Seismic Hazard Mapping for Williston, Vermont

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By

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Objectives

The objectives of the study are to describe and delineate the earthquake related hazard potential within the town limits of Williston, Vermont. This report is a companion to the June 5, 2013 report submitted to the Vermont Geological Survey entitled **"**Seismic Hazard Mapping for the Burlington and Colchester, Vermont USGS 7-1/2 Minute Quadrangles, Vermont Geological Survey Open File Report VG 13-3", which addresses areas to the west.

The map accompanying this report as Plate 1, entitled "Seismic Site Classification for Amplification Potential, Williston, Vermont, dated November 1, 2013", 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 Williston, Vermont. 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 2012 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 Plate 1 are based on a combination of the following data: (1) site specific subsurface information mainly from soil borings available from the Vermont Agency of Transportation, the Vermont Agency of Natural Resources Department of Environmental Conservation Waste Management Interactive Database (WM-ID, 2013), private developers, and design professionals included in Lens (2013) and Knight Engineering (1988); (2) soil profile shear wave velocity measurements made by Springston (2013) for this project at 16 sites; (3) drilled water well information principally providing depth to bedrock and in some instances, general overburden soil descriptions; and, (4) a Vermont Geological Survey surficial geology map developed by Springston and DeSimone (2007) and a bedrock geology map developed by Kim, et al.(2007).

Soil boring data were available from approximately 35 sites. The soil boring data were associated with roadway, bridge, and building projects, and contaminated site investigation and remediation projects, most of which occurred between the 1980's to the present. The equipment, methods, and documentation of drilling and sampling used to obtain this subsurface data varied considerably as a consequence of different objectives for obtaining and using the data, differing drilling and sampling methods employed, as well as variability arising from multiple firms and agencies performing the work. Engineering judgment was used to interpret and apply the data from soil borings to the current criteria for seismic site classification.

The sites with soil boring data are geographically distributed in primarily the northwestern portion of the town mostly in the region between approximately 1 mile east of Route 2A and the western town boundary.

The shear wave velocity measurements were performed at 16 sites all of which were north of Route I-89 and approximately spanned the east-west width of the town.

Water wells were widely distributed through the town as they serve many private residences and some businesses.

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

<u>Seismic Site Class B</u> conditions correspond to the exposed bedrock which has been mapped within the town as part of bedrock geologic mapping performed by Kim, et al. (2007) and surficial geologic mapping performed by Springston and DeSimone (2007). There are numerous outcrops scattered throughout the town both in the hilly upland terrain south of I-89 as well as in the flatter terrain north of I-89 where outcrops occur within areas of lake clay and silt sediments.

Future building projects in outcrop locations will require confirmation of competent rock conditions meeting the IBC criteria for Site Class B. Specifically, this requires the rock to have no more than moderate fracturing and weathering. The confirmation of Seismic Site Class A bedrock 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 this is supported by shear wave velocity measurements as outlined in the IBC (2012).

<u>Seismic Site Class C</u> conditions generally correspond to areas mapped as glacial till and ground moraine. The majority of Site Class C conditions occur in the higher elevation terrain that is predominantly south of I-89.
There are also five areas north of I-89 which are designated with Site Class C conditions. The four most easterly of these zones correspond to local hills which are composed of glacial till and ground moraine soils overlying usually shallow bedrock. The fifth zone is a small zone of locally shallow stiffer soils identified in the shear wave velocity measurements obtained for this study.

<u>Seismic Site Class C/D</u> conditions exist in the higher terrain areas south of I-89 where there are mapped deposits containing varying proportions of sand, gravel, and glacial till. Areas containing these deposits are designated as Seismic Site Class C/D to reflect the potential for less dense conditions than typical of the surrounding Seismic Site Class C deposits.

<u>Seismic Site Class D/E</u> conditions correspond to the remaining areas of the town. These include areas mapped as clay and silt, lake sand sediments, and the alluvium along the Winooski River. This classification is based on several factors. Within 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 criteria. 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.

This classification also applies to clay and alluvial silt and sand deposits along Muddy Brook. Multiple sites in similar terrain to the west contained soil borings which indicated sufficiently thick amounts of soft clay or silt 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.

The Seismic Site Class D/E designation 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 as there were no areas of definitively Seismic Site Class F conditions evident in the subsurface data obtained for this study. However, there are areas where subsurface characteristics may meet the Site Class F soils definition per the IBC (2012), subject to more quantitative evaluation. These include Holocene peat and muck mapped in a few localized narrow deposits in the upland terrain in the south portion of town, which if greater than 10 feet thick, would correspond to Site Class F conditions. Also, should there be areas containing potentially liquefiable soils, sensitive clays, peat or organic soils, highly plastic clays and thick deposits of soft to medium stiff clays, as described in the IBC (2012) criteria, such areas would meet the Seismic Site Class F criteria. In general, potentially liquefiable soils in the Site Class D/E areas, particularly in the alluvial deposits along the Winooski River, represent the most probable of these conditions.

Further explorations and testing are needed for proper liquefaction analyses to be made as per the current industry standards. This would include laboratory test results on soil fines content and special attention to drilling and sampling procedures. As discussed in the following section, the potential for Seismic Site Class F conditions needs to be considered in engineering studies made for individual sites.

Liquefaction Hazard Potential

The liquefaction potential of soils in these quadrangles was considered primarily through the regional geologic mapping criteria 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). There was insufficient quantitative data on subsurface conditions, typically through soil boring logs with associated laboratory testing, for evaluations to be made utilizing current analytical methods.

The evaluation for the study indicates that liquefaction potential exists in soil deposits within Williston except those consisting of dense glacial till and clay. In general, locations with submerged loose sand soils are of concern for liquefaction hazard and as discussed in the preceding section there is relatively more potential for such conditions to exist in the alluvial soils along the Winooski River and to a lesser extent along tributary streams.

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.*

Acknowledgements

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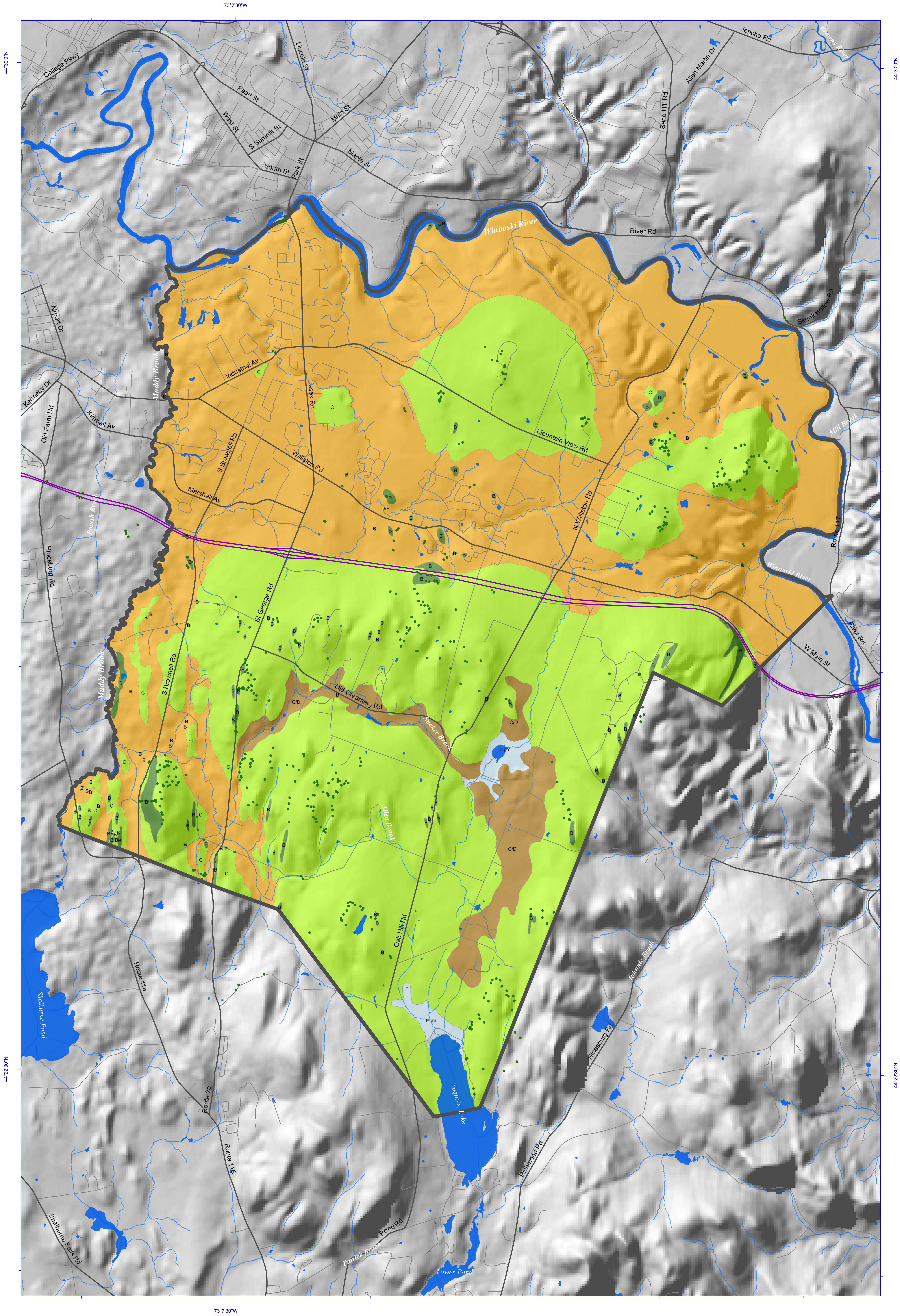

Vermont Geological Survey Seismic Site Classification for Amplification Potential, Town of Williston, Vermont Open File Report VG13-4, Plate 1

This map is to be used in conjunction with the accompanying report (Lens and others, 2013b).

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 this map and described in the accompanying 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.

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Research supported by the Vermont Geological Survey, Dept. of Environmental Conservation, VT ANR and the Earthquake Engineering Research Institute (EERI) through a grant from the Federal Emergency Management Agency. 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, Norwich University, or EERI.

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 Notes 1 and 3)
- Site Class B – Exposed bedrock zone with classification subject to confirmation of competent rock condition with moderate fracturing and weathering or better (See Note 1)
- Site Class B – Exposed bedrock outcrop location with classification subject to confirmation of competent rock condition with moderate fracturing and weathering or better (See Note 1)
- Site Class C - Very dense soil and soft rock
- Site Class C/D - Area where both C and D profile conditions are common
- Site Class D - Stiff soil profile (See Note 3)
- Site Class D/E - Area where both D and E profile conditions are common (See Note 2)
- Site Class E - Soft Soil Profile (See Note 3)
- Site Class F - Soils requiring site specific evaluation (Refer to FEMA 450-1 and IBC 2012 Provisions as referenced below and Note 2)

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 soils or other soil types which correspond to Seismic Site Class F may exist in the areas identified as Site Class D/E on this map. Accordingly, site specific engineering evaluations of subsurface conditions should, where applicable, address the potential for liquefaction and the other instances of potentially unstable soils corresponding to Site Class F conditions in accordance with accepted standards of practice.

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

References:

Lens, J.E., Dewoolkar, M.M., Springston, G.E., and Becker, L.R., 2013a, Seismic Hazard for the Burlington and Colchester, Vermont USGS 7-1/2 Minute Quadrangles: Vermont Geological Survey Open File Report VG13-3, 4 p., plus 2 appendices.

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International Building Code, 2012 Edition, International Code Council, Country Club Hills, IL.

Hpm — Holocene Peat and Muck. Areas of peat and muck soil, which require engineering measures meeting accepted standards of practice before placing structures on these soils.

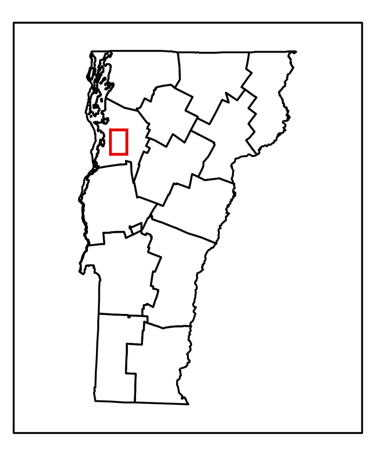
0 1 2 Miles

0 1 2 3 Kilometers

1:24,000

MN N

Magnetic declination 15.5 degrees west, 1987



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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