README DOCUMENTATION NEHRP SITE CLASS MAP OF TETON COUNTY, IDAHO

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Digital Database 6

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WHAT ARE NEHRP SITE CLASSES?

The intensity of ground shaking during an earthquake varies according to the nature of near-surface materials. For example, shaking intensity is generally greater in areas underlain by unconsolidated materials than in those underlain by firm bedrock. Engineers and architects incorporate these local site conditions into their designs to reduce damage from earthquakes. In 1997, the National Earthquake Hazards Reduction Program (NEHRP) established procedures for placing building sites into classes based upon the geotechnical properties of near-surface materials (Table 1; Building Seismic Safety Council, 1997). For each NEHRP site class, coefficients adjust expected earthquake motions for local ground conditions. Earthquake ground motion parameters are produced by the U.S. Geological Survey for all parts of the United States and are available as national seismic hazard maps (http://earthquake.usgs.gov/hazards/products/). NEHRP site classes are not shown on the national seismic hazard maps because local conditions are frequently too variable to accurately depict at the hazard map scale, and/or because the required geotechnical information is unavailable. Both NEHRP site classes and USGS national seismic hazard maps are incorporated into the International Building Code (e.g. IBC, 2009, p. 366-376).

HOW NEHRP SITE CLASSES WERE DETERMINED FOR THIS MAP

The most recent procedures for determining NEHRP site classes are described in Chapter 20 of ASCE/SEI standard 7-10 (ASCE/SEI, 2010, p. 203-205). Site classes (A-F) are determined in engineering studies with geotechnical properties of earth materials within 30 m (100 ft) of the ground surface. Geotechnical properties (Table 1) include average shear wave velocity (Vs30), average standard penetration resistance (N_{av}) and average undrained shear strength (s_u). These geotechnical properties are defined and methods of measurement described in Liu and Evett (2008). Only Vs30 is of interest here. The ASCE/SEI 7-10 procedures cannot be followed strictly in regional studies such as this one because of the lack of suitable geotechnical data for the entire project area. Instead, geologic mapping and soil surveys are used along with available geotechnical data to estimate site classes. This approach has been used to produce regional NEHRP site class maps in a number of areas in the western United States (e.g. Palmer and others, 2004; Wills and others, 2000).

NEHRP site classes were determined in two ways for Teton County: 1) by measurement and interpolation of Vs30 in a study area containing the majority of county population and infrastructure; 2) with the U.S. Geological Survey's Global Vs30 Map Server in the remainder of the county. Details of each procedure are given below.

Vs30 Measurements

The study area for Vs30 measurements (outlined in red on the map and provided in the GIS dataset) contains the majority of Teton County population and infrastructure, including the towns of Tetonia, Driggs, and Victor. Sites for Vs30 measurements were selected on the basis of the following criteria:

a. sites needed to be level enough to permit placement of geophones and the active seismic source along an approximately 100 m (328 ft) straight line;
b. permission from property owners was required;
c. sites should be distributed so as to sample each of the major landforms and surficial deposits present in the study area;
d. several sites should be adjacent to critical infrastructure in towns.

Vs30 measurements were made at 31 sites (Table 2) on July 18-22, 2011, by Jamey Turner and Dan O'Connell of Fugro Consultants, Inc. The Interferometric Multi-Channel Analysis of Surface Waves technique (O'Connell and Turner, 2011) was used. At each site, the following procedures were followed:

1. Twelve 4.5 Hz vertical-component geophones with 8 m (26.2 ft) spacing were laid out along a straight 88 m (288.7 ft) line.
2. The location of line ends were determined at the geophone 1 and geophone 12 points with a GPS receiver.
3. Geophones were acoustically connected to the ground by inserting the spike and, where possible, buried beneath several centimeters (inches) of dirt.
4. Geophones were connected to a DAQLink II 24-bit Acquisition System unit with Panasonic Toughbook CF-19 computer running VScope version 2.4.20 software.
5. At most sites, an active seismic source was provided by pounding an approximately 929 cm^2 x 2.5 cm (1 ft^2 x 1 in) steel plate with a 5.2 kg (11.5 lb) Stanley dead-blow sledgehammer. The plate was positioned on the ground about 5-10 m (16-33 ft) from one end of a geophone line, and moved progressively away from the end during data acquisition. Pounding was continued until at least twenty 40-s records were collected. The plate was then taken to the other end of the line and the pounding procedure repeated. At several sites, the hammer source was replaced with a skid steer front loader. The bucket of the loader was slammed repeatedly on the ground to generate the seismic source, and moved progressively away from the end of line as in the hammer source procedure.
6. Ambient seismic noise was also collected but was not an important source in most cases because of the rural nature of Teton County.
7. Preliminary signal processing was conducted at each site to ensure that sufficient good-quality data was collected.

Post-processing of data was completed in Denver by Fugro Consultants, Inc. (Table 2 and Appendices A, B, C). Vs30 and Vs50 calculations follow those given in the International Building Code (IBC, 2009, Section 1613, Equation 16-40).

Interpolation of Vs30 Measurements

The Vs30 data display spatial patterns related to type of landform and source of earth materials making up the landform. Weaker correlation appears to exist between the age of landforms and Vs30. These findings were used with geologic mapping (Mitchell and Bennett, 1979; Scott, 1982) and soil maps (Soil Survey Staff, 2011) to interpolate Vs30 measurements to other parts of the study area.

The NEHRP site class map of Teton County contains 6 classes. These classes are the same used by Global Vs30 Map Server. They subdivide the classes defined in Table 1 as follows:

a. D1: 240-180 m/s
b. D2: 300-240 m/s
c. D3: 360-300 m/s
d. C1: 490-360 m/s
e. C2: 620-490 m/s
f. C3: 760-620 m/s

Sites with Class A (>1500 m/s), Class B (1500-760 m/s) and Class E (<180 m/s) were not identified in Teton County by measurement or by Global Vs30 Map Server. Class F sites require site specific geotechnical analysis and also were not identified in Teton County.

Alluvial Fans Derived from the Teton Range

Pleistocene glacial climates produced large volumes of gravelly glacial outwash that accumulated as alluvial fans along streams draining the Teton Range. During the Holocene, streams incised through these fans. Such fans are located in the eastern portion of the map along Teton Creek, Darby Creek, Fox Creek, and Trail Creek. The towns of Driggs and Victor together with most of the critical infrastructure of Teton County are built on these fans. The fans become finer grained to the west and coalesce into very low gradient channels, marshes, and wetlands separated by occasional erosional remnants of gravelly fan deposits. Water well logs (IDWR, 2011) indicate that fans are composed of >50 m (>164 ft) of gravel interbedded with clay and sand. Surface exposes indicate gravel clasts are composed of resistant quartzite, carbonate, and sandstone derived mostly from lower Paleozoic and Precambrian rocks of the Teton Range (Mitchell and Bennett, 1979; Love, Reed, and Christiansen, 1992).

On the proximal portion of these fans, Vs30 measurements are remarkably high (Class C3; 760-620 m/s). On this basis, all proximal outwash fans derived from the Teton Range are mapped as C3. Where broad Holocene stream channels cut the fans (e.g. along Teton Creek), Vs30 values decrease to between Class C2 (620-490 m/s) and C1 (490-360 m/s). On distal portions of the fans, Vs30 drops as grain size decreases. For example, at site 8 midway to the Teton River, it is nearly Class D3 (384 m/s). For this reason, distal portions of fans are mapped as Class D3. Soil maps (Soil Survey Staff, 2011) were used to delineate distal fan deposits from alluvium of the Teton River.

Alluvium Derived from Huckleberry Ridge Tuff

Alluvial fans and stream alluvium derived predominantly from erosion of the early Pleistocene Huckleberry Ridge Tuff have Vs30 values consistently between 490-360 m/s (Class C1). These fans include South Leigh Creek, North Leigh Creek, and Badger Creek in the northeast portion of the map. Water well logs (IDWR, 2011) and gravel pits show that these fans and alluvium are composed of sandy decomposed tuff and phenocrysts, welded rhyolite cobbles, and lesser cobbles of quartzite, sandstone, and carbonate. One measurement was made on thin (<45 cm, <18 in) soils derived from loess overlying

Huckleberry Ridge Tuff (site 57, Vs30 = 489 m/s). This suggests that Vs30 for the tuff is Class C2 and uplands composed of thin loess over Huckleberry were mapped accordingly.

Thick Loess Overlying Volcanic Bedrock

Loess deposits ranging from 8.5 to15 m (28 to 48 ft) thick overlie basalt and welded rhyolite tuff on uplands adjacent to the Teton River in the northern portion of the map. Two measurements on such loess (sites 52A, 376 m/s and 52B, 358 m/s) indicate that this material should be assigned to Class C1.

Alluvium of the Teton River

The lowest Vs30 measurement (site 24, 217 m/s; Class D1) was made in fine-grained, organic-rich deposits on a low terrace of the Teton River. Other sites adjacent to the Teton River range from 265 to 306 m/s (Class D2). Soil maps and geomorphic relationships (Soils Survey Staff, 2011) were used to correlate Teton River alluvium and separate it from distal portions of alluvial fans.

Alluvial Fans West of Teton River

On the western side of the map, alluvial fans are present where streams exit the Big Hole Mountains. Strata in the headwaters of these fans are a mixture of Cretaceous fine-grained sedimentary rocks and Tertiary welded tuffs. The largest fans were deposited along Packsaddle Creek, Horseshoe Creek, and Mahogany Creek. There are two generations of landforms in this area. The oldest appear to have been incised and streamlined by flowing water. Soil maps (Soil Survey Staff, 2011) indicate that these landforms are capped with at least 1.5 m (5 ft) of loess. Surfaces of some of these landforms contain NE-trending topographic linears typical of loess deposits. Water wells (IDWR, 2011) show that they consist of tens of meters of clay interbedded with thin gravel deposits. This information suggests that the landforms may be lake deposits containing interbeds of alluvial-fan gravels. The younger landforms appear to be alluvial-fan sediments deposited between the loess-covered hills.

Vs30 measurements on the older landforms (sites 16, 18B. 18C) are much lower than on alluvial fans in the eastern portion of the map, ranging from 288 to 309 m/s (classes D2 to low D3). Based on this information, all of these landforms were mapped as Class D2. One Vs30 measurement on the younger alluvial-fan deposits (site 19, 357 m/s; Class D3) was used to classify these deposits as Class D3 on the map. The relatively low Vs30 may reflect the fine-grained nature of source materials for the fans.

Global Vs30 Map Server

Outside of the detailed study area, Teton County consists of the sparsely populated Big Hole Mountains and gently dipping loess-covered volcanic uplands mostly used for agriculture. In this area, Vs30 was estimated using the U.S. Geological Survey's Global Vs30 Map Server (available at http://earthquake.usgs.gov/hazards/apps/vs30/). Global Vs30 Map Server derives maps of seismic site class using topographic slope as a proxy for Vs30 (Wald and Allen, 2007).

A rectangular region was defined with latitude and longitude coordinates of northwest corner = 43.987499 and -111.429169, and southeast corner = 43.454166 and -110.929169. This rectangle contains all of Teton County plus a buffer region outside of the county boundary. ASCII output from Global Vs30 Map Server was imported into ArcMap and used to produce a map of NEHRP site classes outside of the detailed study area. The same 6 site classes were used as in the detailed study area.

LIMITATIONS ON THE USE OF THIS MAP

This map is based on correlation of Vs30 measurements between widely separated localities and on computer software that uses topography as a proxy for Vs30. Site-specific geotechnical investigations are required to determine actual ground conditions for specific building sites. This map is intended to be used at a scale of 1:50,000. As with all maps, users should not apply this map, either digitally or on paper, at more detailed scales.

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TABLES

Table 1. NEHRP Site Classification (after ASCE/SEI, 2010, p. 205).

Site Class	Vs30	N_{av}	s_u
A. Hard Rock	>1500 m/s (>5000 ft/s)	NA	NA
B. Rock	1500-760 m/s (2500-5000 ft/s)	NA	NA
C. Very Dense Soil and Soft Rock	760-360 m/s (2500-1200 ft/s)	>50	>95.8 kPa (>2000 psf)
D. Stiff Soil	360-180 m/s (1200-600 ft/s)	15-50	47.9-95.8 kPa (2000-1000 psf)
E. Soft Soil	<180 m/s (M600 ft/s)	<15	<47.9 kPa (<1000 psf)
F. Soils susceptible to potential failure under seismic loading, such as liquefiable soils or sensitive clays, peats, or organic lays thicker than 10 ft; thick sections of clays	See Section 20.3.1 of ASCE/SEI 7-10.		

Table 2. Vs30 and Vs50 Depth-Averaged Shear Wave Velocity Results for Teton County, Idaho.

	Geophone 1		**Geophone 12**			
IMASW Site ID	**LAT**	**LONG**	**LAT**	**LONG**	**Vs30 (m/s)**	**Vs50 (m/s)**
Site 4	43.72359	-111.07763	43.72389	-111.07674	513.1	571.4
Site 7	43.72370	-111.11625	43.72376	-111.11740	478.0	558.6
Site 8	43.72428	-111.14853	43.72433	-111.14967	376.7	459.8
Site 16	43.75587	-111.22078	43.75667	-111.22082	288.5	342.9
Site 18	43.75192	-111.20345	43.75122	-111.20288	288.2	342.3
Site 18B	43.75217	-111.20613	43.75132	-111.20598	289.8	336.8
Site 18C	43.75033	-111.20570	43.74953	-111.20570	309.7	360.8
Site 19	43.75497	-111.22882	43.75570	-111.22913	357.6	385.1
Site 24	43.65027	-111.16757	43.65033	-111.16866	217.2	271.5
Site 25	43.81335	-111.15845	43.81390	-111.15780	356.5	444.4
Site 26	43.81337	-111.16435	43.81273	-111.16358	344.7	411.1
Site 27	43.85420	-111.17208	43.85502	-111.17227	409.7	430.2
Site 28	43.86858	-111.17578	43.86935	-111.17600	401.4	511.6
Site 29	43.77295	-111.04670	43.77375	-111.04670	449.1	586.8
Site 31	43.78110	-111.07512	43.78110	-111.07405	427.3	476.5
Site 34	43.73307	-111.10106	43.73403	-111.10037	559.5	635.1
Site 36	43.57174	-111.11271	43.57178	-111.11380	404.7	458.6
Site 38	43.66325	-111.07405	43.66255	-111.07354	672.1	739.6
Site 41	43.74374	-111.10901	43.74373	-111.10792	618.5	675.0
Site 52A	43.88260	-111.27483	43.88300	-111.27585	376.6	496.4
Site 52B	43.86022	-111.27548	43.85948	-111.27555	358.1	482.9
Site 53	43.60670	-111.11704	43.60590	-111.11685	711.5	809.6
Site 54	43.71450	-111.04707	43.71532	-111.04703	627.3	827.8
Site 55	43.64401	-111.11194	43.64476	-111.11188	651.8	676.3
Site 56	43.65973	-111.11203	43.66056	-111.11190	568.5	621.7
Site 57	43.85709	-111.11072	43.85782	-111.11056	489.2	577.5
Site 58	43.63965	-111.18441	43.63966	-111.18550	251.6	306.1
Site 59	43.63967	-111.17204	43.63964	-111.17095	265.4	315.0
Site 60	43.59804	-111.10233	43.59882	-111.10224	723.5	755.8
Site 61	43.59346	-111.10236	43.59421	-111.10227	734.4	776.1
Site 62	43.69425	-111.06852	43.69503	-111.06842	634.4	713.3

Coordinate Datum is NAD83/WGS84.

FUGRO CONSULTANTS INC. DIGITAL REPORT FOR SHEAR WAVE VELOCITY MEASUREMENTS*

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DIGITAL MAP AND GIS FILES*

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Teton_County_Detailed_Study_Area

Metadata
NEHRP_Site_Class_Map_Teton_County _Idaho.htm

ASCII Grid of NEHRP Site Class Map of Teton County
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