U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

SEISMIC SOURCES AND RECURRENCE RATES AS ADOPTED BY USGS STAFF FOR THE PRODUCTION OF THE 1982 AND 1990 PROBABILISTIC GROUND MOTION MAPS FOR ALASKA AND THE CONTERMINOUS UNITED STATES

by

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Open-File Report 95-257

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1995

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Introduction

The construction of a probabilistic ground-motion hazard map for a region follows a sequence of analyses beginning with the selection of an earthquake catalog and ending with the mapping of calculated probabilistic ground-motion values (Hanson and others, 1992). An integral part of this process is the creation of sources used for the calculation of earthquake recurrence rates and ground motions. These sources consist of areas and lines that are representative of geologic or tectonic features and faults.

After the design of the sources, it is necessary to arrange the coordinate points in a particular order compatible with the input format for the SEISRISK-III program (Bender and Perkins, 1987). Source zones are usually modeled as a point-rupture source. Where applicable, linear rupture sources are modeled with articulated lines, representing known faults, or a field of parallel lines, representing a generalized distribution of hypothetical faults. Based on the distribution of earthquakes throughout the individual source zones (or a collection of several sources), earthquake recurrence rates are computed for each of the sources, and a minimum and maximum magnitude is assigned.

Over a period of time from 1978 to 1980 several conferences were held by the USGS to solicit information on regions of the United States for the purpose of creating source zones for computation of probabilistic ground motions (Thenhaus, 1983). As a result of these regional meetings and previous work in the Pacific Northwest, (Perkins and others, 1980), California continental shelf, (Thenhaus and others, 1980), and the Eastern outer continental shelf, (Perkins and others, 1979) a consensus set of source zones was agreed upon and subsequently used to produce a national ground motion hazard map for the United States (Algermissen and others, 1982).

In this report and on the accompanying disk we provide a complete list of source areas and line sources as used for the 1982 and later 1990 seismic hazard maps for the conterminous U.S. and Alaska. These source zones are represented in the input form required for the hazard program SEISRISK-III, and they include the attenuation table and several other input parameter lines normally found at the beginning of an input data set for SEISRISK-III.

Area Source Zones

Areal source zones are used to model earthquakes which can be represented by point ruptures – usually corresponding to low-magnitude earthquakes whose rupture lengths are short. Higher-magnitude earthquakes can be modeled with point ruptures if their recurrence rate is long compared to the return period of the ground motion map being produced. These areal source zones are in what we refer to as quadrilateral form. (See Fig. 1)

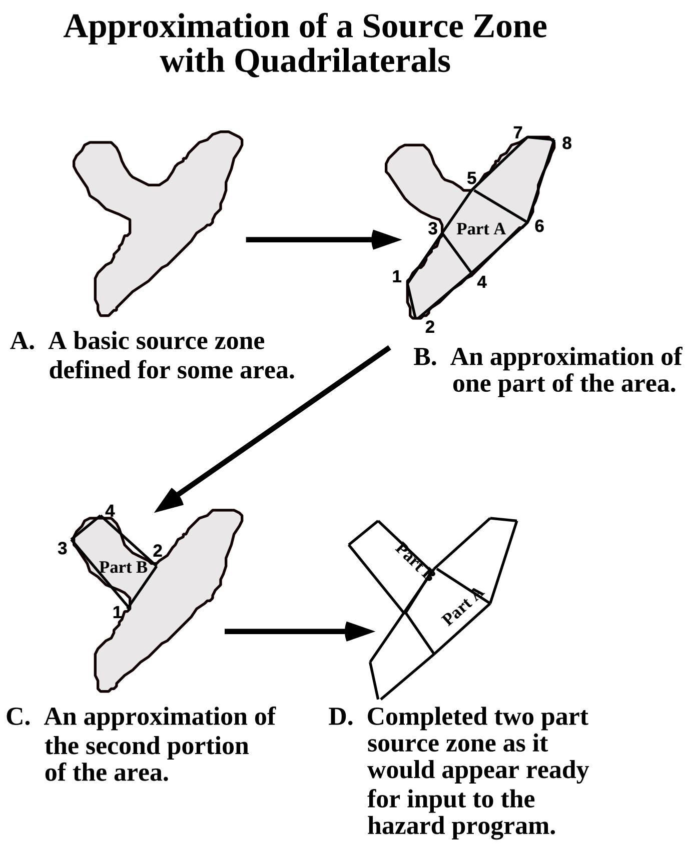


Figure 1 *A brief description of the procedure for defining source zone quadrilaterals.* **A)** *A general source area drawn on a map describing geologic, tectonic, or seismic features.* **B)** *Lower right portion of the area, outlined by three adjacent quadrilaterals whose corner points are paired left to right and bottom to top.* **C)** *Upper left portion of the area, outlined by a single quadrilateral whose corner points are paired left to right and bottom to top.* **D)** *The completed source zone which approximates the original source area in* **A).**

Each source zone has a four-character identifying name along with several other input parameters in the first line associated with each source zone. The line following the source zone name contains the number of lines of pairs of points, the *i*-th part, of *j* parts, of the source zone. The succeeding lines are the coordinate corner points of the quadrilaterals defining the source area. The last two lines associated with each source area contain the recurrence rates for each of the magnitude intervals from the minimum to the maximum magnitude, and the central magnitudes of the interval over the range from a minimum magnitude to a maximum magnitude for a given source.

A more specific description of each of the variables and their FORTRAN format for source area input data sets can be found in Table 1.

When building an input data set using a computer text editor these format specifications must be followed, including the design and ordering for the coordinate points (See Fig.–1).

Table 1
Description of input variables for input source areas

Variable Name	FORTRAN Format	Value	Description
First Line of Input			
num	I2	0	For source areas [2], and for all fault sets after the 1st.
		98	For modeling source boundary uncertainty, *als* specified below
		99	Indicates termination of sequence of source areas and beginning fault sources and for the termination of fault sources after last fault source for end of data.
yrnoc	f10.0		Number of years over which the earthquake occurrences in *noc*(l) (below) apply. If these are annual rates, *yrnoc* is 1.0. Also used as a scaling factor for inputting only significant digits in the recurrence rates.
iprint	I2	–1	No output statistics for the set of occurrences accumulated to this point.
		+1	Output statistics on file –*filename*.016).[3]
		+2	As above plus file for plot, etc. (on output file –*filename*.002).
		+3	Omit statistics output to file –*filename*.016; do file for plot (on output file – *filename*.002).
totl	f10.0		Used for faults only.
dumid	a4		Four character identifier for source zone or fault.
als	f6.2		Source zone boundary location uncertainty, standard deviation in km. When *num* = 98, *als* is used for this and succeeding zones, unless another 98 is encountered.
Second Line of Input			
jseg	i3		Number of pairs of quadrilateral corner points in this source set (*jseg* = nr. of quads + 1). Seismicity to be apportioned by fractional area among *itot* sources.
ifr	i3		Set number (*ifr* =1,2...*itot* in sequence).
itot	i3		Total nr. of sets of quads. (Sum of all pairs in source may not be more than 50.)
Next Two to Several Lines of Input.			
	4f6.2		Coordinate corner points of quadrilaterals in LONGITUDE, LATITUDE pairs, two points per line for *jseg* lines.
Next Input Line			
noc(l)	12f6.2		Number of events expected in *yrnoc* years for the magnitude intervals, *fm(l)* .
Last Input Line			
fm(l)	12f6.2		Center magnitude of the interval for which *noc(l)* occur.

[2] Source boundary uncertainty is not used in this data set.
[3] The SEISRISK-III program will output three output files that have the same first name as the input filename. That is if the input filename is "AREA-1.015", then the three output files will be named "AREA-1.016", "AREA-1.002", and "AREA-1.003".

Figure 2 shows a general source area with the coordinates in the proper sequence of ordered pairs. In this case, *jseg* = 4, indicates there are 4 pairs of coordinate points which describe the source area (3 quadrilaterals). The coordinate points follow in the input stream one pair of points per line for 4 lines in a longitude, latitude order for each point.

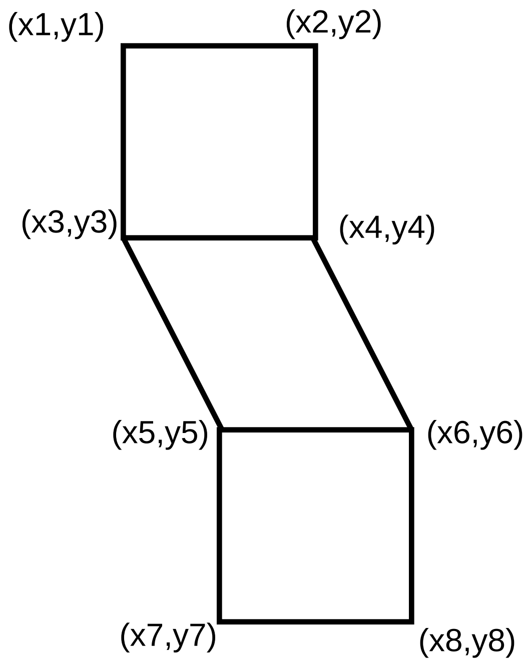


Figure-2 *jseg = 4 in this example: quadrilateral end-point pairs are, (x1,y1)---(x2,y2), (x3,y3)---(x4,y4), (x5,y5)---(x6,y6), (x7,y7)---(x8,y8). Sub regions of a set are defined as shown.*

The next line in the input sequence contains the recurrence rates, the numbers of events expected in *yrnoc* years in each magnitude interval, stored in the variable, *noc(l)***,** for each magnitude interval from the minimum to the maximum magnitude. There can be from 1 to 12 recurrence rates for a given source area.

The last line in the input sequence associated with a source area contains the central magnitude of each magnitude interval and is stored in the variable*, fm(l)*. There can be from 1 to 12 magnitude intervals, one for each corresponding recurrence rate in the previous line.

Figure 3 shows an example of a single input source area for a region located in the Pacific Northwest. For source shapes such as figure 6, where P002 surrounds P001, zone P002 has been drawn in two parts to avoid dealing with superimposed source zones. (This would require removing a

```
                                        Source zone name
                       00 71.52    -1          P002
jseg,ifr,itot  (3i3)     8  1  2
                       123.47 49.00122.38 49.03
                       123.60 48.40122.13 48.70
                       122.68 47.63121.88 48.33
Coordinate pairs       122.35 47.62121.70 48.08
(4f6.2)                122.30 47.50121.62 47.68
                       122.25 47.37121.43 47.52
                       122.35 47.03121.55 47.05
                       122.20 46.75121.70 46.63
jseg,ifr,itot  (3i3)     4  2  2
                       123.03 47.92122.68 47.63
Coordinate pairs       123.25 47.27122.97 47.30
(4f6.2)                122.92 46.80122.78 46.98
                       122.20 46.75122.35 47.03
Rates (12f6.5)         12.51 5.020 2.019 .2035 .081
Magnitudes (12f6.4)    4.9   5.5   6.1   6.7   7.3
```

Figure-3 *A typical source area for use in the SEISRISK-III hazard program. This particular input source area is described in two parts. The second and eleventh lines are read as 'eight pairs of coordinate points in the first of two parts', and 'four coordinate pairs in the second of two parts'.*

portion of the areal rate of the underlying source zone, P002, from the areal rate of the overlaying source zone, P001.) This source zone illustrates the use of two sets of quadrilaterals to define a single source area and the required input FORTRAN format.

Line Sources

Line sources are used to model earthquakes which should be modeled by linear ruptures – higher magnitude earthquakes whose recurrences are no more than a few times longer than return periods of the probabilistic ground motions to be mapped. The function of the line rupture is to provide stretched-out isoseismals approximating the location of the higher ground motions expected to occur close to a fault. (The actual modeled shape of the isoseismal is the locus of points equidistant from the line representing the fault rupture. This shape has been described as "cylindrical with circular caps," or less formally, the "hot dog" model.)

A single fault is described by one or more straight-line segments – if more than one segment, the fault is said to be articulated. A line source is made up of one or more faults. We have usually modeled a known fault by two sources – the fault itself as an articulated line source, and an areal source whose boundaries are drawn 10 km to either side of the fault. This areal source is used to collect the catalog earthquakes when analyzing the seismicity for the fault and is also used to place smaller magnitude earthquakes which may be produced near the fault or on short splays of the main fault. The higher magnitude earthquakes are placed on the fault itself. SEISRISK-III permits "magnitude smoothing" for the highest magnitude category – that is, the rates in the highest magnitude category.

There are also source areas for which frequent large magnitude earthquakes are expected and hence require line ruptures to produce extended isoseismals for the higher-level ground motions, but for which actual future locations are either unknown or for which it would be inaccurate to model only the known surface faulting. Such source areas we have modeled by fields of parallel articulated faults, some fixed distance apart, usually 20 or 30 km. SEISRISK-III performs spatial smoothing of the larger magnitudes on these faults, permitting an approximation to infinitesimal spacing. As with individual faults, we have placed the smaller magnitudes into an areal zone, and the higher magnitudes are allocated to the constituent faults in proportion to their lengths.

A line source may contain up to a maximum of 26 articulated faults and each of these faults may have up to 24 segments. Figure 4 shows a typical line source, consisting of an articulated fault having two segments defined by three coordinate points. The input format is similar to that of the source areas: the first line contains the usual information including the source name. The next line is a header line giving the number of coordinates for the first fault in the source, the number of the fault, and the total number of faults in the source. The next one-to-several lines of input contain the coordinate points in a (8f10.2) FORTRAN format. (There is room for four longitude latitude pairs on each line.) Each succeeding fault in this source has a header line followed by lines containing the corresponding coordinates. As with areal sources, the last two line entries associated with each line source contains on one line, the central magnitudes in each magnitude range, in our case 0.6 magnitude units wide, between minimum and maximum magnitudes and their associated recurrence rates.

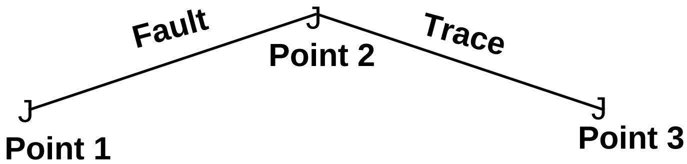


Figure-4 *Articulated line source showing a fault trace defined by three points..*

Next in the input stream are the longitude, latitude end points of each segment of each fault. There can be a maximum of 24 segments for a given articulated fault, and there can be a maximum of 26 articulated faults in a single source.

The next two lines in the input stream are *noc(l)* and *fm(l)* respectively, and are the same as described for source areas.

A general description of the variables and FORTRAN format for line source inputs can be found in Table 2. Again these input parameter descriptions must be followed to insure reliable results.

Figure 5 is an illustration of a set of generalized hypothetical faults modeled in a region.

```
                                                    Source zone name
                                                          |
                                                          v
                          00 28.34    -1           P013
jseg,ifr,itot (3i3)      -->  3  1  3
Coordinate pairs (8f10.2)   129.83    45.17     125.90    43.18     126.08    42.35
jseg,ifr,itot (3i3)      -->  3  2  3
Coordinate pairs (8f10.2)   130.03    44.92     126.33    43.13     126.42    42.60
jseg,ifr,itot (3i3)      -->  2  3  3
Coordinate pairs (8f10.2)   130.25    44.72     126.75    43.00
Rates (12f6.5)           --> 1.456 0.761 0.397
Magnitudes (12f6.5)      --> 6.7   7.3   7.9
```

Figure-5 *This set of input sources is for three hypothetical or generalized line sources or faults found in the Pacific Northwest. The first two line sources are described by three coordinate points and the third line source is described by only two points.*

Table 2
Description of input variables for input line sources

Variable Name	FORTRAN Format	Value	Description
First Line of Input			
num	I2	99	For first fault source.
		00	For each successive fault source input set.
		99	After the last fault source input set.
yrnoc	f10.0		(see Table 1)
iprint	I2		(see Table 1).
totl	f10.0		Distance between faults if this set of faults is a set of generalized hypothetical faults used to approximate a uniform field of faults. The ground motions will be smoothed distance.
		0	If one or more individual faults are used. The ground motions will be smoothed in magnitude
dumid	a4		Four character identifier for source zone or fault.
als *bls* *sigls*	f6.2 f6.2 f5.2		Rupture length parameters for *Length* = 10***(als +bls*m +fr *sigls),* where: *m* – magnitude *als* and *bls* are obtained from a regression of $\log_{10}$ (rupture length) vs magnitude *sigls* – standard deviation of the regression *fr* – number of fractions into which the distribution of log (fault length) is to be divided. (normally 5 for values in the range (–2, +2). If *fr* = 0, the median log value will be used. If all three variables *als*, *bls* and *sigls* are 0 or blank, then either default values are used (1.085, 0.389, and 0.52) or values input for a previous source zone in this data set.
Second Line of Input			
jseg	i3		Number of points in the following articulated fault.
ifr	i3		The order number of this fault in the set of faults in this source (i.e., the “1” in “1 of 5”).
itot	i3		The total number of faults in this source (i.e., the “5” in “1 of 5”).
Next Two to Several Lines of Input.			
	8f10.2		Coordinate corner points of the articulated line source in LONGITUDE, LATITUDE.
Next Input Line			
noc(l)	12f6.2		Number of events expected in *yrnoc* years for each level of seismicity (to a maximum of twelve seismicity levels).
Last Input Line			
fm(l)	12f6.2		Center magnitude of the interval for which *noc(l)* occur.

Rates of Occurrence The expected seismicity for each source zone was developed from an analysis of the historical seismicity either of the source zone itself or from "back-allocation" of an analysis of the seismicity of the region in which the individual source lies. In general, the seismicity analysis was performed by fitting the relationship

$$\log N_c = a + b\, M_c, \qquad (1)$$

where M_c is the center magnitude of a magnitude range, 0.6 magnitude units wide, and N_c is the annual rate of earthquakes in that range. Values of M_c were obtained from the regression equation

$$M_c = 1.3 + 0.6\, I_0, \qquad (2)$$

where I_0 is epicentral intensity (Modified Mercalli scale). If an observed magnitude falls between $M_c - 0.3$ and $M_c + 0.3$, the earthquake is placed in the corresponding M_c category.

The fits to equation (1) were generally done by a minimum chi-square regression, although in the western portion of California a weighted least squares technique was used. In the eastern U.S., regional fits were done using Wiechert's maximum-likelihood method (Wiechert, 1980) to take into account magnitude-dependent completeness times. In both east and west, regionally-fixed *b*–values and weighted *a*–values were used to allocate regional rates to zonal rates in those cases in which individual zones did not have 40 or more historical earthquakes of magnitude larger than 4.0.

Regression equation (2) had been defined in previous studies, (Gutenberg and Richter, 1942), principally using M_L for shocks with M_L of about 6.75 or less and M_S for larger earthquakes. Since instrumental magnitudes were not available for many important earthquakes, extensive use was made of equation (2). In fact, at the time of the analysis for the eastern U.S. (1979 to 1981), eastern U.S. magnitudes were poorly determined and inconsistent, so the analysis was done entirely by using modified Mercalli epicentral intensities. The same M_c vs I_0 relationship was used in the eastern U.S. as in the western U.S., in order to guarantee that the same epicentral intensities would produce the same near-field peak acceleration and peak velocity values in the east as in the west (Algermissen and others, 1982).

The pseudo-magnitudes used for the eastern U.S. now appear to average 0.5 to 0.7 units larger than felt-area magnitudes determined for historical events, for magnitudes in the range 3 to 5.5. Users are cautioned that modern felt-area magnitudes used with modified western attenuation functions would likely under-estimate ground motion hazard in the eastern U.S. Similarly our eastern pseudo-magnitudes should not be used with modern eastern-U.S. attenuation functions for modern magnitudes scales.

SEISRISK-III Input Sources The accompanying disk contains the input sources used in the computation of the 1982 and 1990 ground motion maps (Algermissen and others, 1982); (Algermissen and others, 1990). The disk contains nine input files complete with attenuation tables. Appendices A and B are brief examples of the input data sets showing area sources and line sources for the Puget Sound area and Alaska respectively. Each of these areas was modeled with sources at depth and required the use of separate input data sets using modified attenuation tables, adjusted for depth. Figures 6, 7, 8, and 9 are illustrated views of the source zones. Figure 6 is the Pacific northwest and the Rocky Mountain region source zones to the central plains of the U.S. Figure 7 is of the coastal California source zones. Figure 8 is an illustration of the source zones for the central plains region to the eastern seaboard. Because of the complication of modeling a subduction zone in Alaska, two underlying source areas with two sets of hypothetical generalized articulated line sources where used to model earthquakes at depth (Thenhaus and others, 1985), similar to that used in the Puget Sound region (Perkins and others, 1980). Figure 9-A shows the shallow sources and for clarity, figure 9-B shows the source areas modeling the deeper earthquakes.

The only 2 significant changes in the input files between 1982 and 1990 was, 1) the change in the input attenuation tables to accommodate attenuation variability, and 2) the removal of 2 line sources from the set of eastern sources. Line sources F004 and F015 from EASTCAOST.015 were removed and their associated rates and magnitudes were redistributed to sources areas I004 and I015 respectively in the same input file.

Annual Recurrence Rates

To compare the relative hazard between sources the annual recurrence rates must be area normalized. It is not appropriate to compare a relatively large area that has a relatively low set of annual recurrence rates to a source with the same annual recurrence rates but has a much smaller area by the annual recurrence rates only. To make this comparison, Appendix C has been included showing six tables that include the annual recurrence rates for each magnitude interval and the computed area for each of the input sources. Each table represents a set of input sources as previously discussed, the Pacific Northwest, California sources, Rocky Mountain sources, etc. Within each table each source is listed by name, its computed area, and a range of annual recurrence rates from a minimum to a maximum magnitude. The comparison can be made from source to source by individual magnitude intervals or a cumulative set of magnitude intervals.

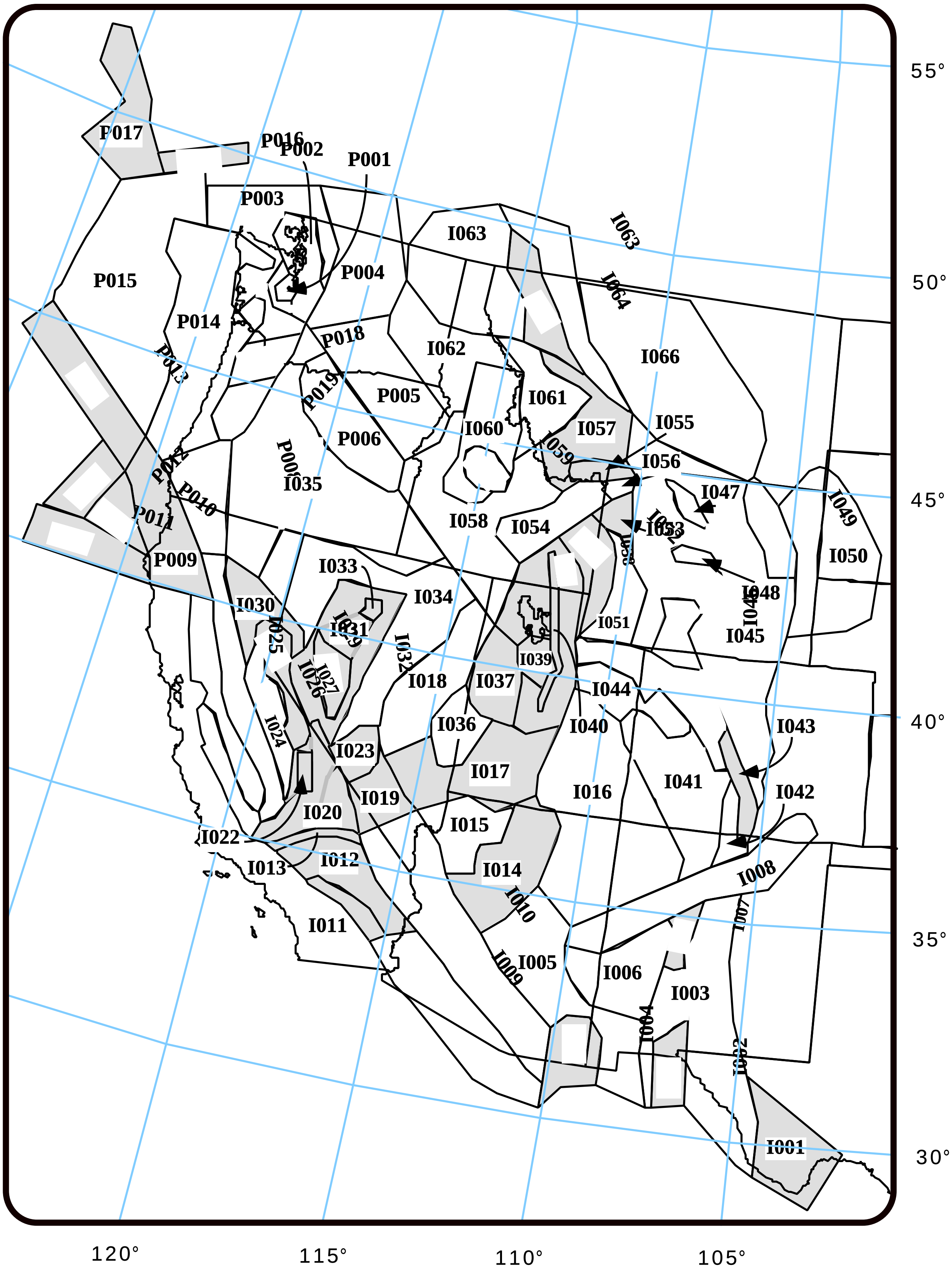


Figure-6 *Pacific Northwest and Rocky Mountain region source zones with those areas that were also modeled using line sources, shown as shaded areas.*

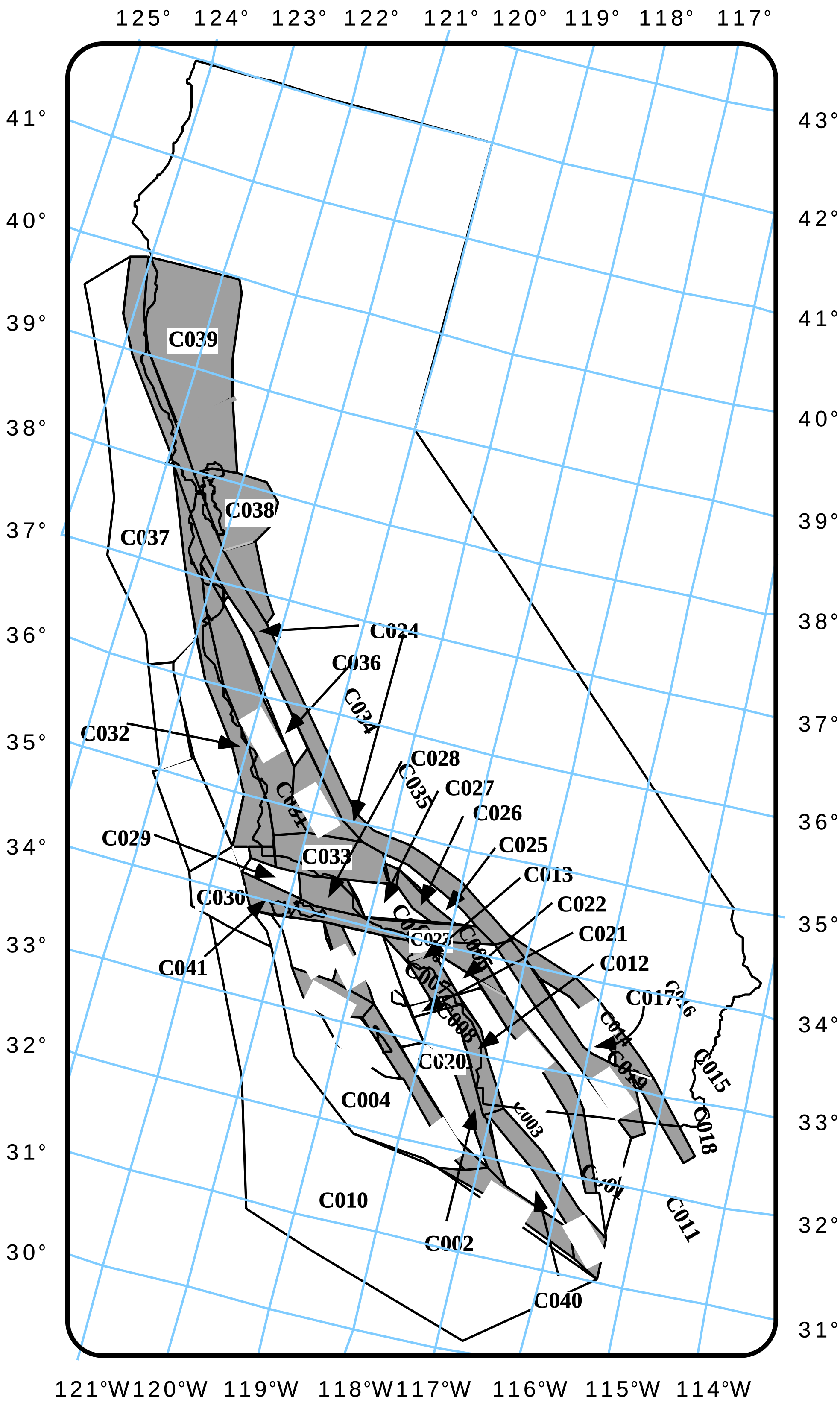


Figure-7 *California source zones, with those areas that were also modeled using line sources shown as shaded areas.*

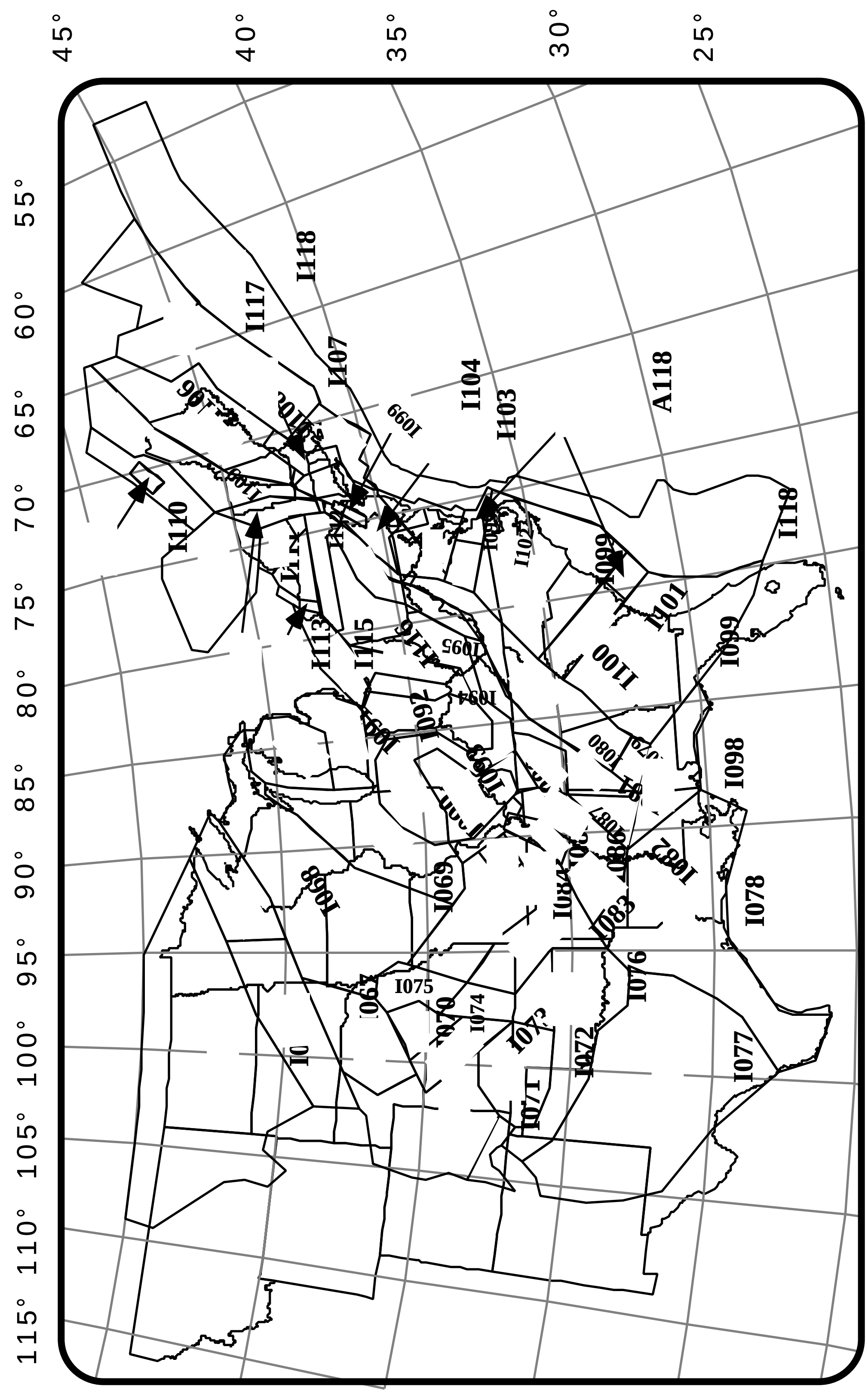
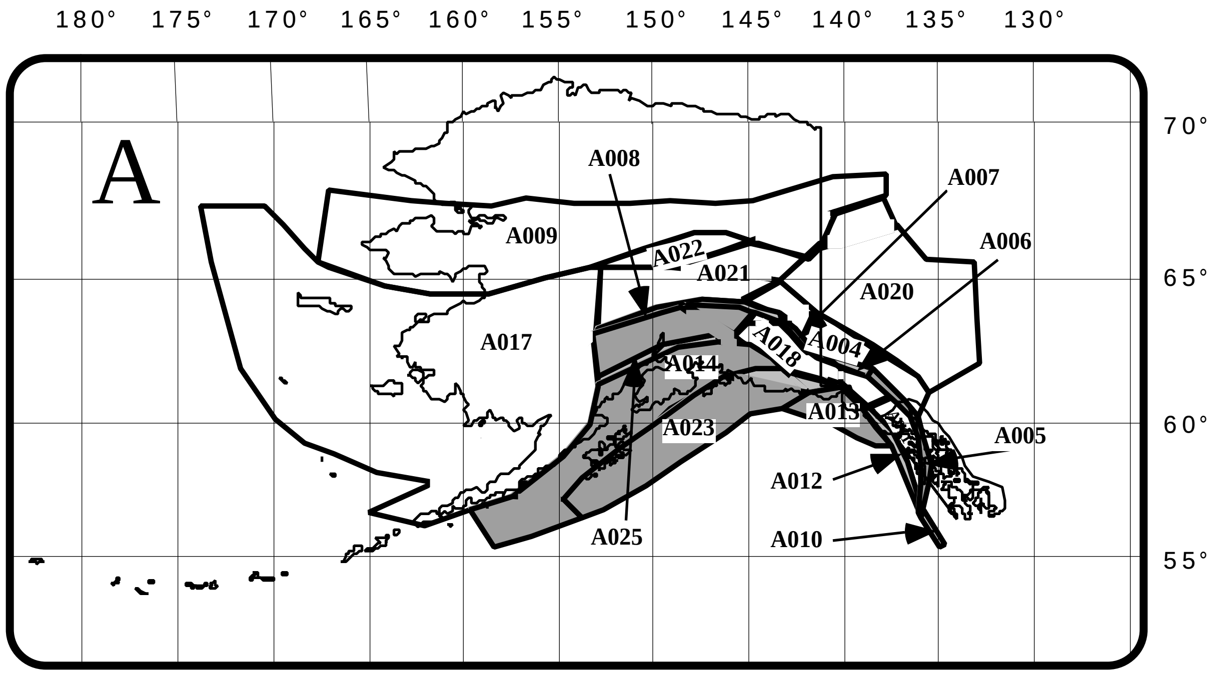


Figure-8 *Central and Eastern U.S. source zones, with those areas that were also modeled using line sources shown as shaded areas.*



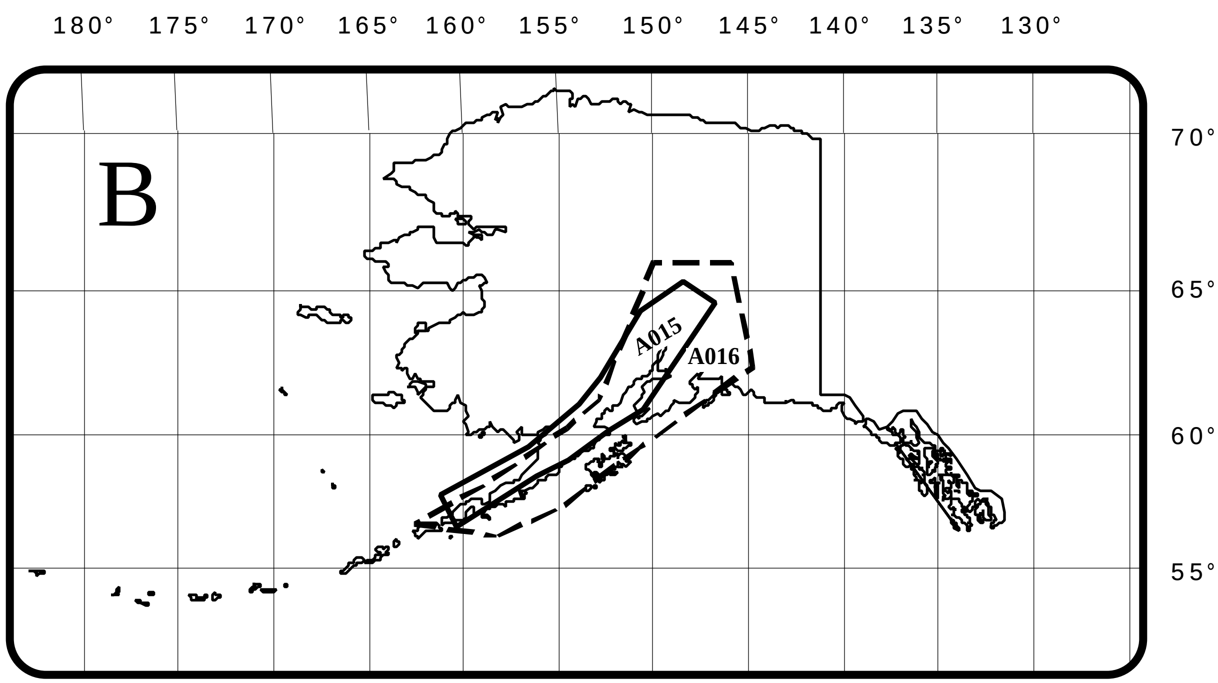


Figure-9 *Surface and subsurface sources for Alaska. Figure 9A shows the sources, modeling shallow earthquakes from 0 to 50 km deep, at the surface of the earth including parallel line sources shown in the shaded areas. Figure 9B illustrates subsurface sources, modeling the subduction zone in the region. The source areas A015 and A016 are used to model earthquakes for deep sources, greater than 100 km, and intermediate sources, 50 to 100 km deep, respectively.*

Appendix A

Area sources and line sources in their SEISRISK-III input format for the Pacific Northwest. For each source area with embedded fault sources, only the larger magnitudes were allowed to occur on the line sources. Source areas Pd01 and Pd02 are coincident sources with P001 and P002 and model only large magnitude earthquakes at depth (Perkins, and others 1980). The attenuation for this portion of the input is the (Schnabel and Seed, 1973) acceleration attenuation function for the western U.S. and has been adjusted to a depth of 75 km.

Deep sources in the Pacific Northwest

```
Puget Sound region deep sources with adjusted attenuation
0 20.
.90 3 10 50 250
1. 0 .5 0
130.00    45.00     117.00    25.00
122.00    42.00     117.00    30.00     .150      .150
 25 25 40 40
0
6 12
'watash79'       8.5       7.6       6.6       5.6       5.2       4.2
      3.22   0.19803   0.14440   0.07426   0.03556   0.00602   0.00149
      6.43   0.19391   0.14027   0.07179   0.03424   0.00578   0.00146
     16.09   0.18483   0.13202   0.06609   0.03160   0.00548   0.00139
     32.18   0.16833   0.11222   0.05289   0.02657   0.00409   0.00107
     64.30   0.14110   0.09407   0.04043   0.01980   0.00313   0.00083
     96.50   0.07756   0.04547   0.01807   0.00949   0.00134   0.00035
    160.90   0.03301   0.01964   0.00734   0.00352   0.00058   0.00016
    321.80   0.01073   0.00627   0.00215   0.00099   0.00017   0.00002
    643.00   0.00281   0.00157   0.00054   0.00025   0.00004   0.00001
   1288.00   0.00070   0.00039   0.00013   0.00006   0.00001   0.00001
   2570.00   0.00017   0.00010   0.00003   0.00002   0.00001   0.00001
   5140.00   0.00008   0.00005   0.00002   0.00001   0.00001   0.00001
00 71.52    -1          Pd01
  3  1  1
122.68 47.63 122.35 47.62
122.97 47.30 122.25 47.37
122.78 46.98 122.35 47.03
.1545 .0622
6.7   7.3
00 71.52    +3          Pd02
  8  1  2
123.47 49.00 122.38 49.03
123.60 48.40 122.13 48.70
122.68 47.63 121.88 48.33
122.35 47.62 121.70 48.08
122.30 47.50 121.62 47.68
122.25 47.37 121.43 47.52
122.35 47.03 121.55 47.05
122.20 46.75 121.70 46.63
  4  2  2
123.03 47.92 122.68 47.63
123.25 47.27 122.97 47.30
122.92 46.80 122.78 46.98
122.20 46.75 122.35 47.03
 .6105 .2452
6.7   7.3
99
```

Shallow sources in the Pacific Northwest

```
Puget Sound region surface sources with attenuation
0 20.
.90 3 10 50 250
1. 0 .5 0
130.00    45.00     117.00    25.00
122.00    42.00     117.00    30.00     .150      .150
 25 25 40 40
0
6 12
watashh79        8.5       7.6       6.6       5.6       5.2       4.2
3.22      .74       .73       .67       .45       .195      .072
6.43      .64       .62       .53       .36       .135      .047
16.09     .49       .43       .32       .19       .052      .02
32.18     .36       .28       .17       .09       .02       .0052
64.3      .21       .14       .06       .035      .0051     .0013
96.5      .12       .07       .03       .0138     .0023     .00042
160.9     .045      .025      .015      .005      .00083    .0001
321.8     .013      .0076     .0026     .0012     .00021    .00003
643.0     .0034     .0019     .00065    .0003     .00005    .00001
1288.0    .00085    .00047    .00016    .00007    .00001    .00001
2570.0    .00021    .00012    .00004    .00002    .00001    .00001
5140.0    .0001     .00006    .00002    .00001    .00001    .00001
00 71.52    -1          P001
  3  1  1
122.68 47.63 122.35 47.62
122.97 47.30 122.25 47.37
122.78 46.98 122.35 47.03
3.164 1.270 0.511 .0515 .0207
4.9   5.5   6.1   6.7   7.3
00 71.52    -1          P002
  8  1  2
123.47 49.00 122.38 49.03
123.60 48.40 122.13 48.70
122.68 47.63 121.88 48.33
122.35 47.62 121.70 48.08
122.30 47.50 121.62 47.68
122.25 47.37 121.43 47.52
122.35 47.03 121.55 47.05
122.20 46.75 121.70 46.63
  4  2  2
123.03 47.92 122.68 47.63
123.25 47.27 122.97 47.30
122.92 46.80 122.78 46.98
122.20 46.75 122.35 47.03
12.51 5.020 2.019 .2035 .0817
4.9   5.5   6.1   6.7   7.3
```

```
00 50.93    -1          P003
  8  1  3
125.77 48.15 126.25 49.03
124.72 48.22 125.38 49.22
123.47 49.00 123.78 49.57
122.93 49.02 122.52 49.82
122.38 49.03 122.07 49.28
121.88 48.33 121.33 48.50
121.70 48.13 121.33 48.08
121.62 47.68 121.43 47.52
  8  2  3
124.72 48.22 123.47 49.00
124.05 48.08 123.60 48.40
123.25 47.88 123.03 47.92
123.27 47.70 123.10 47.67
123.58 47.60 123.25 47.27
124.12 47.60 123.40 47.07
124.40 47.33 123.53 46.92
124.17 46.58 123.95 46.50
  6  3  3
123.53 46.92 123.25 47.27
123.25 46.92 123.07 47.00
123.08 46.75 122.92 46.80
123.08 46.42 122.20 46.75
123.20 46.15 121.70 46.63
123.37 45.83 121.72 46.43
1.827 0.528 0.151 0.042 0.014
4.9   5.5   6.1   6.7   7.3
00 53.33    -1          P004
  4  1  1
122.52 49.82 119.87 50.03
121.33 48.50 118.81 48.25
121.43 47.52 119.07 47.33
121.70 46.63 121.52 46.53
4.416 1.053 0.248 0.062 0.017
4.9   5.5   6.1   6.7   7.3
00 53.33    -1          P005
  4  1  1
121.52 46.53 119.07 47.33
120.82 46.15 119.03 46.93
117.48 44.17 116.38 45.34
116.55 44.74 116.43 44.95
1.57  0.375 0.088 0.022 0.006
4.9   5.5   6.1   6.7   7.3
00 53.33    -1          P006
  6  1  1
121.30 45.80 120.82 46.15
121.37 45.37 120.18 45.78
121.00 44.68 119.23 45.23
119.78 43.96 117.48 44.17
119.21 43.73 117.48 43.48
117.78 43.37 117.55 43.42
0.359 0.086 0.020 0.005 0.001
4.9   5.5   6.1   6.7   7.3
```

```
00 23.08    -1          P008
  4  1  1
123.27 43.53 122.93 43.61
124.80 42.73 122.75 43.00
123.87 41.97 122.42 41.97
122.83 40.97 122.04 41.04
0.144 0.055 0.021 0.008 0.003
4.9   5.5   6.1   6.7   7.3
00 28.34    -1          P009
  5  1  1
125.82 42.22 125.57 43.13
125.45 41.95 124.80 42.73
124.95 41.17 123.87 41.97
124.22 40.52 122.83 40.97
124.00 39.97 122.05 40.00
3.086 1.612 0.842
4.9   5.5   6.1
00 28.34    -1          P010
  3  1  1
125.82 42.22 125.45 41.95
126.32 41.35 124.95 41.17
126.55 40.90 124.22 40.52
6.690 3.495 1.826
4.9   5.5   6.1
00 28.34    -1          P011
  3  1  1
128.00 40.87 126.55 40.90
128.00 40.55 124.22 40.52
128.00 39.98 124.00 39.97
14.26 7.452 3.894
4.9   5.5   6.1
00 28.34    -1          P012
  2  1  1
126.75 42.75 125.82 42.22
127.85 40.90 126.55 40.90
5.492 2.869 1.499
4.9   5.5   6.1
00 28.34    -1          P013
  2  1  1
130.43 44.63 129.78 45.37
125.82 42.22 125.57 43.13
10.22 5.338 2.789
4.9   5.5   6.1
```

```
00 23.08    -1          P014
 12  1  2
123.25 47.88 123.27 47.70
124.08 48.08 123.58 47.60
124.72 48.22 124.12 47.60
126.92 48.05 124.25 47.47
126.80 47.28 124.40 47.33
126.08 46.88 124.28 46.95
125.95 46.17 124.17 46.58
126.02 45.55 123.20 46.15
125.55 45.08 123.53 45.47
125.43 44.48 123.55 44.75
125.57 43.13 123.75 44.03
124.80 42.73 123.27 43.53
  3  2  2
123.25 46.92 123.08 46.75
123.53 46.92 123.08 46.42
123.95 46.50 123.20 46.15
0.962 0.366 0.139 0.053 0.019
4.9   5.5   6.1   6.7   7.3
00 23.08    -1          P015
  9  1  1
126.45 49.40 125.77 48.15
129.08 48.53 126.92 48.05
129.30 47.48 126.80 47.28
129.43 47.00 126.08 46.88
129.53 46.52 125.95 46.17
129.65 46.00 126.02 45.55
129.70 45.77 125.55 45.08
129.75 45.57 125.43 44.48
129.78 45.37 125.57 43.13
3.031 1.154 0.438 0.166 0.060
4.9   5.5   6.1   6.7   7.3
00 23.08    -1          P016
  2  1  1
128.23 49.40 125.33 50.27
127.77 48.98 125.10 49.82
0.433 0.165 0.063
4.9   5.5   6.1
00 28.34    -1          P017
  5  1  1
131.28 51.87 130.58 51.90
131.22 50.92 129.98 57.37
129.87 50.25 129.00 50.48
130.85 49.13 128.83 49.97
129.08 48.53 127.77 48.98
13.01 6.795 3.550
4.9   5.5   6.1
00 50.93    -1          P018
  3  1  1
123.37 45.83 121.72 46.43
123.53 45.47 121.82 45.92
123.55 44.75 122.08 45.32
2.763 0.799 0.229 0.064 0.021
4.9   5.5   6.1   6.7   7.3
```

```
00 50.93    -1          P019
  4  1  1
123.55 44.75 122.08 45.32
123.75 44.03 122.42 44.27
123.47 43.72 122.62 43.88
123.27 43.53 122.93 43.61
0.601 0.174 0.050 0.014 0.005
4.9   5.5   6.1   6.7   7.3
99 28.34    -1          P009
  4  1  2
125.65    42.90     125.00    42.50     124.20    41.57     123.42    39.92
  5  2  2
125.75    42.47     125.45    42.30     124.55    41.00     124.27    40.45
123.75    40.00
0.440 0.230 0.120
6.7   7.3   7.9
00 28.34    -1          P010
  3  1  2
124.70    40.70     125.35    41.10     125.82    41.95
  3  2  2
125.58    40.80     126.05    41.13     126.08    41.67
0.954 0.498 0.260
6.7   7.3   7.9
00 28.34    -1          P011
  2  1  3
124.38    40.15     127.87    40.23
  2  2  3
124.58    40.37     127.88    40.47
  2  3  3
125.22    40.67     127.85    40.73
2.033 1.063 0.554
6.7   7.3   7.9
00 28.34    -1          P012
  2  1  3
126.50    42.58     127.45    41.65
  2  2  3
126.27    42.40     127.55    41.03
  2  3  3
126.00    42.23     127.18    41.03
0.783 0.409 0.213
6.7   7.3   7.9
00 28.34    -1          P013
  3  1  3
129.83    45.17     125.90    43.18     126.08    42.35
  3  2  3
130.03    44.92     126.33    43.13     126.42    42.60
  2  3  3
130.25    44.72     126.75    43.00
1.456 0.761 0.397
6.7   7.3   7.9
00 23.08    -1          P016
  2  1  1
125.17    49.17     127.92    49.90
0.024 0.009
6.7   7.3
```

```
00 28.34    +3          P017
  2  1  4
128.00    48.92     130.70    51.78
  2  2  4
128.42    48.77     131.25    51.67
  2  3  4
128.83    48.63     130.08    49.92
  2  4  4
129.50    48.72     130.42    49.58
1.854 0.969 0.505
6.7   7.3   7.9
99
```

Appendix B

Shallow Sources used in Alaska

```
all shallow Alaska zones
0 30.
.90 3 10 50 250
1 0 .62 0
155.00    65.00     130.00    55.00
150.00    65.00     140.00    55.00      .200      .200
  0  0  0  0
1
40
155.0 62.0 145.0 58.0
6 12
watashh79        8.5       7.6       6.6       5.6       5.2       4.2
3.22      .74       .73       .67       .45       .195      .072
6.43      .64       .62       .53       .36       .135      .047
16.09     .49       .43       .32       .19       .052      .02
32.18     .36       .28       .17       .09       .02       .0052
64.3      .21       .14       .06       .035      .0051     .0013
96.5      .12       .07       .03       .0138     .0023     .00042
160.9     .045      .025      .015      .005      .00083    .0001
321.8     .013      .0076     .0026     .0012     .00021    .00003
643.0     .0034     .0019     .00065    .0003     .00005    .00001
1288.0    .00085    .00047    .00016    .00007    .00001    .00001
2570.0    .00021    .00012    .00004    .00002    .00001    .00001
5140.0    .0001     .00006    .00002    .00001    .00001    .00001
00  10.     -1          A004
  7  1  2
134.50 59.90 135.10 58.90
135.00 60.50 135.90 59.60
137.00 61.40 137.80 60.90
139.40 62.40 140.90 61.50
140.00 62.60 141.60 61.80
141.10 63.10 142.40 62.40
142.80 62.80 143.00 62.70
  2  2  2
141.10 63.10 142.80 62.80
143.30 64.30 145.50 63.50
2.4000.69200.19960.05750.01660.00480
   4.3   4.9   5.5   6.1   6.7   7.3
00  28.25  -1          A005
  7  1  1
134.90 54.70 135.10 55.00
134.50 56.20 134.90 56.20
134.40 57.00 134.90 57.00
134.70 58.10 135.10 58.10
135.10 58.90 135.50 58.90
135.90 59.60 136.30 59.50
137.80 60.90 138.10 60.60
2.0960.91400.39850.17380
   4.3   4.9   5.5   6.1
00  10.0   -1          A006
  2  1  1
137.80 60.90 138.10 60.60
140.90 61.50 141.10 61.30
.24030.1049004540.02000
   4.3   4.9   5.5   6.1
```

```
00  10.0   -1          A007
  4  1  1
140.90 61.50 141.10 61.30
141.60 61.80 141.80 61.60
142.40 62.40 142.70 62.30
143.20 62.80 143.40 62.70
.24030.10490.04540.02000
   4.3   4.9   5.5   6.1
00  28.25  -1          A008
  7  1  2
154.20 62.50 154.30 62.20
150.70 63.30 150.20 63.10
147.90 63.60 148.70 63.30
145.50 63.50 145.70 63.20
144.60 63.30 144.90 63.10
143.40 63.10 143.60 62.80
143.20 62.80 143.30 62.80
  2  2  2
143.40 63.10 143.20 62.80
142.80 62.80 143.00 62.70
.89200.38900.17000.07400
   4.3   4.9   5.5   6.1
00  1.0    -1          A009
 12  1  2
170.20 67.60 170.80 65.00
165.20 67.20 166.90 64.10
163.20 67.10 164.00 63.80
160.50 67.00 160.60 63.80
158.40 67.30 157.30 64.40
155.60 67.10 154.60 64.80
152.30 67.10 151.50 65.50
149.80 67.20 148.40 66.10
147.20 67.10 146.60 66.10
145.00 67.20 145.20 65.80
140.30 68.00 140.00 66.80
137.10 68.10 137.10 67.40
  2  2  2
140.00 66.80 145.20 65.80
140.80 65.60 141.70 65.10
.18830.06240.02070.00680.00230.00080
   4.3   4.9   5.5   6.1   6.7   7.3
00  28.25  -1          A010
  2  1  1
133.50 53.60 133.90 53.40
134.80 55.10 134.90 54.70
4.30701.8800.82000.35800
   4.3   4.9   5.5   6.1
00  10.    -1          A011
  5  1  1
134.90 56.20 135.00 55.70
134.90 57.00 135.70 57.10
135.10 58.10 136.40 57.90
135.50 58.90 136.70 58.40
136.70 59.80 138.10 59.40
4.51601.1340.28470.07150.01800.00450
   4.3   4.9   5.5   6.1   6.7   7.3
```

```
00  28.25  -1          A012
  7  1  1
135.00 55.70 135.10 55.10
135.70 57.10 136.20 57.00
136.40 57.90 136.70 57.80
136.70 58.40 137.20 58.20
138.10 59.40 138.40 59.30
139.40 60.20 139.70 60.10
140.40 60.40 140.10 60.30
8.17803.57001.5580.68000
   4.3   4.9   5.5   6.1
00  28.25  -1          A013
  5  1  1
136.70 57.80 137.50 57.80
137.50 58.50 138.70 58.10
138.40 59.30 140.10 58.60
139.70 60.10 141.70 59.00
141.60 59.90 143.10 59.20
11.3704.96302.1660.94500
   4.3   4.9   5.5   6.1
00  1.0    -1          A014
  3  1  5
160.20 53.40 161.50 55.10
158.00 54.00 159.10 55.70
155.00 54.70 156.10 55.50
  9  2  5
156.10 55.50 159.10 55.70
155.00 56.40 156.10 57.30
152.80 57.60 154.60 58.70
150.70 58.60 154.00 60.10
149.80 59.20 154.10 60.20
148.40 59.80 149.40 61.70
146.60 60.60 146.90 61.90
144.80 60.80 145.10 61.80
143.10 60.80 143.80 61.30
  3  3  5
145.10 61.80 146.90 61.90
146.00 62.20 147.00 62.20
148.70 63.30 149.10 63.20
  2  4  5
146.00 62.20 148.70 63.30
144.90 63.10 145.70 63.20
  3  5  5
149.10 63.20 147.00 62.20
150.20 63.10 150.30 61.80
154.30 62.20 154.10 60.60
7.03602.6380.98930.37100
   4.3   4.9   5.5   6.1
```

```
00  1.0    -1          A018
  3  1  3
138.10 59.40 136.70 59.80
139.40 60.20 138.10 60.60
139.80 60.40 139.80 61.00
  7  2  3
140.10 60.30 139.80 60.40
140.70 60.40 139.80 61.00
142.00 60.60 140.90 61.50
143.10 60.80 141.80 61.60
143.80 61.30 142.70 62.30
145.10 61.80 143.40 62.70
146.00 62.20 145.30 62.70
  2  3  3
145.30 62.70 143.40 62.70
144.90 63.10 143.30 62.80
.26140.09810.03680.013800
   4.3   4.9   5.5   6.1
00  1.0    -1          A021
  4  1  2
153.90 64.80 154.20 62.50
149.90 64.80 150.70 63.30
146.70 64.60 147.90 63.60
143.30 64.30 145.50 63.50
  3  2  2
141.70 65.10 143.30 64.30
143.70 65.40 146.70 64.60
145.20 65.80 149.90 64.80
1.0850.39590.14440.05270.01920.00700
   4.3   4.9   5.5   6.1   6.7   7.3
00  1.0    -1          A022
  3  1  1
154.60 64.80 149.90 64.80
148.40 66.10 146.90 65.40
146.60 66.10 145.20 65.80
.44070.16080.05860.02140.00780.00280
   4.3   4.9   5.5   6.1   6.7   7.3
00  1.0    -1          A023
  7  1  3
155.00 54.70 156.10 55.50
153.70 55.10 155.00 56.40
151.20 56.10 152.80 57.60
149.10 57.10 150.70 58.60
146.50 58.30 148.40 59.80
145.00 59.10 146.60 60.60
143.10 59.20 141.60 59.90
  2  2  3
141.60 59.90 146.60 60.60
143.10 60.80 144.80 60.80
  3  3  3
141.60 59.90 143.10 60.80
140.70 60.00 140.70 60.40
139.70 60.10 140.10 60.30
7.07403.08801.3480.58840
   4.3   4.9   5.5   6.1
```

```
00  28.25  -1          A025
  3  1  1
154.10 60.20 154.10 60.60
149.40 61.70 150.30 61.80
146.90 61.90 147.00 62.20
.20600.09000.03900.01700
   4.3   4.9   5.5   6.1
00  10.0   -1          A017
 12  1  2
173.80 67.00 177.60 64.00
172.80 66.30 177.00 65.00
171.50 65.50 175.30 60.90
170.80 65.00 173.20 58.90
170.00 64.80 171.40 57.90
168.60 64.50 169.80 57.50
167.70 64.30 167.20 56.80
166.90 64.10 163.70 56.30
164.00 63.80 160.20 58.90
160.60 63.80 157.90 60.30
157.30 64.40 154.30 62.20
154.60 64.80 153.90 64.80
  6  2  2
154.30 62.20 154.00 60.10
157.90 60.30 154.60 58.70
160.20 58.90 156.10 57.30
163.70 56.30 159.10 55.70
164.10 56.10 161.50 55.10
167.60 54.90 164.20 54.40
6.53801.8860.54400.15680.04520.01300.00370
   4.3   4.9   5.5   6.1   6.7   7.3   7.9
00  33.80  -1          A020
  6  1  2
131.50 61.10 134.50 59.90
131.60 62.80 135.00 60.50
131.70 64.90 136.40 61.20
134.60 65.00 137.80 61.80
136.30 66.30 141.10 63.10
140.80 65.60 143.30 64.30
  2  2  2
136.30 66.30 140.80 65.60
137.10 67.40 140.00 66.80
10.2802.9650.85610.24710.06830.02030
   4.3   4.9   5.5   6.1   6.7   7.3
99  28.25  -1          AF05
  7  1  1
    135.00     54.85    134.70     56.20    134.65     57.00    134.90     58.10
    135.30     58.90    136.10     59.55    137.95     60.75
.07570.03300.01440.00630
   6.7   7.3   7.9   8.5
00  10.0   -1          AF06
  2  1  1
    137.95     60.75    141.00     61.40
.00870.00380.00170.00080
   6.7   7.3   7.9   8.5
00  10.0   -1          AF07
  4  1  1
    141.00     61.40    141.70     61.70    142.55     62.35    143.30     62.75
.00870.00380.00170.00080
   6.7   7.3   7.9   8.5
```

```
00  1.0    -1          AF08
  7  1  1
    154.25     62.35    150.45     63.20    148.30     63.45    145.60     63.35
    144.75     63.20    143.50     62.95    143.20     63.80
.03200.01400.00600.00300
   6.7   7.3   7.9   8.5
00  28.25  -1          AF10
  2  1  1
    133.70     53.50    134.85     54.90
.15600.06800.03000.01300
   6.7   7.3   7.9   8.5
00  28.25  -1          AF12
  7  1  1
    135.05     55.40    135.95     57.05    136.55     57.85    136.95     58.30
    138.25     59.35    139.55     60.15    139.95     60.35
.29700.13000.05700.02500
   6.7   7.3   7.9   8.5
00  28.25  -1          AF13
  2  1  6
    137.00     57.80    140.10     60.20
  2  2  6
    137.50     57.80    140.70     60.00
  2  3  6
    138.60     58.00    141.30     60.00
  2  4  6
    139.70     58.40    141.90     59.90
  2  5  6
    140.80     58.70    142.20     59.70
  2  6  6
    141.70     59.00    142.70     59.50
.41300.18000.07900.03500
   6.7   7.3   7.9   8.5
00  1.0    -1          AF25
  3  1  1
    154.10     60.40    149.85     61.75    146.95     62.05
.00750.00330.00140.00060
   6.7   7.3   7.9   8.5
```

```
00  1.0    -1          AF14
  3  1 13
    153.90     60.22    151.16     61.08    149.00     61.58
  2  2 13
    154.12     59.65    150.93     60.95
  3  3 13
    154.34     59.07    150.71     60.83    149.00     61.58
  3  4 13
    154.56     58.50    150.48     60.70    149.00     61.58
  5  5 13
    161.46     55.10    158.90     55.70    156.12     57.30    148.24     61.65
    145.44     61.85
  5  6 13
    161.30     54.91    158.45     55.56    155.83     57.06    147.87     61.38
    144.91     61.59
  5  7 13
    161.15     54.71    158.00     55.43    155.54     56.83    147.50     61.11
    147.37     61.34
  5  8 13
    160.99     54.52    157.55     55.29    155.25     56.59    147.13     60.83
    143.84     61.08
  5  9 13
    160.83     54.32    157.10     55.15    154.96     56.35    146.76     60.56
    143.30     60.82
  2 10 13
    160.67     54.13    156.60     55.08
  2 11 13
    160.52     53.93    156.43     54.87
  2 12 13
    160.36     53.74    156.25     54.67
  2 13 13
    160.20     53.54    156.08     54.46
.13910.05220.01960.00730
   6.7   7.3   7.9   8.5
00  1.0    -1          AF21
  4  1  6
    154.10     62.04    150.00     63.26    147.20     63.38    144.90     63.18
  4  2  6
    154.08     61.74    150.00     62.97    146.92     63.15    145.08     62.99
  4  3  6
    154.06     61.44    150.00     62.68    146.64     62.92    145.26     62.80
  4  4  6
    154.04     61.15    150.00     62.38    146.36     62.70    145.44     62.62
  4  5  6
    154.02     60.85    150.00     62.09    146.08     62.47    145.62     62.43
  3  6  6
    154.00     60.55    150.00     61.80    145.80     62.24
.00256.00093
   7.9   8.5
```

```
00  1.0    +3          AF23
  6  1  7
    156.60     55.08    154.92     56.25    150.54     58.58    146.60     60.46
    143.00     60.64    140.10     60.12
  5  2  7
    154.75     56.07    150.32     58.34    146.35     60.25    143.00     60.41
    140.71     60.06
  6  3  7
    156.43     54.87    154.57     55.88    150.09     58.11    146.11     60.03
    143.00     60.18    141.33     60.01
  5  4  7
    154.40     55.70    149.87     57.87    145.86     59.82    143.00     59.95
    141.92     59.95
  6  5  7
    156.25     54.67    154.23     55.52    149.65     57.63    145.61     59.61
    143.00     59.72    142.28     59.72
  5  6  7
    154.05     55.33    149.42     57.40    145.37     59.39    143.00     59.49
    142.64     59.49
  5  7  7
    156.08     54.46    153.88     55.15    149.20     57.16    145.12     59.18
    143.00     59.26
.25690.11210.04890.02140
   6.7   7.3   7.9   8.5
99
99
```

Deep Sources used in Alaska

```
all deep layer Alaska zones
0 30.
.90 3 10 50 250
1 0 .62 0
155.00    65.00     130.00    55.00
150.00    65.00     140.00    55.00      .200      .200
  0  0  0  0
1
40
155.0 62.0 145.0 58.0
6 12
Deep   79        8.5       7.6       6.6       5.6       5.2       4.2
3.22      .135      .060      .021      .018      .00169    .0003
6.43      .129      .059      .019      .0175     .00163    .00029
16.0      .125      .0575     .0185     .016      .0016     .00028
32.18     .120      .054      .018      .013      .00158    .00027
64.3      .1        .046      .0175     .0079     .0013     .00014
96.5      .082      .032      .0137     .0060     .00125    .000098
160.9     .039      .013      .0068     .0012     .0012     .00006
321.8     .0112     .0075     .0028     .0012     .0008     .00003
643.0     .0031     .0019     .00065    .00065    .0004     .00001
1288.0    .00085    .00047    .00016    .00063    .00001    .00001
2570.0    .00021    .00012    .00004    .00004    .00001    .00001
5140.0    .0001     .00006    .00002    .00002    .00001    .00001
 34.00      9.00      17.00      0.00      .20       .20
00 1.0      -1          A015
  6  1  1
162.40 54.80 163.40 56.20
157.70 56.90 158.20 58.20
155.90 57.60 155.20 59.90
153.50 58.80 154.00 60.90
151.40 59.60 151.60 63.50
147.10 63.80 149.00 64.60
1.4030.51170
4.9   5.5
99  1.0     +2          AF15-1.085  .389  .52
  5  1  6
    163.40     56.20    158.20     58.20    154.50     60.60    151.60     63.50
    149.00     64.60
  5  2  6
    163.20     55.92    158.10     57.94    153.88     60.40    150.98     63.31
    148.62     64.44
  5  3  6
    163.00     55.64    158.00     57.68    153.26     60.20    150.36     63.13
    148.24     64.28
  5  4  6
    162.80     55.36    157.90     57.42    152.64     60.00    149.74     62.94
    147.86     64.12
  5  5  6
    162.60     55.08    157.80     57.16    152.02     59.80    149.12     62.76
    147.48     63.96
  6  6  6
    162.40     54.80    157.70     56.90    155.90     57.60    151.40     59.60
    148.50     62.57    147.10     63.80
.18660.06810.02480.00910.00330
   6.1   6.7   7.3   7.9   8.5
99
99
```

Intermediate Depth Sources used in Alaska

```
all deep layer Alaska zones
0 30.
.90 3 10 50 250
1 0 .62 0
155.00    65.00     130.00    55.00
150.00    65.00     140.00    55.00      .200      .200
  0  0  0  0
1
40
155.0 62.0 145.0 58.0
6 12
inter  79        8.5       7.6       6.6       5.6       5.2       4.2
3.22      .3        .133      .051      .024      .00365    .001
6.43      .295      .131      .0495     .0238     .00362    .00099
16.09     .285      .129      .0475     .0226     .00355    .00098
32.18     .247      .125      .044      .0214     .0034     .0009
64.3      .172      .088      .0285     .0137     .0025     .00058
96.5      .166      .055      .0184     .0089     .00147    .00036
160.9     .042      .0248     .009      .00425    .00072    .0001
321.8     .013      .0076     .0026     .0012     .00021    .00003
643.0     .0034     .0019     .00065    .0003     .00005    .00001
1288.0    .00085    .00047    .00016    .00007    .00001    .00001
2570.0    .00021    .00012    .00004    .00002    .00001    .00001
5140.0    .0001     .00006    .00002    .00001    .00001    .00001
 34.00      9.00      17.00      0.00      .20       .20
00 1.0      -1          A016
  5  1  1
160.00 54.40 164.80 54.90
156.10 55.70 160.60 56.60
151.60 58.10 155.90 58.90
144.90 61.40 154.00 60.00
146.20 65.30 150.80 65.30
7.22102.5970
4.9   5.5
```

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99  1.0     +2          AF16-1.085  .389  .52
  6  1 17
    164.80     54.90    160.60     56.60    155.90     58.90    154.00     60.00
    152.50     62.80    150.80     65.30
  2  2 17
    153.43     60.09    152.06     62.83
  6  3 17
    164.20     54.84    160.04     56.49    155.36     55.80    152.86     60.18
    151.63     62.86    150.23     65.30
  2  4 17
    152.29     60.26    151.19     62.89
  6  5 17
    163.60     54.78    159.48     56.38    154.83     58.70    151.73     60.35
    150.75     62.93    149.65     65.30
  2  6 17
    151.16     60.44    150.31     62.96
  6  7 17
    163.00     54.71    158.91     56.26    154.29     58.60    150.59     60.53
    149.88     62.99    149.08     65.30
  2  8 17
    150.02     60.61    149.44     63.02
  6  9 17
    162.40     54.65    158.35     56.15    153.75     58.50    149.45     60.70
    149.00     63.05    148.50     65.30
  2 10 17
    148.88     60.79    148.56     63.08
  6 11 17
    161.80     54.59    157.79     56.04    153.21     58.40    148.31     60.88
    148.13     63.11    147.93     65.30
  2 12 17
    147.74     60.96    147.69     63.14
  6 13 17
    161.20     54.53    157.23     55.93    152.68     58.30    147.18     61.05
    147.25     63.18    147.35     65.30
  2 14 17
    146.61     61.14    146.81     63.21
  6 15 17
    160.60     54.46    156.66     55.81    152.14     58.20    146.04     61.23
    146.38     63.24    146.78     65.30
  2 16 17
    145.47     61.31    145.94     63.27
  6 17 17
    160.00     54.40    156.10     55.70    151.60     58.10    144.90     61.40
    145.50     63.30    146.20     65.30
.93460.33620.12100.04350.01560
   6.1   6.7   7.3   7.9   8.5
99
99
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Appendix C

Annual Rates and Areas

For each source zone the following six tables list the source name, the area, in Km^2, of the source, and a range of **annual** recurrence rates for each magnitude. The recurrence rate entries in the tables indicate the minimum magnitude and maximum magnitude used for a given source zone. To properly compare the relative hazard between source zones the recurrence rates must be normalized by area, to an annual rate per unit area.

Pacific Northwest Source Zones

Zone ID	Area	4.9	5.5	6.1	6.7	7.3	7.9	8.5
P001	2914.05	.04424	.01776	.00714	.00072	.00029		
P002	26170.54	.17492	.07019	.02823	.00285	.00114		
P003	56311.03	.03587	.01037	.00296	.00082	.00027		
P004	60328.50	.08281	.01974	.00465	.00116	.00032		
P005	61071.00	.02944	.00703	.00165	.00041	.00011		
P006	50042.80	.00673	.00161	.00038	.00009	.00002		
P008	29264.38	.00624	.00238	.00091	.00035	.00013		
P009	43220.02	.10889	.05688	.02971	.01553	.00812	.00423	
P010	15491.67	.23606	.12332	.06443	.03366	.01757	.00917	
P011	28921.93	.50318	.26295	.13740	.07174	.03751	.01955	
P012	18770.43	.19379	.10124	.05289	.02763	.01443	.00752	
P013	42059.29	.36062	.18836	.09841	.05138	.02685	.01401	
P014	105866.97	.04168	.01586	.00602	.00230	.00082		
P015	140359.02	.13133	.05000	.01898	.00719	.00260		
P016	12453.60	.01876	.00715	.00273	.00104	.00004		
P017	104771.82	.45907	.23977	.12526	.06542	.03419	.01782	
P018	14507.83	.05425	.01569	.00450	.00126	.00041		
P019	15012.53	.01180	.00342	.00098	.00027	.00010		

Sub-surface Source Zones

Zone ID	Area	4.9	5.5	6.1	6.7	7.3	7.9	8.5
Pd01	2914.05				.00216	.00087		
Pd02	26170.54				.00854	.00343		

California Source Zones

Zone ID	Area	4.9	5.5	6.1	6.7	7.3	7.9	8.5
C001	3757.26	.23877	.09076	.03444	.01323	.00502		
C002	2375.59	.05969	.02269	.00861	.00331	.00125		
C003	4101.90	.11938	.04538	.01722	.00661	.00251		
C004	14943.18	.11938	.04538	.01722	.00661	.00251		
C005	4561.84	.01846	.00699	.00265				
C006	2220.18	.05969	.02269	.00861	.00331	.00125		
C007	2670.73	.05969	.02269	.00861	.00331	.00125		
C008	2771.01	.01846	.00699	.00265				
C009	3162.62	.01846	.00699	.00265				
C010	67122.00	.06918	.02630	.01000				
C011	5374.98	.29272	.11130	.04234	.01611	.00614		
C012	2766.69	.07245	.02753	.01046	.00399	.00152		
C013	2662.03	.13621	.05178	.01970	.00751	.00284		
C014	7902.48	.20120	.04401	.00962	.00210	.00046	.00010	
C015	6747.03	.52960	.18790	.06670	.02370	.00840	.00290	
C016	6070.77	.06970	.02153	.00665	.00206	.00064	.00020	
C017	2052.01	.00914	.00303	.00100	.00033	.00011		
C018	8096.49	.35670	.11650	.03810	.01240	.00410		
C019	10946.51	.12162	.04625	.01756	.00668			
C020	6599.38	.07329	.02787	.01059				
C021	1879.98	.04136	.01573	.00596				
C022	895.01	.00920	.00350	.00134				
C023	4145.33	.04950	.02101	.00893	.00379	.00161	.00069	
C024	17459.64	.74000	.28100	.10600	.04000	.01500	.00570	.00210
C025	1757.91	.01447	.00411	.00118	.00032	.00011		
C026	1151.91	.02603	.00739	.00212	.00058	.00019		
C027	2471.53	.01460	.00619	.00263	.00112	.00047		
C028	2203.00	.05525	.02346	.00997	.00424	.00179		
C029	1419.87	.00998	.00424	.00180	.00076	.00033		
C030	5246.44	.01380	.00524	.00199	.00076			
C031	10033.18	.14704	.04546	.01407	.00435			
C032	8665.55	.19580	.06950	.02470	.00870	.00310	.00110	
C033	6183.49	.09800	.04160	.01769	.00751	.00318	.00136	
C034	10083.13	.20740	.06410	.01980	.00610	.00190	.00060	
C035	3705.48	.00586	.00146	.00036	.00009	.00002		
C036	3512.60	.09090	.02350	.00610	.00160			
C037	34209.95	.25333	.07824	.02417				
C038	7874.12	.23840	.06880	.01980	.00571	.00165	.00048	
C039	19829.92	.12710	.04510	.01600	.00570	.00200	.00072	
C040	2796.62	.06015	.02288	.00869				
C041	1789.39	.03589	.01523	.00648	.00275	.00116	.00049	

Rocky mountain Region Source Zones

Zone ID	Area	4.9	5.5	6.1	6.7	7.3	7.9	8.5
I001	39602.81	.04200	.00777	.00144	.00027	.00005		
I002	16883.62	.00700	.00136	.00026	.00005	.00001		
I003	102469.40	.01600	.00291	.00053	.00010	.00002		
I004	24235.61	.06500	.01861	.00533	.00153	.00044		
I005	72939.83	.01700	.00318	.00059	.00011	.00002		
I006	40203.11	.02500	.00463	.00086	.00016	.00003		
I007	9210.72	.07800	.01452	.00270	.00050	.00009		
I008	58402.99	.03900	.00721	.00133				
I009	64002.98	.05600	.01616	.00467				
I010	95079.61	.06000	.01731	.00499	.00144	.00042		
I011	8704.28	.12500	.02836	.00643	.00146	.00033		
I012	32047.16	.07900	.01788	.00405	.00092	.00021		
I013	5177.09	.01300	.00307	.00073	.00017	.00004		
I014	49462.80	.09100	.01690	.00314	.00058	.00011		
I015	27373.38	.00300	.00050	.00008	.00001			
I016	136002.23	.02700	.00499	.00092				
I017	60109.51	.18000	.04675	.01214	.00315	.00082		
I018	47086.29	.07500	.02155	.00619	.00178	.00051		
I019	18828.12	.03367	.00968	.00278	.00080	.00023		
I020	35365.91	.42000	.09560	.02174	.00495	.00112		
I022	3750.30	.04500	.01013	.00230				
I023	12205.83	.04400	.01261	.00362	.00104	.00030		
I024	13357.89	.06200	.01403	.00317	.00072	.00016		
I025	24079.81	.03800	.00860	.00194				
I026	37771.16	.10800	.02445	.00554				
I027	19661.46	.02500	.00563					
I029	18312.95	.30000	.06823	.01552	.00353	.00080		
I030	22957.73	.13400	.03054	.00696	.00159	.00036		
I031	47073.06	.52465	.15068	.04327	.01627	.00467		
I032	12357.63	.13817	.03968	.01139				
I033	2200.17	.02458	.00706	.00203				
I034	100029.41	.17914	.05145	.01478	.00424	.00122		
I035	146190.84	.05763	.01655	.00475	.00137	.00039		
I036	18725.96	.00500	.00139	.00039				
I037	24865.38	.01300	.00331	.00084	.00022	.00005		
I038	55974.55	.20900	.05419	.01405	.00364	.00094		
I039	8721.16	.03100	.00801	.00207	.00053	.00014		
I040	7975.40	.07500	.01933	.00498	.00128	.00033		
I041	60119.61	.04500	.00830	.00153	.00028	.00005		
I042	9675.30	.00300	.00050	.00008				
I043	11489.48	.00900	.00176	.00034	.00007	.00001		
I044	23695.65	.02100	.00390	.00073				
I045	230779.66	.08500	.01584	.00295				
I046	15398.94	.00268	.00058	.00013				
I047	5179.92	.00090	.00019	.00004				
I048	4005.95	.00069	.00015	.00003				
I049	20202.18	.00350	.00075	.00017				
I050	77750.43	.03200	.00602	.00113				
I051	20665.31	.00359	.00077	.00017				
I052	23317.65	.04900	.01264	.00326	.00084	.00022		

I053	8179.81	.00900	.00225	.00056	.00014	.00004
I054	26591.16	.00500	.00139	.00039		
I055	7752.59	.17400	.04499	.01163	.00301	.00080
I056	3215.12	.04600	.01195	.00311		
I057	37763.48	.17200	.04469	.01161	.00302	.00078
I058	81512.45	.05100	.01314	.00338	.00087	.00022
I059	9875.88	.05000	.01302	.00339		
I060	38171.20	.00900	.00225	.00056		
I061	31012.90	.02300	.00594	.00154	.00040	.00010
I062	48460.92	.00900	.00225	.00056		
I063	78832.88	.03300	.00844	.00216		
I064	26354.06	.08700	.02266	.00590	.00154	.00400
I065	38011.53	.03900	.01001	.00257		
I066	134834.31	.00300	.00050	.00008		

Central U.S. Source Zones

Zone ID	Area	4.9	5.5	6.1	6.7	7.3	7.9	8.5
I067	143225.53	.02691	.00939	.00328				
I068	94353.27	.01010	.00352	.00123				
I069	356275.34	.00205	.00072	.00025				
I070	102670.86	.01239	.00432	.00151				
I071	196788.94	.00410	.00143	.00050				
I072	89344.20	.00707	.00247	.00086				
I073	47563.01	.00821	.00286	.00100				
I074	31668.12	.00094	.00033	.00011				
I075	46081.76	.02271	.00792	.00276				
I076	216712.13	.05143	.01794	.00626				
I077	490786.63	.01210	.00422	.00147				
I078	376470.16	.01531	.00534	.00186				
I079	66513.58	.01075	.00375	.00131				
I080	31078.84	.01042	.00364	.00127				
I081	60636.30	.00713	.00249	.00087				
I082	37541.93	.01239	.00432	.00151				
I083	105164.28	.00347	.00121	.00042				
I084	122187.16	.01436	.00501	.00175				
I085	15145.82	.01327	.00463	.00161				
I086	16321.06	.01614	.00563	.00196				
I087	23448.63	.10419	.03635	.01268	.00442	.00154	.00054	.00019
I088	19461.96	.03385	.01181	.00412				
I089	72338.66	.05473	.01909	.00666				
I090	160099.42	.02129	.00743	.00259				
I091	75713.31	.00225	.00078	.00027				
I092	74902.89	.00928	.00324	.00113				
I093	314051.81	.00935	.00326	.00114				
I094	76774.98	.03780	.01319	.00460				
I095	32753.41	.02059	.00718	.00251				
I096	55619.61	.00933	.00326	.00114				
I097	572327.94	.00403	.00141	.00049				
I098	138963.63	.00424	.00148	.00052				

Eastern U.S. Source Zones

Zone ID	Area	4.9	5.5	6.1	6.7	7.3	7.9	8.5
I099	616322.81	.07928	.02532	.00808	.00258	.00082		
I100	151890.88	.13501	.04311	.01377	.00439	.00140		
I101	46525.64	.05978	.01909	.00610	.00194	.00062		
I102	20576.84	.03043	.00972	.00310	.00099	.00032		
I103	64306.00	.10584	.03380	.01079	.00344	.00110		
I104	5417.13	.01770	.00565	.00180	.00058	.00018		
I106	118167.29	.00623	.00199	.00064	.00020			
I107	23441.37	.06097	.01947	.00496	.00158	.00050		
I108	162124.58	.09382	.02996	.00957	.00305			
I109	55128.98	.09648	.03081	.00984	.00314	.00100	.00032	
I110	7331.05	.03399	.01085	.00347	.00110	.00035	.00011	
I111	138813.27	.10353	.03306	.01056	.00336	.00108		
I112	20903.83	.00489	.00156	.00050	.00016			
I113	32240.45	.02373	.00758	.00242	.00077			
I114	29176.88	.00241	.00077	.00025	.00008			
I115	6305.41	.01863	.00595	.00190	.00061	.00019		
I116	45970.20	.02166	.00692	.00221	.00070			
I117	256222.92	.01261	.00403	.00129	.00041	.00013		
I118	606412.00	.00405	.00129	.00041	.00013	.00004		
A118	31675.00	.00021	.00007	.00002	.00001	.00000		

Alaska Source Zones

Zone ID	Area	4.9	5.5	6.1	6.7	7.3	7.9	8.5
A004	72143.00	.06920	.01996	.00575	.00166	.00048		
A005	17767.00	.03235	.01411	.00615	.00268	.00117	.00051	.00022
A006	5545.00	.01049	.00454	.00200	.00087	.00038	.00017	.00008
A007	3862.00	.01049	.00454	.00200	.00087	.00038	.00017	.00008
A008	18088.00	.01377	.00602	.00262	.00113	.00050	.00021	.00011
A009	381391.00	.06240	.02070	.00680	.00230	.00080		
A010	5090.00	.06655	.02903	.01267	.00552	.00241	.00106	.00046
A011	28243.00	.11340	.02847	.00715	.00180	.00045		
A012	16419.00	.12637	.05515	.02407	.01051	.00460	.00202	.00088
A013	39421.00	.17568	.07667	.03345	.01462	.00637	.00280	.00124
A014	310086.00	2.6380	.98930	.37100	.13910	.05220	.01960	.00730
A015	213797.00	1.4030	.51170	.18660	.06810	.02480	.00910	.00330
A016	425656.00	7.2210	2.5970	.93460	.33620	.12100	.04350	.01560
A017	1038810.00	.18860	.05440	.01568	.00452	.00130	.00037	
A018	57471.00	.09810	.03680	.01380				
A020	257229.00	.08772	.02533	.00731	.00202	.00060		
A021	106067.00	.39590	.14440	.05270	.01920	.00700	.00256	.00093
A022	30107.00	.16080	.05860	.02140	.00780	.00280		
A023	184730.00	3.0880	1.3480	.58840	.25690	.11210	.04890	.02140
A025	14016.00	.00319	.00138	.00060	.00027	.00012	.00005	.00002

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