Seismic Site Class, Amplification, and Liquefaction Hazard Mapping for the Burlington and Colchester, Vermont USGS 7-1/2 Minute Quadrangles

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By

John E. Lens and Mandar M. Dewoolkar
School of Engineering, University of Vermont

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Objectives

The objectives of this study were to describe and delineate the earthquake related hazard potential within the Burlington and Colchester, Vermont 7.5 minute United States Geological Survey (USGS) quadrangles using regional maps.

The map accompanying this report, entitled "Seismic Site Classification for Amplification Potential, Burlington and Colchester 7.5 Minute Quadrangles, 2011", depicts the seismic site classification for amplification potential at a regional scale. Subsurface conditions can vary abruptly and borings and/or other characterization techniques are required to estimate site classification at any specific location. This map is not to be used in place of proper site-specific engineering evaluation with appropriate subsurface explorations and testing which are performed under the direction of a qualified engineering professional in accordance with accepted standards of practice.

Background

Northwestern Vermont is an area of greater earthquake hazard potential relative to elsewhere in Vermont and the northeast United States based on probabilistic seismic hazard analysis performed by the USGS. The USGS Open File Report 2008-1128 entitled Documentation for the 2008 Update of the United States National Seismic Hazard Map (Petersen, et.al., 2008), presents a probabilistic evaluation of the seismic ground shaking potential, including descriptions of the predictive modeling used to estimate the earthquake shaking motions. These motions correspond to an earthquake with a return period of about 2,500 years. This return period is specified in the National Earthquake Hazard Reduction Program (NEHRP, 2003) Recommended Provisions for Seismic Regulations for New Buildings and Other Structures, FEMA 450-1/2003 Edition, Part 1. It is also in the current State Building Code for structural design and follows the current national practice as set forth in the International Building Code (IBC).

The probable intensity of ground shaking in northwestern Vermont is less than that in more recognized seismic hazard risk areas of the United States but it has the fifth highest probable intensity in the continental United States. The seismic ground shaking risk is expected to be greater in four regions of the continental US, namely the West Coast states, eastern Utah and Western Wyoming, the New Madrid, Missouri and Charleston, South Carolina locale (Petersen, et. al., 2008).

The earthquake shaking hazard in northwestern Vermont derives from its proximity to areas of significant seismic activity in the northern portion of New York State and the St. Lawrence River valley in Canada.

Recognizing the seismic hazard potential in Vermont is important and beneficial because it provides opportunity to take appropriate precautions in terms of preparedness, and the knowledge thereof facilitates proper design of structures and lifeline facilities such as roadways, pipelines, and electrical transmission lines.

Seismic Site Classifications

This study specifically addresses seismic risks in the Burlington and Colchester Quadrangles. These risks include ground shaking, amplification of bedrock motions within overlying soil profiles, and the potential for soils to liquefy and/or laterally spread in situations where earthquake shaking is intense and long enough to weaken the soils to a liquefied or nearly liquefied condition.

The subsurface conditions in this quadrangle range from competent rock and stiff soils to soft and loose soils. In rock and stiff soils, there is limited expected amplification of bedrock motions. With increasingly softer and looser soil, the ground motions from an earthquake are expected to be amplified above the motions originating in the underlying bedrock. Soil Seismic Site Classifications given on the maps and described in this report correspond to the relative stiffness of the soil and rock profile conditions within the quadrangle area. It is important to recognize that Seismic Site Classifications are based solely on the soil and rock conditions within the top 100 feet (30 meters) of subsurface profile and are independent of the amount of ground shaking that is predicted to occur.

These Seismic Site Classifications are established according to criteria in the International Building Code 2006 edition. Seismic Site Classification B indicates limited amplification at ground surface of the predicted bedrock motions. Seismic Site Classifications C through E correspond to increasing amplification potential of the bedrock motion generated by an earthquake. Seismic Site Classification A, which is subject to specific confirmation of hard rock conditions actually being present at a site, corresponds to a modest reduction in ground motions predicted from an earthquake at such a site compared to a site with the presumed softer rock of Seismic Site Class B.

The seismic site classifications shown on Figure 1 are based on a combination of the following data: (1) Site specific subsurface information which primarily includes soil borings, along with a limited number of cone penetration test (CPT) soundings, including shear wave velocity measurements at some of the CPT soundings, and shear wave velocity measurements made by Springston (2011b) on behalf of the Vermont Geological Survey at sites including one location along the Burlington waterfront, and two sites at the University of Vermont campus, and several sites in the Colchester Quadrangle; (2) drilled water well information principally providing depth to bedrock and general overburden soil descriptions in Wright, (1998); bedrock outcrop mapping by Springston (2011a); and (3) the Vermont Geological Survey surficial geology maps by Wright (2009) and Wright, et. al., (2009).

Soil boring data used for seismic site classification were available from approximately 45 sites in the Burlington Quadrangle and 20 sites in the Colchester quadrangle. Each site contained between 1 and about 20 soil borings, with most sites consisting of 1 to 5 borings. The Burlington quadrangle soil boring data were associated with bridge and building projects ranging from the 1960's to the present. The sites are geographically distributed in primarily the northern half of that quadrangle. Sites in the southern half of the quadrangle are more limited, corresponding to the comparatively less infrastructure and building

development than in the northern half, with the sites being scattered along Route 7 and in the Shelburne Village area and no soil boring sites in the southeast corner of the quadrangle. In contrast to the soil borings, water wells were most common in the less developed portions of the quadrangle, where they provided private water supplies.

The Colchester quadrangle is overall less developed than the Burlington quadrangle, which is reflected in less available soil boring data. The majority of the soil boring data were from the Circumferential Highway project route within the southern portion of the quadrangle. Shear wave velocity measurements at 8 sites in the center and northern portions of the quadrangle augmented the soil boring data. There is a substantial amount of water well data in this quadrangle, as with the less developed portions of the Burlington quadrangle.

The conditions encompassed by the seismic site classifications correspond to the following:

Seismic Site Class B conditions correspond to the exposed bedrock which has been mapped within the quadrangles. These include the exposed rock alongside the Winooski River in Winooski, Colchester, Burlington and South Burlington as well as a large number of generally smaller outcrops scattered throughout the quadrangles. These are exposed bedrock zones with their classification remaining subject to confirmation of competent rock conditions meeting the IBC criteria for site class B, which are specifically a rock with no more than moderate fracturing and weathering. The confirmation of Seismic Site Class A conditions requires evaluation by a geotechnical engineer, geologist, or engineering geologist/seismologist. In accordance with the IBC seismic site classifications, zones of hard bedrock can be classified as Seismic Site Class A provided they are supported by shear wave velocity measurements as outlined in the IBC (2006).

Seismic Site Class C conditions generally correspond to areas mapped as glacial till in Burlington, Colchester, Milton, South Burlington, Shelburne, St. George, and Williston along with an area in Winooski between the Winooski River and the northern extent of the Burlington quadrangle where surficial soils are mapped as fine, medium and coarse sand and where bedrock is within 5 meters of ground surface based on the water well and boring information from Wright (1998).

Seismic Site Class D/E conditions correspond to the remaining areas. These include areas mapped as medium fine sand in Burlington and South Burlington, a wide variety of sands, gravels and clay in Colchester, artificial fill (i.e., not naturally deposited soil) along the Lake Champlain waterfront and adjacent to the Intervale, and all of the alluvium along the Winooski River. This classification is based on several factors. Within each of these deposits there are soil borings with locally loose and soft soils which meet the site class E conditions, as well relatively firmer soils meeting the site class D conditions. Local variations can be abrupt, with D and E conditions sometimes both present at a site, and sometimes sharp transitions occurring from firmer B and C to D/E conditions. In addition, this site class condition is applied to areas mapped as Champlain Sea "clay" within the uplands areas of South Burlington and Shelburne otherwise mapped as glacial till. There is also a zone north of Appletree Point in Burlington which meets these conditions. This classification applied to the Champlain Sea "clay" deposits within the glacial till uplands is based on multiple sites where soil borings indicated sufficiently thick amounts of soft clay leading to a seismic site classification of E based on a weighted average of standard penetration test (SPT) blow count values per the IBC criteria. In Shelburne, the area along the LaPlatte River which is shown on the surficial geologic map by Wright, et.al, (2009) as medium fine sand, alluvium, and Champlain Sea "clay" in Shelburne is also designated as Seismic Site Class D/E. Existing subsurface data indicate relatively thick deposits of soft and loose granular soils transitioning over short distances from the surrounding site class C

conditions of glacial till. This seismic site class reflects the variability in site class conditions indicated by the existing subsurface data for the corresponding soil deposits and the observed overall variability in the composition of those deposits.

Seismic Site Class F conditions are not explicitly depicted on Figure 1 but this evaluation suggests that there could be areas where subsurface characteristics meet the Site Class F soils definition per the IBC (2006). These include swamp deposits that are greater than 10 feet thick, and areas containing potentially liquefiable soils as well as sensitive clays, peat or organic soils, highly plastic clays and thick deposits of soft to medium stiff clays, as described in the IBC (2006) criteria.

There were no definitively Seismic Site Class F conditions evident on a widespread basis in the subsurface data obtained for this study. In scattered locations in the areas designated as Seismic Site Class D/E there were soils with low SPT blow count values which indicated that they could potentially be liquefiable. However, further data would be needed for proper liquefaction analyses, as per Youd, et.al, (2001), including laboratory test results on soil fines content and complete explanations of the drilling procedures, which were not available for this study. As discussed in the following section, the potential for Seismic Site Class F conditions at specific sites needs to be considered in engineering studies made for specific individual sites in these quadrangles.

Liquefaction Hazard Potential

The liquefaction potential of soils in these quadrangles was evaluated using two methods. The first method involved the criteria based on regional geologic mapping described in Youd and Perkins (1978), and which is reiterated in the current Hazus – MH MR5 (2011) user manual, Table 9.1, and as discussed in Holzer, et. al (2011). Second, where some quantitative data on subsurface conditions, typically soil boring logs, were available evaluations were made utilizing analytical methods prescribed by Youd, et. al., (2001). The amount of information available for such site specific analytical liquefaction evaluations was limited.

The evaluation indicates that liquefaction potential exists in soil deposits except those consisting of dense glacial till and clay. It is clear that site specific liquefaction potential analyses using accepted standards of practice need to be part of the subsurface condition evaluations performed at sites in these quadrangles.

Recommendations

The overriding recommendation with the use of the data contained in this report and accompanying map is to recognize that these data are for use at a regional scale. *This report and map should not be used in place of proper site-specific seismic evaluation using site-specific subsurface conditions both of which should be performed under the direction of a qualified engineering professional in accordance with accepted standards of practice.*

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Vermont Geological Survey Seismic Site Classification for Amplification Potential, Burlington and Colchester 7.5 Minute Quadrangles

Research supported by the Vermont Geological Survey, Dept. of Environmental Conservation, VT ANR. Map produced in cooperation with the School of Engineering, University of Vermont and the Department of Geology and Environmental Science, Norwich University. This map is for planning purposes only. The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. Government, the State of Vermont, The University of Vermont, or Norwich University.

Seismic Site Class Definitions

The following seismic site classifications are based on criteria in the references cited below obtained using a combination of sources of data on subsurface conditions in the quadrangle area. The classifications and boundaries between categories shown on this map are approximate and intended to depict conditions on a regional scale. Subsurface conditions can vary abruptly and borings and/or other characterization techniques are required to estimate site classification at a given location. This map is not to be used in place of proper engineering evaluation of subsurface conditions at specific sites which should be performed under the direction of a qualified engineering professional in accordance with accepted standards of practice.

🟪	Site Class A - Hard Rock (Requires shear wave velocity measurements, See References and Note 3)
🟩	Site Class B – Exposed bedrock zone with classification subject to confirmation of competent rock condition with moderate fracturing and weathering or better.
🟩	Site Class C - Very dense soil and soft rock
🟨	Site Class D - Stiff soil profile (See Note 3)
🟧	Site Class D/E - Area where both D and E profile conditions are common
🟥	Site Class E - Soft Soil Profile (See Note 3)
🟥	Site Class F - Soils requiring site specific evaluation (Refer to FEMA 450-1 and IBC 2006 Provisions as referenced below)

Note 1: Localized bedrock outcrop zones are widely distributed in this quadrangle and where present may potentially meet Site Class B or better conditions, subject to evaluation by a geotechnical engineer or engineering geologist/seismologist.

Note 2: Localized zones of potentially liquefiable soil exist within this quadrangle in areas identified as Site Class D/E on this map. Areas of man-made filled land along Lake Champlain, ponds, and watercourses are more likely to contain such zones but the potential for liquefiable soil is not limited to filled land areas. Accordingly, site specific engineering evaluations of subsurface conditions in this quadrangle should, where applicable, address the potential for liquefaction in accordance with accepted standards of practice. Sites where potentially liquefiable soils exist will correspond to Seismic Site Class F conditions according to the criteria in the International Building Code.

Note 3. This category is included in this legend but it is not present as individual polygons on this map.

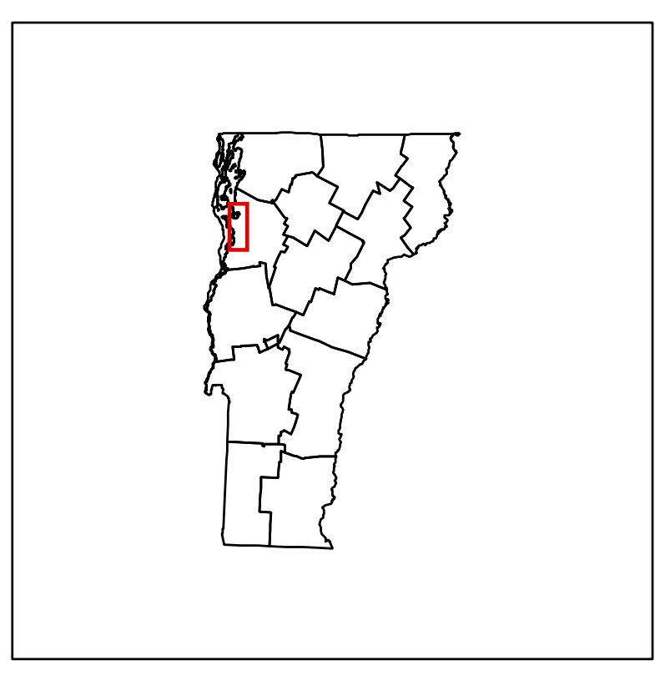
References:

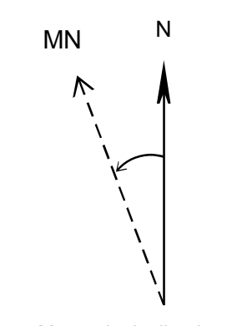
National Earthquake Hazard Reduction Program (NEHRP) Recommended Provisions for Seismic Regulations for New Buildings and Other Structures, FEMA 450-1/2003 Edition, Part 1: Provision, Building Seismic Safety Council, National Institute of Building Sciences.

International Building Code, 2006 Edition, International Code Council, Country Club Hills, IL.

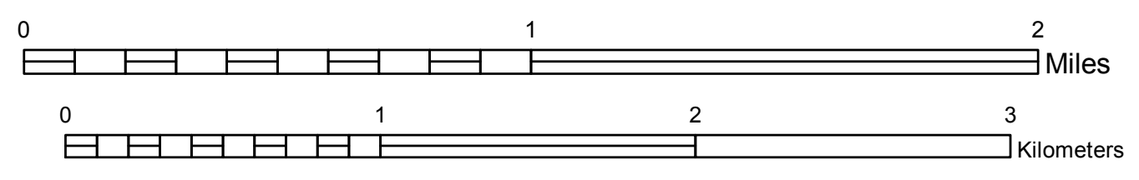
swp	Swamp deposit. Area where assessment of underlying surficial material was not made.

▭	Town Boundaries
―	Interstates
―	Major Roads
―	Minor Roads
―	Streams
■	Water Bodies
▭	USGS 24K Quadrangle Boundary





Magnetic declination
15.5 degrees west, 1987



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Base maps from U.S. Geological Survey. Coordinate System: Vermont State Plane, meters, NAD 83. Geographic coordinates shown at topo corners are in NAD 83.

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