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Digital Mapping Process of Seismic Design Category Information for Residential Construction in Washington

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Introduction

The 2003 International Residential Code (IRC)(International Code Council, 2003) was adopted in 2004 by the Washington State Legislature as the official state building code for one- and two-family dwellings and townhouses not more than three stories in height and with separate means of egress. Poelstra and Palmer (2004) published seismic design category (SDC) maps, based on this 2003 IRC using the 1996 National Seismic Hazard Maps (Frankel and others, 1996), to assist local building officials, property owners, and developers of residential construction in Washington. The recently published 2006 IRC (International Code Council, 2006a, b), adopted for use in Washington beginning on July 1, 2007, requires changes in previously determined seismic design categories that had been ranked (from lower to higher) as A, B, C, D_0, D_1, D_2, and E. The higher the rank of the SDC, the more restrictive the required building code provisions, which increases the cost of building design and construction. In the 2006 IRC, the former seismic design category D_1 of the 2003 IRC is subdivided into categories D_0 and D_1, as defined in Section R301.2.2, specifically in Table R301.2.2.1.1, of the 2006 IRC (International Code Council, 2006b). In addition, the 2002 National Seismic Hazard Maps (Frankel and others, 2002) were incorporated into the new IRC maps.

Accordingly, two new types of digital map data for seismic design categories are being prepared. These digital data include two ESRI shapefiles that contain information on seismic design categories determined based on (1) the assumption that the entire state is site class D, which is the default value in the IRC where no site class information is available and (2) seismic design categories based on available NEHRP site class information provided by the Washington State Department of Natural Resources (Poelstra and Palmer, 2004).

Calculation Method for Seismic Design Category Maps

To generate seismic design categories, we first calculated S_{DS} values (design spectral response acceleration) at 5 percent critical damping by using the 2003 revision of the U.S. Geological Survey’s 2002 short-period (0.2 sec) accelerations (S_S) with 2 percent probability of exceedance in 50 years (Frankel and others, 2002; Nicolas Luco, USGS, written commun., 2007), which represent the maximum considered earthquake (MCE) of standard ASCE/SEI 7-05 (American Society of Civil Engineers, 2006). These 0.05 decimal-degree gridded S_S values can be downloaded in ASCII format from the USGS-HMGP website at *http://earthquake.usgs.gov/research/hazmaps/*.

The following procedure is used for production of maps showing seismic design categories of the geologic materials:

1. The maximum considered earthquake (MCE) spectral response acceleration values for short periods (S_S) are adjusted for site class effect (S_{MS}) using the following equation (International Code Council, 2006a, section 1613.5.3):

$$S_{MS} = F_a S_s \quad (1)$$

where S_S is the mapped spectral acceleration for short periods (0.2 sec) and F_a is the site coefficient defined from Table 1 (default site class D is shaded).

Table 1. F_a site coefficients given in the IBC 2006 (International Code Council, 2006a).

Site class	Mapped spectral response acceleration at short periods				
	$S_S \le 0.25$	$S_S = 0.50$	$S_S = 0.75$	$S_S = 1.00$	$S_S \ge 1.25$
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.2	1.2	1.1	1.0	1.0
D	1.6	1.4	1.2	1.1	1.0
E	2.5	1.7	1.2	0.9	0.9
F	*	*	*	*	*

2. The 5 percent damped design spectral response acceleration (S_{DS}) at short periods is determined from the following equation (International Code Council, 2006a, section 1613.5.4):

$$S_{DS} = \frac{2}{3} S_{MS} \tag{2}$$

3. Finally, we determined the seismic design categories using the S_{DS} values (Table 2).

Table 2. Seismic design categories described in given in Table R301.2.2.1.1 of the 2006 IRC (International Code Council, 2006b).

Seismic Design Category	Calculated SDS (g)
A	$S_{DS} \le 0.17$
B	$0.17 < S_{DS} \le 0.33$
C	$0.33 < S_{DS} \le 0.50$
D0	$0.50 < S_{DS} \le 0.67$
D1	$0.67 < S_{DS} \le 0.83$
D2	$0.83 < S_{DS} \le 1.17$
E	$S_{DS} > 1.17$

Processing Steps for Seismic Design Category Map Data Using Default Site Class D

This dataset is generated using two principal software applications: Microsoft Excel and ESRI ArcGIS. A flowchart (Figure 1) shows processing steps and associated software with related script names (Cakir and Walsh, 2007):

1. Input is gathered from the U.S. Geological Survey (USGS) National Seismic Hazard Maps website (*http://earthquake.usgs.gov/research/hazmaps/*), which is the 2003 revision of the USGS 2002 short-period (0.2 sec) accelerations (S_S) having a 2 percent probability of exceedance in 50 years. These acceleration values are in ASCII format.
2. By using equations (1) and (2) as described in section 1613 of the 2006 International Building Code (IBC), S_s input values, and the assumption for a default site class D, we calculated S_{ds} values in Microsoft Excel.
3. We then converted these S_{ds} values from Excel to an ESRI (ArcGIS) point shapefile.
4. This shapefile was later converted to an ArcGIS grid with a 100-foot cell size.
5. By using a MapAlgebra script in the Spatial Analyst Tool of the ArcGIS, we then assigned seismic design categories in numerical form because grid-based calculation requires values (in a subsequent step, letter class designations are assigned in ArcMap).
6. We then converted this grid file to a polygon shapefile and assigned seismic design categories given in Table 2.
7. Finally, we generated the seismic design category map by dissolving this polygon shapefile. Likewise for the Poelstra and Palmer (2004) seismic design category map, we also used site class F (peat deposits) as an overlay on this final dissolved map. (Note that site class F includes peat deposit sites which may or may not liquefy, therefore requiring detailed geotechnical investigation.)

Processing Steps for Seismic Design Category Map Data Using an Available Seismic Site Class Map

This dataset generation uses the statewide NEHRP site class map (Palmer and others, 2007). Site class values are combined with short period accelerations from the 2002 version of the USGS National Seismic Hazard Map to yield seismic design values in the manner prescribed in the IRC 2006. This dataset is intended to aid the end users who want to implement the changes in seismic design categories given in the 2006 IRC.

Site class F attribute data directly excluded from the NEHRP site class map were joined to seismic-design categories. Site class F represents peat deposits, which require detailed geotechnical investigations. The user may also

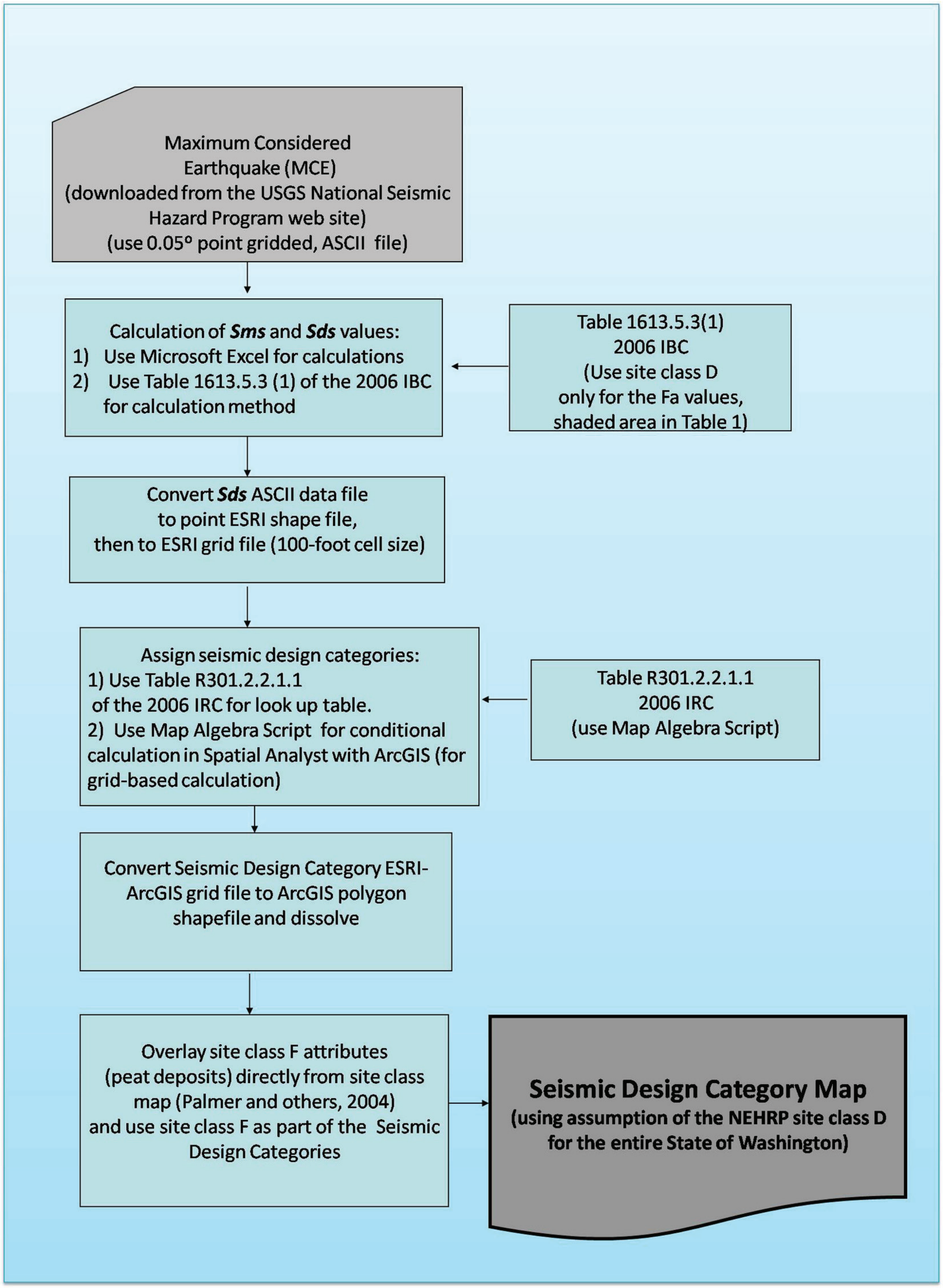

Figure 1. Flowchart showing the processing steps for generating seismic design categories with assumption of the assigned NEHRP site class D for Washington State.

incorporate the liquefaction susceptibility map (Palmer and others, 2007), which is not presented in our seismic design categories, to determine other areas that could be considered to be site class F based on their potential for liquefaction failure during an earthquake.

This dataset is generated using ESRI ArcGIS software (*http://www.esri.com*). A flowchart (Figure 2) shows processing steps. To produce seismic design categories with inclusion of the statewide NEHRP site class information (Palmer and others, 2007) the following steps were used:

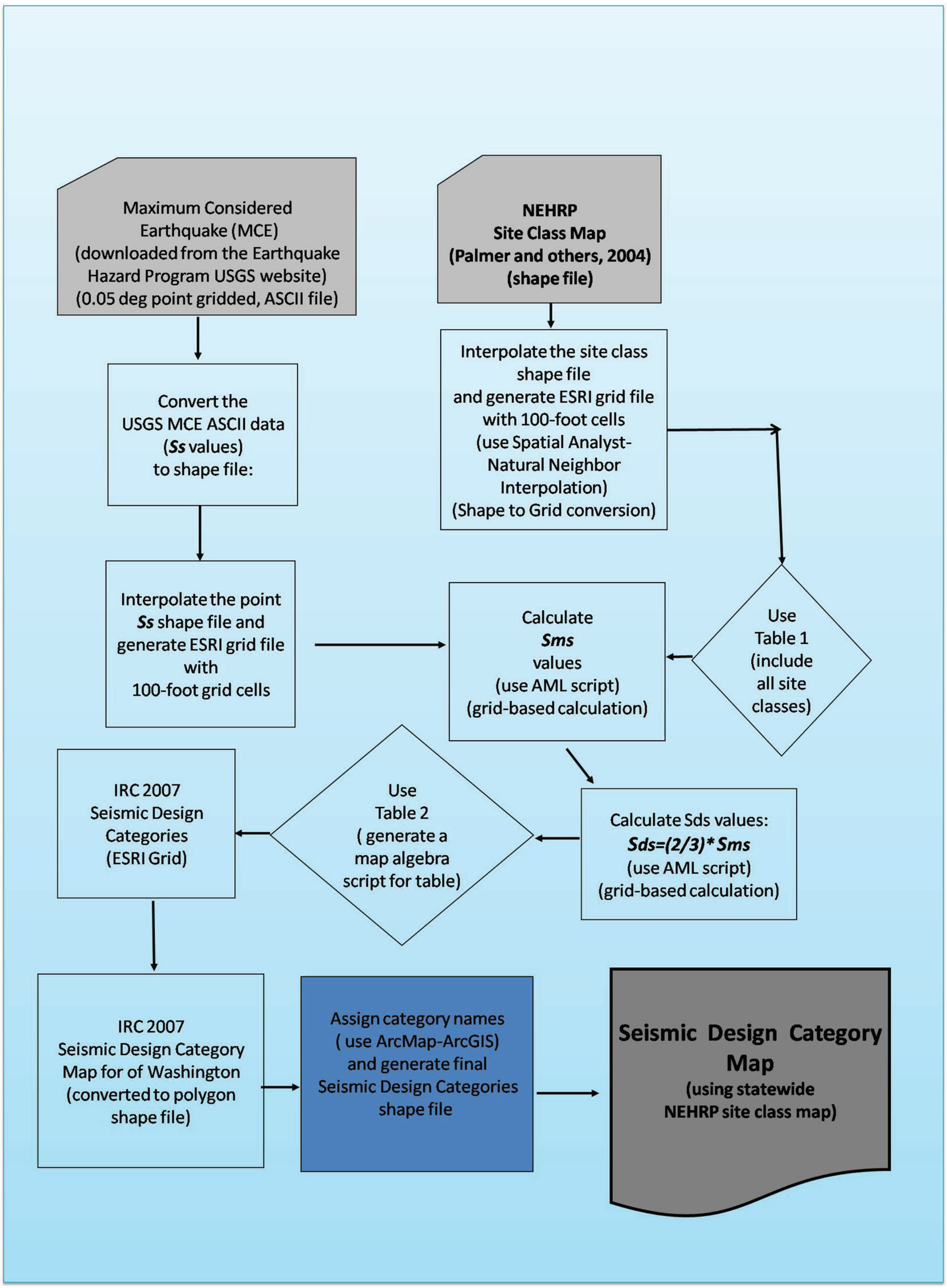

Figure 2. Flow chart showing processing steps for generating seismic design categories using the available NEHRP site class map produced by Palmer and others (2007).

1. Inputs were gathered from (a) the USGS National Seismic Hazard Maps website (*http://earthquake.usgs.gov/research/hazmaps/*), which is the 2003 revision of the USGS 2002 short-period (0.2 sec.) accelerations (S_S) having a 2 percent probability of exceedance in 50 years (these acceleration values are in ASCII format) and (b) the NEHRP seismic site class map (Palmer and others, 2004) converted to a 100-foot ESRI grid. These two inputs and their processing steps are shown in Figure 2.

2. Equations (1) and (2), as also described in section 1613 of the 2006 IBC, were used to calculate S_{ds} values for assigning the seismic design categories. We calculated S_{DS} values using an AML script.

3. Using a MapAlgebra script in Spatial Analyst Tool of ArcGIS, we then assigned seismic design categories.

4. We then converted this grid file to polygon shapefile and assigned seismic design categories given in Table 2.

5. Finally, we generated the seismic design category map by dissolving this polygon shapefile and directly overlaying the site class F, which requires detailed geotechnical investigation. One must note that site class F includes peat deposits. Here the site class F (representation of peat deposits) attribute is directly extracted from site class map (Palmer and others, 2007).

After generating the shapefiles of the seismic design categories, demographic information used as an overlay and graphical editing were completed to generate final static maps (Figures 3 and 4) (Cakir and Walsh, 2007). In addition, Arc geodatabase (SDE and .mxd files) are generated from the shapefiles. Finally, these IRC maps are presented on the Washington Division of Geology and Earth Resources interactive mapping site (*http://wigm.dnr.wa.gov/*; Figure 5).

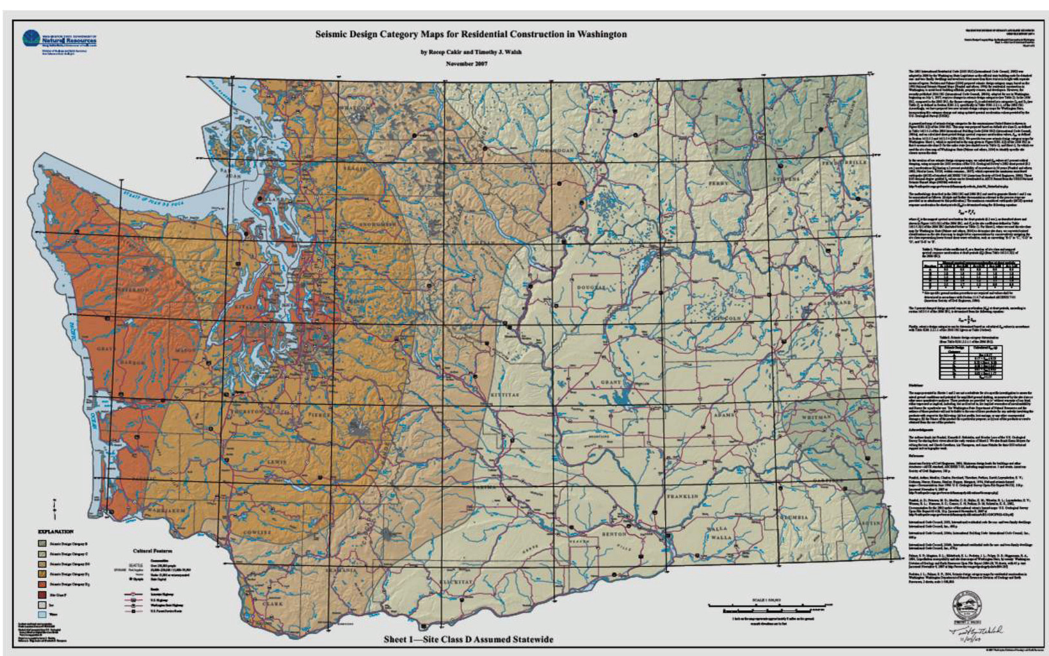

Figure 3. Seismic design category map with the assumption of site class D (Cakir and Walsh, 2007).

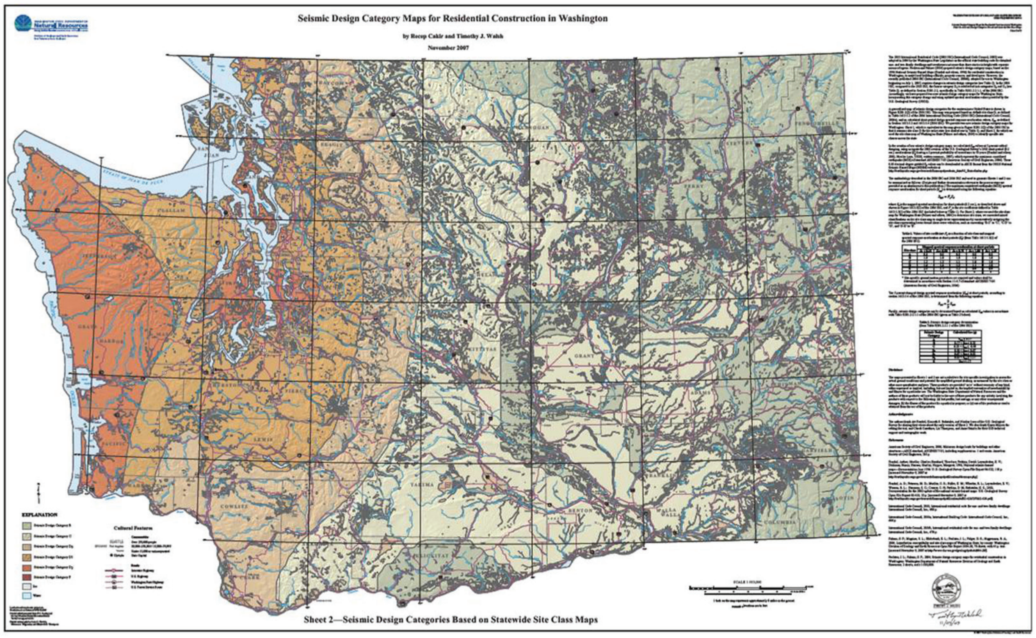

Figure 4. Seismic design category map using the NEHRP site class map for Washington State (Cakir and Walsh, 2007).

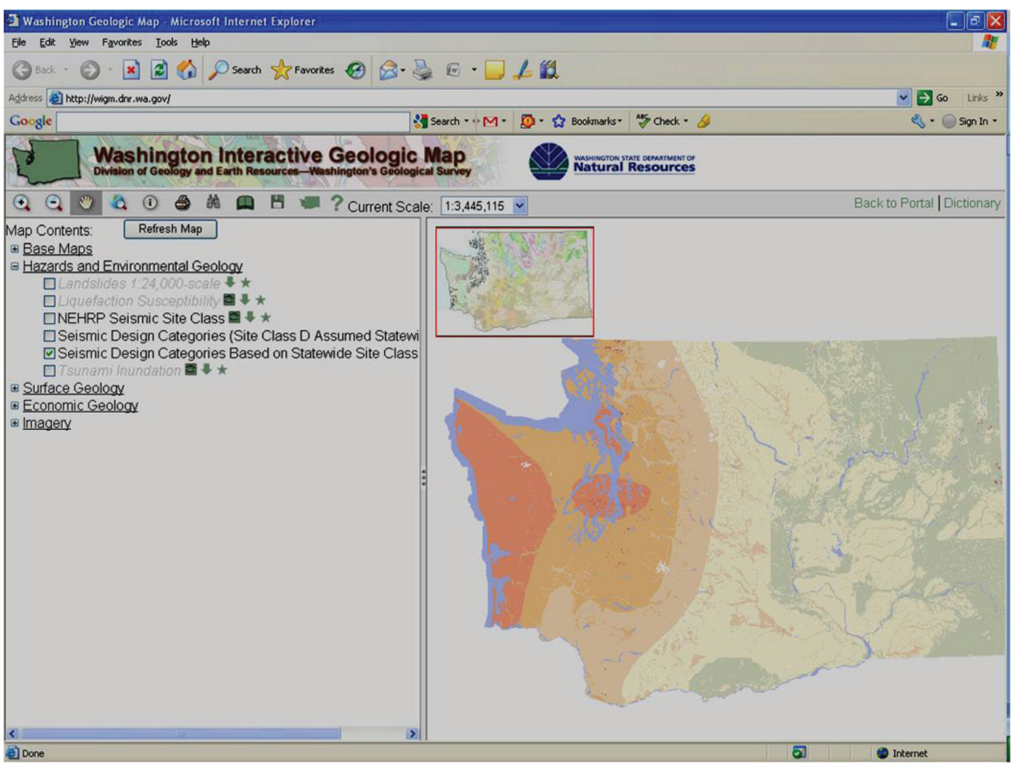

Figure 5. Washington Division of Geology and Earth Resources interactive mapping site (*http://wigm.dnr.wa.gov/*).

Conclusions

Two new types of digital map data for seismic design categories are being prepared to assist local building officials, property owners and developers in Washington State. These digital data include two ESRI shapefiles that contain information on seismic design categories determined, based on (1) the assumption that the entire state is site class D, if no site class information is available and (2) available statewide NEHRP site class information provided by the Washington State Department of Natural Resources (Poelstra and Palmer, 2004; Cakir and Walsh, 2007).

The default (first) site class D map that we generated in digital form provides a better and more manageable (in terms of digital map data manipulations such as zoom in and out, and overlay capacities) compared to the paper map given in Figure R301.2(2) of the 2006 IRC (International Code Council, 2006b). The second seismic design category map data present more realistic seismic design categories incorporating seismic site effects, in relation to local geology, based on the NEHRP site class map of Washington State. These two versions of the IRC digital map data are available through Washington State Geologic Information Portal – Interactive Mapping server (*http://wigm.dnr.wa.gov/*) and ftp site, which give users a variety of options to print out and view more presentable maps.

Acknowledgments

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