WASHINGTON STATE BUILDING CODE HISTORY

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WASHINGTON SCHOOL EARTHQUAKE PERFORMANCE ACCESSMENT TOOL

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1. Introduction

This document provides an overview of Washington State Uniform Building Code (UBC) Seismic Zones and assumed Washington State building code adoption histories. The tables in this document relate the code adoption history to the code levels designated within the FEMA Hazus program (Pre-Code, Low Code, Moderate Code, and High Code) including interpolations between these Hazus code levels.

Washington State adopted a state-wide building code in 1975. When Washington State adopted a state-wide building code in 1975, the most recent version of the UBC was the 1973 version. Therefore, between 1975-1977 the 1973 UBC was the governing building code in the state of Washington.

Tables 1-4 outline how the seismic zones within Washington State changed throughout the different versions of the UBC and how that affected the calculation of seismic forces on buildings. The tables also present a timeline for code adoption within the state. Therefore, it is important for engineers using these tables to know which code the building was designed to as that will affect how the seismic forces were calculated and the level of assumed seismicity within the building's region.

Figures 2-13 are seismic zone maps from different versions of the UBC ranging from 1935-1994. These maps show how the seismic zones within the state changed over time with some regions increasing in seismicity.

The following assumptions were map when developing Tables 1-4:

- Washington State typically adopted new editions of the building code mid-year in the following year, most commonly on July 1st.
- The seismic hazard for Washington State is based upon seismic zone maps published in the UBC
- There is a lag in time between when the newest version of a UBC was published and when it would be applicable for a given year of construction
- Engineering judgement will be required when determine the UBC version (if unknown) for buildings built close to the year of adoption

The appendix of this document provides supporting information for the dates and seismic design levels provided in Tables 1-4. The information presented in Tables A-1 and A-2 are from the Hazus Earthquake Technical Manual for relating UBC seismic zones to seismic design levels. Table A-3 shows the code adoption history and dates for when various UBC and IBC versions were adopted by the state of Washington.

1. Summary of UBC Seismic Zone Maps

The UBC developed seismic zone maps that characterize different regions in zones. Lower zone numbers correlate to low seismicity in the region, and higher zone numbers correspond to higher seismicity. From 1935-1946 UBC the country was broken up into three zones (Zones 1-3). The 1949 UBC introduced four zones (Zone 0-3). The 1976 UBC expanded the seismic zones to five (Zones 0-4), and in the 1988 UBC Zone 2 was split into Zone 2A and 2B to bring the total number of zones to six.

Table 1 summarizes the seismic zones within different regions in Washington State. Figures 2-13 show the UBC seismic zone maps for Washington State in different editions of the UBC. Over time, as engineers and seismologist have learned more about the seismicity in Washington State, the state has been characterized as a higher zone.

There are three distinct regions within Washington State: coastal, Puget sound region, and eastern Washington. In the 1988 UBC, the Puget sound region expanded to the west, east, and south. Figure 1 shows the difference in how the Puget sound region was defined before the 1988 UBC and after. Therefore, in Table 1, there are four regions defined: (i) coastal, (ii) Puget sound, (iii) extended Puget sound, and (iv) eastern.

In today's practice, engineers use the International Building Code (IBC) which does not use seismic zones, but rather site specific acceleration parameters to characterize the seismicity at each building site.

Tables 1-4 summarize how engineers have designed for buildings in Washington State over time:

- Table 1 summarizes the UBC seismic zones in different regions of Washington State from the 1935 UBC to the 1997 UBC
- Tables 2 and 3 summarize how these UBC seismic zones correspond with different Hazus Seismic Design Levels in varying editions of the UBC
- Table 4 summarizes how engineers were calculated the base shear for buildings in different version of the UBC

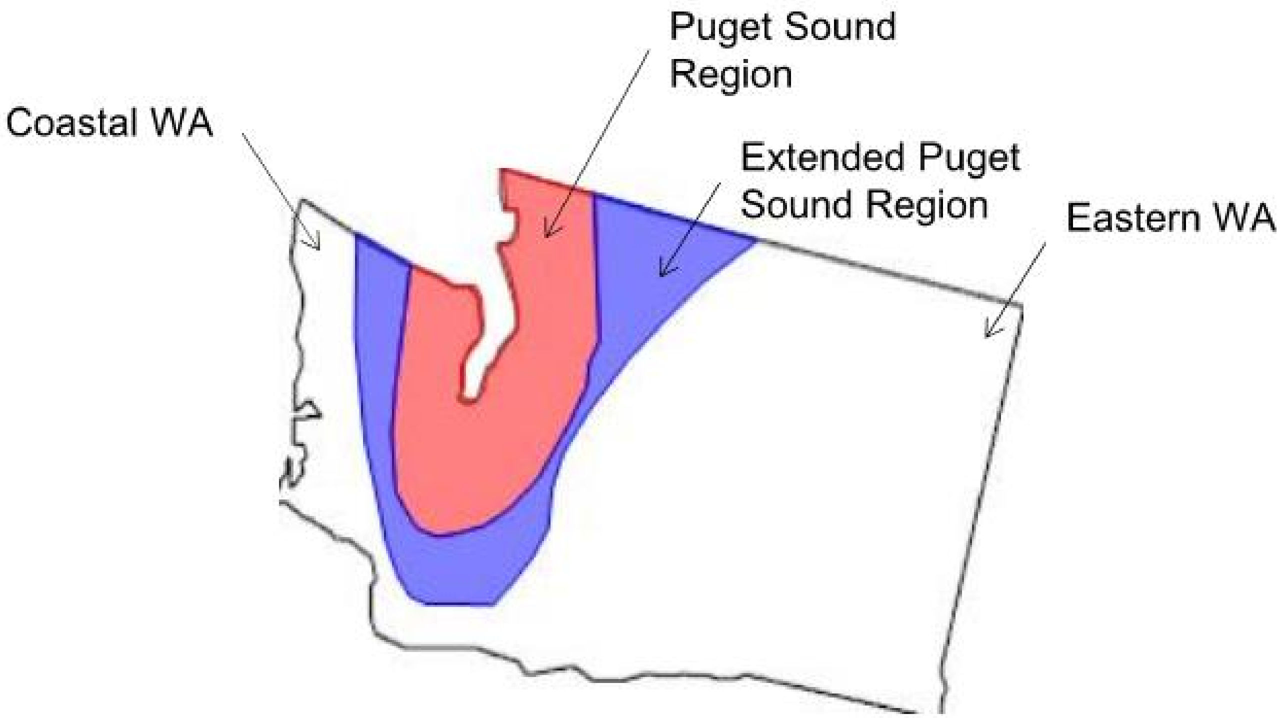

Figure 1 Summary of WA state areas for UBC Seismic Zones

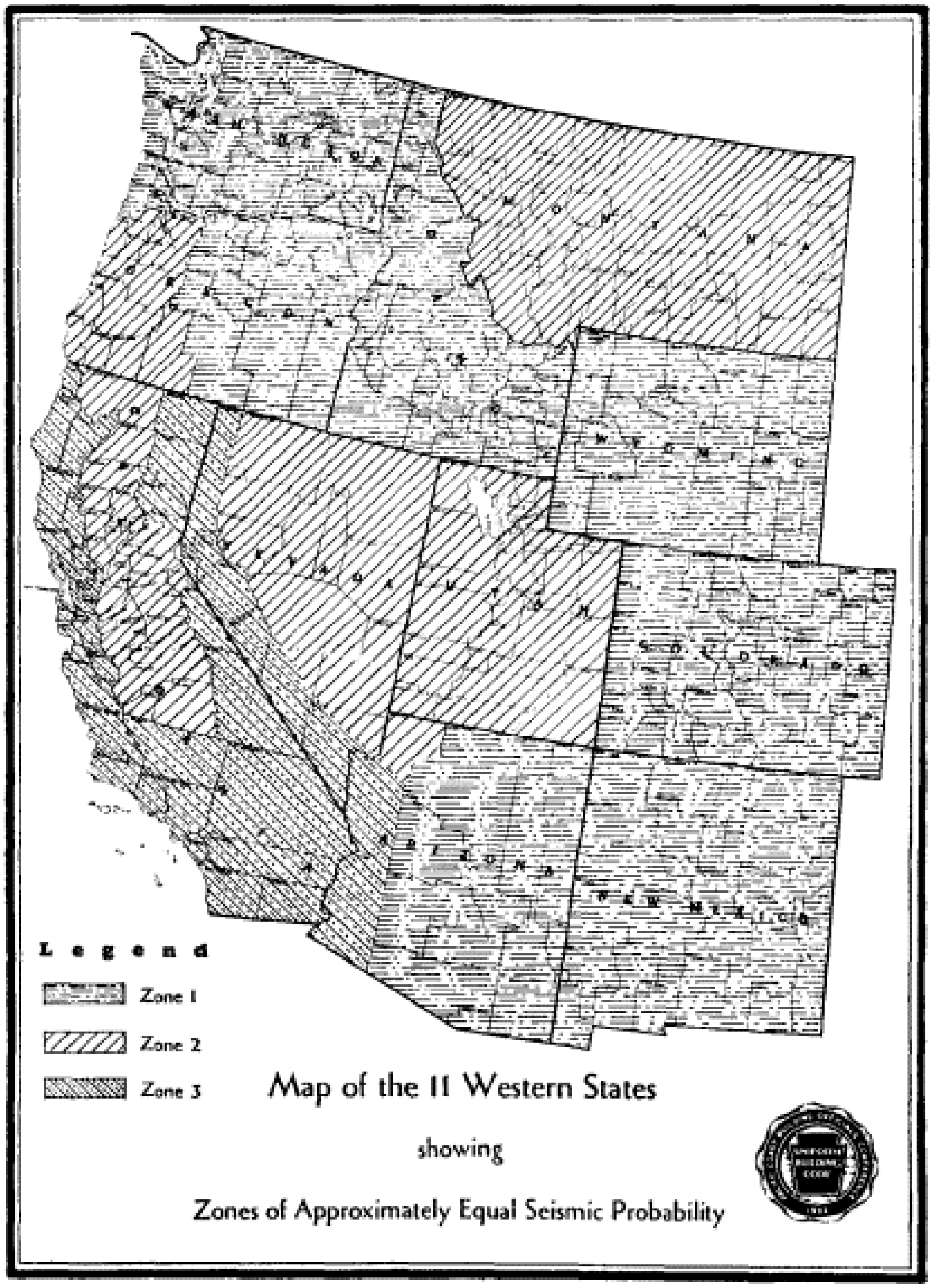

Figure 2 1935, 1937, 1940, 1943 and 1946 UBC Seismic Zones in Washington State

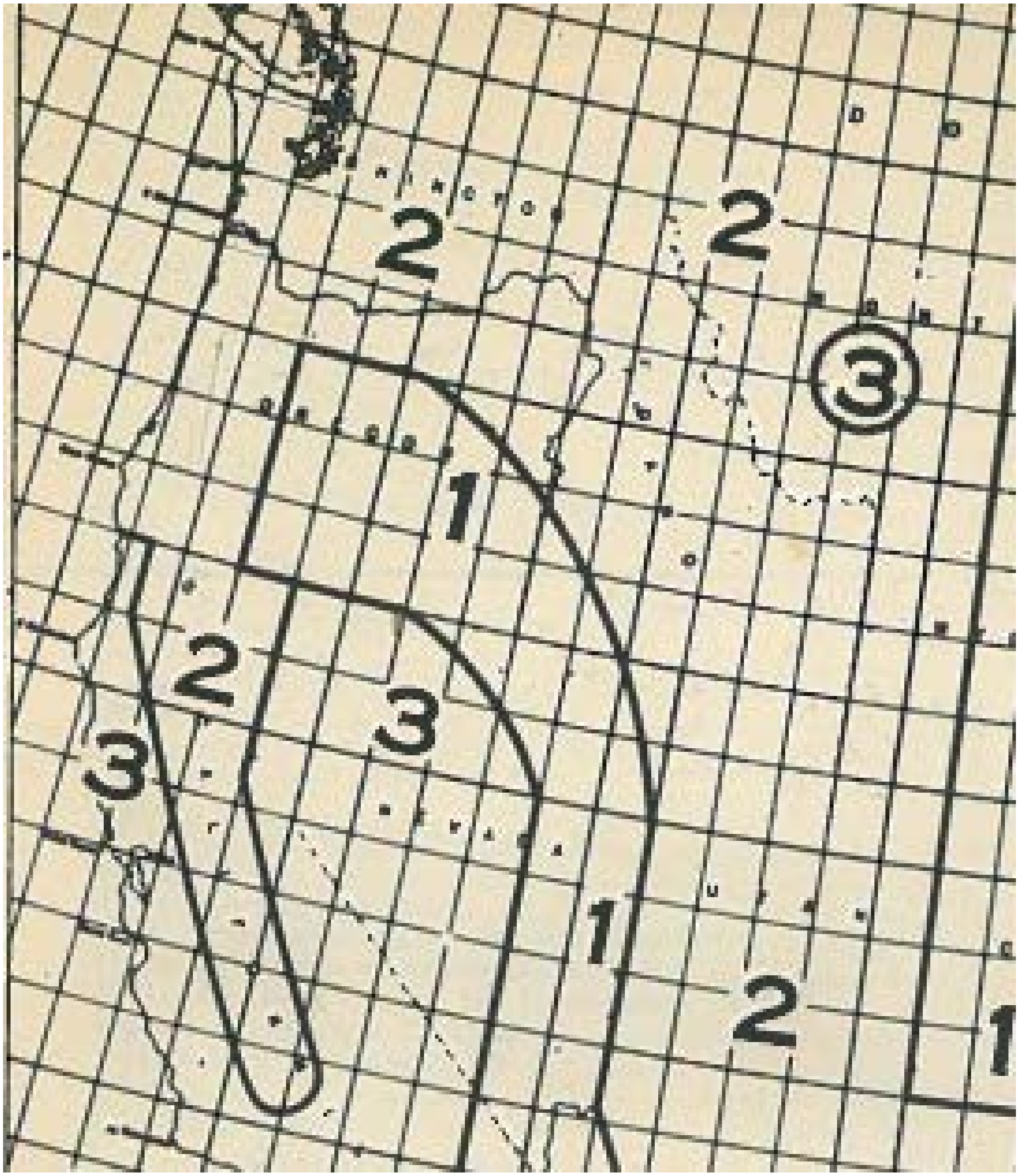

Figure 3 1949 UBC Seismic Zones in Washington State

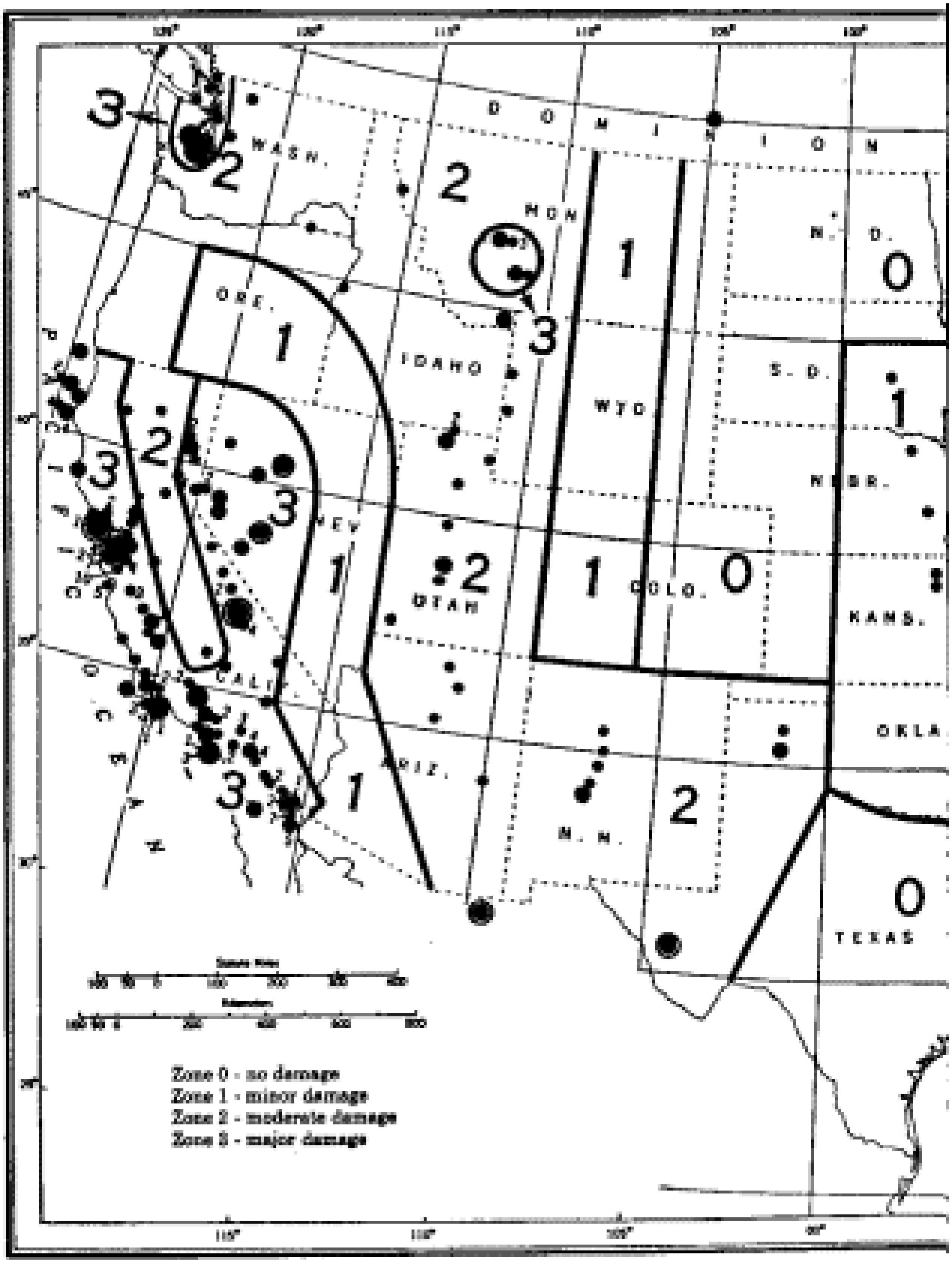

Figure 4 **1952 UBC Seismic Zones in Washington State (Washington State Zones do not change for 1955, 1958, 1961 and 1964 UBC)**

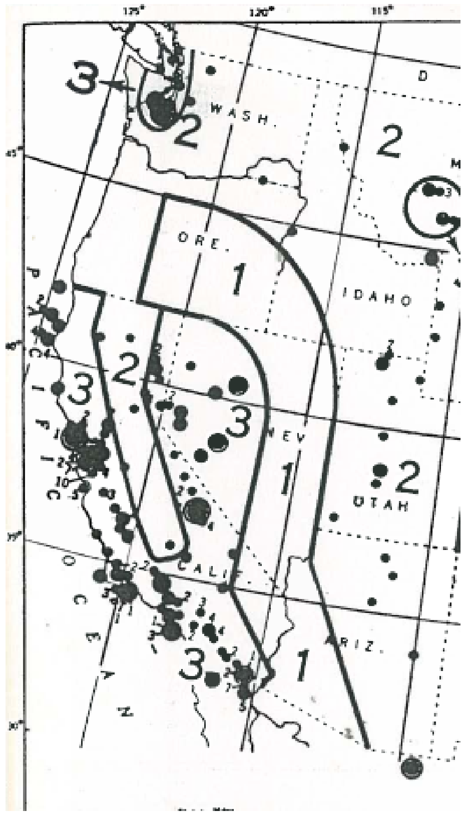

Figure 5 **1967 UBC Seismic Zones in Washington State (Same as 1952 UBC)**

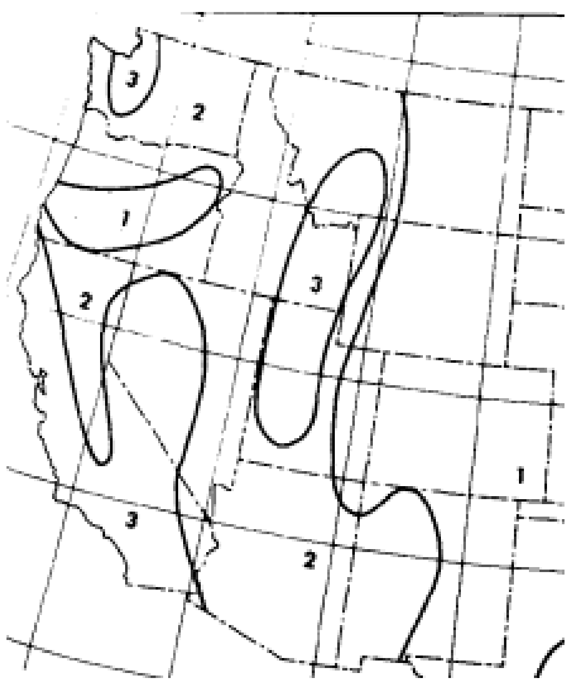

Figure 6 **1970 UBC Seismic Zones in Washington State**

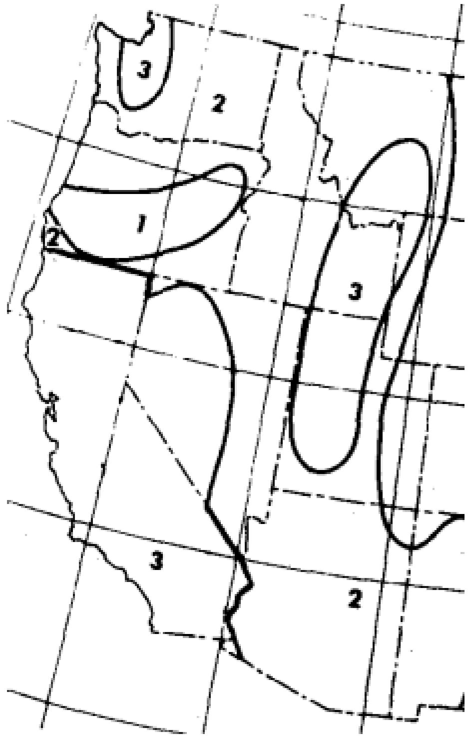

Figure 7 **1973 UBC Seismic Zones in Washington State**

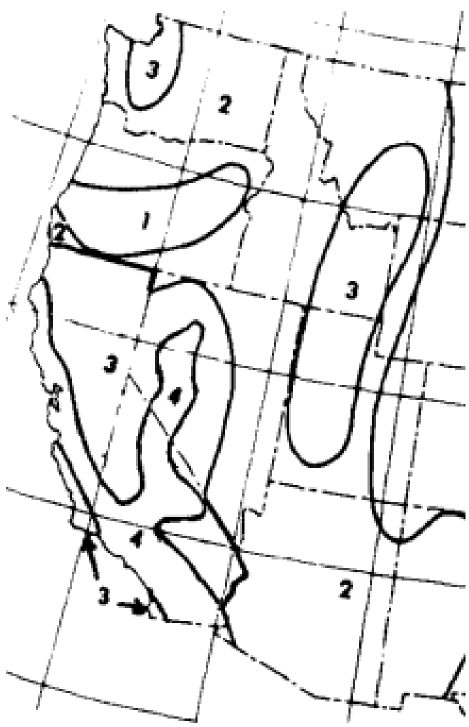

Figure 8 **1976 UBC Seismic Zones in Washington State**

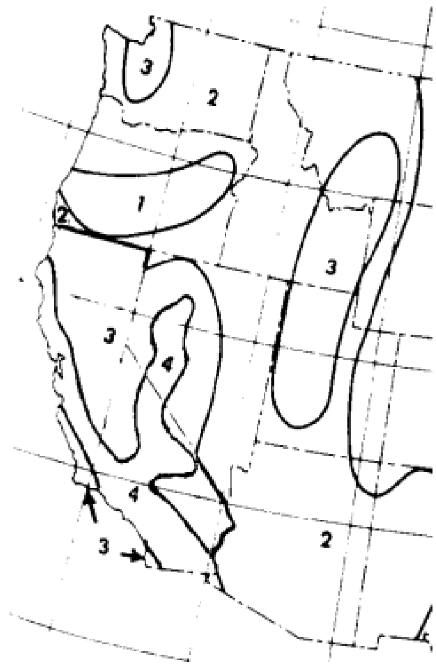

Figure 9 1979 UBC Seismic Zones in Washington State

Figure 10 1982 UBC Seismic Zones in Washington State

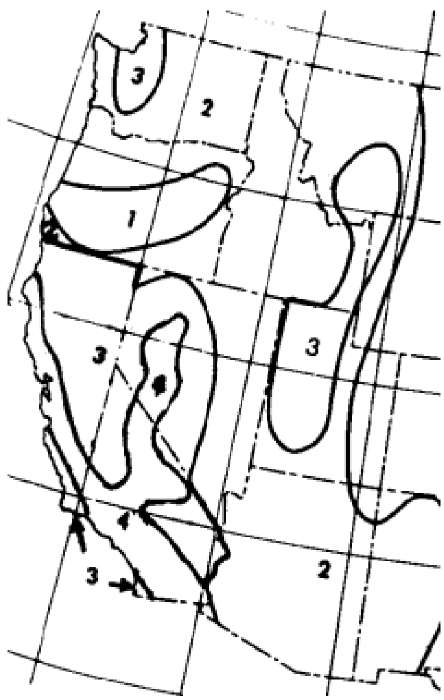

Figure 11 1985 UBC Seismic Zones in Washington State

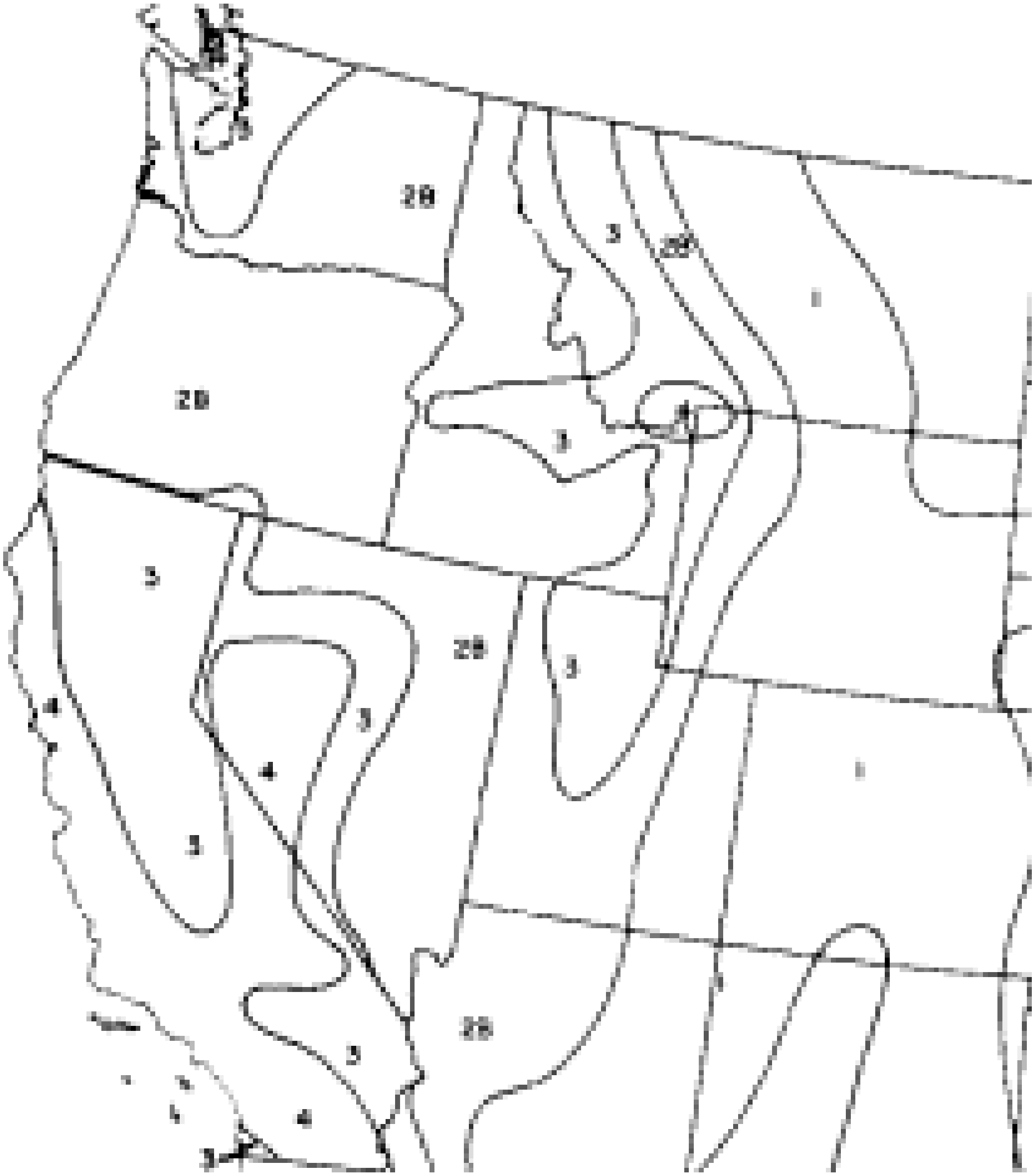

Figure 12 1988 UBC Seismic Zones in Washington State
(Washington State Zones do not change for 1991 UBC)

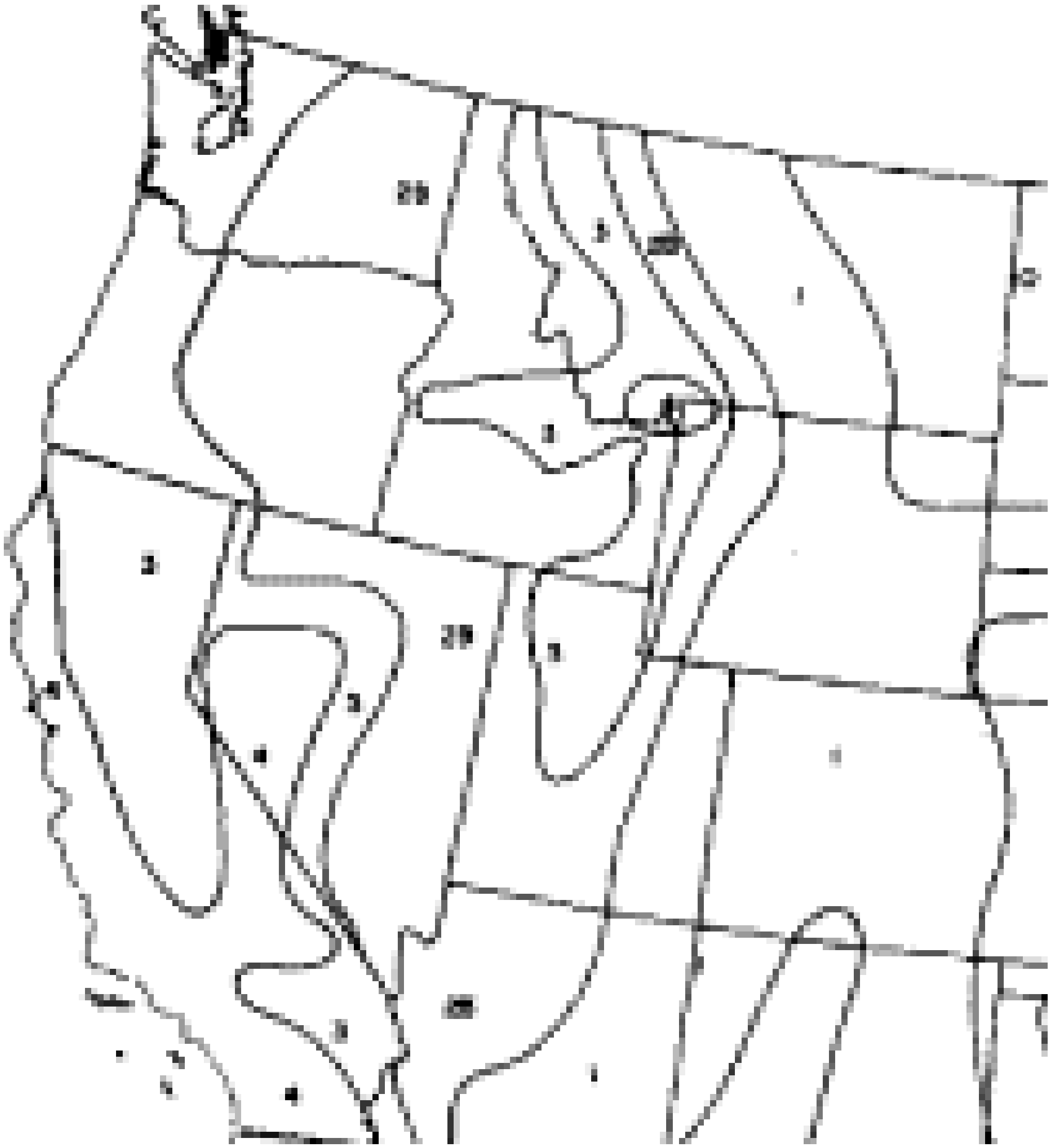

Figure 13 1994 UBC Seismic Zones in Washington State
(Washington State Zones do not change for 1997 UBC)

2. Description of Methodology

Hazus uses seismic fragility curves to determine the probability of structural damage. These fragility curves are dependent upon a seismic code level of the building: pre-, low-, moderate-, and high-. The default relationship between these code levels and the UBC seismic zone maps is shown in Tables A-1 and A-2. These tables do not accurate display the different advances in earthquake and structural engineering throughout the various version of the UBC. Therefore, we have developed relationships that are applicable to Washington State and these are shown in Tables 2 and 3.

The State of Washington adopted a state building code in 1975. We have assumed that buildings built after 1976 are in compliance with the building code in place at the time of design and construction. Since there was no state building code prior to 1975, buildings built before this time period are classified as Pre-Code buildings.

Table 1 summarizes the seismic zones within Washington State in each version of the UBC. As shown in Figure 1, in the 1988 UBC, the Puget Sound region become larger, expanding to the west, east, and south. Therefore, the “extended Puget sound area” represents the difference in the two regions (blue region in Figure 1).

Washington State building codes are typically adopted in July of the year following the code edition. Buildings built within two years after the code year are assumed to be built under the previous edition. For example, the 1988 UBC was adopted by Washington State in 1989. Buildings built between 1988 and 1990 are assumed to be built in accordance with the 1985 UBC. Buildings constructed after 1990 will be constructed to the 1988 UBC. This is a default value, and engineers have the ability to override this when the code edition is provided.

We have identified five major shifts in seismic design criteria from the 1973 UBC to present day. These shifts represent the shifts in code levels presented in Table 3 and summarized below:

- <u>1976 UBC:</u>
    - Introduces an importance factor to the base shear equation
    - Shifts number of seismic zones from three zones to four zones
- <u>1988 UBC:</u>
    - Broadens the location of the Puget sound region and therefore includes more of the state in the Zone 3 category (see Figure 1).
    - Introduces a new seismic zone category 2B. The coastal and eastern areas of Washington State are characterized as Zone 2B.
    - Develops a new equation to calculate seismic base shear that considers ductility of lateral force resisting system (see Table 4)
- <u>1994 UBC:</u>
    - Seismic zone map characterizes Western Washington as Zone 3
- <u>1997 UBC:</u>
    - Develops a new equation to calculate seismic base shear

- 2003 IBC
  - Buildings are design to site-specific acceleration parameters rather than generalized seismic zones
  - Many locations in Eastern Washington have lower site-specific PGA than that assumed by UBC Zone 2B

Table 2 relates the UBC versions to year of construction for a building. This table provides commentary for the shifts in the seismic code levels. Tables A-1 and A-2 assign the same code-level for buildings in Zones 2B and 3, which do not have the same seismicity, and therefore should have different fragility functions associated with them. This difference is shown in Table 4 that summarizes how the base shear in these two zones was calculated. We have also established additional seismic design levels than what is shown in Tables A-1 and A-2. These additional levels represent code shifts over time. For instance, in Tables 2 and 3, "Low-Moderate" represents a fragility function half way between the Low and Moderate Code levels defined by Hazus.

In addition, Tables A-1 and A-2 do not provide any shifts in seismic design level after 1975. Washington State did not have a state building code until 1975, and from the outline provided on the previous page and Table 4, the base shear calculations have changed multiple times between 1975 and present day. Therefore, buildings built using today's standards would not have the same fragility function as a building built in previous years. For example, Seismic Zone 3 in the 1970s or 1980s has a lower level of seismic performance than a building designed to the 1990s editions of the UBC or a building built in the 2000s under the IBC. For these reasons we have adapted Tables A-1 and A-2 to fit the building code history within Washington State and reflect the advances within structural engineering. These adaptations are shown in Tables 2 and 3.

Table 1 Summary of Seismic Zones in Washington State

UBC Version	Coastal WA	Puget Sound Area	Extended Puget Sound Area	Eastern WA	Max. No. of Zones
1935	1	1	1	1	3 (1-3)
1937	1	1	1	1	3 (1-3)
1940	1	1	1	1	3 (1-3)
1943	1	1	1	1	3 (1-3)
1946	1	1	1	1	3 (1-3)
1949	2	2	2	2	4 (0-3)
1952	2	3	2	2	4 (0-3)
1955	2	3	2	2	4 (0-3)
1958	2	3	2	2	4 (0-3)
1961	2	3	2	2	4 (0-3)
1964	2	3	2	2	4 (0-3)
1970	2	3	2	2	4 (0-3)
1973	2	3	2	2	4 (0-3)
1976	2	3	2	2	5 (0-4)
1979	2	3	2	2	5 (0-4)
1982	2	3	2	2	5 (0-4)
1985	2	3	2	2	5 (0-4)
1988	2B	3	3	2B	6 (0-4, 2A, 2B)
1991	2B	3	3	2B	6 (0-4, 2A, 2B)
1994	3	3	3	2B	6 (0-4, 2A, 2B)
1997	3	3	3	2B	6 (0-4, 2A, 2B)

The above seismic zones were used until Washington adopted the IBC in 2004. Under the IBC, site-specific seismic hazard data are used for seismic design, rather than using seismic zones.

Table 2 Washington Building Code History

WA Year Built		UBC Zone	Seismic Zone Area				Notes
Start Year (Code Ed.)	Through End Year		Coastal	Puget Sound	Extended Puget Sound	Eastern	
0	1975	N/A	Pre-Code (Pending Engineer Override)				1949: WA designated Zone 2, but no state building code 1952-1958: WA designated Zone 3, but no state building code No state building code before 1975
1976 ('73 UBC)	1977	2/3	Pre-Low	Low-Moderate	Pre-Low	Pre-Low	1973 UBC Puget sound region designated Zone 3 out of 3 1973 UBC coastal and eastern WA designated Zone 2 out of 3
1978 ('76 UBC)	1984	2/3	Low	Moderate	Low	Low	1976 UBC Puget sound region designated Zone 3 out of 4 1976 UBC coastal and eastern WA designated Zone 2 out of 4
1985 ('82 UBC)	1986	2/3	Low	Moderate	Low	Low	1982 UBC Puget sound region designated Zone 3 out of 4 1982 UBC coastal and eastern WA designated Zone 2 out of 4
1987 ('85 UBC)	1989	2/3	Low	Moderate	Low	Low	1985 UBC Puget sound region designated Zone 3 out of 4 1985 UBC coastal and eastern WA designated Zone 2 out of 4
1990 ('88 UBC)	1992	2B/3	Low-Moderate	Moderate-High	Moderate-High	Low-Moderate	1988 UBC Puget sound region gets larger from 1985 designated Zone 3 out of 4 1988 UBC Eastern and Coastal regions designated Zone 2B out of 4
1993 ('91 UBC)	1995	2B/3	Low-Moderate	Moderate-High	Moderate-High	Low-Moderate	1991 UBC Puget sound region designated Zone 3 out of 4 1991 UBC Eastern and Coastal regions designated Zone 2B out of 4
1996 ('94 UBC)	1998	2B/3	Moderate-High	Moderate-High	Moderate-High	Low-Moderate	1994 UBC Puget sound (including extended Puget sound) region and costal region is designated Zone 3 out of 4 1994 UBC Eastern WA designated Zone 2B out of 4
1999 ('97 UBC)	2004	2B/3	High	High	High	Moderate	1997 UBC requires additional detailing requirements
2005 (IBC)	Present	N/A	High	High	High	Low-Moderate	2002 WA State adopted the IBC. Eastern WA seismicity decreases from UBC

Table 3 defines seven seismic design time periods for four geographical areas within Washington State. As previously mentioned, there are five major shifts in the seismic design criteria which includes shifts in calculation of seismic forces, shifts in the seismicity within each of the regions, and additional detailing requirements. These shifts are summarized on pages 13-14, and below:

1. Buildings built before 1976: Pre-Code assumption, engineers may override this assumption when documentation of seismic design basis is available.
2. Buildings built between 1976-1977: Applicable building code is the 1973 UBC.
3. Buildings built between 1978-1989: Applicable building codes are 1976 UBC-1985 UBC. The 1976 UBC has additional seismic zones and a modified equation to determine the seismic design forces on buildings.
4. Buildings built between 1990-1995: Applicable buildings codes are 1988 and 1991 UBC. The 1988 UBC has additional seismic zones and a modified equation to determine the seismic design forces on buildings.
5. Buildings built between 1996-1998: Applicable building code is 1994 UBC. Coastal Washington State seismic zone was increased to 3 from 2B.
6. Building built between 1999-2004: Applicable building code is 1997 UBC. Seismic design force equation was updated to incorporate ductility of building systems.
7. Buildings built after 2005: Applicable building code is the IBC. Seismic design forces and seismicity at building site is determined using site-specific acceleration parameters.

Table 3 Pre-Mitigation Hazus Fragility Assignments

UBC Version	Range Year Built	Coastal	Puget Sound	Extended Puget Sound	Eastern
2003 IBC	2005-present	High	High	High	Low-Moderate
1997 UBC	1999-2004	High	High	High	Moderate
1994 UBC	1996-1998	Moderate-High	Moderate-High	Moderate-High	Low-Moderate
1988 - 1991 UBC	1990-1995	Low-Moderate	Moderate-High	Moderate-High	Low-Moderate
1976 - 1985 UBC	1978-1989	Low	Moderate	Low	Low
1973 UBC	1976-1977	Pre-Low [a]	Low-Moderate	Pre-Low	Pre-Low [a]
1900	<= 1975	Pre- [a]	Pre- [a]	Pre- [a]	Pre- [a]

[a]W1 buildings in Pre-Code time period are classified as Low-Code

The following conclusions can be made from Table 3:

- Buildings built to older codes have lower seismic performance
- Eastern Washington buildings built to the 1991 or 1994 UBC codes may have been designed to a similar seismicity than they would be design to using today's IBC
- Eastern Washington buildings built to the 1997 UBC code may have been designed to a higher seismicity than they would be design to using today's IBC
- Buildings built to the 1997 UBC or IBC codes generally were designed to similar seismicity

Table 4 summarizes the methodology for calculating seismic forces at certain floors and base shear per UBC. The seismic force equations shown for 1935-1961 are by floor rather than for the whole building. In the 1964 UBC the seismic force equation shifted to calculating a base shear and distributing this base shear throughout the building based upon floor mass and height. The seismic force equation changed again in the 1988 UBC which adopted "R" factors that represented ductility of various seismic force resisting systems.

Table 4 Summary of Seismic Force Calculations

UBC Version	Seismic Force Eqn.	Zone 1	Zone 2	Zone 2B	Zone 3	Zone 4
1935 1937 1940 1943 1946	F = CW	C = 0.02	C = 0.04	N/A	C = 0.08	N/A
1949 1952 1955 1958 1961	F = CW	$\frac{0.15}{(N^a+4.5)}$	$\frac{0.30}{(N^a+4.5)}$	N/A	$\frac{0.60}{(N^a+4.5)}$	N/A
1964 1967 1970 1973	V = ZKCW	Z = 1/4 $C = 0.1^b$ K^c	Z = 1/2 $C = 0.1^b$ K^c	N/A	Z = 1 $C = 0.1^b$ K^c	N/A
1976 1979 1982 1985	$V = ZIKCSW^e$	Z = 3/16 C^d K^c	Z = 3/8 C^d K^c	N/A	Z = 3/4 C^d K^c	Z = 1 C^d K^c
1988 1991 1994	$V = ZICW/R_w$	Z = 0.075	Z = 0.15	Z = 0.20	Z = 0.30	Z = 0.40
1997	$V = C_v^g IW/R^h T$	Z = 0.075 $C_v = 0.18$	Z = 0.15 $C_v = 0.32$	Z = 0.20 $C_v = 0.40$	Z = 0.30 $C_v = 0.54$	Z = 0.40 $C_v = 0.96N_v$

[a]N is the number of stories above the story under consideration
[b]C = 0.10 for one and two story buildings (most schools fall into this category)
[c]K is dependent upon seismic force resisting system and varies between 0.67-1.33
[d]C = 1/(15*sqrt(T))
[e]S is a numerical coefficient for site-structure resonance
[f]R_w is dependent upon lateral system and the amount of ductility within the system
[g]C_v is dependent upon the zone and Z-factor. Values presented are for site class D soil
[h]R is dependent upon lateral system and the amount of ductility within the system

3. Appendix – FOR REFERENCE ONLY

HAZUS Methodology and Guidance:
"Older areas of construction, not conforming to modern standards, should be modeled using a lower level of seismic design. For example, in areas of high seismicity (e.g., coastal California), buildings of newer construction (e.g., post-1973) are best represented by High-Code damage functions, while buildings of older construction would be best represented by Moderate-Code damage functions, if built after about 1940, or by Pre-Code damage functions, if built before about 1940 (i.e., before seismic codes existed). Pre-Code damage functions are appropriate for modeling older buildings that were not designed for earthquake load, regardless of where they are located in the United States. Guidance is provided to expert users in Section 5.7 for selection of appropriate building damage functions." (Hazus EQ Technical Manual 2.1 page 15-27). Table A-1 is a summary of the correlation between seismic design level within Hazus and the UBC seismic zones. Table A-2 shows how these seismic design levels change with time. Note the values within Table A-2 are the default options within Hazus.

Table A-1 Summary of seismic design level and UBC seismic zones used within Hazus

Seismic Design Level	Uniform Building Code Seismic Zone	Map Area NEHRP Provisions
High-Code	4	7
Moderate-Code	2B	5
Low-Code	1	3
Pre-Code	0	1

This table is really the same as the one on the following page, with the omission of the clearly illogical application of the same code level to different zones. "Expert users may tailor the damage functions to their study area of interest by determining the appropriate fraction of each building type that conforms essentially to modern-Code provisions (based on age of construction). Buildings deemed not to conform to modern-Code provisions should be assigned a lower seismic design level or defined as Pre-Code buildings if not seismically designed. For instance, older buildings located in High-Code seismic design areas should be evaluated using damage functions for either Moderate-Code buildings or Pre-Code buildings, for buildings that pre-date seismic codes. Table 5.20 provides guidance for selecting appropriate building damage functions based on building location (i.e., seismic region) and building age. The years shown as break-off points should be considered very approximate and may not be appropriate for many seismic regions, particularly regions of low and moderate seismicity where seismic codes have not been routinely enforced." (Hazus EQ Technical Manual 2.1 - Expert users section 5.7 page 15-82)

Table A-2 Summary of seismic design level and UBC seismic zones used within Hazus varying with year

UBC Seismic Zone (NEHRP Map Area)	Post-1975	1941-1975	Pre-1941
Zone 4 (Map Area 7)	High-Code	Moderate-Code	Pre-Code (W1 = Moderate-Code)
Zone 3 (Map Area 6)	Moderate-Code	Moderate-Code	Pre-Code (W1 = Moderate-Code)
Zone 2B (Map Area 5)	Moderate-Code	Low-Code	Pre-Code (W1 = Low-Code)
Zone 2A (Map Area 4)	Low-Code	Low-Code	Pre-Code (W1 = Low-Code)
Zone 1 (Map Area 2/3)	Low-Code	Pre-Code (W1 = Low-Code)	Pre-Code (W1 = Low-Code)
Zone 0 (Map Area 1)	Pre-Code (W1 = Low-Code)	Pre-Code (W1 = Low-Code)	Pre-Code (W1 = Low-Code)

Table A-3 Summary code adoption within Washington State 1975-2004 (Table provided by Washington State Building Code Council)

<table>
<tr><th>Year</th><th>Model Code</th></tr>
<tr><td>1975</td><td rowspan="2">1973 UBC</td></tr>
<tr><td>1976</td></tr>
<tr><td>1977</td><td rowspan="7">1976 UBC</td></tr>
<tr><td>1978</td></tr>
<tr><td>1979</td></tr>
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<tr><td>1981</td></tr>
<tr><td>1982</td></tr>
<tr><td>1983</td></tr>
<tr><td>1984</td><td rowspan="2">1982 UBC</td></tr>
<tr><td>1985</td></tr>
<tr><td>1986</td><td rowspan="3">1985 UBC</td></tr>
<tr><td>1987</td></tr>
<tr><td>1988</td></tr>
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<tr><td>1997</td></tr>
<tr><td>1998</td><td rowspan="6">1997 UBC</td></tr>
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<tr><td>2003</td></tr>
<tr><td>2004</td><td>2003 IBC</td></tr>
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Note: Years 2005-present day not shown in table