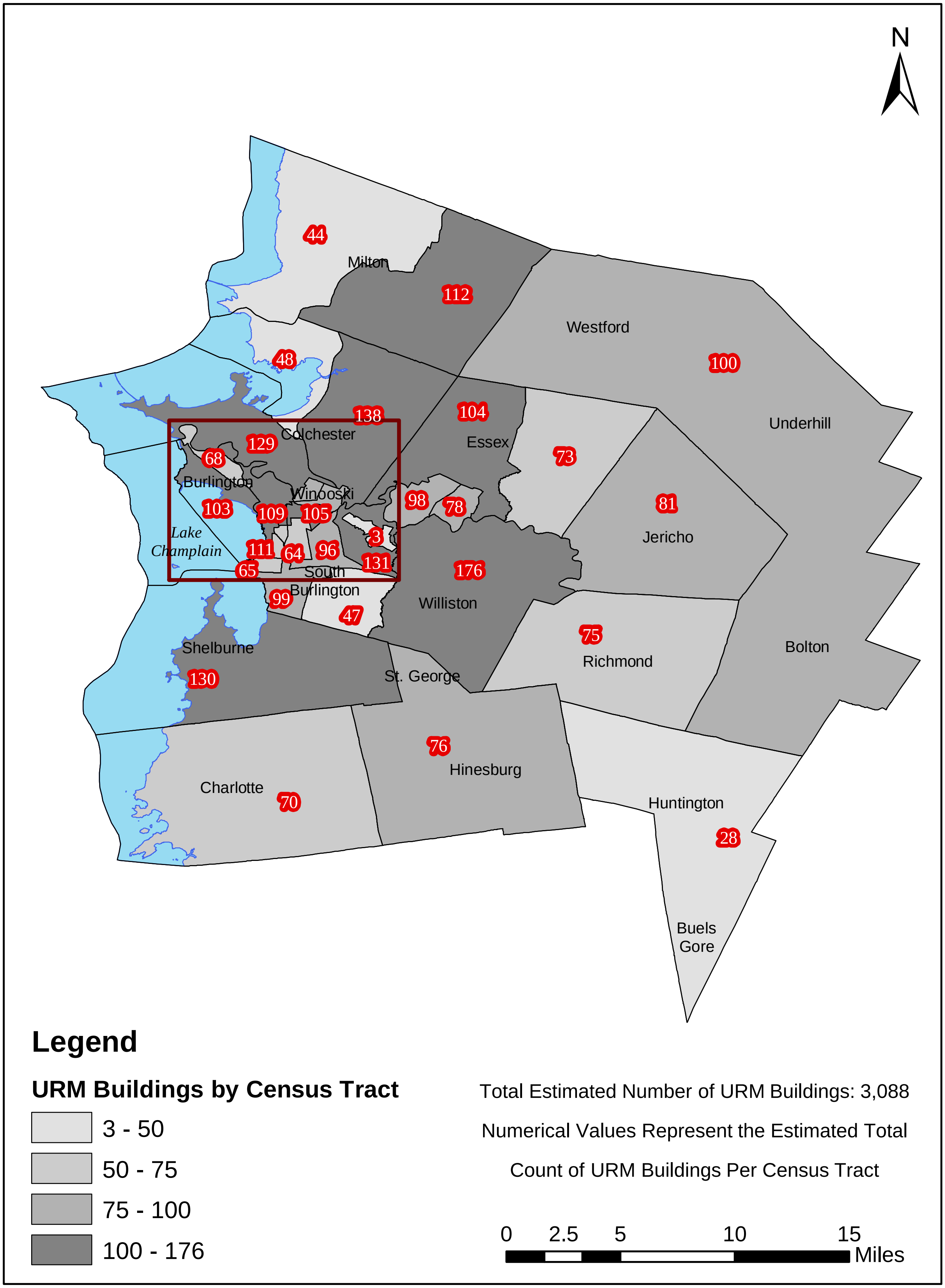
URM building information can be very useful in helping to identify risk, develop mitigation strategies, and raise public awareness. URM buildings have been proven, through evidence from past earthquakes, to be potentially dangerous buildings during an earthquake. They are also vulnerable to hurricane wind and fire. One reason is that they tend to be some of the oldest buildings in use and they rely on unreinforced masonry load bearing walls that can collapse during an earthquake. Many URM buildings date back to the 1700s and 1800s, and into the 1930s, when building codes and modern construction techniques were nonexistent. In addition, it is very expensive and sometimes cost-prohibitive to provide seismic sufficient retrofitting techniques to meet these modern standards.

The preliminary estimated count and location of URM Buildings contained herein can be used as an incentive to create an inventory of URM buildings using the FEMA Rapid Observation of Vulnerability and Estimation of Risk (ROVER) program. This can begin the process of documenting the extent of the problem and identifying possible structural and non-structural mitigation opportunities.

Disclaimer

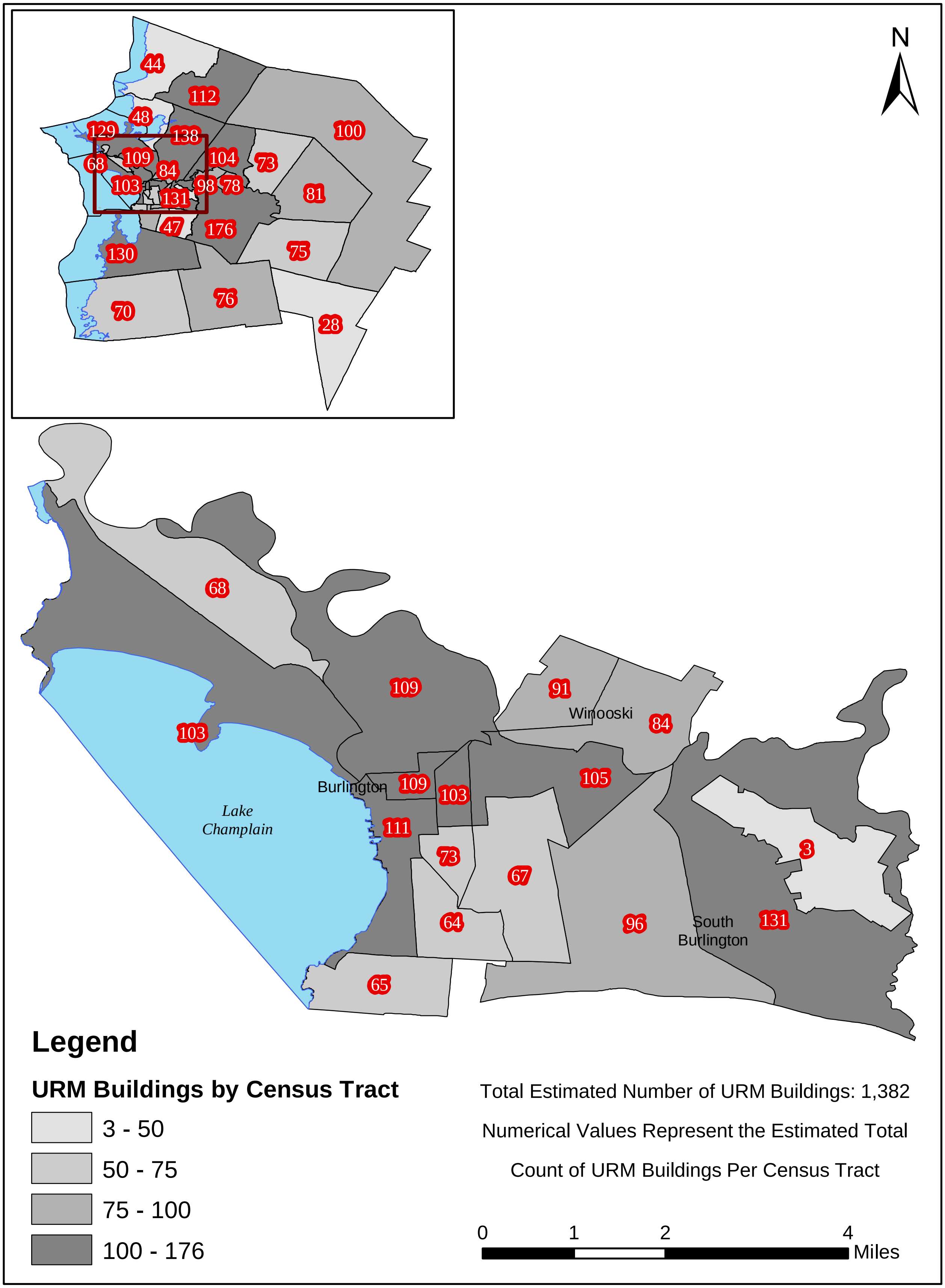
The regional inventory of URM buildings in this report was developed using FEMA's HAZUS-MH loss estimation methodology software that is based on current scientific and engineering knowledge. URM inventories contained in HAZUS-MH were estimated using census and other building data and professional engineering judgment specific to each state. Nevertheless, there are uncertainties inherent in any loss estimation models and software. Therefore, there will be significant differences between the estimates contained in this report and the actual number of URM buildings and their specific locations. The only way to determine the actual number of URM buildings in an area is to undertake an engineering based survey and structural analysis. The numbers contained in this report are strictly estimates.

Chittenden County, Vermont
Estimated Number of Unreinforced Masonry Buildings (URM)
by Census Tract

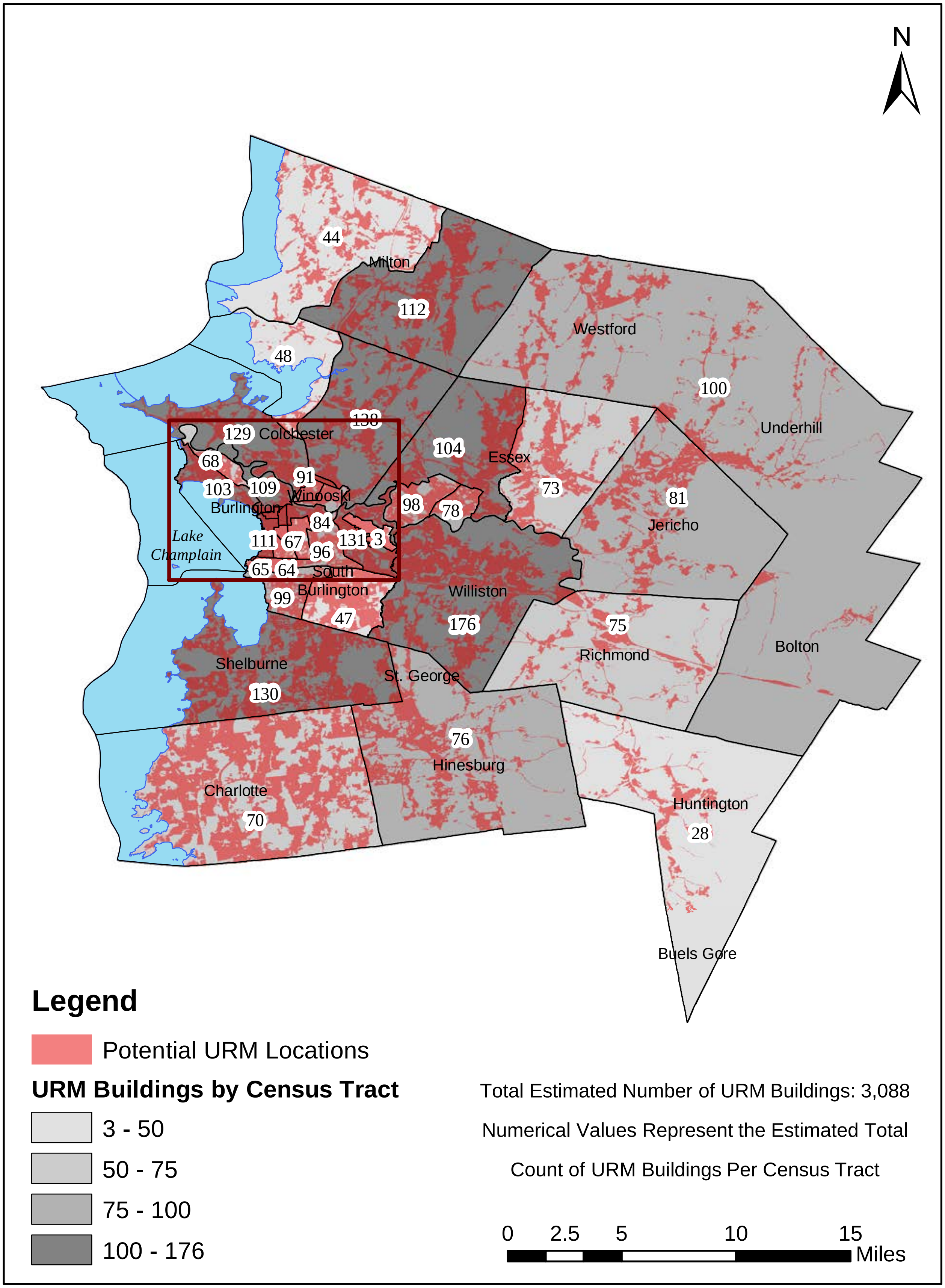


Map 2

Estimated Number of Unreinforced Masonry Buildings (URM) by Census Tract for the Most Densely Populated Areas in Chittenden County, Vermont



Chittenden County, Vermont
Estimated Number of Unreinforced Masonry Buildings (URM) by Census Tract and Potential Locations by Developed Area



Map 4

Estimated Number of Unreinforced Masonry Buildings (URM) by Census Tract and Potential Locations by Most Densely Populated Areas in Chittenden County, Vermont