TABLE B-1

ATTENUATION MODELS UPDATED PER FEEDBACK OF 6/27/84

** BASE CASE - GENERIC SOIL ** FILE ATNFB

1 ** D13 ** (CAMPBELL, 1982) X1 NE&SE				0.0	999.0	8.1	
2.600	.777	.797	.012	.898	25.	-.0027	
2 ** D13 ** (CAMPBELL, 1982) X1 NC				0.0	999.0	8.1	
2.600	.777	.797	.012	.898	25.	-.0022	
3 ** D13 ** (CAMPBELL, 1982) X1 SC				0.0	999.0	8.1	
2.600	.777	.797	.012	.898	25.	-.0035	
4 ** D13 ** (CAMPBELL, 1982) X3 & X4				0.0	999.0	8.1	
2.600	.777	.797	.012	.898	0.0	-.0028	1.0
5 ** D21 ** (NUTTLI, 1983) X1 NE&SE				0.0	999.0	9.1	
3.892	1.313	.576	1.15	64.	-.0027	4.4	5.77
6 ** D21 ** (NUTTLI, 1983) X1 NC				0.0	999.0	9.1	
3.892	1.313	.576	1.15	64.	-.0022	4.4	5.77
7 ** D21 ** (NUTTLI, 1983) X1 SC				0.0	999.0	9.1	
3.892	1.313	.576	1.15	64.	-.0035	4.4	5.77
8 ** D21 ** (NUTTLI, 1983) X2,X3,X4				0.0	999.0	9.1	
3.892	1.313	.576	1.15	0.0	-.00281	4.4	999.
9 ** D22 ** (ATKINSON, 1984) X1 NE&SE				0.0	999.0	6.1	
4.126	.673	-.0015	100.0				
10 ** D22 ** (ATKINSON, 1984) X1 NC				0.0	999.0	6.1	
4.126	.673	-.0012	100.0				
11 ** D22 ** (ATKINSON, 1984) X1 SC				0.0	999.0	6.1	
4.126	.673	-.0019	100.0				
12 ** D22 ** (ATKINSON, 1984) X4				0.0	999.0	6.1	
4.126	.673	-.0028	100.0				
13 ** D22 ** (ATKINSON-BOORE,1984)X2,X3				0.0	999.0	7.1	
3.343	.673	-.0018	49.0	1.35	-2.77	2.760	70.
14 ** A3-G16 ** (TRIFUNAC) X2,X5				0.0	999.0	1.1	
1.950	0.0	0.0	.670	-.00074	-.780	0.0	0.0
15 ** A3-G41 ** (GUP-NUT,MURPHY-O'B) X4				15.0	999.0	1.1	
2.400	0.0	.550	.320	-.00035	-1.050	0.0	0.0
16 EQUATION *** A3 - G31 *** X2				15.0	999.0	1.1	
2.980	.0	-.130	.630	-.00069	-.740	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0

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17   EQUATION  ###  G53   ### X2                      0.0      999.0      2.1
   1.470    1.1[illegible]0     .0   -.00170     -.880        .0        .0       .0
      .0       .0      .0       .0        .0        .0        .0       .0
18   EQUATION  ### A1 - G16 ### X2                   10.0      999.0      1.1
   1.730       .0      .0     .670   -.00035     -.840        .0       .0
      .0       .0      .0       .0        .0        .0        .0       .0
19   EQUATION  ### A1 - G31 ### X2                   10.0      999.0      1.1
   2.770       .0   -.130     .630   -.00033   -.79000        .0       .0
      .0       .0      .0       .0        .0        .0        .0       .0
20   EQUATION  ### A1 - G41 ### X2                   10.0      999.0      1.1
   2.300       .0    .550     .320   -.00017    -1.080        .0       .0
      .0       .0      .0       .0        .0        .0        .0       .0
21   EQUATION  ### A3 - G41 ### X2                   15.0      999.0      1.1
   2.400       .0    .550     .320   -.00035    -1.050        .0       .0
      .0       .0      .0       .0        .0        .0        .0       .0
22   EQUATION  ### A4 - G16 ### X2                    0.0      999.0      1.1
  .04500       .0      .0     .670   -.00308     -.210        .0       .0
      .0       .0      .0       .0        .0        .0        .0       .0
23   EQUATION  ### A4 - G31 ### X2                    0.0      999.0      1.1
   1.[illegible]       .0   -.130     .630   -.00290     -.200        .0       .0
      .0       .0      .0       .0        .0        .0        .0       .0
24   EQUATION  ### A4 - G41 ### X2                    0.0      999.0      1.1
   1.490       .0    .550     .320   -.00147     -.780        .0       .0
      .0       .0      .0       .0        .0        .0        .0       .0
25   EQUATION  ### A5 - G16 ### X2                    0.0      999.0      1.1
    .110       .0      .0     .670   -.00268     -.450        .0       .0
      .0       .0      .0       .0        .0        .0        .0       .0
26   EQUATION  ### A5 - G31 ### X2                   00.0      999.0      1.1
   1.240       .0   -.130     .630   -.00252     -.420        .0       .0
      .0       .0      .0       .0        .0        .0        .0       .0
27   EQUATION  ### A5 - G41 ### X2                    0.0      999.0      1.1
   1.550       .0    .550     .320   -.00128     -.890        .0       .0
      .0       .0      .0       .0        .0        .0        .0       .0
28   EQUATION  ###  G52   ### X2                     15.0      999.0      5.1
   1.470       .0   1.200   -1.020        .0        .0        .0       .0
      .0       .0      .0       .0        .0        .0        .0       .0
29   EQUATION  ###  D14   ### X2                      0.0      999.0      1.1
   1.481    1.150      .0       .0   -.01360     -.833    .00172       .0
      .0       .0      .0       .0        .0        .0        .0       .0
30   EQUATION  ###  G51   ### X2                      0.0      999.0      2.1
   3.160    1.240      .0       .0    -1.240      25.0        .0       .0
      .0       .0      .0       .0        .0        .0        .0       .0
31   EQUATION  ### A5 - G22 ### X2                    0.0      999.0      1.1
   2.230       .0      .0     .510   -.00200     -.655        .0       .0
      .0       .0      .0       .0        .0        .0        .0       .0
32   EQUATION  ### A1 - G22 ### X2                   10.0      999.0      1.1
   3.474       .0      .0     .510   -.00027     -.950        .0       .0
      .0       .0      .0       .0        .0        .0        .0       .0
33   EQUATION  ### A4 - G22 ### X2                    0.0      999.0      1.1
   2.189       .0      .0     .510   -.00235     -.471        .0       .0
      .0       .0      .0       .0        .0        .0        .0       .0
34   EQUATION  ### A3 - G22 ### X2                   15.0      999.0      1.1
   3.642       .0      .0     .510   -.00056     -.910        .0       .0
      .0       .0      .0       .0        .0        .0        .0       .0
35 ** DV22 ** (ATKINSON,EQ.19-23) X2,X3               0.0      999.0      7.1
  -3.842    1.350   -.0007    25.0     1.350    -1.840    -4.501   70.

36 ** DV22 ** (ATKINSON,EQ.24) X1,X4                  0.0      999.0      6.1
  -2.950    1.350      .0    100.0
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37   EQUATION   *** A3 - GV12 *** X2                 15.0      999.0      1.1
      -.110        .0        .0        .670     -.00074      -.780        .0           .0
        .0         .0        .0         .0          .0          .0        .0           .0
38   EQUATION   *** A3 - GV31 *** X2                 15.0      999.0      1.1
      -.990        .0      .170        .510     -.00056      -.600        .0           .0
        .0         .0        .0         .0          .0          .0        .0           .0
39   EQUATION   ***  GV52  *** X2                     0.0      999.0      1.1
      -.924      .950        .0         .0      -.00230      -.765        .0           .0
        .0         .0        .0         .0          .0          .0        .0           .0
40   EQUATION   ***  DV21  *** X2                     0.0        4.4      3.1
     -3.110     1.150   -.00122       -.420       1.300     -4.370     1.000           .0
     -8.290     2.300   -.00122       -.420       2.100     -7.970     1.000           .0
41 *** DV21 ***  X3, X4                               0.0      999.0      9.1
     -3.110    -8.290     1.150       2.300          .0     -.00122      4.4   999.0

42 *** DV21 ***  X1, NE-SE                            0.0      999.0      9.1
     -3.110    -8.290     1.150       2.300          .0     -.00074      4.4   999.0

43 *** DV21 ***  X1, NC                               0.0      999.0      9.1
     -3.110    -8 290     1.150       2.300          .0     -.00060      4.4   999.0

44 *** DV21 ***  X1, SC                               0.0      999.0      9.1
     -3.110    -8.290     1.150       2.300          .0     -.00095      4.4   999.0

45   EQUATION   *** A1 - GV12 *** X2                 10.0      999.0      1.1
      -.330        .0        .0        .670     -.00035      -.840        .0           .0
        .0         .0        .0         .0          .0          .0        .0           .0
46   EQUATION   *** A1 - GV22 *** X2                 10.0      999.0      1.1
      -.970        .u        .0        .920     -.00048     -.1210        .0           .0
        .0         .0        .0         .0          .0          .0        .0           .0
47   EQUATION   *** A1 - GV31 *** X2                 10.0      999.0      1.1
      -.160        .0      .170        .510     -.00027      -.640        .0           .0
        .0         .0        .0         .0          .0          .0        .0           .0
48   EQUATION   *** A3 - GV22 *** X2                 15.0      999.0      1.1
 -    .670         .0        .0        .920     -.00101     -1.140        .0           .0
        .0         .0        .0         .0          .0          .0        .0           .0
49   EQUATION   *** A4 - GV12 *** X2                  0.0      999.0      1.1
     -2.020        .0        .0        .670     -.00310      -.210        .0          .9 )
        .0         .0        .0         .0          .0          .0        .0           .0
50   EQUATION   *** A4 - GV22 *** X2                  0.0      999.0      1.1
     -3.290        .0        .0        .920     -.00420      -.350        .0           .0
        .0         .0        .0         .0          .0          .0        .0           .0
51   EQUATION   *** A4 - GV31 *** X2                  0.0      999.0      1.1
     -2.440        .0      .170        .510     -.)0230      -.160        .0           .0
        .0         .0        .0         .0          .0          .0        .0           .0
52   EQUATION   *** A5 - GV12 *** X2                  0.0      999.0      1.1
     -1.950        .0        .0        .670     -.00270      -.45n        .0         .96n
        .0         .0        .0         .0          .0          .0        .0           .0
53   EQUATION   *** A5 - GV22 **  X2                  0.0      999.0      1.1
     -3.200        .0        .0        .920     -.00370      -.610        .0           .0
        .0         .0        .0         .0          .0          .0        .0           .0
54   EQUATION   *** A5 - GV31 *** X2                 00.0      999.0      1.1
 -    2.400        .0      .170        .510      .00200      -.340        .0           .0
        .0         .0        .0         .0          .0          .0        .0           .0
55   EQUATION   ***   GV51   *** X2                  15.0      999.0      1.1
     -6.720     2.300        .0         .0          .0     -1.000         .0           .0
        .0         .0        .0         .0          .0          .0        .0           .0
56   EQUATION   ***   DV12   *** X2                   0.0      999.0      1.1
   -7.86000     2.300        .0         .0      -.00760      -.840    .00099           .0
        .0         .0        .0         .0          .0          .0        .0           .0
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57 EQUATION *** GV53 *** X2				0.0	999.0	1.1	
-5.38000	1.700	.0	.0	-.00100	-.756	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0
58 ** SEP 1, FREQ 1 **			X2	15.0	999.0	1.1	
-4.33470	.0	.0	.88600	-.00410	.06100	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0
59 ** SEP 1, FREQ 2 **			X2	15.0	999.0	1.1	
-3.04800	.0	.0	.81600	-.00380	-.10000	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0
60 ** SEP 1, FREQ 3 **			X2	15.0	999.0	1.1	
-1.15400	.0	.0	.65000	-.00300	-.34600	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0
61 ** SEP 1, FREQ 4 **			X2	15.0	999.0	1.1	
-.76180	.0	.0	.62000	-.00280	-.43300	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0
62 ** SEP 1, FREQ 5 **			X2	15.0	999.0	1.1	
-.57730	.0	.0	.56[illegible]	-.00260	-.48700	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0
63 ** SEP 1, FREQ 6 **			X2	15.0	999.0	1.1	
-1.16040	.0	.0	.56000	-.00250	-.60500	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0
64 ** SEP 1, FREQ 7 **			X2	15.0	999.0	1.1	
-1.52400	.0	.0	.56000	-.00260	-.61200	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0
65 ** SEP 1, FREQ 8 **			X2	15.0	999.0	1.1	
-2.34400	.0	.0	.550	-.00250	-.56500	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0
66 ** SEP 1, FREQ 9 **			X2	15.0	999.0	1.1	
-2.70700	.0	.0	.550	-.00250	-.54200	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0
67 ** SEP 2, FREQ 1 **			X2	15.0	999.0	1.1	
-1.48500	.0	.0	.74000	-.00050	-.53600	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0
68 ** SEP 2, FREQ 2 **			X2	15.0	999.0	1.1	
-.60780	.0	.0	.71000	-.00060	-.63700	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0
69 ** SEP 2, FREQ 3 **			X2	15.0	999.0	1.1	
.58583	.0	.0	.57000	-.00070	-.71900	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0
70 ** SEP 2, FREQ 4 **			X2	15.0	999.0	1.1	
.59820	.0	.0	.57000	-.00070	-.76200	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0
71 ** SEP 2, FREQ 5 **			X2	15.0	999.0	1.1	
.39270	.0	.0	.52000	-.00070	-.740	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0
72 ** SEP 2, FFEQ 6 **			X2	15.0	999.0	1.1	
-.94000	.0	.0	.56000	-.00070	-.77500	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0
73 ** SEP 2, FREQ 7 **			X2	15.0	999.0	1.1	
- 1.320	.0	.0	.57000	-.00070	-.76800	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0
74 ** SEP 2, FREQ 8 **			X2	15.0	999.0	1.1	
- 2.100	.0	.0	.58000	-.00070	-.76100	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0
75 ** SEP 2, FREQ 9 **			X2	15.0	999.0	1.1	
-2.38000	.0	.0	.59000	-.00070	-.76000	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0
76 ** ATC, D21 ** FREQ 1, .5 HZ,			X4	0.0	4.4	3.1	
1.97955	.57600	-.00281	-.41700	1.30100	-4.37100	.0	.0
-.57045	1.150	-.00281	-.41700	2.100	-7.96800	.0	.0

```
77  ** ATC, D21 ** FREQ 2,  1.0 HZ,  X4        0.0        4.4       3.1
  2.09134   .57600   -.00281   -.41700   1.30100  -4.37100        .0        .0
  -.45866   1.150    -.00281   -.41700   2.100    -7.96800        .0        .0
78  ** ATC, D21 ** FREQ 3,  2.5 HZ,  X4        0.0        4.4       3.1
  2.05212   .57600   -.00281   -.41700   1.30100  -4.37100        .0        .0
  -.49788   1.150    -.00281   -.41700   2.100    -7.96800        .0        .0
79  ** ATC, D21 ** FREQ 4,  3.3 HZ,  X4        0.0        4.4       3.1
  1.77449   .57600   -.00281   -.41700   1.30100  -4.37100        .0        .0
  -.77551   1.150    -.00281   -.41700   2.100    -7.96800        .0        .0
80  ** ATC, D21 ** FREQ 5,  5.0 HZ,  X4        0.0        4.4       3.1
  1.35898   .57600   -.00281   -.41700   1.30100  -4.37100        .0        .0
 -1.19102   1.150    -.00281   -.41700   2.100    -7.96800        .0        .0
81  ** ATC, D21 ** FREQ 6, 10.0 HZ,  X4        0.0        4.4       3.1
   .43263   .57600   -.00281   -.41700   1.30100  -4.37100        .0        .0
 -2.11737   1.150    -.00281   -.41700   2.100    -7.96800        .0        .0
82  ** ATC, D21 ** FREQ 7, 12.5 HZ,  X4        0.0        4.4       3.1
   .10861   .57600   -.00281   -.41700   1.30100  -4.37100        .0        .0
 -2.44139   1.150    -.00281   -.41700   2.100    -7.96800        .0        .0
83  ** ATC, D21 ** FREQ 8, 20.0 HZ,  X4        0.0        4.4       3.1
  -.54483   .57600   -.00281   -.41700   1.30100  -4.37100        .0        .0
 -3.09483   1.150    -.00281   -.41700   2.100    -7.96800        .0        .0
84  ** ATC, D21 ** FREQ 9, 25.0 HZ,  X4        0.0        4.4       3.1
  -.83745   .57600   -.00281   -.41700   1.30100  -4.37100        .0        .0
 -3.38745   1.150    -.00281   -.41700   2.100    -7.96800        .0        .0
85  ** NRC, D21 **    FREQ 1,    .5 HZ,X4      0.0        4.4       3.1
  2.20656   .57600   -.00281   -.41700   1.30100  -4.37100        .0        .0
  -.34344  1.15000   -.00281   -.41700   2.10000  -7.96800        .0        .0
86  ** NRC, D21 **    FREQ 2,   1.0 HZ,X4      0.0        4.4       3.1
  2.10784   .57600   -.00281   -.41700   1.30100  -4.37100        .0        .0
  -.44216  1.15000   -.00281   -.41700   2.10000  -7.96800        .0        .0
87  ** NRC, D21 **    FREQ 3,   2.5 HZ,X4      0.0        4.4       3.1
  1.97740   .57600   -.00281   -.41700   1.30100  -4.37100        .0        .0
  -.57260  1.15000   -.00281   -.41700   2.10000  -7.96800        .0        .0
88  ** NRC, D21 **    FREQ 4,   3.3 HZ,X4      0.0        4.4       3.1
  1.66913   .57600   -.00281   -.41700   1.30100  -4.37100        .0        .0
  -.88087  1.15000   -.00281   -.41700   2.10000  -7.96800        .0        .0
89  ** NRC, D21 **    FREQ 5,   5.0 HZ,X4      0.0        4.4       3.1
  1.20815   .57600   -.00281   -.41700   1.30100  -4.37100        .0        .0
 -1.34185  1.15000   -.00281   -.41700   2.10000  -7.96800        .0        .0
90  ** NRC, D21 **    FREQ 6,  10.0 HZ,X4      0.0        4.4       3.1
   .39139   .57600   -.00281   -.41700   1.30100  -4.37100        .0        .0
 -2.15861  1.15000   -.00281   -.41700   2.10000  -7.96800        .0        .0
91  ** NRC, D21 **    FREQ 7,  12.5 HZ,X4      0.0        4.4       3.1
   .06872   .57600   -.00281   -.41700   1.30100  -4.37100        .0        .0
 -2.48128  1.15000   -.00281   -.41700   2.10000  -7.96800        .0        .0
92  ** NRC, D21 **    FREQ 8,  20.0 HZ,X4      0.0        4.4       3.1
  -.67358   .57600   -.00281   -.41700   1.30100  -4.37100        .0        .0
 -3.22358  1.15000   -.00281   -.41700   2.10000  -7.96800        .0        .0
93  ** NRC, D21 **    FREQ 9,  25.0 HZ,X4      0.0        4.4       3.1
 -1.01833   .57600   -.00281   -.41700   1.30100  -4.37100        .0        .0
 -3.56833  1.15000   -.00281   -.41700   2.10000  -7.96800        .0        .0
94 ** TRIF.-AND.,1977, FREQ 1 ** X2,X5          .0      999.0      10.1
     1.255      .350    -4.383       3.2    -.0011     -1.17     3.619    -2.383
       1.0  -5.743        .5
95 ** TRIF.-AND., 977, FREQ 2 ** X2,X5          .0      999.0      10.1
     1.047      .327    -3.813       3.2    -.0011     -1.17     3.769    -2.423
       1.0  -5.050
96 ** TRIF.-AND.,1977, FREQ 3 ** X2,X5          .0      999.0      10.1
     1.000      .284    -3.172       3.2    -.0011     -1.17     2.751    -1.209
       2.0  -4.134
```

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 97 ** TRIF.-AND.,1977, FREQ 4 ** X2,X5          .0      999.0      10.1
    1.030     .284     -3.199       3.2      -.0011      -1.17     2.652   -1.206
       2.0 -3.856
 98 ** TRIF.-AND.,1977, FREQ 5 ** X2,X5          .0      999.0      10.1
    1.100     .285     -3.257       3.2      -.0011      -1.17     2.629   -1.202
       2.0 -3.441
 99 ** TRIF.-AND.,1977, FREQ 6 ** X2,X5          .0      999.0      10.1
    1.150     .294     -3.485       3.2      -.0011      -1.17     2.568   -1.162
       2.0 -2.748
100 ** TRIF.-AND.,1977, FREQ 7 ** X2,X5          .0      999.0      10.1
    1.133     .298     -3.553       3.2      -.0011      -1.17     2.568   -1.155
       2.0 -2.524
101 ** TRIF.-AND.,1977, FREQ 8 ** X2,X5          .0      999.0      10.1
    1.078     .304     -3.634       3.2      -.0011      -1.17     2.591   -1.161
       2.0   -2.054
102 ** TRIF.-AND.,1977, FREQ 9 ** X2,X5          .0      999.0      10.1
    1.045     .307     -3.652       3.2      -.0011      -1.17     2.613   -1.170
       2.0 -1.831
103  ** ATC, G51 ** FREQ 1,   .5 HZ, X2         0.0      999.0       2.1
   1.24955    1.240        .0        .0      -1.240       25.0        .0        .0
  -1.91045       .0        .0        .0          .0         .0        .0        .0
104  ** ATC, G51 ** FREQ 2,  1.0 HZ, X2         0.0      999.0       2.1
   1.36134    1.240        .0        .0      -1.240       25.0        .0        .0
  -1.79866       .0        .0        .0          .0         .0        .0        .0
105  ** ATC, G51 ** FREQ 3,  2.5 HZ, X2         0.0      999.0       2.1
   1.32212    1.240        .0        .0      -1.240       25.0        .0        .0
  -1.83788       .0        .0        .0          .0         .0        .0        .0
106  ** ATC, G51 ** FREQ 4,  3.3 HZ, X2         0.0      999.0       2.1
   1.04449    1.240        .0        .0      -1.240       25.0        .0        .0
  -2.11551       .0        .0        .0          .0         .0        .0        .0
107  ** ATC, G51 ** FREQ 5,  5.0 HZ, X2         0.0      999.0       2.1
    .62898    1.240        .0        .0      -1.240       25.0        .0        .0
  -2.53102       .0        .0        .0          .0         .0        .0        .0
108  ** ATC, G51 ** FREQ 6, 10.0 HZ, X2         0.0      999.0       2.1
   -.29737    1.240        .0        .0      -1.240       25.0        .0        .0
  -3.45737       .0        .0        .0          .0         .0        .0        .0
109  ** ATC, G51 ** FREQ 7, 12.5 HZ, X2         0.0      999.0       2.1
   -.62139    1.240        .0        .0      -1.240       25.0        .0        .0
  -3.78139       .0        .0        .0          .0         .0        .0        .0
110  ** ATC, G51 ** FREQ 8, 20.0 HZ, X2         0.0      999.0       2.1
  -1.27483    1.240        .0        .0      -1.240       25.0        .0        .0
  -4.43483       .0        .0        .0          .0         .0        .0        .0
111  ** ATC, G51 ** FREQ 9, 25.0 HZ, X2         0.0      999.0       2.1
  -1.56745    1.240        .0        .0      -1.240       25.0        .0        .0
  -4.72745       .0        .0        .0          .0         .0        .0        .0
112  ** ATC, G52 ** FREQ 1,   .5 HZ,  X2       15.0      999.0       5.1
   -.44045       .0     1.200    -1.020          .0         .0        .0        .0
  -1.91045       .0        .0        .0          .0         .0        .0        .0
113  ** ATC, G52 ** FREQ 2,  1.0 HZ,  X2       15.0      999.0       5.1
   -.32866       .0     1.200    -1.020          .0         .0        .0        .0
  -1.79866       .0        .0        .0          .0         .0        .0        .0
114  ** ATC, G52 ** FREQ 3,  2.5 HZ,  X2       15.0      999.0       5.1
   -.36788       .0     1.200    -1.020          .0         .0        .0        .0
  -1.83788       .0        .0        .0          .0         .0        .0        .0
115  ** ATC, G52 ** FREQ 4,  3.3 HZ,  X2       15.0      999.0       5.1
   -.64551       .0     1.200    -1.020          .0         .0        .0        .0
  -2.11551       .0        .0        .0          .0         .0        .0        .0
116  ** ATC, G52 ** FREQ 5,  5.0 HZ,  X2       15.0      999.0       5.1
  -1.06102       .0     1.200    -1.020          .0         .0        .0        .0
  -2.53102       .0        .0        .0          .0         .0        .0        .0
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117 ** ATC, G52 **	FREQ 6,	10.0 HZ,	X2	15.0	999.0	5.1	
-1.98737	.0	1.200	-1.020	.0	.0	.0	.0
-3.45737	.0	.0	.0	.0	.0	.0	.0
118 ** ATC, G52 **	FREQ 7,	12.5 HZ,	X2	15.0	999.0	5.1	
-2.31139	.0	1.200	-1.020	.0	.0	.0	.0
-3.78139	.0	.0	.0	.0	.0	.0	.0
119 ** ATC, G52 **	FREQ 8,	20.0 HZ,	X2	15.0	999.0	5.1	
-2.96483	.0	1.200	-1.020	.0	.0	.0	.0
-4.43483	.0	.0	.0	.0	.0	.0	.0
120 ** ATC, G52 **	FREQ 9,	25.0 HZ,	X2	15.0	999.0	5.1	
-3.25745	.0	1.200	-1.020	.0	.0	.0	.0
-4.72745	.0	.0	.0	.0	.0	.0	.0
121 ** ATC, G53 **	FREQ 1,	.5 HZ,	X2	0.0	999.0	2.1	
-.44045	1.100	.0	-.00170	-.880	.0	.0	.0
-1.91045	.0	.0	.0	.0	.0	.0	.0
122 ** ATC, G53 **	FREQ 2,	1.0 HZ,	X2	0.0	999.0	2.1	
-.32866	1.100	.0	-.00170	-.880	.0	.0	.0
-1.79866	.0	.0	.0	.0	.0	.0	.0
123 ** ATC, G53 **	FREQ 3,	2.5 HZ,	X2	0.0	999.0	2.1	
-.36788	1.100	.0	-.00170	-.880	.0	.0	.0
-1.83788	.0	.0	.0	.0	.0	.0	.0
124 ** ATC, G53 **	FREQ 4,	3.3 HZ,	X2	0.0	999.0	2.1	
-.64551	1.100	.0	-.00170	-.880	.0	.0	.0
-2.11551	.0	.0	.0	.0	.0	.0	.0
125 ** ATC, G53 **	FREQ 5,	5.0 HZ,	X2	0.0	999.0	2.1	
-1.06102	1.100	.0	-.00170	-.880	.0	.0	.0
-2.53102	.0	.0	.0	.0	.0	.0	.0
126 ** ATC, G53 **	FREQ 6,	10.0 HZ,	X2	0.0	999.0	2.1	
-1.98737	1.100	.0	-.00170	-.880	.0	.0	.0
-3.45737	.0	.0	.0	.0	.0	.0	.0
127 ** ATC, G53 **	FREQ 7,	12.5 HZ,	X2	0.0	999.0	2.1	
-2.31139	1.100	.0	-.00170	-.880	.0	.0	.0
-3.78139	.0	.0	.0	.0	.0	.0	.0
128 ** ATC, G53 **	FREQ 8,	20.0 HZ,	X2	0.0	999.0	2.1	
-2.96483	1.100	.0	-.00170	-.880	.0	.0	.0
-4.43483	.0	.0	.0	.0	.0	.0	.0
129 ** ATC, G53 **	FREQ 9,	25.0 HZ,	X2	0.0	999.0	2.1	
-3.25745	1.100	.0	-.00170	-.880	.0	.0	.0
-4.72745	.0	.0	.0	.0	.0	.0	.0
130 ** NRC, G51 **	FREQ 1,	.5 HZ.	X2	0.0	999.0	2.1	
1.47656	1.240	.0	.0	-1.240	25.0	.0	.0
-1.68344	.0	.0	.0	.0	.0	.0	.0
131 ** NRC, G51 **	FREQ 2,	1.0 HZ,	X2	0.0	999.0	2.1	
1.37784	1.240	.0	.0	-1.240	25.0	.0	.0
-1.78216	.0	.0	.0	.0	.0	.0	.0
132 ** NRC, G51 **	FREQ 3,	2.5 HZ,	X2	0.0	999.0	2.1	
1.24740	1.240	.0	.0	-1.240	25.0	.0	.0
-1.91260	.0	.0	.0	.0	.0	.0	.0
133 ** NRC, G51 **	FREQ 4,	3.3 hZ,	X2	0.0	999.0	2.1	
.93913	1.240	.0	.0	-1.240	25.0	.0	.0
-2.22087	.0	.0	.0	.0	.0	.0	.0
134 ** NRC, G51 **	FREQ 5,	5.0 HZ,	X2	0.0	999.0	2.1	
.47815	1.240	.0	.0	-1.240	25.0	.0	.0
-2.68185	.0	.0	.0	.0	.0	.0	.0
135 ** NRC, G51 **	FREQ 6,	10.0 HZ,	X2	0.0	999.0	2.1	
-.33861	1.240	.0	.0	-1.240	25.0	.0	.0
-3.49861	.0	.0	.0	.0	.0	.0	.0
136 ** NRC, G51 **	FREQ 7,	12.5 HZ,	X2	0.0	999.0	2.1	
-.66128	1.240	.0	.0	-1.240	25.0	.0	.0
-3.82128	.0	.0	.0	.0	.0	.0	.0

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137  ** NRC, G51 ** FREQ 8, 20.0 HZ,  X2       0.0     999.0      2.1
  -1.40358   1.240      .0      .0   -1.240     25.0       .0       .0
  -4.56358     .0       .0      .0      .0       .0        .0       .0
138  ** NRC, G51 ** FREQ 9, 25.0 HZ,  X2       0.0     999.0      2.1
  -1.74833   1.240      .0      .0   -1.240     25.0       .0       .0
  -4.90833     .0       .0      .0      .0       .0        .0       .0
139  ** NRC, G52 ** FREQ 1,   .5 HZ,  X2      15.0     999.0      5.1
   -.21344     .0    1.200  -1.020      .0       .0        .0       .0
  -1.68344     .0       .0      .0      .0       .0        .0       .0
140  ** NRC, G52 ** FREQ 2,  1.0 HZ,  X2      15.0     999.0      5.1
   -.31216     .0    1.200  -1.020      .0       .0        .0       .0
  -1.78216     .0       .0      .0      .0       .0        .0       .0
141  ** NRC, G52 ** FREQ 3,  2.5 HZ,  X2      15.0     999.0      5.1
   -.44260     .0    1.200  -1.020      .0       .0        .0       .0
  -1.91260     .0       .0      .0      .0       .0        .0       .0
142  ** NRC, G52 ** FREQ 4,  3.3 HZ,  X2      15.0     999.0      5.1
   -.75087     .0    1.200  -1.020      .0       .0        .0       .0
  -2.22087     .0       .0      .0      .0       .0        .0       .0
143  ** NRC, G52 ** FREQ 5,  5.0 HZ,  X2      15.0     999.0      5.1
  -1.21185     .0    1.200  -1.020      .0       .0        .0       .0
  -2.68185     .0       .0      .0      .0       .0        .0       .0
144  ** NRC, G52 ** FREQ 6, 10.0 HZ,  X2      15.0     999.0      5.1
  -2.02861     .0    1.200  -1.020      .0       .0        .0       .0
  -3.49861     .0       .0      .0      .0       .0        .0       .0
145  ** NRC, G52 ** FREQ 7, 12.5 HZ,  X2      15.0     999.0      5.1
  -2.35128     .0    1.200  -1.020      .0       .0        .0       .0
  -3.82128     .0       .0      .0      .0       .0        .0       .0
146  ** NRC, G52 ** FREQ 8, 20.0 HZ,  X2      15.0     999.0      5.1
  -3.09358     .0    1.200  -1.020      .0       .0        .0       .0
  -4.56358     .0       .0      .0      .0       .0        .0       .0
147  ** NRC, G52 ** FREQ 9, 25.0 HZ,  X2      15.0     999.0      5.1
  -3.43833     .0    1.200  -1.020      .0       .0        .0       .0
  -4.90833     .0       .0      .0      .0       .0        .0       .0
148  ** NRC, G53 ** FREQ 1,   .5 HZ,  X2       0.0     999.0      2.1
   -.21344   1.100      .0  -.00170    -.880      .0        .0       .0
  -1.68344     .0       .0      .0      .0       .0        .0       .0
149  ** NRC, G53 ** FREQ 2,  1.0 HZ,  X2       0.0     999.0      2.1
   -.31216   1.100      .0  -.00170    -.880      .0        .0       .0
  -1.78216     .0       .0      .0      .0       .0        .0       .0
150  ** NRC, G53 ** FREQ 3,  2.5 HZ,  X2       0.0     999.0      2.1
   -.44260   1.100      .0  -.00170    -.880      .0        .0       .0
  -1.91260     .0       .0      .0      .0       .0        .0       .0
151  ** NRC, G53 ** FREQ 4,  3.3 HZ,  X2       0.0     999.0      2.1
   -.75087   1.100      .0  -.00170    -.880      .0        .0       .0
  -2.22087     .0       .0      .0      .0       .0        .0       .0
152  ** NRC, G53 ** FREQ 5,  5.0 HZ,  X2       0.0     999.0      2.1
  -1.21185   1.100      .0  -.00170    -.880      .0        .0       .0
  -2.68185     .0       .0      .0      .0       .0        .0       .0
153  ** NRC, G53 ** FREQ 6, 10.0 HZ,  X2       0.0     999.0      2.1
  -2.02861   1.100      .0  -.00170    -.880      .0        .0       .0
  -3.49861     .0       .0      .0      .0       .0        .0       .0
154  ** NRC, G53 ** FREQ 7, 12.5 HZ,  X2       0.0     999.0      2.1
  -2.35128   1.100      .0  -.00170    -.880      .0        .0       .0
  -3.82128     .0       .0      .0      .0       .0        .0       .0
155  ** NRC, G53 ** FREQ 8, 20.0 HZ,  X2       0.0     999.0      2.1
  -3.09358   1.100      .0  -.00170    -.880      .0        .0       .0
  -4.56358     .0       .0      .0      .0       .0        .0       .0
156  ** NRC, G53 ** FREQ 9, 25.0 HZ,  X2       0.0     999.0      2.1
  -3.43833   1.100      .0  -.00170    -.880      .0        .0       .0
  -4.90833     .0       .0      .0      .0       .0        .0       .0
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157 ** NWK, G51-GV51 **		FREQ 1, X2		15.0	2000.0	2.1	1.1
-6.21922	2.300	.0	.0	.0	-1.000	.0	.0
2.76669	1.240	.0	.0	-1.240	25.0	.0	.0
158 ** NWK, G51-GV51 **		FREQ 2, X2		15.0	2000.0	2.1	1.1
-6.21922	2.300	.0	.0	.0	-1.000	.0	.0
2.07354	1.240	.0	.0	-1.240	25.0	.0	.0
159 ** NWK, G51-GV51 **		FREQ 3, X2		15.0	2000.0	2.1	1.1
-6.21922	2.300	.0	.0	.0	-1.000	.0	.0
1.15725	1.240	.0	.0	-1.240	25.0	.0	.0
160 ** NWK, G51-GV51 **		FREQ 4, X2		15.0	2000.0	2.1	1.1
-6.21922	2.300	.0	.0	.0	-1.000	.0	.0
.87962	1.240	.0	.0	-1.240	25.0	.0	.0
161 ** NWK, G51-GV51 **		FREQ 5, X2		15.0	2000.0	2.1	1.1
-6.21922	2.300	.0	.0	.0	-1.000	.0	.0
.46410	1.240	.0	.0	-1.240	25.0	.0	.0
162 ** NWK, G51-GV51 **		FREQ 6, X2		15.0	2000.0	2.1	1.1
-6.21922	2.300	.0	.0	.0	-1.000	.0	.0
-.34737	1.240	.0	.0	-1.240	25.0	.0	.0
163 ** NWK, G51-GV51 **		FREQ 7, X2		15.0	2000.0	2.1	1.1
-6.21922	2.300	.0	.0	.0	-1.000	.0	.0
-.68884	1.240	.0	.0	-1.240	25.0	.0	.0
164 ** NWK, G51-GV51 **		FREQ 8, X2		15.0	2000.0	2.1	1.1
-6.21922	2.300	.0	.0	.0	-1.000	.0	.0
-1.40807	1.240	.0	.0	-1.240	25.0	.0	.0
165 ** NWK, G51-GV51 **		FREQ 9, X2		15.0	2000.0	2.1	1.1
-6.21922	2.300	.0	.0	.0	-1.000	.0	.0
-1.74954	1.240	.0	.0	-1.240	25.0	.0	.0
166 ** NWK, G52-GV52 **		FREQ 1, X2		0.0	2000.0	5.1	1.1
-.42322	.950	.0	.0	-.00230	-.765	.0	.0
1.07669	.0	1.200	-1.020	.0	.0	.0	.0
167 ** NWK, G52-GV52 **		FREQ 2, X2		0.0	2000.0	5.1	1.1
-.42322	.950	.0	.0	-.00230	-.765	.0	.0
.38354	.0	1.200	-1.020	.0	.0	.0	.0
168 ** NWK, G52-GV52 **		FREQ 3, X2		0.0	2000.0	5.1	1.1
-.42322	.950	.0	.0	-.00230	-.765	.0	.0
-.53275	.0	1.200	-1.020	.0	.0	.0	.0
169 ** NWK, G52-GV52 **		FREQ 4, X2		0.0	2000.0	5.1	1.1
-.42322	.950	.0	.0	-.00230	-.765	.0	.0
-.81038	.0	1.200	-1.020	.0	.0	.0	.0
170 ** NWK, G52-GV52 **		FREQ 5, X2		0.0	2000.0	5.1	1.1
-.42322	.950	.0	.0	-.00230	-.765	.0	.0
-1.22590	.0	1.200	-1.020	.0	.0	.0	.0
171 ** NWK, G52-GV52 **		FREQ 6, X2		0.0	2000.0	5.1	1.1
-.42322	.950	.0	.0	-.00230	-.765	.0	.0
-2.03737	.0	1.200	-1.020	.0	.0	.0	.0
172 ** NWK, G52-GV52 **		FREQ 7, X2		0.0	2000.0	5.1	1.1
-.42322	.950	.0	.0	-.00230	-.765	.0	.0
-2.37884	.0	1.200	-1.020	.0	.0	.0	.0
173 ** NWK, G52-GV52 **		FREQ 8, X2		0.0	2000.0	5.1	1.1
-.42322	.950	.0	.0	-.00230	-.765	.0	.0
-3.09807	.0	1.200	-1.020	.0	.0	.0	.0
174 ** NWK, G52-GV52 **		FREQ 9, X2		0.0	2000.0	5.1	1.1
-.42322	.950	.0	.0	-.00230	-.765	.0	.0
-3.43954	.0	1.200	-1.020	.0	.0	.0	.0
175 ** NWK, G53-GV53 **		FREQ 1, X2		0.0	2000.0	2.1	1.1
-4.87922	1.700	.0	.0	-.00100	-.756	.0	.0
1.07669	1.100	.0	-.00170	-.880	.0	.0	.0
176 ** NWK, G53-GV53 **		FREQ 2, X2		0.0	2000.0	2.1	1.1
-4.87922	1.700	.0	.0	-.00100	-.756	.0	.0
.38354	1.100	.0	-.00170	-.880	.0	.0	.0

177 ** NWK, G53-GV53 ** FREQ 3, X2				0.0	2000.0	2.1		1.1
-4.87922	1.700	.0	.0	-.00100	-.756	.0		.0
-.53275	1.100	.0	-.00170	-.880	.0	.0		.0
178 ** NWK, G53-GV53 ** FREQ 4, X2				0.0	2000.0	2.1		1.1
-4.87922	1.700	.0	.0	-.00100	-.756	.0		.0
-.81038	1.100	.0	-.00170	-.880	.0	.0		.0
179 ** NWK, G53-GV53 ** FREQ 5, X2				0.0	2000.0	2.1		1.1
-4.87922	1.700	.0	.0	-.00100	-.756	.0		.0
-1.22590	1.100	.0	-.00170	-.880	.0	.0		.0
180 ** NWK, G53-GV53 ** FREQ 6, X2				0.0	2000.0	2.1		1.1
-4.87922	1.700	.0	.0	-.00100	-.756	.0		.0
-2.03737	1.100	.0	-.00170	-.880	.0	.0		.0
181 ** NWK, G53-GV53 ** FREQ 7, X2				0.0	2000.0	2.1		1.1
-4.87922	1.700	.0	.0	-.00100	-.756	.0		.0
-2.37884	1.100	.0	-.00170	-.880	.0	.0		.0
182 ** NWK, G53-GV53 ** FREQ 8, X2				0.0	2000.0	2.1		1.1
-4.87922	1.700	.0	.0	-.00100	-.756	.0		.0
-3.09807	1.100	.0	-.00170	-.880	.0	.0		.0
183 ** NWK, G53-GV53 ** FREQ 9, X2				0.0	2000.0	2.1		1.1
-4.87922	1.700	.0	.0	-.00100	-.756	.0		.0
-3.43954	1.100	.0	-.00170	-.880	.0	.0		.0
184 ** NWK, D21/DV21 ** FREQ 1, X3,X4				0.0	2000.	9.1	9.1	
-2.609	-7.789	1.150	2.300	.0	-.00122	4.4		2000.
3.499	.920	.576	1.15	0.0	-.0028	4.4		999.
185 ** NWK, D21/DV21 ** FREQ 2, X3,X4				0.0	2000.	9.1	9.1	
-2.609	-7.789	1.150	2.300	.0	-.00122	4.4		2000.
2.806	.227	.576	1.15	0.0	-.0028	4.4		999.
186 ** NWK, D21/DV21 ** FREQ 3, X3,X4				0.0	2000.	9.1	9.1	
-2.609	-7.789	1.150	2.300	.0	-.00122	4.4		2000.
1.889	-.690	.576	1.15	0.0	-.0028	4.4		999.
187 ** NWK, D21/DV21 ** FREQ 4, X3,X4				0.0	2000.	9.1	9.1	
-2.609	-7.789	1.150	2.300	.0	-.00122	4.4		2000.
1.612	-.967	.576	1.15	0.0	-.0028	4.4		999.
188 ** NWK, D21/DV21 ** FREQ 5, X3,X4				0.0	2000.	9.1	9.1	
-2.609	-7.789	1.150	2.300	.0	-.00122	4.4		2000.
1.196	-1.383	.576	1.15	0.0	-.0028	4.4		999.
189 ** NWK, D21/DV21 ** FREQ 6, X3,X4				0.0	2000.	9.1	9.1	
-2.609	-7.789	1.150	2.300	.0	-.00122	4.4		2000.
.385	-2.194	.576	1.15	0.0	-.0028	4.4		999.
190 ** NWK, D21/DV21 ** FREQ 7, X3,X4				0.0	2000.	9.1	9.1	
-2.609	-7.789	1.150	2.300	.0	-.00122	4.4		2000.
.043	-2.536	.576	1.15	0.0	-.0028	4.4		999.
191 ** NWK, D21/DV21 ** FREQ 8, X3,X4				0.0	2000.	9.1	9.1	
-2.609	-7.789	1.150	2.300	.0	-.00122	4.4		2000.
-.676	-3.255	.576	1.15	0.0	-.0028	4.4		999.
192 ** NWK, D21/DV21 ** FREQ 9, X3,X4				0.0	2000.	9.1	9.1	
-2.609	-7.789	1.150	2.300	.0	-.00122	4.4		2000.
-1.018	-3.597	.576	1.15	0.0	-.0028	4.4		999.
193 ** NWK, D21/DV21 ** FREQ 1, X1,NE-SE				0.0	2000.	9.1	9.1	
-2.609	-7.789	1.150	2.300	.0	-.00074	4.4		2000.
3.499	.920	.576	1.15	64.	-.0027	4.4		5.77
194 ** NWK, D21/DV21 ** FREQ 2, X1,NE-SE				0.0	2000.	9.1	9.1	
-2.609	-7.789	1.150	2.300	.0	-.00074	4.4		2000.
2.806	.227	.576	1.15	64.	-.0027	4.4		5.77
195 ** NWK, D21/DV21 ** FREQ 3, X1,NE-SE				0.0	2000.	9.1	9.1	
-2.609	-7.789	1.150	2.300	.0	-.00074	4.4		2000.
1.889	-.690	.576	1.15	64.	-.0027	4.4		5.77
196 ** NWK, D21/DV21 ** FREQ 4, X1,NE-SE				0.0	2000.	9.1	9.1	
-2.609	-7.789	1.150	2.300	.0	-.00074	4.4		2000.
1.612	-.967	.576	1.15	64.	-.0027	4.4		5.77

197 ** NWK,	D21/DV21 **	FREQ 5,	X1,NE-SE	0.0	2000.	9.1	9.1	
	-2.609	-7.789	1.150	2.300	.0	-.00074	4.4	2000.
	1.196	-1.383	.576	1.15	64.	-.0027	4.4	5.77
198 ** NWK,	D21/DV21 **	FREQ 6,	X1,NE-SE	0.0	2000.	9.1	9.1	
	-2.609	-7.789	1.150	2.300	.0	-.00074	4.4	2000.
	.385	-2.194	.576	1.15	64.	-.0027	4.4	5.77
199 ** NWK,	D21/DV21 **	FREQ 7,	X1,NE-SE	0.0	2000.	9.1	9.1	
	-2.609	-7.789	1.150	2.300	.0	-.00074	4.4	2000.
	.043	-2.536	.576	1.15	64.	-.0027	4.4	5.77
200 ** NWK,	D21/DV21 **	FREQ 8,	X1,NE-SE	0.0	2000.	9.1	9.1	
	-2.609	-7.789	1.150	2.300	.0	-.00074	4.4	2000.
	-.676	-3.255	.576	1.15	64.	-.0027	4.4	5.77
201 ** NWK,	D21/DV21 **	FREQ 9,	X1,NE-SE	0.0	2000.	9.1	9.1	
	-2.609	-7.789	1.150	2.300	.0	-.00074	4.4	2000.
	-1.018	-3.597	.576	1.15	64.	-.0027	4.4	5.77
202 ** NWK,	D21/DV21 **	FREQ 1,	X1,NC	0.0	2000.	9.1	9.1	
	-2.609	-7.789	1.150	2.300	.0	-.00060	4.4	2000.
	3.499	.920	.576	1.15	64.	-.0022	4.4	5.77
203 ** NWK,	D21/DV21 **	FREQ 2,	X1,NC	0.0	2000.	9.1	9.1	
	-2.609	-7.789	1.150	2.300	.0	-.00060	4.4	2000.
	2.806	.227	.576	1.15	64.	-.0022	4.4	5.77
204 ** NWK,	D21/DV21 **	FREQ 3,	X1,NC	0.0	2000.	9.1	9.1	
	-2.609	-7.789	1.150	2.300	.0	-.00060	4.4	2000.
	1.889	-.690	.576	1.15	64.	-.0022	4.4	5.77
205 ** NWK,	D21/DV21 **	FREQ 4,	X1,NC	0.0	2000.	9.1	9.1	
	-2.609	-7.789	1.150	2.300	.0	-.00060	4.4	2000.
	1.612	-.967	.576	1.15	64.	-.0022	4.4	5.77
206 ** NWK,	D21/DV21 **	FREQ 5,	X1,NC	0.0	2000.	9.1	9.1	
	-2.609	-7.789	1.150	2.300	.0	-.00060	4.4	2000.
	1.196	-1.383	.576	1.15	64.	-.0022	4.4	5.77
207 ** NWK,	D21/DV21 **	FREQ 6,	X1,NC	0.0	2000.	9.1	9.1	
	-2.609	-7.789	1.150	2.300	.0	-.00060	4.4	2000.
	.385	-2.194	.576	1.15	64.	-.0022	4.4	5.77
208 ** NWK,	D21/DV21 **	FREQ 7,	X1,NC	0.0	2000.	9.1	9.1	
	-2.609	-7.789	1.150	2.300	.0	-.00060	4.4	2000.
	.043	-2.536	.576	1.15	64.	-.0022	4.4	5.77
209 ** NWK,	D21/DV21 **	FREQ 8,	X1,NC	0.0	2000.	9.1	9.1	
	-2.609	-7.789	1.150	2.300	.0	-.00060	4.4	2000.
	-.676	-3.255	.576	1.15	64.	-.0022	4.4	5.77
210 ** NWK,	D21/DV21 **	FREQ 9,	X1,NC	0.0	2000.	9.1	9.1	
	-2.609	-7.789	1.150	2.300	.0	-.00060	4.4	2000.
	-1.018	-3.597	.576	1.15	64.	-.0022	4.4	5.77
211 ** NWK,	D21/DV21 **	FREQ 1,	X1,SC	0.0	2000.	9.1	9.1	
	-2.609	-7.789	1.150	2.300	.0	-.00095	4.4	2000.
	3.499	.920	.576	1.15	64.	-.0035	4.4	5.77
212 ** NWK,	D21/DV21 **	FREQ 2,	X1,SC	0.0	2000.	9.1	9.1	
	-2.609	-7.789	1.150	2.300	.0	-.00095	4.4	2000.
	2.806	.227	.576	1.15	64.	-.0035	4.4	5.77
213 ** NWK,	D21/DV21 **	FREQ 3,	X1,SC	0.0	2000.	9.1	9.1	
	-2.609	-7.789	1.150	2.300	.0	-.00095	4.4	2000.
	1.889	-.690	.576	1.15	64.	-.0035	4.4	5.77
214 ** NWK,	D21/DV21 **	FREQ 4,	X1,SC	0.0	2000.	9.1	9.1	
	-2.609	-7.789	1.150	2.300	.0	-.00095	4.4	2000.
	1.612	-.967	.576	1.15	64.	-.0035	4.4	5.77
215 ** NWK,	D21/DV21 **	FREQ 5,	X1,SC	0.0	2000.	9.1	9.1	
	-2.609	-7.789	1.150	2.300	.0	-.00095	4.4	2000.
	1.196	-1.383	.576	1.15	64.	-.0035	4.4	5.77
216 ** NWK,	D21/DV21 **	FREQ 6,	X1,SC	0.0	2000.	9.1	9.1	
	-2.609	-7.789	1.150	2.300	.0	-.00095	4.4	2000.
	.385	-2.194	.576	1.15	64.	-.0035	4.4	5.77

217	** NWK,	D21/DV21	** FREQ 7,	X1,SC	0.0	2000.	9.1	9.1	
	-2.609	-7.789	1.150	2.300	.0	-.00095	4.4		2000.
	.043	-2.536	.576	1.15	64.	-.0035	4.4		5.77
218	** NWK,	D21/DV21	** FREQ 8,	X1,SC	0.0	2000.	9.1	9.1	
	-2.609	-7.789	1.150	2.300	.0	-.00095	4.4		2000.
	-.676	-3.255	.576	1.15	64.	-.0035	4.4		5.77
219	** NWK,	D21/DV21	** FREQ 9,	X1,SC	0.0	2000.	9.1	9.1	
	-2.609	-7.789	1.150	2.300	.0	-.00095	4.4		2000.
	-1.018	-3.597	.576	1.15	64.	-.0035	4.4		5.77
220	** NWK,	D22/DV22	** FREQ 1,	X1,NE-SE	0.0	2000.	6.1	6.1	
	-2.449	1.350	.0	100.0					
	3.733	.673	-.0015	100.0					
221	** NWK,	D22/DV22	** FREQ 2,	X1,NE-SE	0.0	2000.	6.1	6.1	
	-2.449	1.350	.0	100.0					
	3.040	.673	-.0015	100.0					
222	** NWK,	D2[illegible]/DV22	** FREQ 3,	X1,NE-SE	0.0	2000.	6.1	6.1	
	-2.449	1.350	.0	100.0					
	2.123	.673	-.0015	100.0					
223	** NWK,	D2[illegible]DV22	** FREQ 4,	X1,NE-SE	0.0	2000.	6.1	6.1	
	-2.449	[illegible].350	.0	100.0					
	1.846	.673	-.0015	100.0					
224	** NWK,	D22/DV22	** FREQ 5,	X1,NE-SE	0.0	2000.	6.1	6.1	
	-2.449	1.350	.0	100.0					
	1.430	.673	-.0015	100.0					
225	** NWK,	D22/DV22	** FREQ 6,	X1,NE-SE	0.0	2000.	6.1	6.1	
	-2.449	1.350	.0	100.0					
	.619	.673	-.0015	100.0					
226	** NWK,	D22/DV22	** FREQ 7,	X1,NE-SE	0.0	2000.	6.1	6.1	
	-2.449	1.350	.0	100.0					
	.277	.673	-.0015	100.0					
227	** NWK,	D22/DV22	** FREQ 8,	X1,NE-SE	0.0	2000.	6.1	6.1	
	-2.449	1.350	.0	100.0					
	-.442	.673	-.0015	100.0					
228	** NWK,	D22/DV22	** FREQ 9,	X1,NE-SE	0.0	2000.	6.1	6.1	
	-2.449	1.350	.0	100.0					
	-.784	.673	-.0015	100.0					
229	** NWK,	D22/DV22	** FREQ 1,	X1,NC	0.0	2000.	6.1	6.1	
	-2.449	1.350	.0	100.0					
	3.733	.673	-.0012	100.0					
230	** NWK,	D22/DV22	** FREQ 2,	X1,NC	0.0	2000.	6.1	6.1	
	-2.449	1.350	.0	100.0					
	3.040	.673	-.0012	100.0					
231	** NW[illegible],	D22/DV22	** FREQ 3,	X1,NC	0.0	2000.	6.1	6.1	
	-2.44[illegible]	1.350	.0	100.0					
	2.123	.673	-.0012	100.0					
232	** NWK,	D22/DV22	** FREQ 4,	X1,NC	0.0	2000.	6.1	6.1	
	-2.449	1.350	.0	100.0					
	1.846	.673	-.0012	100.0					
233	** NWK,	D22/DV22	** FREQ 5,	X1,NC	0.0	2000.	6.1	6.1	
	-2.449	1.350	.0	100.0					
	1.430	.673	-.0012	100.0					
234	** NWK,	D22/DV22	** FREQ 6,	X1,NC	0.0	2000.	6.1	6.1	
	-2.449	1.350	.0	100.0					
	.619	.673	-.0012	100.0					
235	** NWK,	D22/DV22	** FREQ 7,	X1,NC	0.0	2000.	6.1	6.1	
	-2.449	1.350	.0	100.0					
	.277	.673	-.0012	100.0					
236	** NWK,	D22/DV22	** FREQ 8,	X1,NC	0.0	2000.	6.1	6.1	
	-2.449	1.350	.0	100.0					
	-.442	.673	-.0012	100.0					

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237 ** NWK, D22/DV22 ** FREQ 9, X1,NC              0.0      2000.        6.1   6.1
     -2.449      1.350          .0      100.0
      -.784       .673      -.0012      100.0
238 ** NWK, D22/DV22 ** FREQ 1, X1,SC              0.0      2000.        6.1   6.1
     -2.449      1.350          .0      100.0
      3.733       .673      -.0019      100.0
239 ** NWK, D22/DV22 ** FREQ 2, X1,SC              0.0      2000.        6.1   6.1
     -2.449      1.350          .0      100.0
      3.040       .673      -.0019      100.0
240 ** NWK, D22/DV22 ** FREQ 3, X1,SC              0.0      2000.        6.1   6.1
     -2.449      1.350          .0      100.0
      2.123       .673      -.0019      100.0
241 ** NWK, D22/DV22 ** FREQ 4, X1,SC              0.0      2000.        6.1   6.1
     -2.449      1.350          .0      100.0
      1.846       .673      -.0019      100.0
242 ** NWK, D22/DV22 ** FREQ 5, X1,SC              0.0      2000.        6.1   6.1
     -2.449      1.350          .0      100.0
      1.430       .673      -.0019      100.0
243 ** NWK, D22/DV22 ** FREQ 6, X1,SC              0.0      2000.        6.1   6.1
     -2.449      1.350          .0      100.0
       .619       .673      -.0019      100.0
244 ** NWK, D22/DV22 ** FREQ 7, X1,SC              0.0      2000.        6.1   6.1
     -2.449      1.350          .0      100.0
       .277       .673      -.0019      100.0
245 ** NWK, D22/DV22 ** FREQ 8, X1,SC              0.0      2000.        6.1   6.1
     -2.449      1.350          .0      100.0
      -.442       .673      -.0019      100.0
246 ** NWK, D22/DV22 ** FREQ 9, X1,SC              0.0      2000.        6.1   6.1
     -2.449      1.350          .0      100.0
      -.784       .673      -.0019      100.0
247 ** NWK, D22/DV22 ** FREQ 1, X3                 0.0      2000.        7.1   7.1
     -3.341      1.350      -.0007       25.0    1.350     -1.840     -4.000   70.
      2.950       .673      -.0018       49.0    1.350     -2.770      2.367   70.
248 ** NWK, D22/DV22 ** FREQ 2, X3                 0.0      2000.        7.1   7.1
     -3.341      1.350      -.0007       25.0    1.350     -1.840     -4.000   70.
      2.257       .673      -.0018       49.0    1.350     -2.770      1.674   70.
249 ** NWK, D22/DV22 ** FREQ 3, X3                 0.0      2000.        7.1   7.1
     -3.341      1.350      -.0007       25.0    1.350     -1.840     -4.000   70.
      1.340       .673      -.0018       49.0    1.350     -2.770       .757   70.
250 ** NWK, D22/DV22 ** FREQ 4, X3                 0.0      2000.        7.1   7.1
     -3.341      1.350      -.0007       25.0    1.350     -1.840     -4.000   70.
      1.063       .673      -.0018       49.0    1.350     -2.770       .480   70.
251 ** NWK, D22/DV22 ** FREQ 5, X3                 0.0      2000.        7.1   7.1
     -3.341      1.350      -.0007       25.0    1.350     -1.840     -4.000   70.
       .647       .673      -.0018       49.0    1.350     -2.770       .064   70.
252 ** NWK, D22/DV22 ** FREQ 6, X3                 0.0      2000.        7.1   7.1
     -3.341      1.350      -.0007       25.0    1.350     -1.840     -4.000   70.
      -.164       .673      -.0018       49.0    1.350     -2.770      -.747   70.
253 ** NWK, D22/DV22 ** FREQ 7, X3                 0.0      2000.        7.1   7.1
     -3.341      1.350      -.0007       25.0    1.350     -1.840     -4.000   70.
      -.506       .673      -.0018       49.0    1.350     -2.770     -1.089   70.
254 ** NWK, D22/DV22 ** FREQ 8, X3                 0.0      2000.        7.1   7.1
     -3.341      1.350      -.0007       25.0    1.350     -1.840     -4.000   70.
     -1.225       .673      -.0018       49.0    1.350     -2.770     -1.808   70.
255 ** NWK, D22/DV22 ** FREQ 9, X3                 0.0      2000.        7.1   7.1
     -3.341      1.350      -.0007       25.0    1.350     -1.840     -4.000   70.
     -1.567       .673      -.0018       49.0    1.350     -2.770     -2.150   70.
256 ** NWK, D13/DV21 ** FREQ 1, X3                 0.0      2000.        8.1   9.1
     -2.609     -7.789       1.150      2.300       .0     -.00122       4.4   2000.
      2.207       .777        .797       .012     .898        0.0     -.0028   1.0
```

257	** NWK,	D13/DV21	** FREQ 2, X3		0.0	2000.	8.1	9.1
	-2.609	-7.789	1.150	2.300	.0	-.00122	4.4	2000.
	1.514	.777	.797	.012	.898	0.0	-.0028	1.0
258	** NWK,	D13/DV21	** FREQ 3, X3		0.0	2000.	8.1	9.1
	-2.609	-7.789	1.150	2.300	.0	-.00122	4.4	2000.
	.597	.777	.797	.012	.898	0.0	-.0028	1.0
259	** NWK,	D13/DV21	** FREQ 4, X3		0.0	2000.	8.1	9.1
	-2.609	-7.789	1.150	2.300	.0	-.00122	4.4	2000.
	.320	.777	.797	.012	.898	0.0	-.0028	1.0
260	** NWK,	D13/DV21	** FREQ 5, X3		0.0	2000.	8.1	9.1
	-2.609	-7.789	1.150	2.300	.0	-.00122	4.4	2000.
	-.096	.777	.797	.012	.898	0.0	-.0028	1.0
261	** NWK,	D13/DV21	** FREQ 6, X3		0.0	2000.	8.1	9.1
	-2.609	-7.789	1.150	2.300	.0	-.00122	4.4	2000.
	-.907	.777	.797	.012	.898	0.0	-.0028	1.0
262	** NWK,	D13/DV21	** FREQ 7, X3		0.0	2000.	8.1	9.1
	-2.609	-7.789	1.150	2.300	.0	-.00122	4.4	2000.
	-1.249	.777	.797	.012	.898	0.0	-.0028	1.0
263	** NWK,	D13/DV21	** FREQ 8, X3		0.0	2000.	8.1	9.1
	-2.609	-7.789	1.150	2.300	.0	-.00122	4.4	2000.
	-1.968	.777	.797	.012	.898	0.0	-.0028	1.0
264	** NWK,	D13/DV21	** FREQ 9, X3		0.0	2000.	8.1	9.1
	-2.609	-7.789	1.150	2.300	.0	-.00122	4.4	2000.
	-2.310	.777	.797	.012	.898	0.0	-.0028	1.0

TABLE B.2

FUNCTIONS FOR PREDICTION MODELS

```
C
C       MODEL A  (MODEL INDEX = 1)
C       *******
C       LOG(ACC) = A1 + A2*MB + A3*ML + A4*IO + A5*R + A6*LOG(R) +
C                  A7*MB*R + A8
        FUNCTION AMODEL (XM,XI,R,ALR,ATTN,L)
        DIMENSION ATTN(1)
        AMODEL = ATTN(1+L) + XM*(ATTN(2+L)+ATTN(3+L)) + XI*ATTN(4+L) +
     +     R*ATTN(5+L) + ATTN(6+L)*ALR + ATTN(7+L)*XM*R + ATTN(8+L)
        RETURN
        END
C
C
C       MODEL B  (MODEL INDEX = 2)
C       *******
C       LOG(ACC) = B1 + B2*MB + B3*MBLG + B4*R + B5*LOG(B6+R) + B7*MB*R +
C                  B8*MB*MB*R
        FUNCTION BMODEL (XM,XI,R,ATTN,L)
        DIMENSION  ATTN(1)
        BMODEL = ATTN(1+L) + (ATTN(2+L)+ATTN(3+L))*XM + ATTN(4+L)*R +
     +     ATTN(5+L)*ALOG(ATTN(6+L)+R) + R*XM*(ATTN(7+L)+ATTN(8+L)*XM)
        RETURN
        END
C
C
C       MODEL C  (MODEL INDEX = 3)
C       *******
C       LOG(ACC) = C1 + C2*MB + C3*R + C4*LOG(R*(C7+R)+EXP(C5*MB+C6))
        FUNCTION CMODEL (XM,XI,R,ATTN,L)
        DIMENSION  ATTN(1)
        CMODEL = ATTN(1+L) + ATTN(2+L)*XM + ATTN(3+L)*R +
     +     ATTN(4+L)*ALOG(R*(ATTN(7+L)+R)+EXP(ATTN(5+L)*XM+ATTN(6+L)))
        RETURN
        END
C
C
C       MODEL D  (MODEL INDEX = 4)
C       *******
C       LOG(ACC) = D1 + D2*MB + D3*R + D4*LOG(R+D5*EXP(D6*MB+D7))
        FUNCTION DMODEL (XM,XI,R,ATTN,L)
        DIMENSION ATTN(1)
        DMODEL = ATTN(1+L) + ATTN(2+L)*XM + ATTN(3+L)*R +
     +     ATTN(4+L)*ALOG(R+ATTN(5+L)*EXP(ATTN(6+L)*XM+ATTN(7+L)))
        RETURN
        END
C
```

```
C
C       MODEL E  (MODEL INDEX = 5)
C       *******
C       LOG(ACC) = E1 + E3*MBLG + E4*LOG(R)
        FUNCTION EMODEL (XM,XI,R,ALR,ATTN,L)
        DIMENSION ATTN(1)
        EMODEL = ATTN(L+1) + ATTN(L+3)*XM + ATTN(L+4)*ALR
        RETURN
        END
C
C
C       MODEL F (MODEL INDEX = 6)
C       *******
C       LOG(ACC) = F1 + F2*MB + F3*SQRT(R*R+F4) - .5*LOG(R*R+F4)
        FUNCTION FMODEL (XM,R,ATTN,L)
        DIMENSION ATTN(1)
        FMODEL = ATTN(1+L) + ATTN(2+L)*XM
        RH2 = R*R + ATTN(4+L)
        FMODEL = FMODEL + ATTN(3+L)*SQRT(RH2) - .5*ALOG(RH2)
        RETURN
        END
C
C
C       MODEL G (MODEL INDEX = 7)
C       *******
C       RH .LE. 70 KM:
C          LOG (ACC) = G1 + G2*MB + .5*LOG((G5*MB+G6)/(R*R+G4))
C       RH .GT. 70 KM:
C          LOG(ACC) = G7 + G2*MB + .5*LOG(G5*MB+G6) + G3*SQRT(R*R+G4)
C                    -.4165*LOG(R*R+G4)
        FUNCTION GMODEL (XM,R,ATTN,L)
        DIMENSION ATTN(1)
        RS = ATTN(8+L)
        T1 = ATTN(5+L)*XM + ATTN(6+L)
        RH2 = R*R + ATTN(4+L)
        IF (R .GT. RS)  GO TO 10
        GMODEL = ATTN(L+1) + ATTN(L+2)*XM + .5*ALOG(T1/RH2)
        RETURN
10      GMODEL = ATTN(L+7) + ATTN(L+2)*XM + .5*ALOG(T1) +
     +          ATTN(L+3)*SQRT(RH2) - .4165*ALOG(RH2)
         RETURN
        END
C
C       MODEL H (MODEL INDEX = 8)
C       *******
C       LOG(ACC) = H1 + H2*XM + H3*LOG((SQRT(R*R+H6)+H4*EXP(H5*XM)) -
C                  H7*SQRT(R*R+H6)
        FUNCTION XHMODEL (XM,R,ATTN,L)
        DIMENSION A(3),B(3),ATTN(1)
        DATA  A /1.,2.,0./, B /0.,-5.64,8.35/
        IF(ATTN(L+8).LE.0) GO TO 20
        IF(XM.LT.5.6) YM=1.02*XM+.3
        IF(XM.GE.5.6) YM=1.64*XM-3.16
        GO TO 30
20      CONTINUE
        I = (XM - 4.3) / 1.35
        I = I + 1
        IF (I .LT. 1)  I = 1
        IF (I .GT. 3)  I = 3
        YM = A(I)*XM + B(I)
```

```
30    RH = R
      IF (ATTN(L+6) .GT. 0.)  RH = SQRT (R*R + ATTN(L+6))
      XHMODEL = ATTN(L+1) + ATTN(L+2)*YM - ATTN(L+3)*ALOG(RH+
     +           (ATTN(L+4)*EXP(ATTN(L+5)*YM))) + ATTN(L+7)*RH
      RETURN
      END
C
C
C     MODEL I (MODEL INDEX = 9)
C     *******
C     LOG(ACC) = I1 + I2*XM - I3*LOG((R*R+I4) + EXP(I5*XM+I6)) -
C                I7*(R-1)
      FUNCTION XIMODEL (XM,R,ATTN,L)
      DIMENSION B(2),C(2),D(2),ATTN(1)
      DATA  B /1.308,2.1/, C /-4.371,-7.968/, D /-1.73,.456/
      RT = R
      I = 1 + (XM/ATTN(L+7))
      IF (I .GT. 2) I = 2
      XH = ATTN(L+5)
      IF(XH.LE.0.) GO TO 40
      IF (XM .GT. ATTN(L+8))  XH = 10. ** ((XM*D(2)+D(1))*2)
      RH = R*R + XH
      XL=RH
      RT = SQRT (RH)
      GO TO 50
40    XL=R*R  + EXP(B(I)*XM+C(I))
50    XIMODEL = ATTN(L+I) + ATTN(L+2+I)*XM - .417*ALOG(XL) +
     +           ATTN(L+6)*(RT-1.)
      RETURN
      END
C
C
C
C
```

TABLE B.3

TRIFUNAC-ANDERSON 'S SPECTRAL MODEL

```
      SUBROUTINE TRIFUN  (XI,R,ALR,VL,ATTN,CORSITE,P)

C     THIS ROUTINE RETURNS THE PROBABILITY OF THE SPECTRAL VELOCITY
C     BEING SMALLER THAN VL FOR A SITE LOCATED AT DISTANCE R FROM THE
C     SOURCE OF INTENSITY XI.
C     THE SITE CORRECTION FACTOR IS GIVEN BY ITS NATURAL LOG., CORSITE.
C     THE EQUATIONS ARE TAKEN FROM TRIFUNAC AND ANDERSON REPORT CE 77-03
C     OF USC.

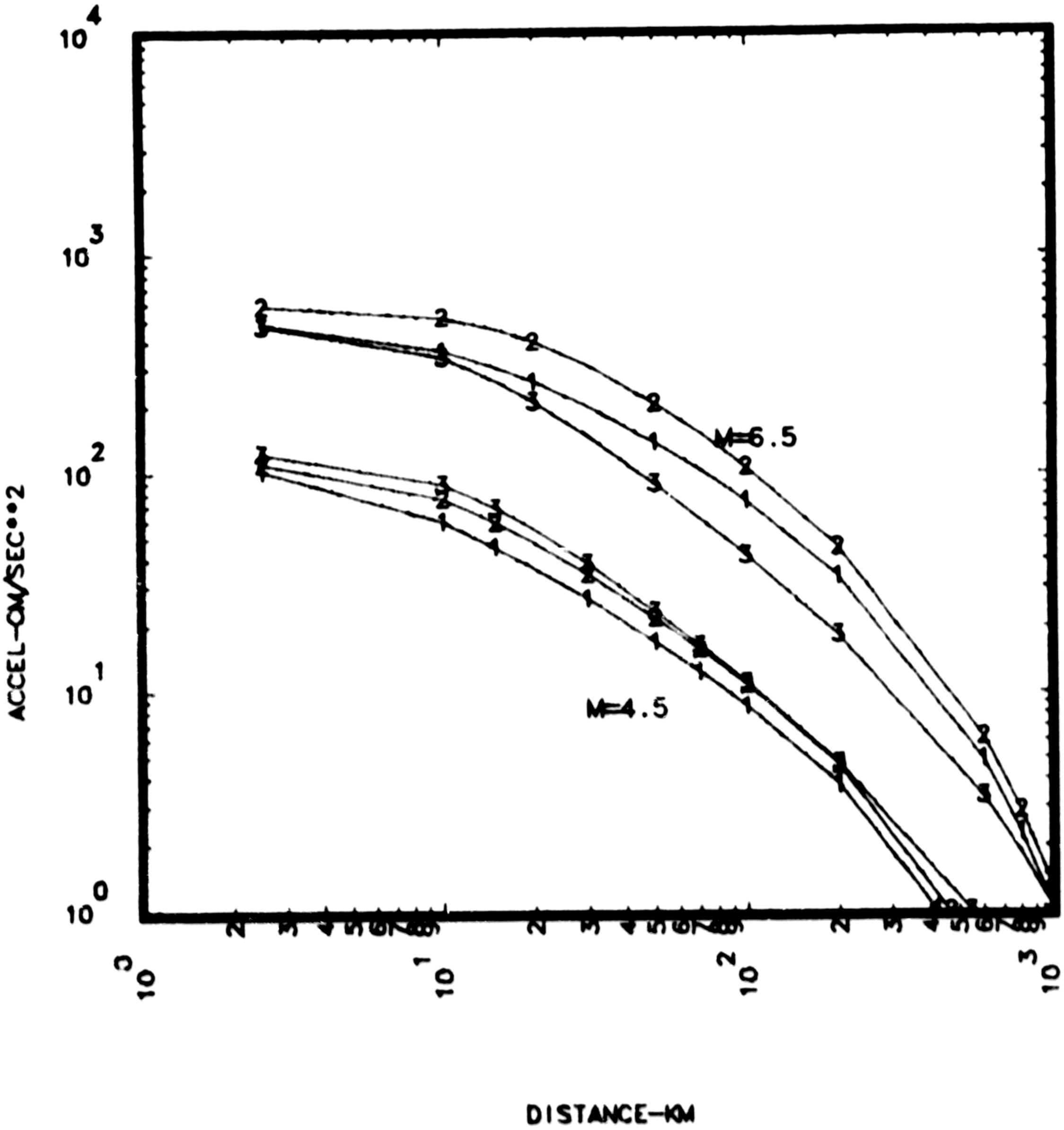
      DIMENSION  ATTN(1)
C     CONVERT VL FROM CM/SEC TO SA IN G'S
      VL1 = VL+ATTN(12)

C     CALCULATE THE ATTENUATED INTENSITY VIA MODIFIED GUPTA-NUTTLI EQ.
      XIS = ATTN(4) + XI + ATTN(5)*R + ATTN(6)*ALR

C     CALCULATE THE PL
      PL = ((VL1/2.30259) - ATTN(2)*XIS - ATTN(3) - (CORSITE/2.30259))
     +     / ATTN(1)

C     CALCULATE THE PA
      Z = EXP (ATTN(7)*PL + ATTN(8))
      P = 1. - EXP(-Z)
      IF (ATTN(11) .GT. 1.)  P = P*P
      RETURN
      END
```

EXPERT 1'S PGA MODELS FOR REGIONS 1&2

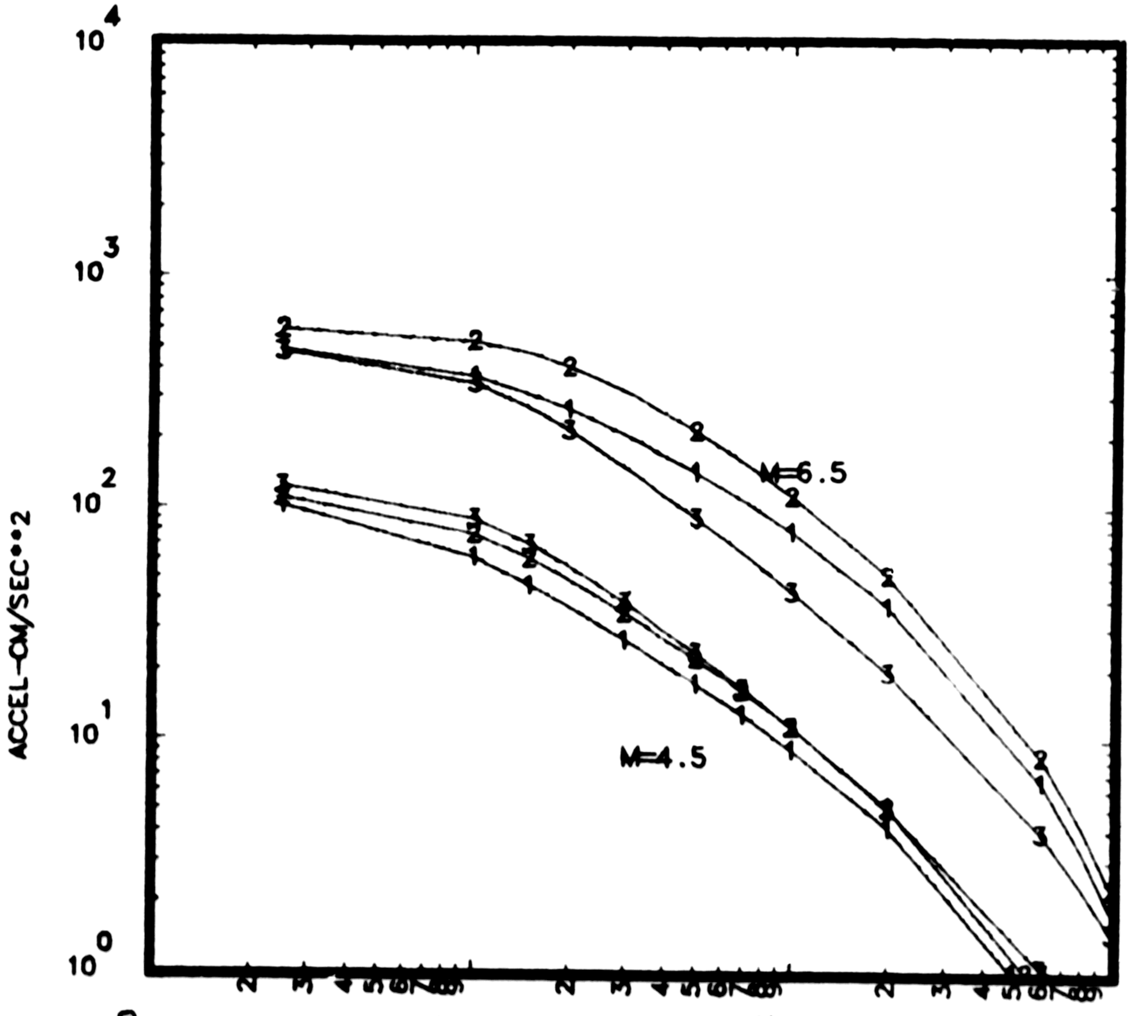


KEY:

Plot Number	Model Number (Table B.1
1	1
2	5
3	g

Figure B.1

EXPERT 1'S PGA MODELS FOR REGION 3

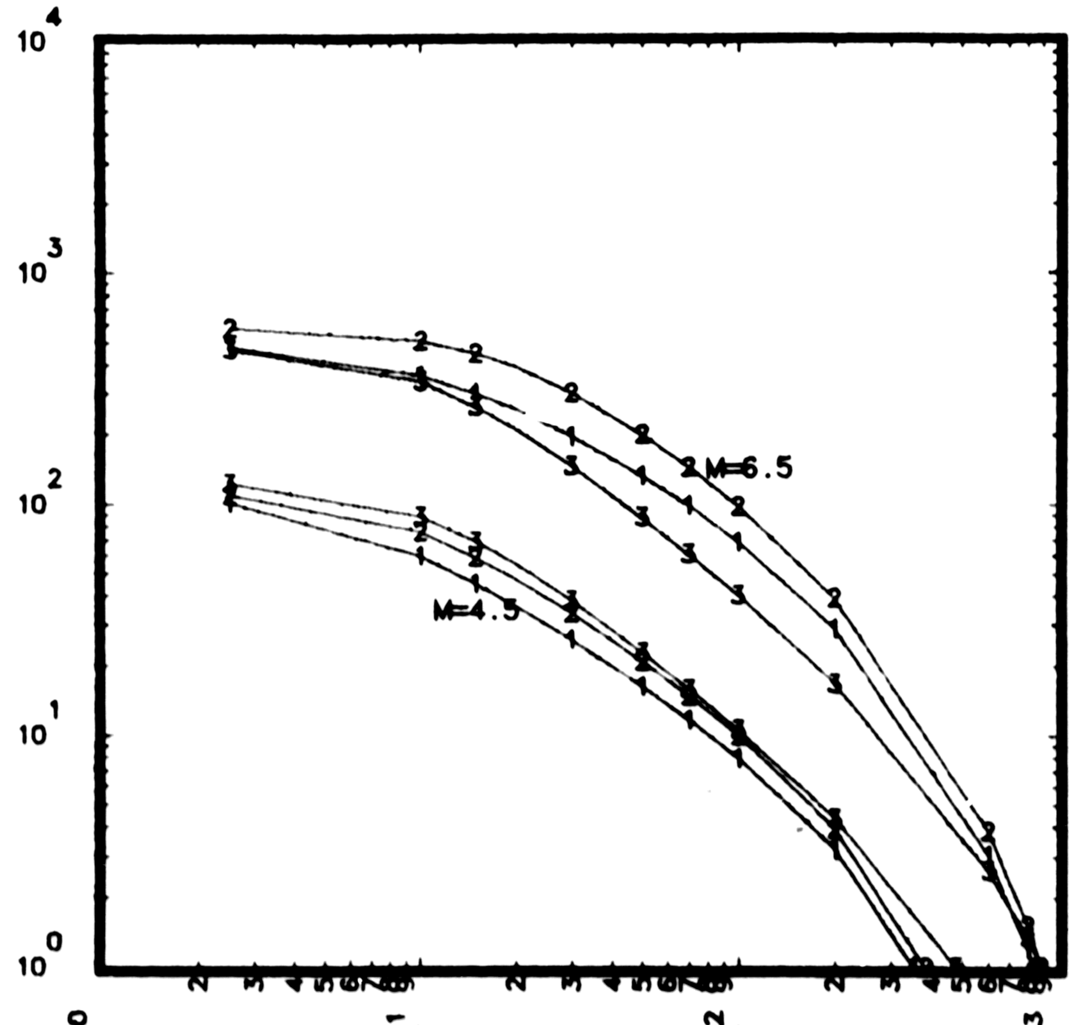


KEY:

Plot Number	Model Number (Table
1	2
2	6
3	10

Figure B.2

EXPERT 1'S PGA MODELS FOR REGION 4

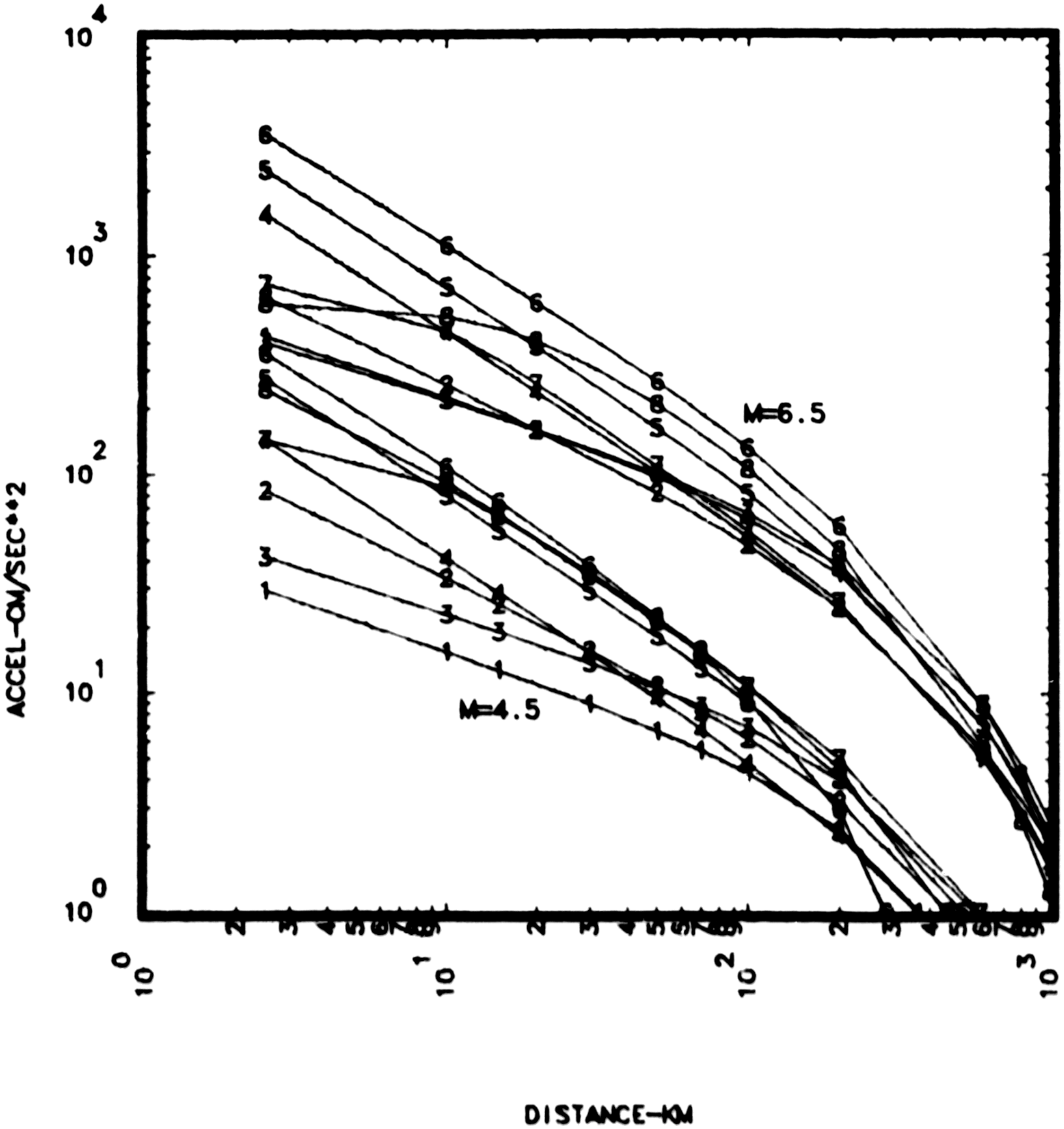


KEY:

Plot Number	Model Number (Table B1)
1	3
2	7
3	11

Figure B.3

EXPERT 2'S PGA MODELS FOR REGION 1

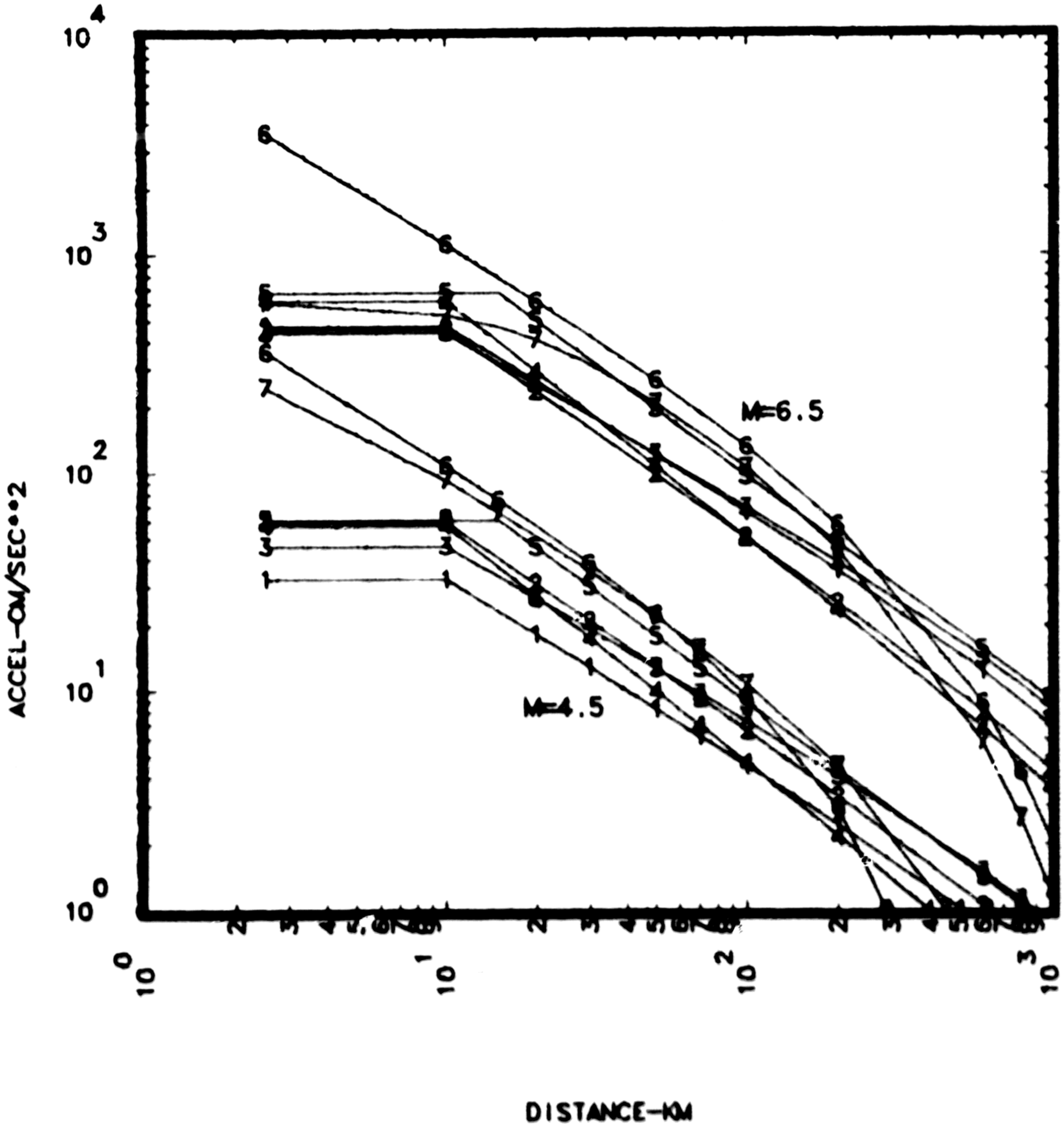


KEY:

Plot Number	Model Number (Table
1	25
2	31
3	26
4	27
5	17
6	29
7	13
8	8

Figure B.4

EXPERT 2'S PGA MODELS FOR REGION 2

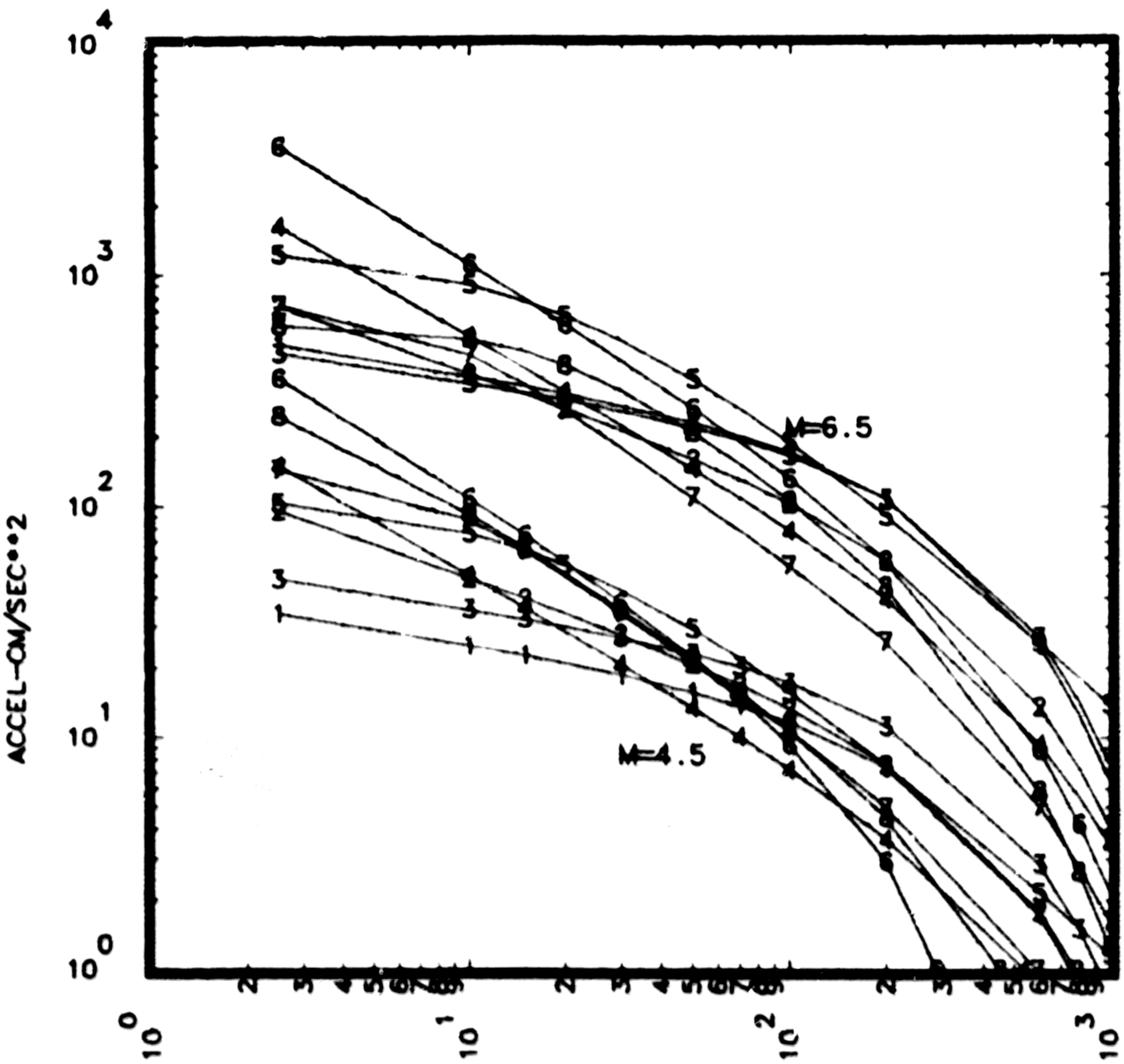


KEY:

Plot Number	Model Number (Table B1)
1	18
2	32
3	19
4	20
5	28
6	29
7	8

Figure B.5

EXPERT 2'S PGA MODELS FOR REGION 3

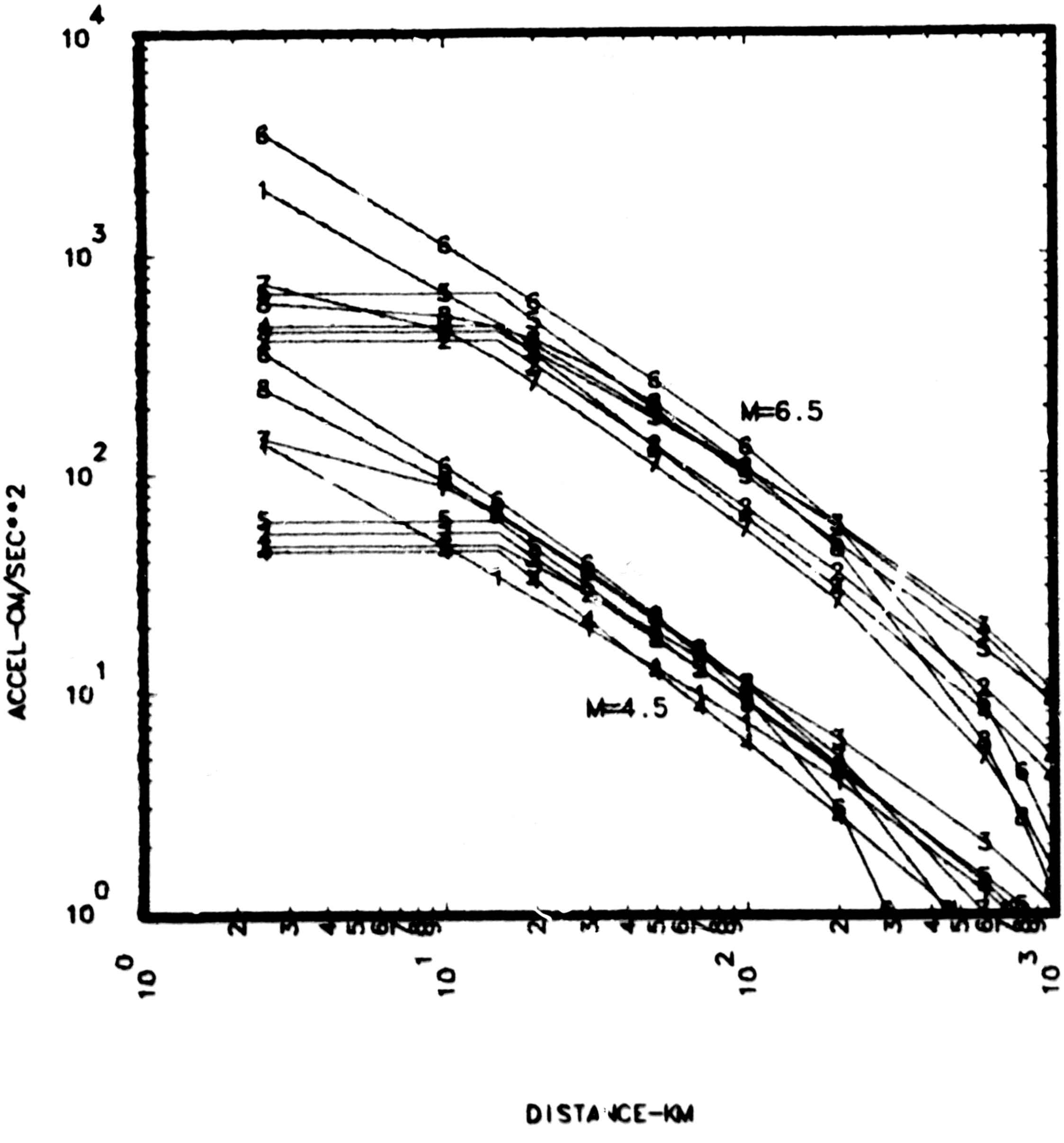


KEY:

Plot Number	Model Number (Table
1	22
2	33
3	23
4	24
5	30
6	29
7	13
8	8

Figure B.6

EXPERT 2'S PGA MODELS FOR REGION 4

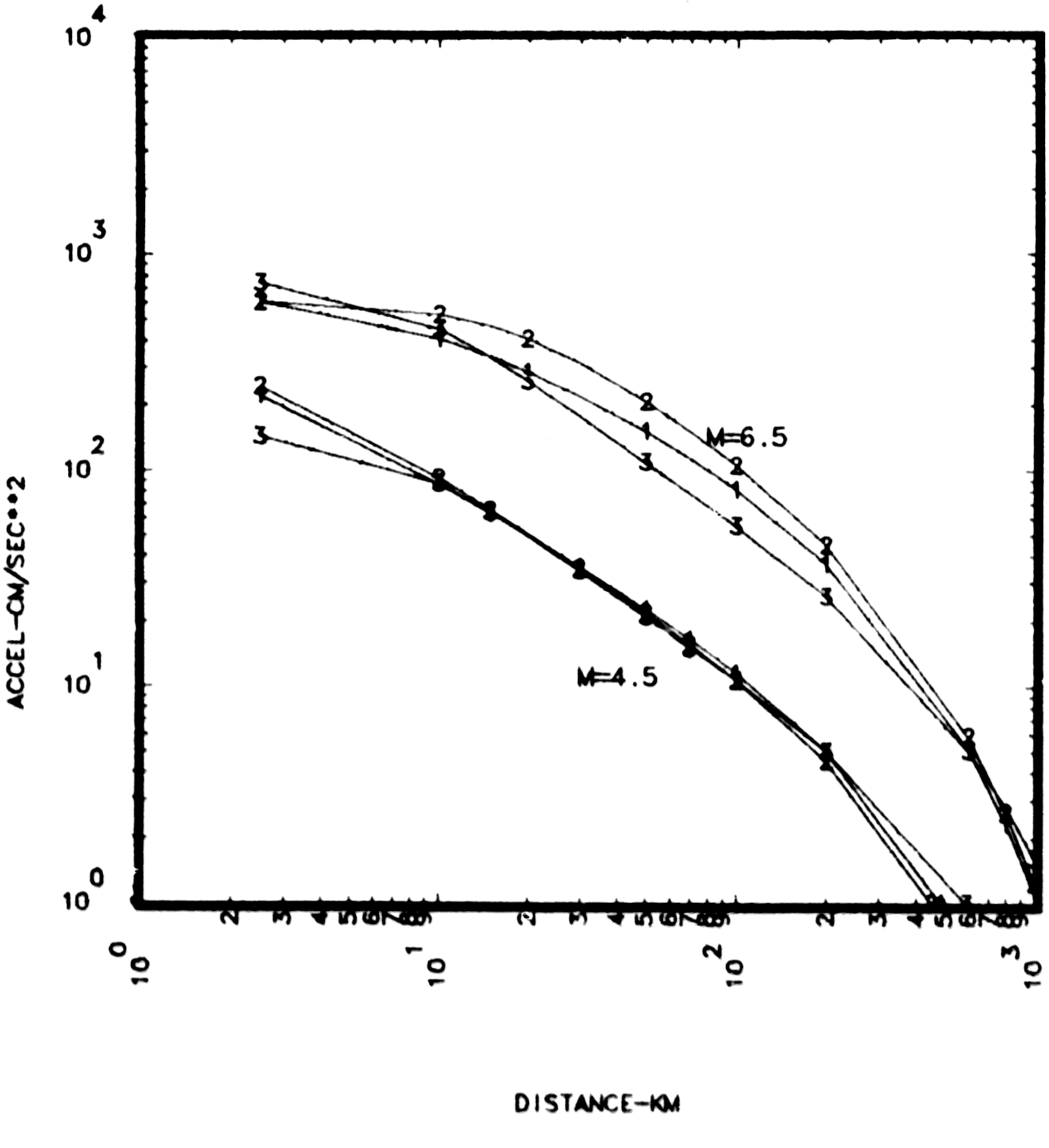


KEY:

Plot Number	Model Number (Table B1)
1	14
2	34
3	16
4	21
5	28
6	29
7	13
8	8

Figure B.7

EXPERT 3'S PGA MODELS FOR ALL REGIONS

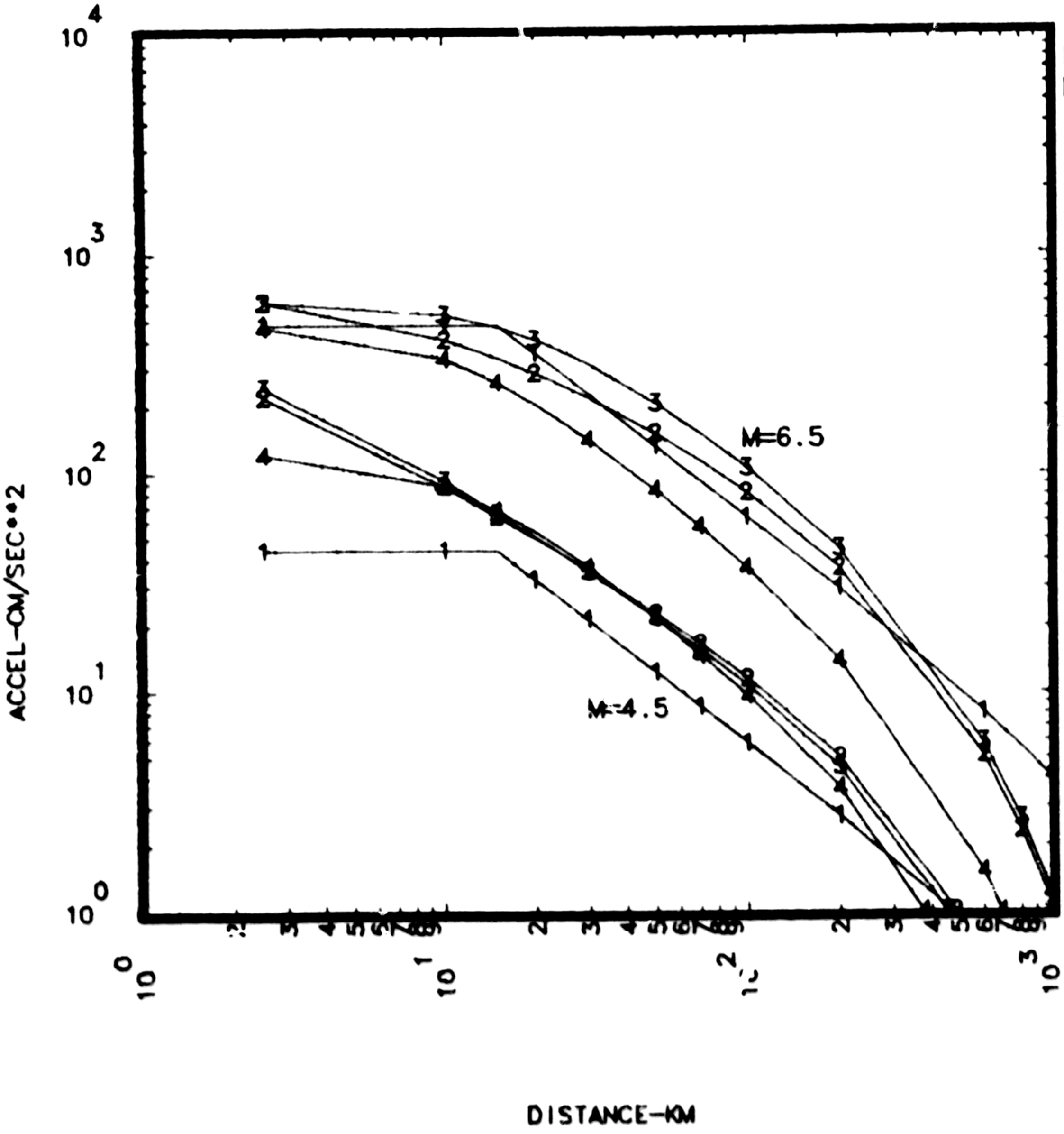


KEY:

Plot Number	Model Number (Table B
1	4
2	8
3	13

Figure B.8

EXPERT 4'S PGA MODELS FOR ALL REGIONS

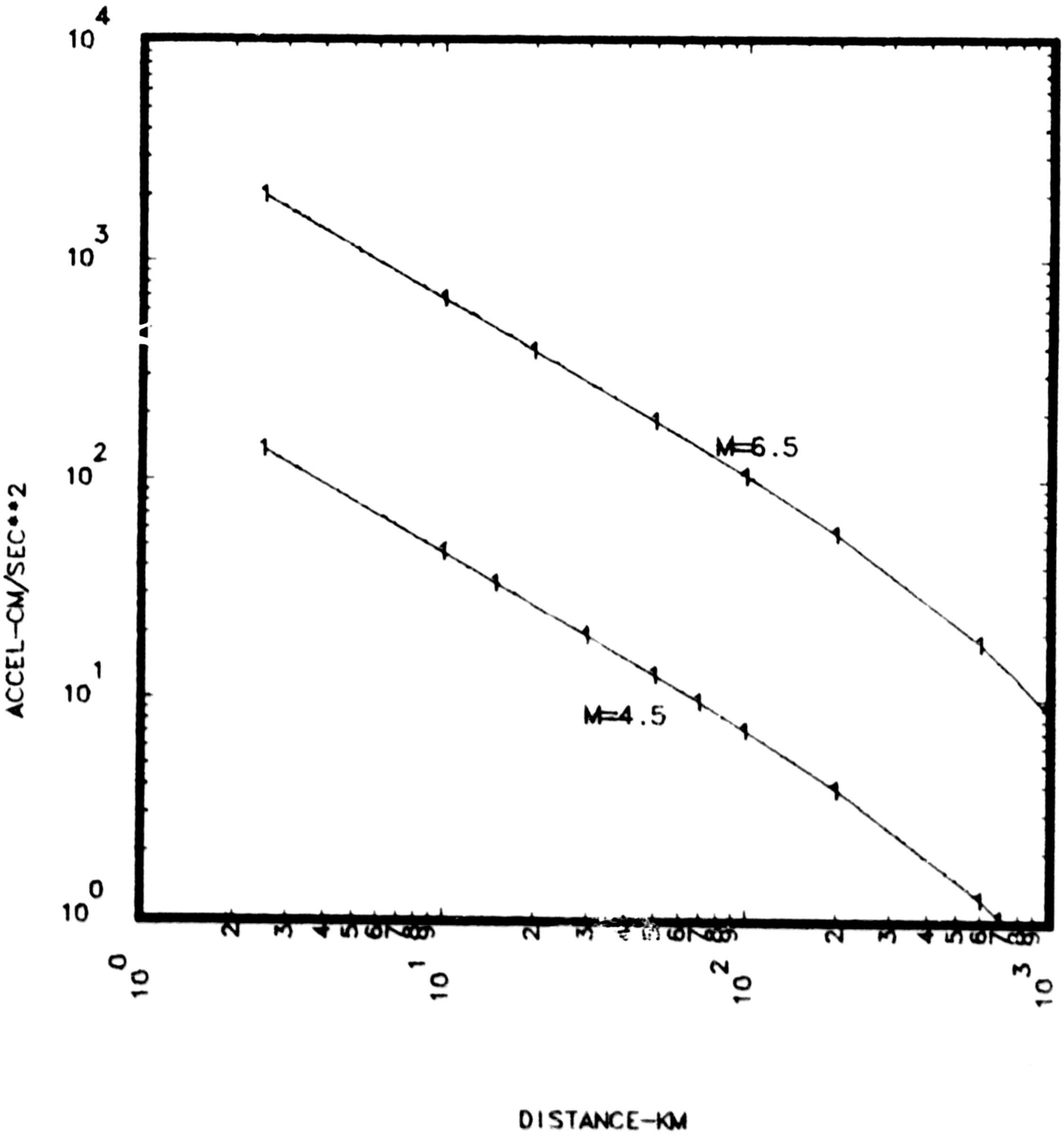


KEY:

Plot Number	Model Number (Table B1)
1	21
2	4
3	8
4	12

Figure B.9

EXPERT 5'S PGA MODEL FOR ALL REGIONS



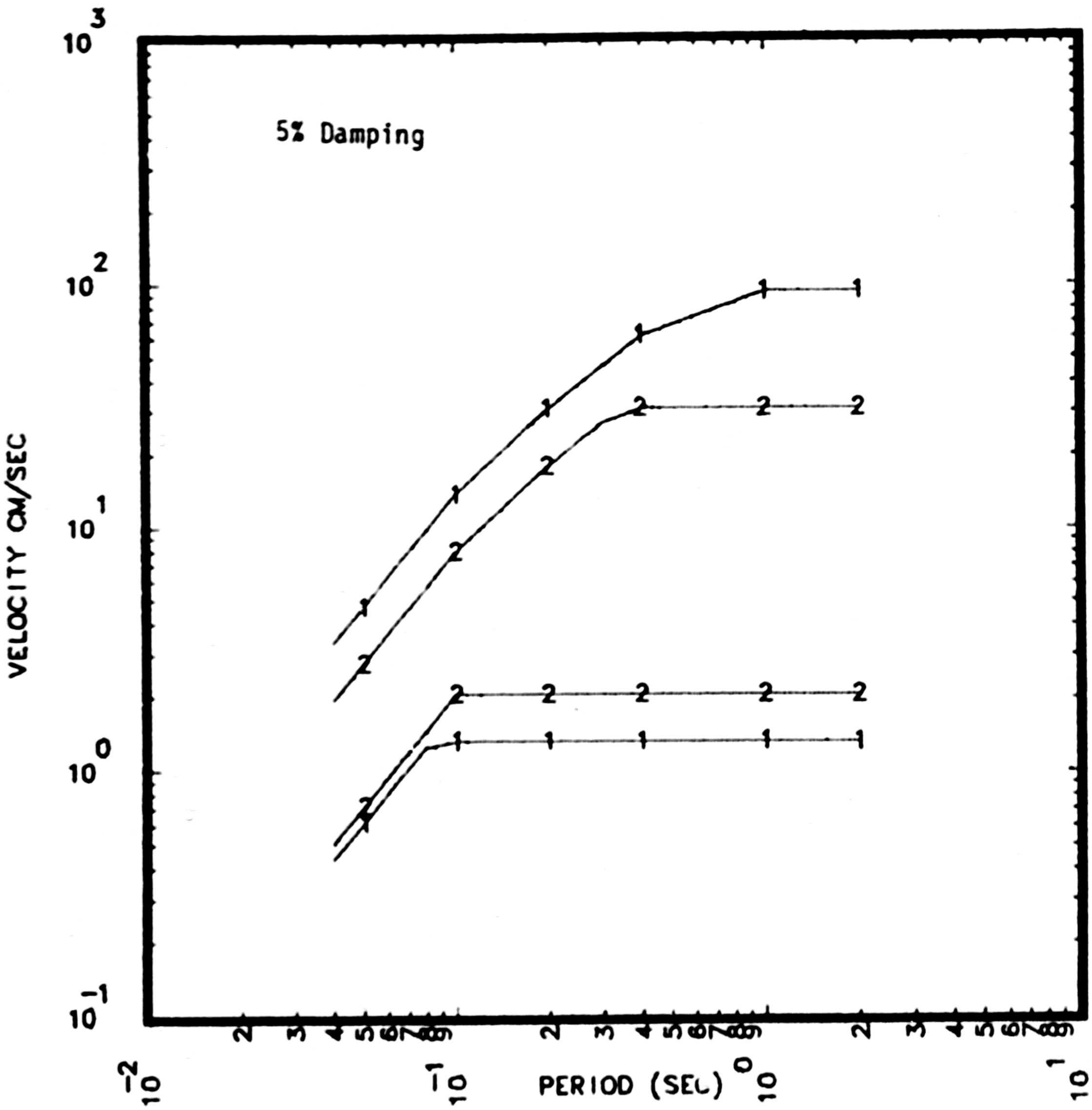
KEY:

Plot Number	Model Number (Table B
1	14

Figure B.10

EXPERT 1'S SPECTRAL MODELS FOR ALL REGIONS

R=15. KM M=4.5 & 6.5



KEY:

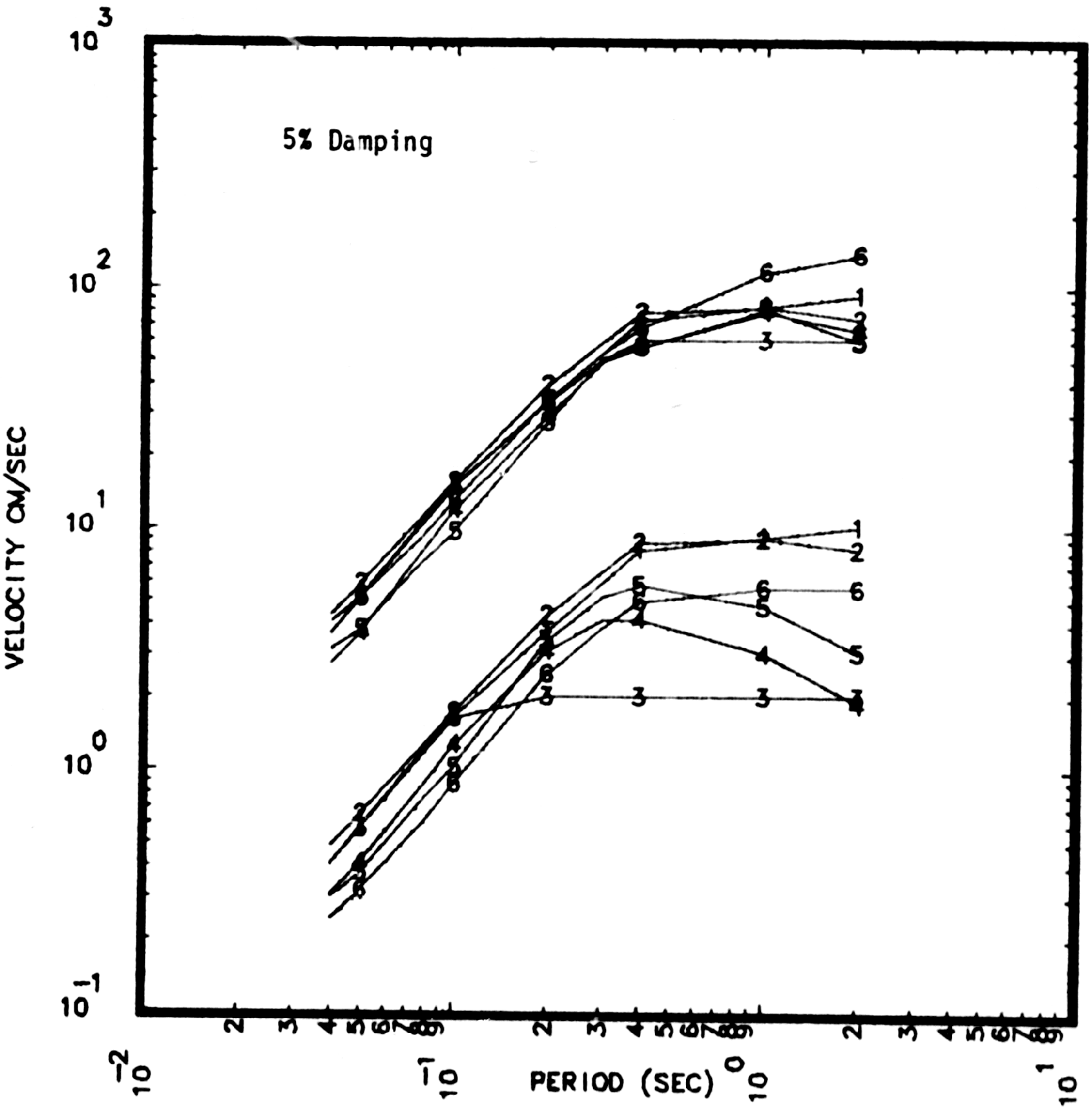
Plot Number	Model Number (Table B1)
1	193
2	220
(region 1 & 2)	
1	202
2	229
(Region 3)	
1	211
2	238
(Region 4)	

Note: The above plot pertain to regions 1 & 2. For region 3 & 4, the value of the parameter γ is slightly different. The difference is such, however that it would not appear on these plots. For region 3, the curve 1 & 2 correspond to model numbers 202 & 229, and for region 4, they correspond to models 211 and 238.

Figure B.11

EXPERT 2'S SPECTRAL MODELS FOR REGION 1

R=15. KM   M=4.5 & 6.5



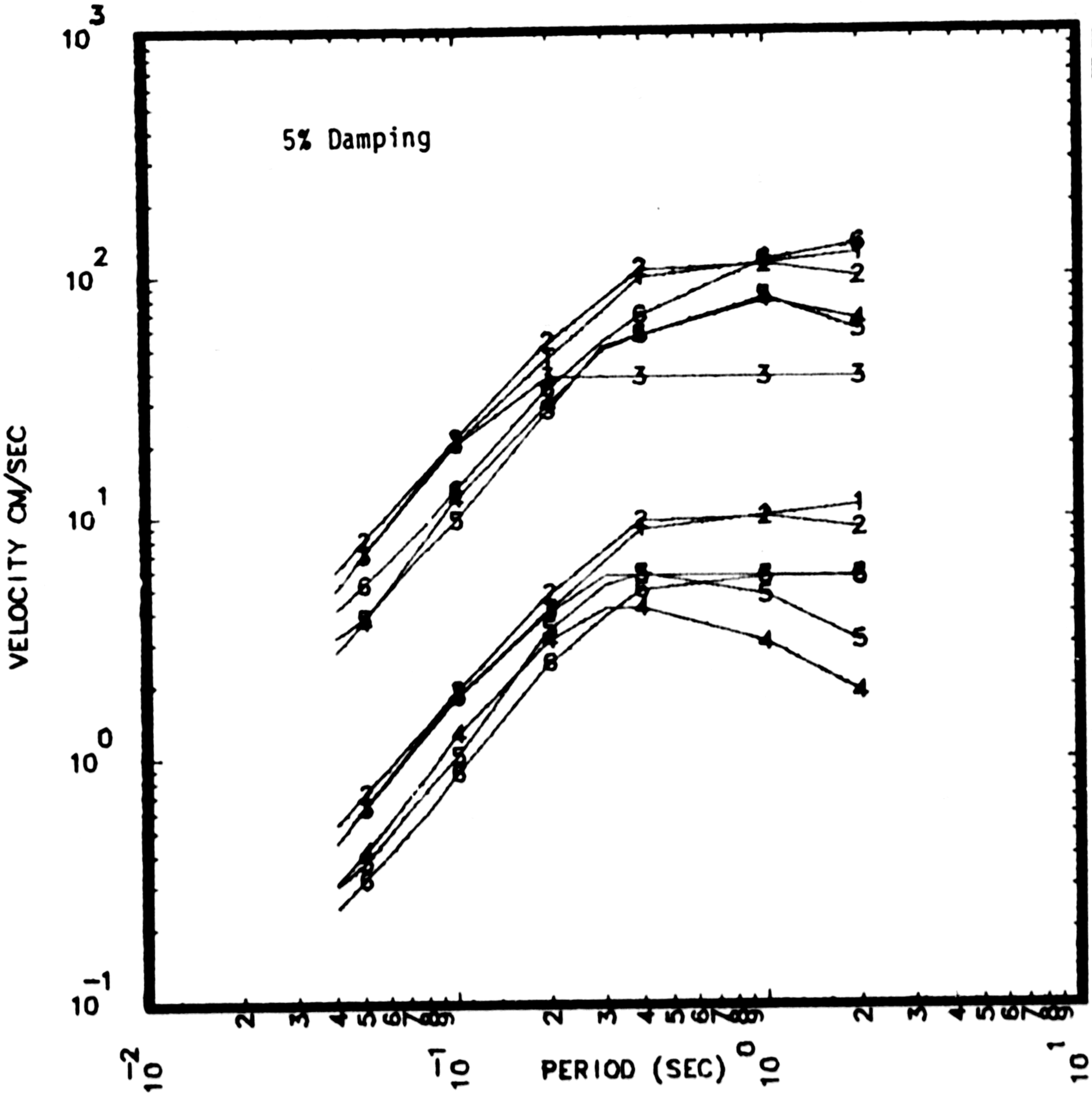
KEY:

Plot Number	Mode Numb (Table
1	148
2	121
3	175
4	58
5	67
6	94

Figure B. 12

EXPERT 2'S SPECTRAL MODELS FOR REGION 2

R=15. KM M=4.5 & 6.5



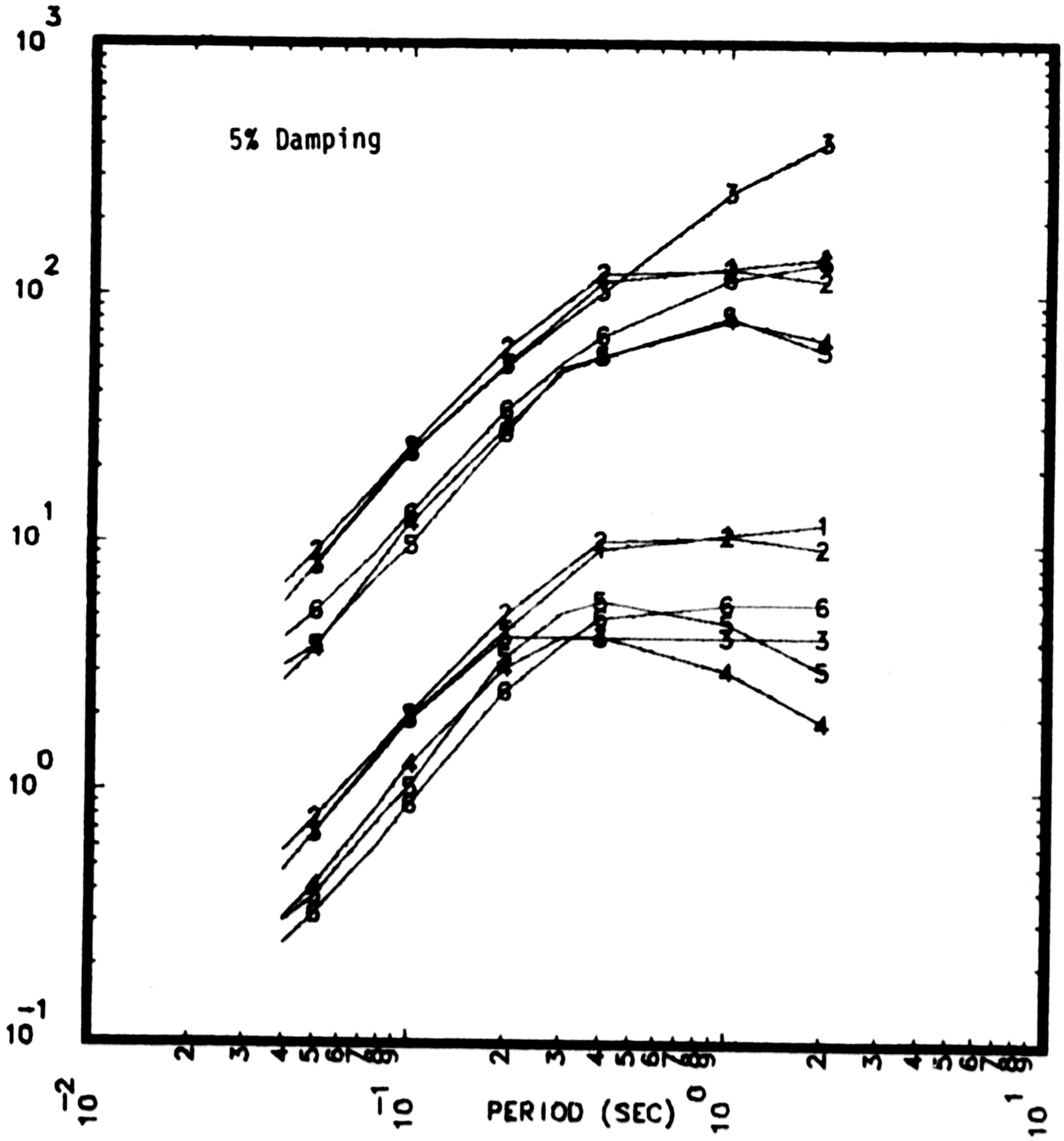
KEY:

Plot Number	Model Number (Table B1)
1	139
2	112
3	166
4	58
5	67
6	94

Figure B.13

EXPERT 2'S SPECTRAL MODELS FOR REGION 3

R=15. KM M=4.5 & 6.5



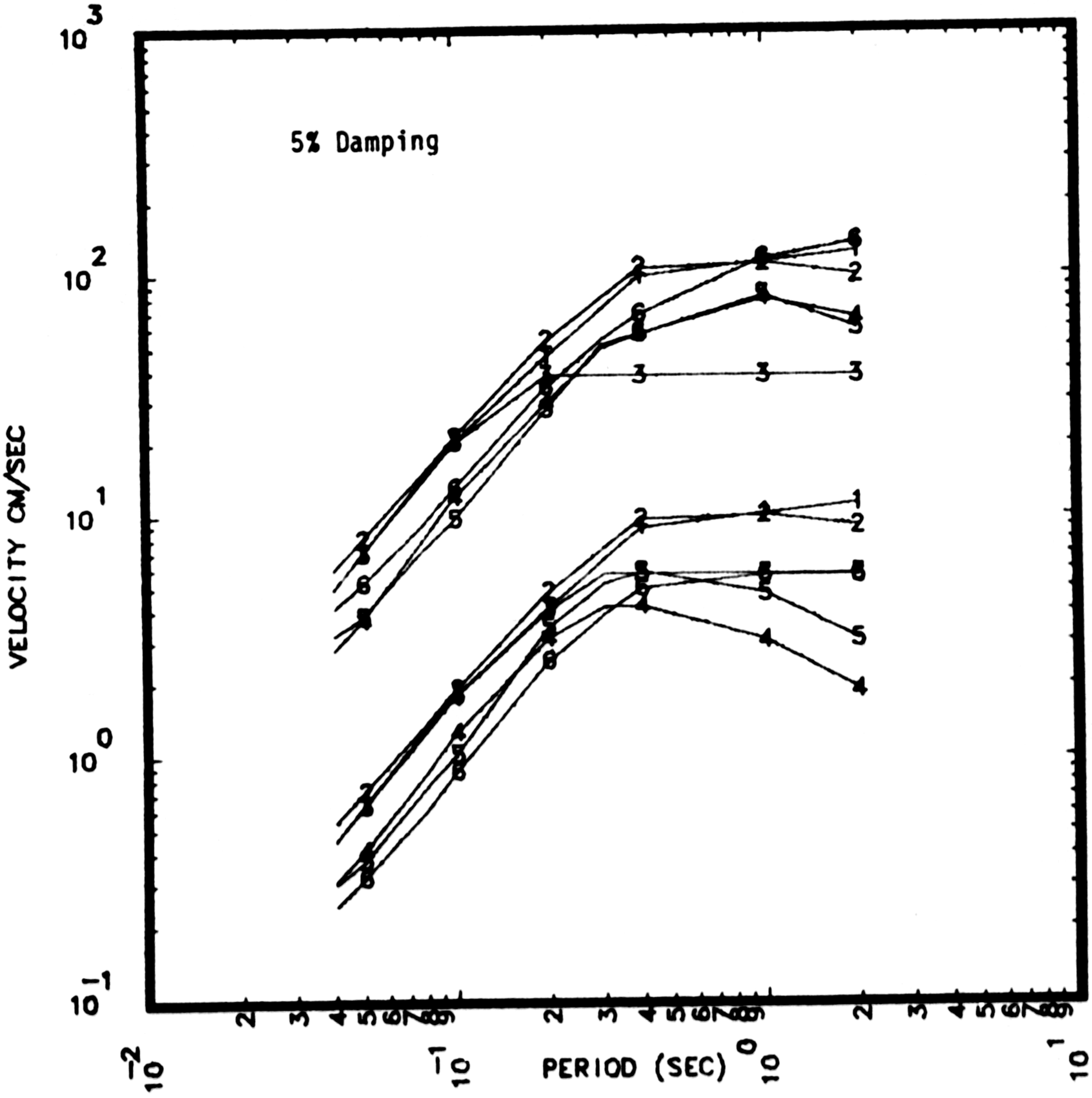
KEY:

Plot Number	Model Number (Table B
1	130
2	103
3	157
4	58
5	67
6	94

Figure B.14

EXPERT 2'S SPECTRAL MODELS FOR REGION 4

R=15. KM M=4.5 & 6.5



KEY:

Plot Number	Model Number (Table B1)
1	139
2	112
3	166
4	58
5	67
6	94

Figure B.15

EXPERT 3'S SPECTRAL MODELS FOR ALL REGIONS

R=15.KM M=4.5 & 6.6

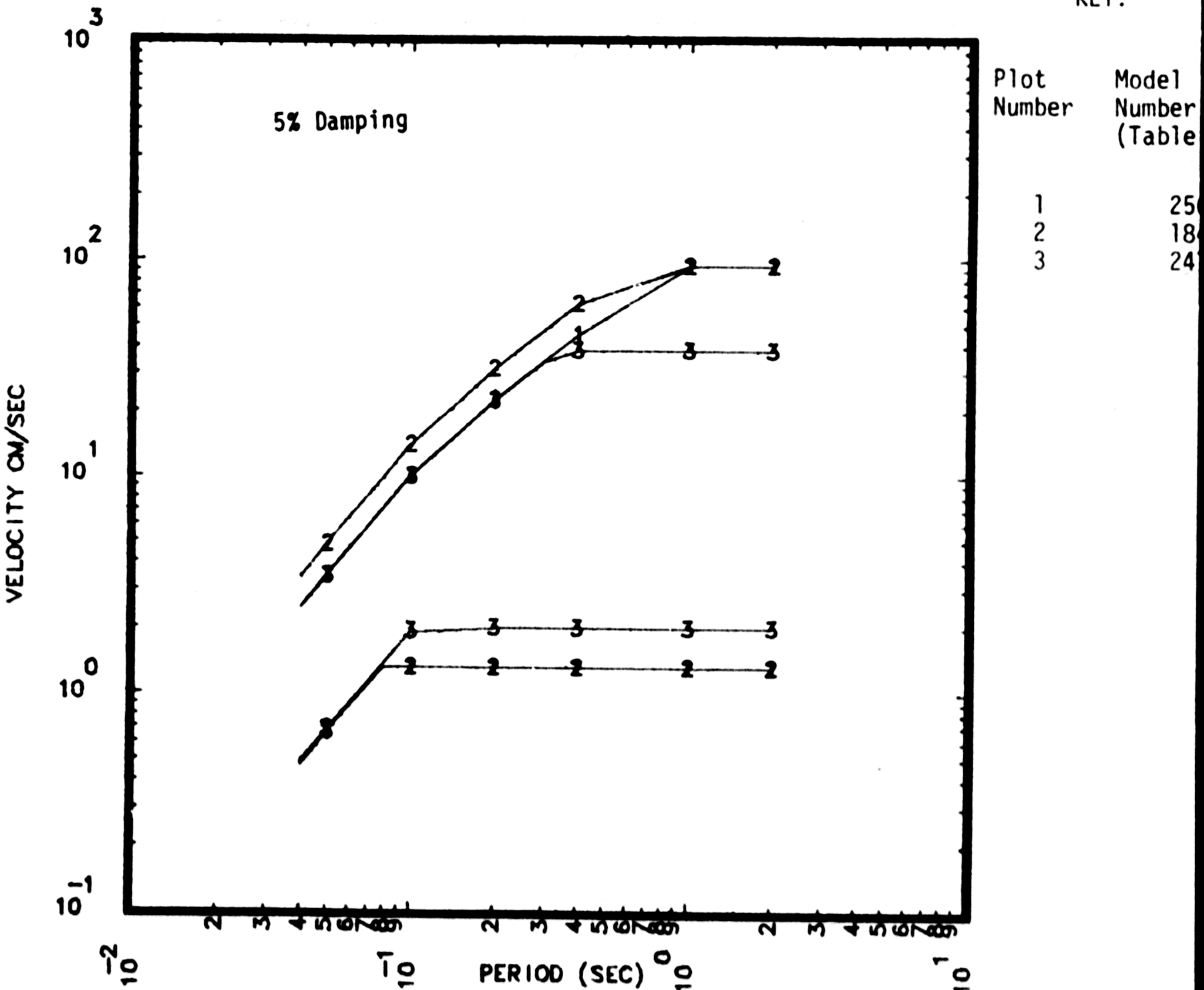
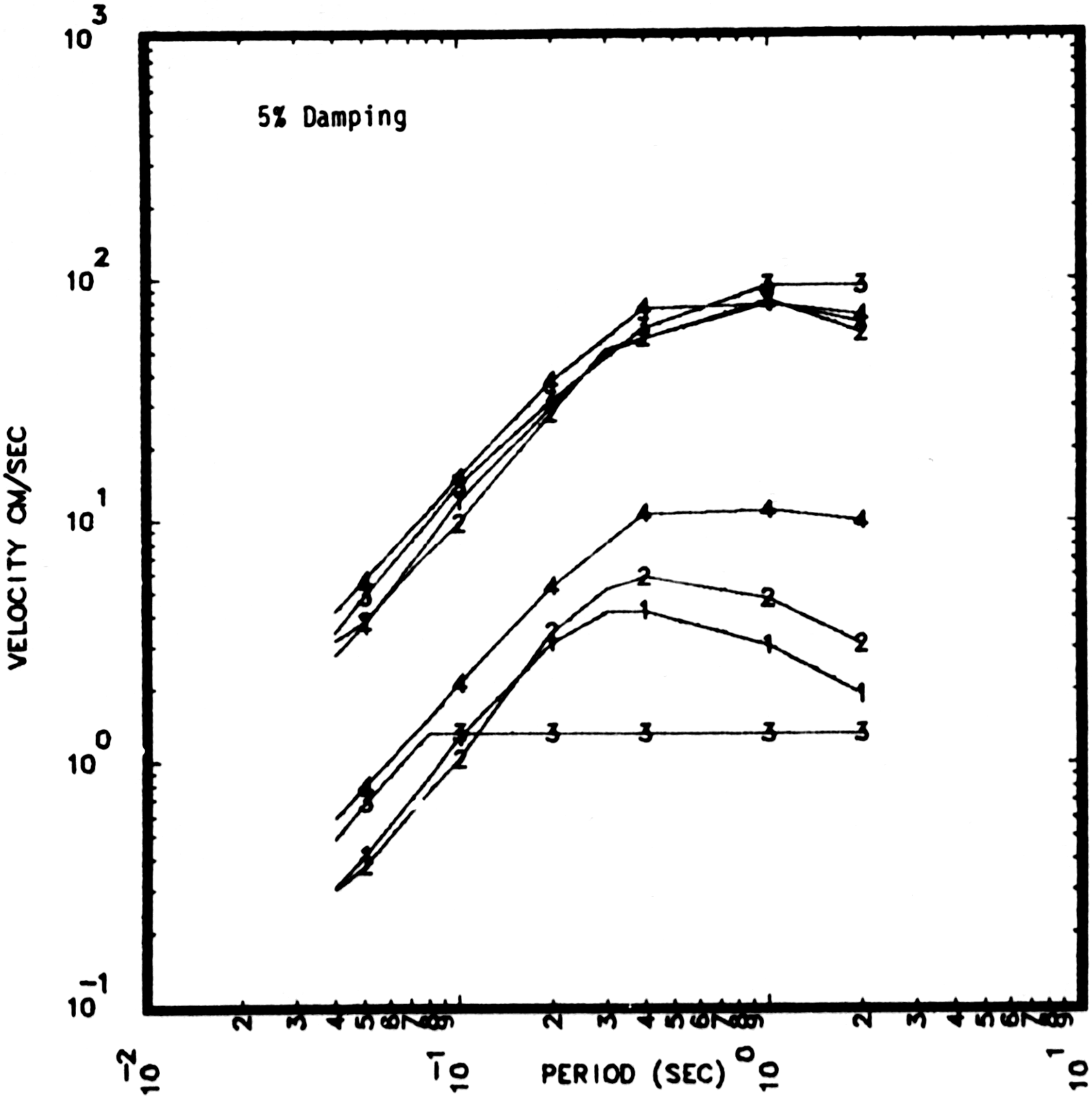


Figure B.16

EXPERT 4'S SPECTRAL MODELS FOR ALL REGIONS

R=15. KM   M=4.5 & 6.5



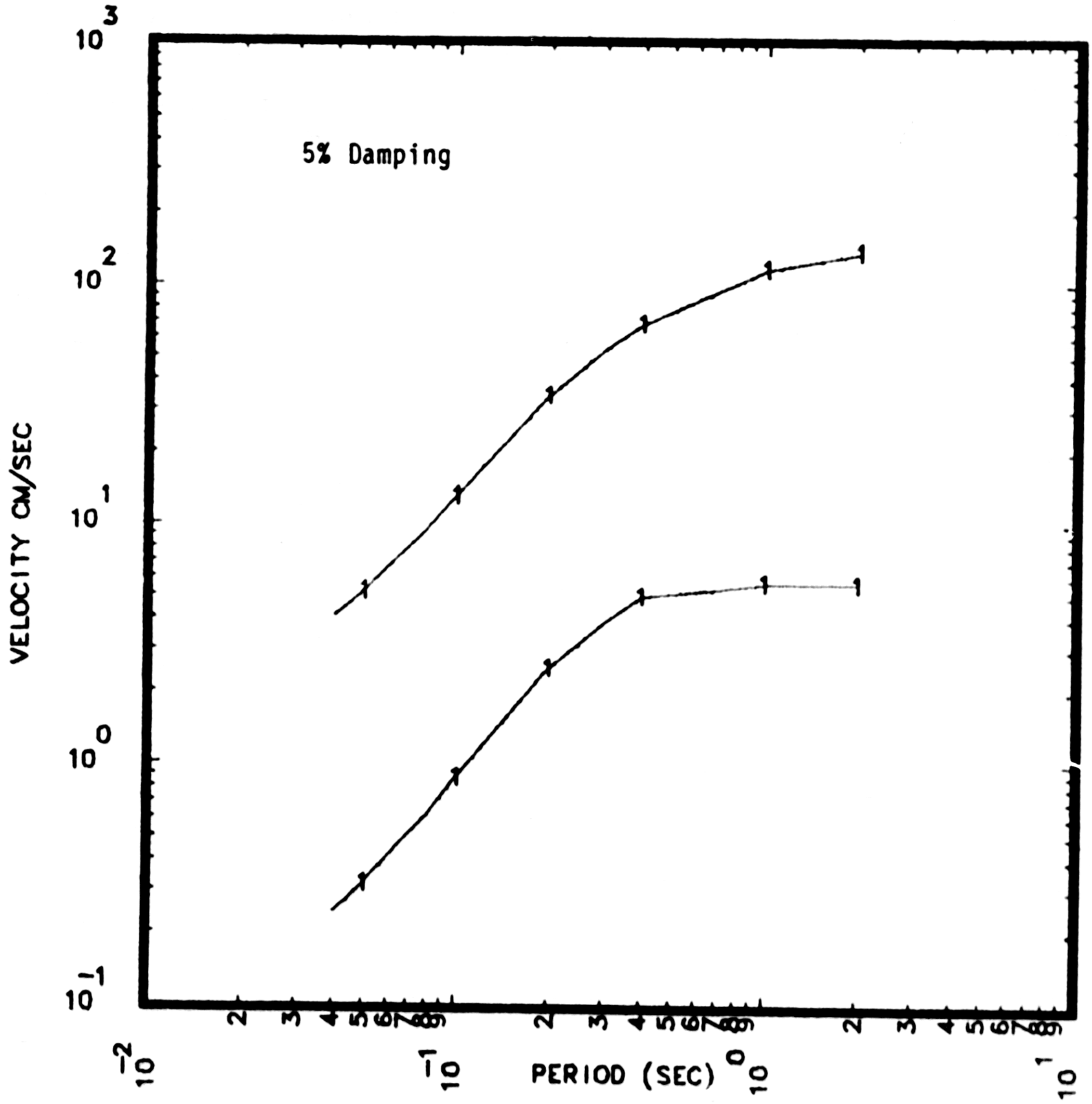
KEY:

Plot Number	Model Number (Table B1
1	58
2	67
3	184
4	76
5	85

Figure B.17

EXPERT 5'S SPECTRAL MODEL FOR ALL REGIONS

R=15. KM   M=4.5 & 6.5



KEY:

Plot Number	Model Number (Table
1	94

Figure B.18

APPENDIX C

Seismic Hazard Analysis Calculations

C.1 Introduction

Seismic hazard at a site is usually quantified through seismic hazard curves for the peak values of ground motion parameters, e.g. peak ground acceleration, at the site. The seismic hazard curve is a description of the probability during a given period of time, e.g., per year, that one or more earthquakes occur which result in the peak, over the duration of the earthquake, value of the ground motion parameter at the site exceeding the value a, given as a function of a. Figure C.1 illustrates a typical hazard curve for the peak ground acceleration (PGA) at a site shown on a logarithm scale, where the commonly used notation $A > a$ refers to the event that one or more earthquakes occur resulting in the PGA at the site exceeding a (cm/sec^2). It should be noted that the event $A > a$ is equivalent to the event that the maximum, over all earthquakes affecting the site, PGA is greater than a.

Evaluation of the seismic hazard curve at a site typically involves four steps:

- o Identification of seismic sources.
- o Specification of the seismicity for each source.
- o Specification of an attenuation/ground motion model.
- o Evaluation of the hazard curve or hazard spectrum.

For the Eastern United States (EUS) seismicity project steps 1 through 3 were implemented by the formation of two panels:

- o A panel of experts familiar with geological and seismological characteristics throughout the EUS.

- o A panel of experts familiar with the development of: (1) attenuation/ground motion models used to relate ground motion parameters at a site to characteristics of an earthquake at the source; and (2) methods for modeling the effects of local soil conditions on ground motion at the site.

Opinions about the appropriate parameters and models were elicited from members of the two panels in the following form:

- o Seismic Sources

  Seismic sources were identified by eliciting maps which partition the EUS into zones (area, line or point sources) representing regions of uniform seismicity in terms of occurrence rate and range and distribution of magnitude.

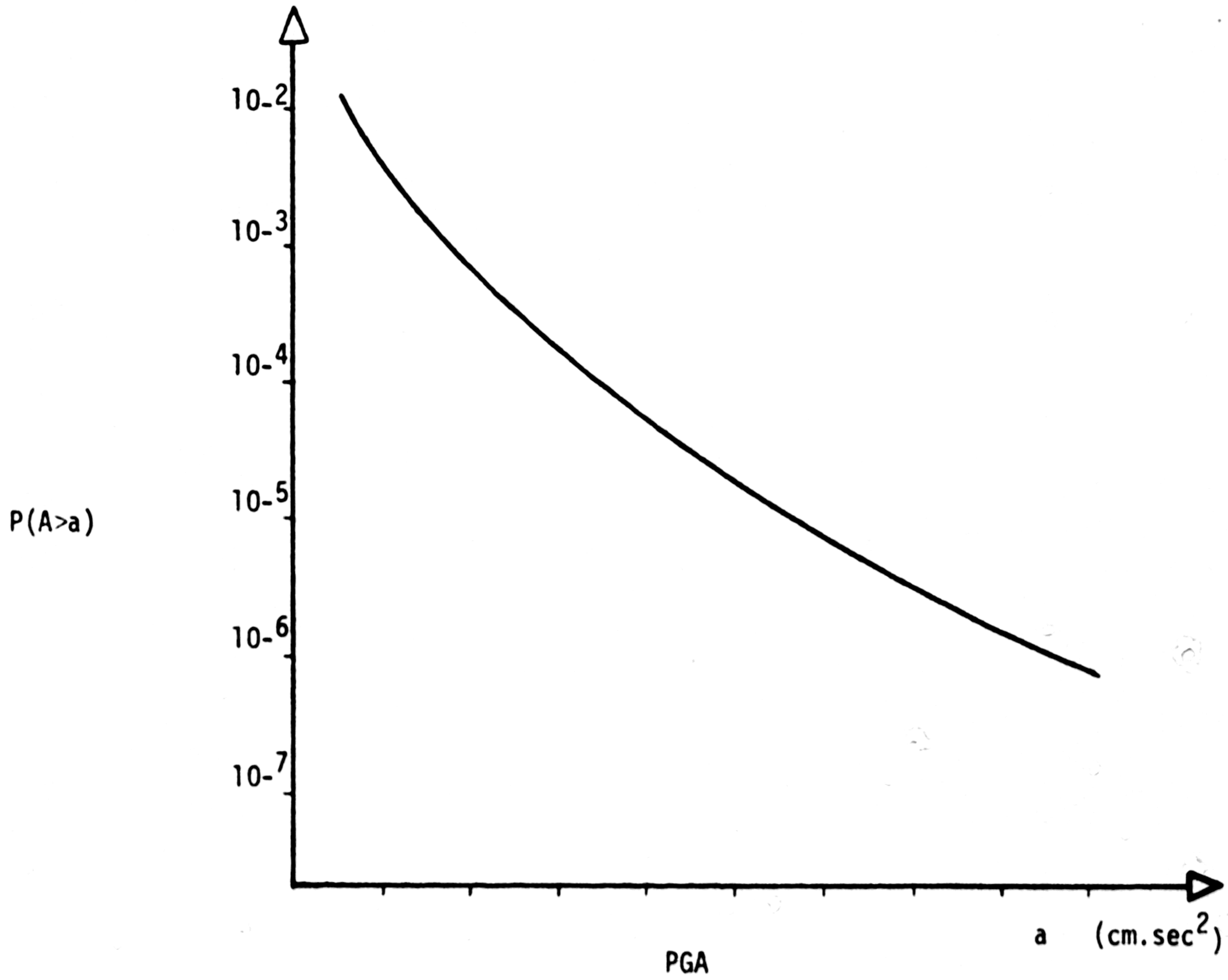


Fig. C.1. Typical seismic hazard curve.

- **Seismicity**

  For each zone, seismicity information was elicited from the experts in terms of the:

  - Occurrence rate of earthquakes with magnitude above a minimum level, $M_0 = 3.75\ M_{bLg}$ or IV MMI.
  - Upper magnitude cutoff, M_U, representing the largest magnitude expected to occur within a zone.
  - Distribution of magnitudes represented by a magnitude-recurrence relation.

- **Attenuation/Ground Motion Model**

  Weights, representing the panelists' confidence in the applicability of a model, for a catalogue of attenuation/ground motion models were elicited.

- **Local Site Effect**

  Weights, representing the panelists' confidence in the applicability of a method, for a collection of methods to adjust ground motion due to the effects of local site conditions were elicited.

Discussions about the elicitation, compilation and interpretation of the experts' opinions are given in other sections of this report. This appendix will concentrate on the methodology used to evaluate the seismic hazard curve (and spectra) at a site.

C.2 Philosophy of the Evaluation Methodology

Evaluation of the seismic hazard curve at a site is based on a probabilistic approach using the experts' opinions about seismicity and ground motion to specify models for the random events influencing the seismic hazard at a site. The method assumes that events, such as the occurrence of earthquakes within a zone, affecting ground motion at a site are subject to inherent physical variation and hence are properly treated as random events. Thus, the maximum value of a ground motion parameter experienced at a site over a period of time is a random quantity or variable. The hazard curve gives the probability of one or more earthquakes occurring resulting in the maximum value exceeding the value a. It is assumed to represent the likelihood, based on the inherent variation in the physical world, that the physical conditions will exist that lead to the maximum value of the ground motion parameter exceeding a. That is, the occurrence of an earthquake is assumed to be a random event and, if an earthquake does occur, the magnitude of the event and attenuation of ground motion from source to site are all subject to inherent variability. Thus, the ground motion at a site is variable and any ground motion parameter is properly considered a random variable. The seismic hazard curve is a description of the probability distribution of the maximum value of the ground motion parameter.

The probabilistic approach is based on modeling the physical variation by probability distributions and using these distributions to evaluate the probabilities of interest, i.e., the seismic hazard curve. However, characteristics of the distributions describing nature are unknown, thus the opinions of the experts are elicited to estimate these characteristics. Thus, the methodology produces an estimate of the seismic hazard curve which is based on the opinions provided by the experts on the two panels.

The evaluation method also recognizes that expert opinions about seismological properties and ground motion models are based on limited knowledge about the physical phenomena affecting these parameters, hence expert opinions are subject to uncertainty. The uncertainties associated with the experts' opinions do not contribute to the level of seismic hazard but do influence the effectiveness of the evaluation process in estimating the hazard. The experts' uncertainties are incorporated into the hazard analyses by developing a set of bounds for the hazard curve. The level of uncertainty is quantified by modeling the experts' uncertainties by probability distribution. A second source of uncertainty associated with a probabilistic analysis is the choice of probabilistic models used to model physical phenomena. These mathematical models are only approximations to the real world. The choice of models is a matter of judgement by the analyst and, like experts' opinions about seismicity and ground motion, are based on limited knowledge of the physical world. Uncertainties associated with the choice of mathematical models is more difficult to assess. Also, a comparison between different models can only be made if the evaluation of seismic hazard using competing models is actually done. This is not always possible. Thus, this type of uncertainty is not an integral part of the evaluation of hazard. However, sensitivity analyses have been conducted which describe the effect on the hazard estimates of some of the modeling assumptions.

The method for evaluating the seismic hazard curve at a site involves a two-stage estimation process:

- o A single hazard curve, referred to as the 'best estimate' hazard curve, is evaluated using the experts' best estimate evaluations of seismic sources, seismicity and attenuation/ground motion models.

- o The uncertainty in estimating the seismic hazard due to the uncertainties associated with the experts' opinions is quantified by evaluating bounds for the seismic hazard which reflect the experts' uncertainties. This analysis is called an 'uncertainty analysis'.

In addition to reflecting the uncertainty of a single pair (i.e., seismicity and attenuation experts) of experts, the uncertainty analysis, when the hazard estimates are combined over several experts, will also reflect the variation in opinions among experts. As part of the uncertainty analysis, in addition to the uncertainty bounds for the hazard curves, a "mean" hazard curve can also be produced. The arithmetic mean and geometric mean are options. These hazard curves are potential estimates of the hazard at a site if one wants to describe the hazard by a single curve. Thus, they are alternatives to the "best estimate" hazard curve. However, it must be realized that the "mean" hazard curve is not produced from a single set of seismic and ground motion parameters as is the best estimate curve. Rather, like the uncertainty bounds, it is the locus of points representing the mean value of P(A>a) at each value of a. The mean is taken with respect to the distribution of P(A>a) at each a due to the experts' uncertainty distributions.

Because the elicitation process involves several experts, at times it will be necessary to combine the information derived from several experts to evaluate a hazard curve which reflects the combined opinions of the several experts. The method developed for combining over experts is based on a self evaluation by the experts of their level of expertise with regard to seismological issues and attenuation/ground motion modeling respectively. For the seismicity panelists the self-evaluation was done for four regions, NE, SE, NC, SC, in the EUS. These four self weights were combined into a single weight which was used when combining over seismicity experts. The method of combining over experts, essentially a weighted average, assumes that the self weights reflect not only the experts' level of overall knowledge about seismological issues (or attenuation/ground motion modeling) but also reflects the experts' abilities to translate this knowledge into responses about characteristics of probability distributions. Thus, the method assumes that the self weights are a quantification of an individual's judgment of the utility of their opinions for estimating the seismic hazard. The weights for combining the self weights for the four regions are the probabilities that the largest value at the site of the ground motion parameter comes from each region. These probabilities, at the site, will vary for different sites.

Although self weights were used for the present analysis, the same methods could be used with weights derived from other sources such as weights from peers or weights developed by the analyst or any user of the methodology. The important criterion is that the weights should reflect some judgment of the utility of an experts' opinions for estimating the seismic hazard. That is, the weights should be a judgment of how well the estimated hazards, based on the experts' opinions, can be expected to describe the real seismic hazard.

C.3 Mathematical Background and Assumptions

C.3.1 Seismic Hazard Curve

Seismic hazard at a site is quantified by the values of a ground motion parameter, at the site, which is exceeded with a given probability in a specified number of years. The mathematical development of hazard relations will be based on peak ground acceleration (PGA) although identical relations hold for peak ground velocity (PGV) and spectral acceleration or velocity as well.

The parameter of interest is the probability that the PGA at the site will exceed a given value, a, at least once within the specified time period, t years. This probability, expressed as a function of a and denoted P(A > a), is called the seismic hazard curve at the site. As noted earlier, the hazard curve is the tail of the complement of the cumulative distribution function for the random variable (i.e., the maximum PGA at the site, over all earthquakes affecting the site).

Typically, the region affecting ground motion at a site consists of a number of seismic source zones. The seismic hazard at the site is a combination of the hazard from all relevant sources. In addition, the value of the ground motion parameter, e.g. peak ground acceleration, will depend on both the distance of the source from the site as well as the magnitude of the earthquake at its source.

The following assumptions about the occurrence of earthquakes throughout the EUS form the basis for the probability calculations used to evaluate the hazard curve at a site:

- o For each zone, it is assumed that earthquakes could occur randomly over time and uniformly at random within the zone.
- o All earthquakes are assumed to be point sources, thus the fact that earthquakes are created by the rupture of tectonic faults of finite length is neglected.
- o The occurrence of earthquakes is assumed to be independent between zones.
- o The occurrence rate of earthquakes within a zone is considered to be constant; its value is based on the seismic and tectonic conditions that presently exist within the zone.

We further assume that:

- o The expected number of earthquakes of magnitude m or greater, $\Lambda(m)$, occurring within a zone can be described by the magnitude-recurrence relation

$$\log \Lambda(m) = H(m) \qquad M_0 \le m \le M_U$$

  The functional form of H(m) is based on information elicited from the experts.

- o Given the magnitude of an earthquake at its source and the distance of the site from the source, it is assumed that the physical variation in the PGA at the site is described by some probability distribution. For other than the Trifunac model of spectra (model #94 in Table B-1) the distribution was a lognormal distribution.

The hazard analysis is based on considering the effect above the minimum magnitude M_o. Under the assumption that earthquakes occur at random over time, the number $N_t(m)$ of earthquakes with magnitude greater than M, $m > M_o$, occurring within a zone in a time period of t years is a Poisson random variable with parameter $\Lambda(m)$. Thus, the probability of exactly n earthquakes with magnitudes greater than m in t years is

$$P[N_t(m)=n] = [t\Lambda(m)]^n e^{-t\Lambda(m)}/n! \qquad n=0, 1, ... \qquad (C.1)$$

The occurrence rate $\Lambda(m)$ can be expressed as $\lambda_o P(M>m|M>Mo)$ where λ_o is the expected member of earthquakes of magnitude greater than the minimum M_o and $P(M>m|M>M_o)$ is the probability, given an earthquake, that the magnitude exceeds m conditional on the magnitude exceeding M_o. Two models for the occurrence rate $\Lambda(m)$ based on alternative views of the conditional distribution of magnitude given an earthquake were used. These are discussed in Sec. C.3.2.

Using the assumption that earthquakes are point sources which occur at random uniformly throughout a zone, if $N_t(r,m)$ is the number of earthquakes in t years of magnitude greater than m occurring at points in the zone which are r(km) to r+dr(km) from the site, then $N_t(r,m)$ is a Poisson random variable with parameter

$$\Lambda(m)\ f_R(r)dr \qquad (C.2)$$

where $f_R(r)$ is the density function for the distribution of the distance from the site to the points within the zone and $\Lambda(m)$ now denotes the occurrence rate per unit area per year. The distribution $f_R(r)$ is the proportion of a given zone located within specific ranges of distance from the site (see Sec. 2).

Given an earthquake of magnitude greater than m at a distance (r,r+dr) from the site the ground motion parameter, e.g. PGA, at the site depends on the attenuation of the source energy between the source and the site. We assume this to be a random process. Specifically, we assume the PGA at the site is a lognormal random variable such that the mean of the logarithm of PGA is given by the attenuation/ground motion model which depends on m and r. This assumption was also made for spectra, except for Trifunac's model which is itself a distribution function. We denote the conditional probability of PGA exceeding the value a by $P(A > a|m,r)$.

Let $N_t(a)$ denote the random variable, the number of earthquakes occurring in a zone in t years such that the PGA at the site is greater than a. The probability that one or more earthquakes occur in t years resulting in the PGA at the site exceeding a, denoted $P(A_t > a)$, is given by

$$P(A_t > a) = P(N_t(a) \geq 1) \qquad (C.3)$$

Considering the range of magnitudes (M_o, M_U), where M_U is the upper magnitude cutoff, and all distances r>0, $N_t(a)$ is a Poisson random variable with parameter ($\lambda_a t$), where

$$\lambda_a = \lambda_o \int_{M_o}^{M_U} \int_{r>o} P(A > a|m,r) f_R(r) dr \; dF_M(m|M_o,M_U) \qquad (C.4)$$

and $F_M(m|M_o, M_U)$ denotes the distribution function of the distribution of magnitudes given an earthquake, conditional on minimum magnitude M_o and upper magnitude cutoff M_U.

In our analysis we approximated the integral numerically by subdividing both the distance and magnitude range into subintervals. Distances out to 1250 km were considered and subdivided into 18 subintervals. Details of the partition are given in Section 2.3. Let $\Pi(r_k)$ denote the proportion of the zone at distances in the kth subinterval, i.e.

$$\Pi(r_k) = \int_{\substack{r \text{ in} \\ k\text{-th subinterval}}} f_R(r) dr \qquad (C.5)$$

Similarly, magnitudes were partitioned into subintervals of length 0.25 (M_{blg}) or 0.5 (MMI). Let m_j, the midpoint of the jth magnitude subinterval, be the representative value for the jth subinterval, and let

$$\lambda(m_j) = \lambda_o \int_{m_j-\Delta}^{m_j+\Delta} dF_M(m|M_o,M_U) \qquad (C.6)$$

$$= \Lambda(m_j - \Delta) - \Lambda(m_j + \Delta)$$

= the expected number of earthquakes per year per unit area with magnitudes in the jth subinterval ($m_j - \Delta$, $m_j + \Delta$)

Then, the parameter $\lambda_a t$ for the Poisson distribution of $N_t(a)$ is

$$\lambda_a t \doteq t \sum_{j=1}^{J} \lambda(m_j) \sum_{k=1}^{K} \pi(r_k) P(A > a|m_j,r_k) \qquad (C.7)$$

Therefore, for a given source zone q, the probability that the maximum PGA at the site, in a time period of length t, due to earthquakes occurring in zone q exceeds a is

$$P_q(A_t > a) = P_q(N_t(a) \geq 1)$$

$$= 1 - \exp[-t \sum_{j=1}^{J} \lambda_q(m_j) \sum_{k=1}^{K} \Pi_q(r_k) P(A > a|m_j, r_k)] \quad (C.8)$$

where $\lambda_q(\cdot)$ and $\Pi_q(\cdot)$ are dependent on the zone.

Finally, under the assumption that events between zones are independent, the seismic hazard in t years at a site can be evaluated by

$$P(A_t > a) = 1 - \Pi_q[1 - P_q(A_t > a)]$$

$$= 1 - \Pi_q\{\exp[-t \sum_{j=1}^{J} \lambda_q(m_j) \sum_{k=1}^{K} \Pi_q(r_k) P(A > a|m_j, r_k)]\} \quad (C.9)$$

In the analysis the range of accelerations a is also discretized, thus the hazard is actually evaluated at a finite number (10) of accelerations, a_i, $i=1, \ldots I=10$.

C.3.2 Magnitude-Recurrence Models

The hazard at a site, as described by the hazard curve, depends on the occurrence rate $\Lambda(m)$ of earthquakes of magnitudes m or greater. The occurrence rate varies with m and depends on the occurrence rate Λ_o of earthquakes of magnitudes greater than the minimum M_o and the distribution of earthquake magnitudes $F_M(m|M_o, M_U)$. The dependence of $\Lambda(m)$, the occurrence rate or expected number of earthquakes per unit time per unit area, on m is called the magnitude-recurrence relationship. Two primary models for the magnitude-recurrence relationship were used in the hazard analysis for this project.

A common model for approximating the distribution of earthquake magnitudes, given an earthquake, is the exponential model. If Λ_o is the expected number of earthquakes of magnitudes M_o or greater and if $F_M(m|M_o)$, the distribution of magnitudes given an earthquake conditional on magnitude $M > M_o$, is exponential, the expected number of earthquakes of magnitude m or greater is

$$\Lambda(m) = \lambda_o e^{-\beta(m-M_o)} \qquad m>M_o \quad (C.10)$$

$$= \lambda_o e^{\beta M_o} e^{-\beta m}$$

or

$$\log_{10} \Lambda(m) = \log_{10}\lambda_o + \beta M_o \log_{10}e - \beta m \log_{10}e \quad (C.11)$$

which has the form

$$\log_{10}\Lambda(m) = a + b\,m \qquad (C.12)$$

with

$$b = -\beta < 0$$

$$a = \log_{10}\lambda_o - b\,M_o$$

This model assumes that magnitude can be arbitrarily large. Physically, this is not possible. Since the principle contributors to the hazard at a site are large magnitudes, the assumption of arbitrarily large magnitude is unacceptable. Thus, an upper magniltude cutoff, i.e. largest possible magnitude, is assumed. This was one of the parameters elicited from the seismicity panel.

To accomodate the limiting magnitude, some adjustment must be made in the magnitude-recurrence model in Equation C.11. Two adjustments were considered:

1. LLNL Model

   The basic philosophy in the LLNL model is that the linear model, Eq. (C.12),

$$\log_{10}\Lambda(m) = a + bm \qquad (C.13)$$

is applicable for some range (M_{LB}, M_{UB}) of magnitudes, subject to the two obvious restrictions

- o $\Lambda(M_o) = \lambda_o$, i.e., $\log_{10}\Lambda(M_o) = \log_{10}\lambda_o$
- o $\Lambda(M_U) = 0$, i.e., $\log_{10}\Lambda(M_U) = -\infty$

Under this philosophy the linear model in Eq. (C.13) must be adjusted to satisfy the restrictions in the intervals (M_o, M_{LB}) and (M_{UB}, M_U). An adjusted model is shown in Fig. C.2.

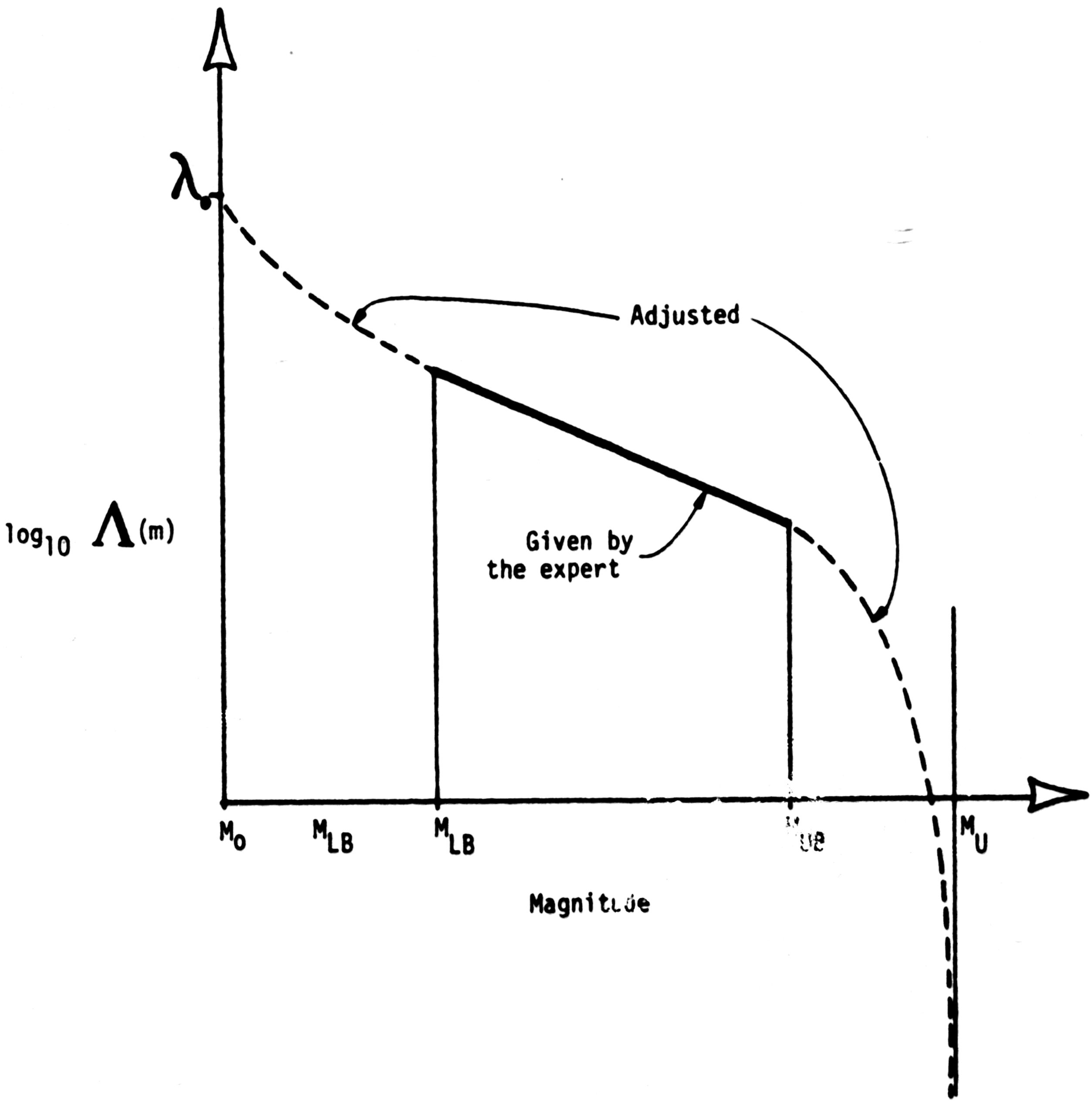


Fig. C.2. LLNL adjusted magnitude-recurrence model.

The adjustments to the exponential model, based on the LLNL philosophy, in the two regions are respectively;

- (M_o, M_{LB}): quadratic polynomial subject to
  - $\Lambda(M_o) = \lambda_o$
  - $\log_{10}\Lambda(M_{LB}) = a + b\,M_{LB}$
  - derivative of $\Lambda(m)$ is continuous at $m = M_{LB}$

- (M_{UB}, M_U): model

$$\Lambda(m) = \alpha e^{\beta m}\,(m-M_U)^2$$

subject to

- $\log_{10}\Lambda(M_{UB}) = a + bM_{UB}$
- derivative of $\Lambda(m)$ is continuous at $m = M_{UB}$

Further details on the use of the LLNL model in the hazard analysis are given in Section C.5.2.

2. Truncated Exponential Model

A second method for adjusting the exponential magnitude-recurrence model in Eq. C.12 is based on assuming the distribution of magnitudes, conditional on $M_o < m < M_U$, to be a truncated exponential distribution. That is,

$$P(M > m|M_o, M_U) = \frac{e^{-\beta(m-M_o)}\left[1 - e^{-\beta(M_U-m)}\right]}{\left[1 - e^{-\beta(M_U-M_o)}\right]} \quad (C.14)$$

The adjusted magnitude-recurrence model is

$$\log_{10}\Lambda(m) = \log_{10}\lambda_o + \beta\,M_o\log_{10}e - \beta\,m\,\log_{10}e$$

$$+ \log_{10}\left[1 - e^{-\beta(M_U-m)}\right] - \log_{10}\left[1 - e^{-\beta(M_U-M_o)}\right] \quad (C.15)$$

which is of the form

$$\log_{10}\Lambda\,(m) = a + bm + G(m) \quad (C.16)$$

where

$$a = \log_{10} \lambda_o - \beta M_o \log_{10} e$$

$$b = -\beta \log_{10} e$$

$$G(m) = -\log_{10}\left[1 - e^{-\beta(M_U - M_o)}\right] + \log_{10}\left[1 - e^{-\beta(M_U - m)}\right]$$

such that

$$G(M_o) = 0$$

A plot of the truncated exponential model is shown in Fig. C.3.

Details of the use of this model in the hazard analysis is given in Sec. C.5.2.

Although the seismicity panelists were given the choice of any model for the magnitude-recurrence relationship, all but one expert chose the linear model. These experts were then asked to choose between the two alternative adjustments. One expert chose a piecewise linear model. In this case separate adjustments were made, if necessary, in the intervals (M_o, M_{LB}) and (M_{UB}, M_U).

C.3.3 Uniform Hazard Spectrum

The notion of a uniform hazard spectrum (UHS) is discussed in detail in ([1], Section 5.0). However, we summarize some of the mathematical aspects relevant to the evaluation methodology. A uniform hazard spectrum is developed such that for each frequency the spectral amplitude has the same probability of being exceeded in t years.

Based on the method outlined in the previous section, the hazard curve, i.e. the probability that the maximum PGA per year (in t years) exceeds the value a or the probability of exceedence, is assessed independently for each frequency. Assuming that the occurrence of earthquakes is a Poisson process, for each frequency, f (assuming t = 1 year),

$$P(A_f > a) = 1 - e^{-\lambda_a} \qquad (C.17)$$

where λ_a is the expected number of events per year such that the peak spectral acceleration at the site exceeds a. Therefore, the time between events such that $A_f > a$, denoted $T(A_f > a)$, has expected value

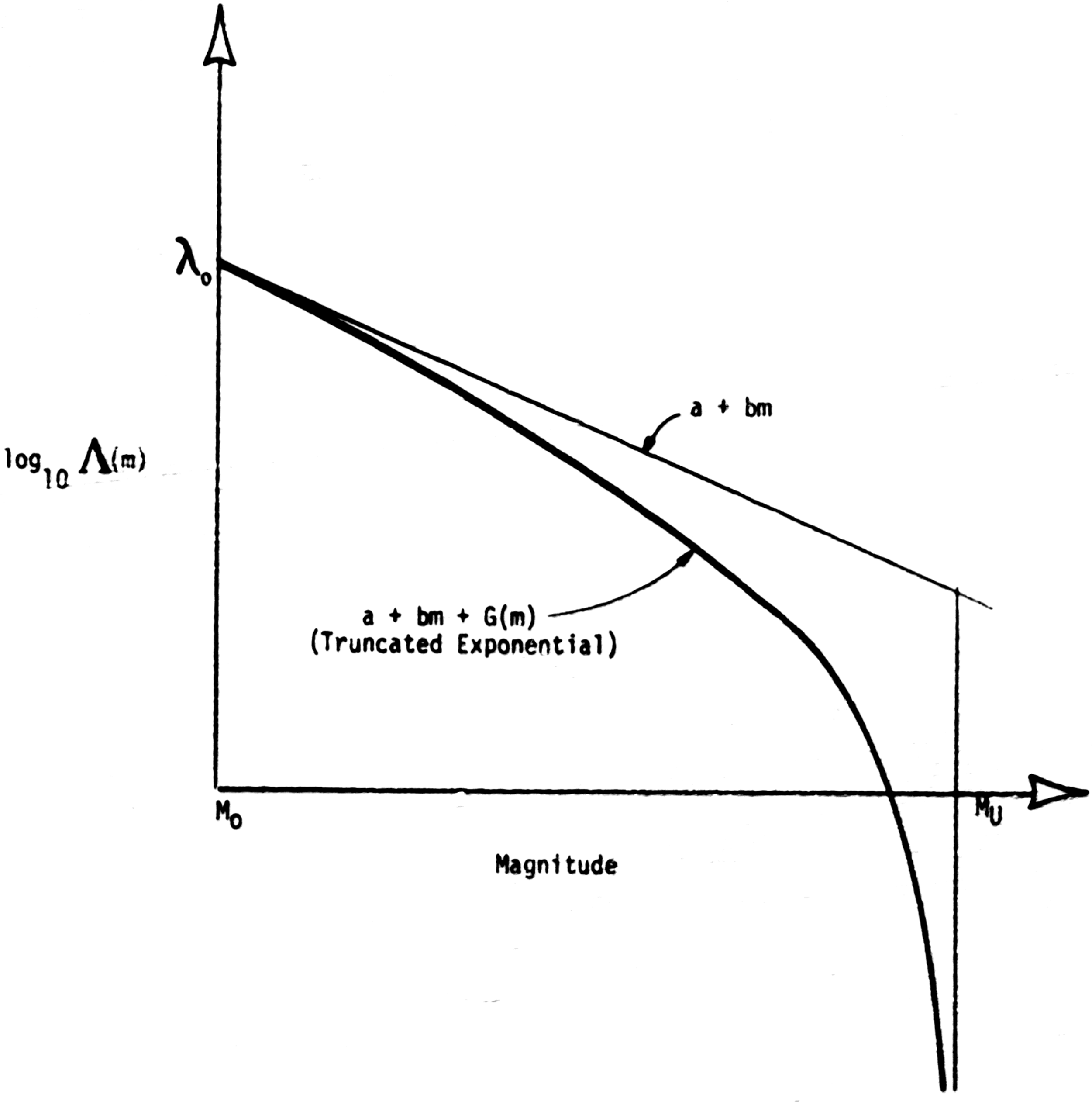


Fig. C.3. Truncated exponential magnitude-recurrence model.

$$RP_f(a) = \varepsilon[T(A_f > a)] = \lambda_a^{-1} \quad (C.18)$$

which is the return period of events such that $A_f > a$ at the site. Therefore the relation between the return period and the probability of exceedence is

$$RP_f(a) = \{-\ln[1 - P(A_f > a)]\}^{-1}$$

$$\doteq [P(A_f > a)]^{-1} \quad , \quad (C.19)$$

for long return periods.

A typical plot of the return period, on the log scale, versus a is shown in Fig. C.4 for two frequencies. For a return period of interest, e.g., 10,000 years, the spectral PGA's corresponding to the return period are used as the spectral amplitudes for the different frequencies f_1, f_2, ... (9 frequencies were included in the analysis).

C.3.4 Weights for Seismicity Experts

Both seismicity and attenuation/ground motion model information were elicited from several experts. Thus, seismic hazard curves could be estimated using information from any pair of experts--a seismic expert and a ground motion model expert. In addition, it may be appropriate to combine the opinions of the experts. This could be done at two points in the evaluation process

- o A consensus could be reached on a single set (or a finite collection) of values for the seismicity parameters as well as agreement on the 'best' attenuation/ground motion model or set of models.
- o The opinions of the individual experts, i.e. a seismic and ground motion expert pair, could be used to evaluate a seismic hazard curve and then the resulting hazard curves could be combined to form a combined hazard curve which represents, in some fashion, the opinions of all the experts.

We feel it is important to retain the diversity of opinions that might have existed between the experts, thus hazard curves were evaluated for every pair, i.e. seismicity-ground motion pair, of experts and these were subsequently combined to evaluate an 'average' hazard curve.

The method for combining the individual results is based on a weighted average of the individual hazard curves or uncertainty distributions. The weights for the attenuation model experts are the normalized values of the self-weights the experts provided. The weights for the seismicity experts are themselves a weighted average of the four regional self-weights provided by the experts.

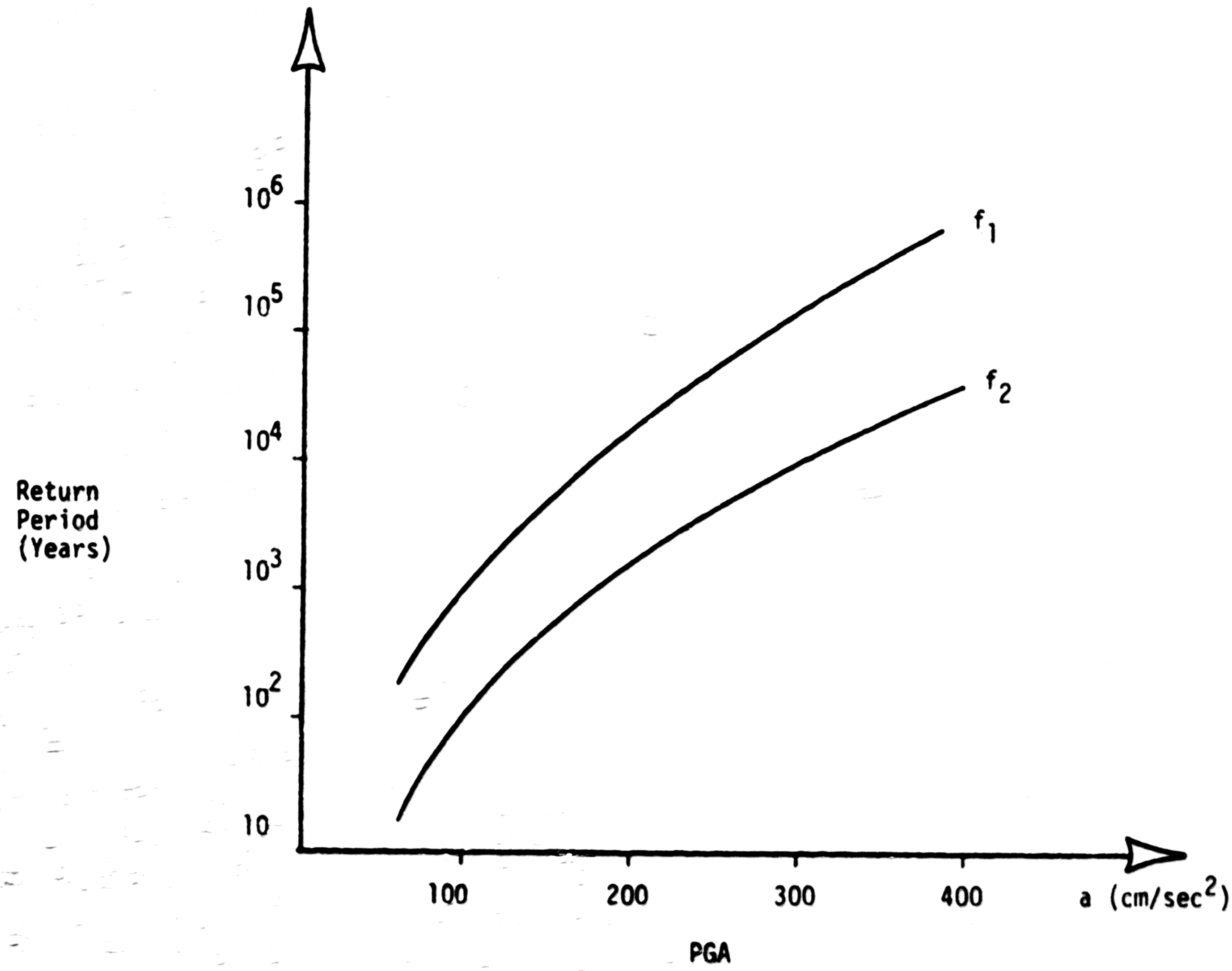


Fig. C.4. Relationship between spectral acceleration and return period.

Although the following development is not entirely consistent with the general philosophy of the overall evaluation process, it does provide a convenient basis for combining the regional self-weights for the seismicity experts into a single 'self-weight'.

Let s index the sth seismic expert, s=1, . . ., S and let w index the wth region of the EUS, w = 1, 2, 3, 4. Also let W_{sw} denote the self-weight of expert s in the wth region. Let

$$A_w = \max_{\substack{q \text{ in wth} \\ \text{region}}} (A_q;\ q = 1 \ldots N_w)$$

be the maximum PGA at the site due to earthquakes originating in the wth region. Based on the best estimate information from the sth expert, his assessment of the cumulative distribution function for A_w is

$$\Omega_{sw}(a) = \prod_{\substack{q \text{ in wth} \\ \text{region}}} \left[1 - \hat{P}_{sw}(A_q > a)\right] \tag{C.20}$$

where $\hat{P}_{sw}(\cdot)$ is the estimated probability based on the best estimate of the seismic parameters provided by the sth expert.

One way of interpreting $\Omega_{sw}(\cdot)$ is to consider it to be the expert's assessment of the value of A_w, the maximum PGA at the site due to earthquakes in the wth region. In this context, one might also consider the expert's self weight W_{sw} as an expression of his utility for $\Omega_{sw}(\cdot)$ as a predictor of A_w.

For the hazard analysis the parameter of interest is

$$A = \max_w (A_w : w = 1, \ldots, 4)$$

the maximum PGA at the site. Given the assessment $\Omega_{sw}(\cdot)$ for A_w, the sth expert's assessment of A is

$$\Omega_s(a) = \prod_w \Omega_{sw}(a)$$

$$= \prod_w \prod_{\substack{q \text{ in wth} \\ \text{region}}} \{1 - \hat{P}_{sw}(A_q > a)\} \tag{C.21}$$

Then, the expected utility for $\Omega_s(a)$ as a predictor of A is

$$W_s = \sum_w W_{sw} P(A = A_w) \tag{C.22}$$

where $P(A = A_w)$ is the probability that the maximum PGA at the site results from an earthquake originating in the wth region. The normalized value of W_s is the weight assigned to the sth seismicity expert where $P(A = A_w)$ is estimated from the expert's best estimate $P_{s_w}(A_t > a)$ of the distribution of the maximum PGA at a site due to earthquakes originating in the wth region.

The experts were not asked to give their opinions about the value of A nor were they asked about their utility for their opinions, thus, this development of W_s does not model precisely the elicitation conducted in this project. However, it does provide a rational method for combining the self weights in the 4 regions into a single weight for each seismicity expert. In addition, it does have some appealing features:

- o weights vary between sites
- o the weight will be "high" if the self weight is highest in the regions with the highest probability of producing the maximum PGA at the site.
- o the weight will be "low" if the self weight is highest in the regions with the lowest probability of producing the maximum PGA at the site.

C.4 Summary of Elicitation Results - Inputs for the Evaluation Process

Detailed discussions of the elicitation, compilation and interpretation of the experts' opinions are presented in previous sections of the report. However, to provide continuity in the presentation of the probabilistic calculations it is necessary to summarize the elicited opinions as they are used as inputs into the estimation of the seismic hazard at a site.

C.4.1 Seismic Source Indentification

Each seismicity expert was asked to identify seismic sources throughout the EUS, expressed in terms of a complete zonation of the region. Identification of zones throughout the EUS was elicited in two forms:

- o A 'best estimate' map, representing, in the expert's opinion, the most appropriate zonation of the EUS.
- o Alternative zonations representing the expert's uncertainty about the zonation, produced by
  - • expressing a 'level of confidence' or degree of belief that a zone should be identified as a source separate from the surrounding area

suggesting alternative configurations for individual zones or clusters of zones along with a measure of degree of belief for each configuration.

Using the program module COMAP the collection of all possible maps along with the degree of belief (probability) for each map could be produced. Actually, a maximum of 30 maps, with the highest probabilities, were inputs into the analysis.

C.4.2 Seismicity Parameters

For each zone identified on the maps for a seismicity expert estimates of the following seismicity parameters and models were elicited

- o the upper magnitude cutoff, M_U - largest magnitude expected to occur under current geologic and tectonic conditions
- o the occurrence rate λ_o of earthquakes with magnitude greater than a minimum M_o(3.75m_{blg} or IV MMI) - λ_o is the expected number of events per year with magnitude greater than M_o
- o the magnitude recurrence model,

$$\log_{10} \Lambda(m) = H(m)$$

which relates the expected number of events per year with magnitudes greater than m, $\Lambda(m)$, to the level m.

Information elicited about these parameters, used as inputs into the analyses, were

- o Upper magnitude cutoff, M_U
  - • Best estimate, $\hat{M}_U$
  - • Bounds (M_{UL}, M_{UU}) which represent the expert's level of confidence in the resources he relied on to estimate M_U. The range M_{UL}, M_{UU} was treated as absolute bounds for M_U. Thus we assumed that M_U, in the opinion of the expert, will not exceed M_{UU}. Conversely, we assume it is the experts opinion that M_U will exceed M_{UL}.
- o Occurrence rate, λ_o
  - • Best estimate, $\hat{\lambda}_o$
  - • Bounds (λ_{oL}, λ_{oU}) which represent the expert's 'confidence' in the resources used to estimate λ_o. We treated λ_{oL} as the value of which the expert is 97.5% confident, based on the available resources, is the lowest value of λ_o. Conversely, λ_{oU} is the

value which the expert is 97.5% confident is the largest value of λ_0.

o Magnitude (intensity) recurrence relation

- A mathematical model for the magnitude recurrence relation, H(m), i.e. for the relationship between the logarithm of the expected number of earthquakes with magnitude greater or equal to m and the magnitude m. All but one expert chose a linear model

$$H(m) = a + bm \qquad (C.23)$$

The exceptional model was a piecewise linear model

$$H(m) = \begin{cases} a_1 + b_1 m & (M_{LB1}, M_{UB1}) \\ a_2 + b_2 m & (M_{LB2}, M_{UB2}) \end{cases}$$

- The range of magnitudes (M_{LB}, M_{UB}), $M_o \le M_{LB} < M_{UB} \le M_U$, over which the model is applicable.

- A choice between the two alternative adjustments, (1) LLNL or (2) Truncated exponential, to the linear model to accomodate a finite maximum earthquake magnitude.

- Best estimates and bounds for each of the parameters, i.e., a's, b's, in the model. The bounds for the coefficients were interpreted in the same way as the bounds for λ_o.

- A choice between 3 levels of correlation:
  - zero correlation, i.e. independence
  - 'moderate' negative correlation
  - 'perfect', i.e., -1.0, correlation

  between the estimates of the coefficients a, b (see Vol. 2, Questionnaire 5 for more details).

C.4.3 Attenuation/Ground Motion Models

Elicitation of opinions about attenuation/ground motion models was based on providing the experts with a catalogue of models for each of the ground motion parameters, PGA, peak ground velocity (PGV), and spectral acceleration and velocity. Seven classes of PGA and PGV models were identified, five of which were intensity based models and two classes which were empirically derived models relating the ground motion parameter directly to the source characteristics.

The experts were asked to express their opinions in the following form. For each of the four regions NE, SE, NC, SC and the two magnitude scales M_{bLg} and MMI,

- o The 'best estimate' model - the attenuation/ground motion model which, in their opinion, best models the expected ground motion at a site in terms of the source parameters, e.g. m, r.

- o A subset of up to seven (six for spectra) models with associated levels of confidence; these models represent their uncertainty in predicting the expected ground motion at a site given the source magnitude and the source-to-site distance.

Part of the hazard analysis is based on the assumption that, given an earthquake of magnitude m at a distance r(km) from the site, the ground motion parameter at the site is variable. We assumed that the variation is approximated by a truncated distribution due to ground motion saturation. For all but the Trifunac spectra model (Model #94 of Table 3-1) the ground motion model describes the mean of the distribution as a function of m and r.

In addition, the following were elicited:

- o The best estimate and bounds for the coefficient of variation (standard deviation of the logarithm of the ground motion parameter) except for the Trifunac model.

- o A choice between 4 models of saturation (described in Vol. 2, Questionnaire 6).

  I: an absolute maximum acceleration, independent of m and r

  II: maximum acceleration as a function of m and r; described by a fixed number of standard deviations from the mean

  III: an envelope of I and II

  IV: no saturation

  The information elicited was best estimates of

  I: an absolute maximum acceleration, a_1

  II: number, n, of standard deviations

  III: both an a_1 and an n.

The uncertainty between the ground motion models was summarized by considering the collection of models, with the corresponding confidences (probabilities) analogous to the treatment of the zonation maps. The bounds for the coefficient of variation was interpreted in the same way as the bounds for the seismicity parameters.

C.4.4 Correction for Local Site Effects

Most of the ground motion models in the catalogue of models considered for the hazard analysis are based on data derived from sites with different types of soil, e.g. hard rock, shallow soil, deep soil. However, it is known that the local soil conditions can have a significant effect on the values of the ground motion parameters for a given earthquake magnitude and distance. Thus, it is appropriate to consider adjustments to the ground motion models to account for the local site effects. Two types of corrections, which are described in detail in Sec. 3 and Vol. 2 Questionnaire 6, were considered in the hazard analysis. Therefore, the experts were asked to choose between three methods for handling the effects of local site conditions:

- o no correction to the basic ground motion model
- o a simple correction, i.e. only two types of sites--rock, soil
- o a categorical correction, i.e., a more extensive catagorization of site soil types

C.5 Evaluation Methodology

C.5.1 Introduction

If the parameters of the probability models, e.g. expected values, $\Lambda(m)$, and coefficients of the attenuation models, were all known, evaluation of the seismic hazard curve is straightforward and would follow the mathematical methods outlined in Section C.3. However, these parameters are not known so they must be estimated. Values of these parameters were elicited from experts, thus estimation of the hazard curve at a site is based on subjective judgements. Because opinions can only be based on limited knowledge of the physical factors affecting seismicity and attenuation of ground motion, there are uncertainties associated with these opinions. Therefore, the methods used to estimate a hazard curve should recognize the uncertainties associated with the values of the parameters based on expert opinions. The uncertainties associated with subjective assessments of physical phenomena are recognized in the procedure used to estimate the hazard at a site. The procedure involves a two-step estimation process:

- o Evaluation of a 'best estimate' hazard curve, i.e., evaluation of a hazard curve based on the experts' best estimates of the model parameters, e.g., $\hat{M}_U$, $\hat{\lambda}_o$.
- o Evaluation of a set of curves derived from the uncertainty in $P(A_t > a)$, for each a, attributable to the uncertainties in the estimates of the model parameters, i.e., quantification of the 'confidence', i.e., degree of belief or level of knowledge, about the model parameters, expressed by the experts.

The evaluation process also recognizes that there is a potential difference in the level of expertise between the members of each of the panels. Thus, whenever estimates are combined over experts, the combined estimate is based on weighting the estimates of the individual experts.

A summary graphical description of the overall estimation process is given in Fig. C.5. Although the description is given in terms of estimating a hazard curve, comparable calculations are performed for spectral velocities which in turn are used to estimate the uniform hazard spectrum.

C.5.2 Best Estimate Calculations

The method for evaluating the "best estimate" hazard curve is a straightforward application of the equations in Section C.3. The best estimates, as provided by each expert, are used as the parameters of the models and distributions needed to estimate the hazard curve at a site.

The flow chart of the seismic hazard calculations in Fig. C.5 is followed in describing the best estimate analysis:

Inputs

- o Per seismicity expert, s
  - o Self weights for the four regions: W_{sw}: $w = 1,2,3,4$
  - o Best estimate map consisting of
    - Zone index, q
    - δ_{wq} - Identifier of regional location of qth zone
    - $\{\Pi_q(r_k);\ K = 1, \ldots K\}$ - distribution of distances from site of points in qth zone
    - Best estimate occurrence rate $\hat{\lambda}_{oq}$ for each zone
    - Best estimate of upper magnitude cutoff $\hat{M}_{Uq}$ for each zone
    - Best estimate model coefficients and range for magnitude-recurrence model, $(\hat{a}_q, \hat{b}_q;\ M_{LBq}, M_{UBq})$
    - choice between LLNL and truncated exponential models for adjusting the magnitude recurrence model
  - o Per attenuation expert, u
    - Self weights, W_{Au}
    - "Best Estimate" attenuation model, $\hat{G}_u(m, r)$
    - Best estimate of random variation for ground motion parameter, $\hat{\sigma}_{Ru}$
    - Choice of model for ground motion saturation
    - Choice of method for correcting for local site effects

Calculation of Probability Parameters

- o Conditional probability of PGA given magnitude m and range r, $P(A > a|m, r)$--derived from a truncated lognormal distribution with

START

↓

IDENTIFY
SEISMICITY EXPERT(s)

↓

CALL ALEAS

- o Read in inputs
- o Calculate necessary probability parameters
- o Evaluate best estimate (BE) hazard curve for each ground motion expert
- o Evaluate BE hazard curve combined over ground motion experts
- o Evaluate weight W_s for seismicity expert
- o Evaluate contribution γ_{sq} from qth zone
- o Do uncertainty analysis for each ground motion expert
- o Compute bounds for $P(A > a)$ for all a for each ground motion expert
- o Compute bounds for $P(A > a)$ combined over all ground motion experts

↓

OUTPUT
RESULTS FOR
sth SEISMICITY
EXPERT

↓

CREATE FILE
OF RESULTS FOR
COMB

↓

ITERATE OVER
$s = 1, \ldots S$

↓

CALL COMB

- o Read in inputs
- o Combine BE hazard curves over all experts
- o Compute bounds for $P(A > a)$ for all values of a combined over all experts

↓

OUTPUTS

- o Combined BE hazard curves
- o 15th, 50th and 85th percentile curves
- o Optional; mean hazard curve

Fig. C.5. Summary flow chart of the seismic hazard calculations.

parameters for all models other than Trifunac's model of spectra (Model #94 in Table B-1)

$$\mu_u(m, r) = \hat{G}_u(m, r)$$

$$s_u = \hat{\sigma}_{Ru}$$

o Expected number of events with magnitude $m_j (j = 1, \dots J)$, $\lambda_{sq}(m_j)$

To assess $\lambda_{sq}(m_j)$ for all $j = 1, \dots, J$ it is necessary to have the occurrence rate $\Lambda_{sq}(m)$ identified for all m in $(M_o, \hat{M}_{Uq})$ where $\hat{M}_{Uq}$ is the best estimate of the upper magnitude cutoff in the qth zone.

1. If LLNL model selected:

- If $M_{LBq} = M_o$, $M_{UBq} \geq \hat{M}_{Uq}$,

  then

  $$\hat{\Lambda}_{sq}(M_o) = 10^{(\hat{a}_q + \hat{b}_q M_o)}$$

  $$\hat{\lambda}(m_J) = \hat{\Lambda}_{sq}(m_J - \Delta) \text{ if } 10^{(\hat{a}_q + \hat{b}_q \hat{M}_{Uq})} = 0$$

  where Δ is one-half the width of a magnitude segment created in the discretization of the magnitude axis.

- If $M_o < M_{LBq}$ or $M_{UBq} < \hat{M}_{Uq}$

  for $M_o \leq m \leq M_{LBq}$, $\hat{\Lambda}_{sq}(m)$ is based on a quadratic polynomial model subject to

  $$\hat{\Lambda}_{sq}(M_o) = \hat{\lambda}_{oq}$$

  $$\hat{\Lambda}_{sq}(M_{LBq}) = 10^{(\hat{a}_q + \hat{b}_q M_{LBq})}$$

  the derivative of $\hat{\Lambda}_{sq}(m)$ is continuous at $m = M_{LBq}$

- for $M_{UBq} \leq m \leq \hat{M}_{Uq}$, $\hat{\Lambda}_{sq}(m)$ is based on the model

  $$\Lambda_{sq}(m) = \alpha e^{\beta m}(m - \hat{M}_{Uq})^2$$

subject to

$$\Lambda_{sq}(M_{UBq}) = 10^{(\hat{a}_q + \hat{b}_q \hat{M}_{UBq})}$$

the derivation of $\hat{\Lambda}_{sq}(m)$ is continuous at $m = M_{UBq}$

A graphical illustration of the adjusted occurence rate $\hat{\Lambda}(m)$, assuming a linear magnitude recurrence relation

$$\log_{10}\Lambda(m) = a + bm$$

is given in Fig. C.6.

2. If truncated exponential model selected:

- If $M_{LBq} = M_o$, for $M_o < m < \hat{M}_{Uq}$,

$$\log_{10}\hat{\Lambda}_{sq}(m) = a + bm - \log_{10}[1 - e^{-\beta(MUq - Mo}]$$

$$+ \log_{10}[1 - e^{-\beta(\hat{M}Uq - m)}]$$

where

$$\beta = -b(\log_{10}e)^{-1}$$

- If $M_o < M_{LB}$,

for $M_o \le m \le M_{LBq}$, $\hat{\Lambda}_{sq}(m)$ is based on a quadratic polynomial model subject to

$$\hat{\Lambda}_{sq}(M_o) = \hat{\lambda}_{oq}$$

$$\hat{\Lambda}_{sq}(M_{LB}) = 10^{\hat{a}_q + \hat{b}_q M_{LBq}}$$

the derivative of $\hat{\Lambda}_{sq}(m)$ is continuous at $m = M_{LB}$ for $M_{LBq} \le m < M_{Uq}$

$$\log_{10}\hat{\Lambda}_{sq} = a + bm - \log_{10}[1 - e^{-\beta(\hat{M}_{Uq} - M_{LBq})}]$$

$$+ \log_{10}[1 - e^{-\beta(\hat{M}_{Uq} - m)}]$$

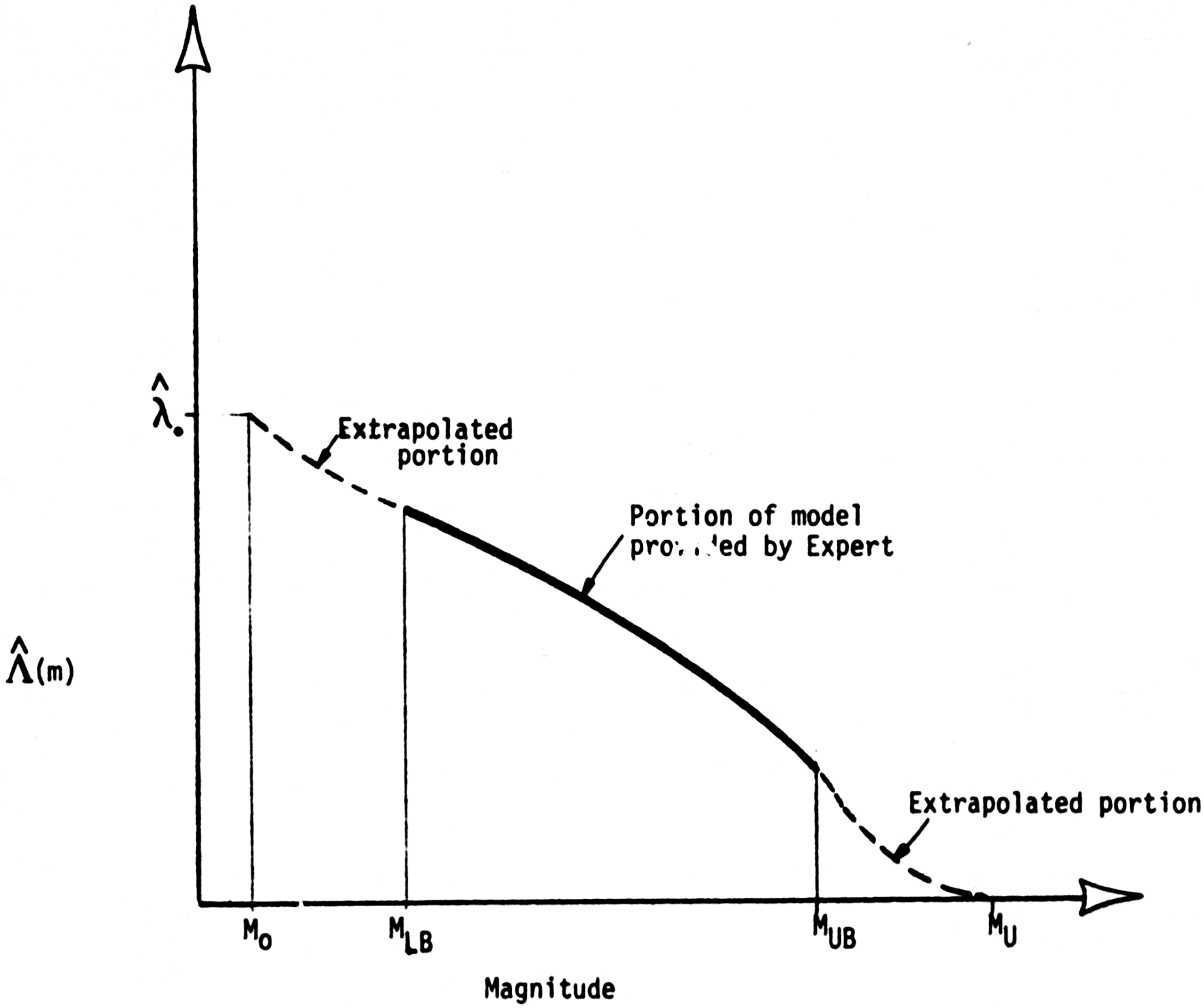


Fig. C.6. Adjustment of the magnitude-recurrence relation.

where

$$\beta = -b(\log_{10}e)^{-1}$$

Given the adjusted occurrence rate function $\hat{\Lambda}_{sq}(m)$, the expected number of earthquakes in the qth zone with magnitude in the jth segment $(m_j - \Delta, m_j + \Delta)$, based on the sth expert's seismicity parameters for the qth zone, is

$$\hat{\lambda}_{sq}(m_j) = \hat{\Lambda}_{sq}(m_j - \Delta) - \hat{\Lambda}_{sq}(m_j + \Delta)$$

<u>Best Estimate Hazard Calculations</u>

For each seismicity expert, s

- Best estimate hazard at the site due to events in the qth zone

$$\hat{P}_{suq}(A_t > a) = 1 - \exp\{-t \sum_{j=1}^{J} \hat{\lambda}_{sq}(m_j) \sum_{k=1}^{K} \pi_{sq}(r_k) \hat{P}_u(A > a \mid m_j, r_k)\}$$

for $a = a_1, a_2, \ldots, a_I$

- Best estimate hazard at the site due to events over all zones in the best estimate map

$$\hat{P}_{su}(A_t > a) = 1 - \prod_q \exp\{-t \sum_{j=1}^{J} \hat{\lambda}_{sq}(m_j) \sum_{k=1}^{K} \pi_{sq}(r_k) \hat{P}_u(A > a \mid m_j, r_k)\}$$

for $a = a_1, a_2, \ldots, a_I$

- Best estimate hazard at the site due to events in the qth zone, combined over ground motion experts

$$\hat{P}_{sq}(A_t > a) = \{\sum_u W_{Au} \hat{P}_{suq}(A_t > a)\} / \sum_u W_{Au}$$

- Best estimate hazard at the site due to events over all zones in the best estimate map, combined over ground motion experts

$$\hat{P}_s(A_t > a) = \{ \sum_u W_{Au} \hat{P}_{su}(A_t > a)\} / \sum_u W_{Au}$$

We have used the terminology "best estimate" to identify these hazard curves. In reality these curves are the hazard curves at a site based on specific values, the experts' best estimates, for the inputs. Given the uncertainties associated with the inputs the best estimate hazard curve is unlikely to coincide with some estimate of the hazard curve in the classical statistical sense, such as mean, median, mode, or maximum likelihood.

Other Calculations

o Two other calculations, in addition to the best estimate hazard curves, are:

- Per cent of hazard at a site attributable to the qth zone

$$Y_{sq}(a) = \frac{\hat{P}_{sq}(A_t > a)}{\hat{P}_s(A_t > a)}$$

- Weight for sth seismicity expert

  A discussion of the background for evaluating a single weight for each seismicity expert is given in Section C.3.4. The weight for the sth seismicity expert, W_s, is the weighted average of the self weights in the four regions, i.e.

$$W_s = \sum_{w=1}^{4} W_{sw} \hat{P}_s(A = A_w)$$

where $\hat{P}_s(A = A_w)$ is the estimate, based on the sth expert's best estimate inputs, of the probability that the maximum PGA at the site is due to an earthquake originating in a zone in the wth region, which is the normalized value of

$$\hat{P}_s(A = A_w) = \{ \sum_{a_i} [\prod_{w' \neq w} \hat{P}_s(A_{w'} \leq a_i)][\hat{P}_s(A_w \leq a_{i+1}) - \hat{P}_s(A_w \leq a_i)]\} / \hat{P}_s(A > a_i)$$

where

$$\hat{P}_s(A_w \leq a_{I+1}) = 1$$

for all w, and

$$\hat{P}_s(A_w \le a) = \prod_q [\hat{P}_{sq}(A \le a)]^{\delta_{wq}}, \; a = a_1, \ldots, a_I; \; w = 1, \ldots, 4$$

$$\delta_{wq} = \begin{cases} 1 & \text{if the qth zone is in the wth region} \\ 0 & \text{otherwise} \end{cases}$$

Note that $P_s(A_w \le a)$ is the probability that the maximum PGA at the site due to earthquakes from the wth region is no greater than a.

Although the best estimate calculations have been presented in terms of the PGA, analogous calculations are applicable for the PGV and spectral accelerations or velocities. If a uniform hazard spectrum is the desired output, a best estimate hazard or probability of exceedance curve is evaluated for several (9) frequencies or periods. Then the spectral amplitude for the uniform hazard spectrum is evaluated as follows:

- o For return period RP, let a_i be the acceleration such that for frequency f,

$$\ln P(A_f > a_i) > \ln RP^{-1} > \ln P(A_f > a_{i+1})$$

Based on a linear interpolation of the probability of exceedance curve, the spectral amplitude at f is

$$a_{RP}(f) = \exp\left\{\ln a_i - \frac{\ln\left(\frac{a_i}{a_{i+1}}\right)}{\left[\ln \frac{P(A_f > a_i)}{P(A_f > a_{i+1})}\right]} \ln\left[\frac{P(A_f > a_i)}{(RP)^{-1}}\right]\right\}$$

If $\ln RP^{-1} > \ln P(A_f > a_I)$, the spectral amplitude at f is evaluated by a quadratic extrapolation of $\ln P(A_f > a)$.

Finally, after the best estimate calculations are completed for all seismicity experts, the best estimate curves are combined over all seismicity experts to produce the combined best estimate hazard curve. Following the philosophy that the weights are a measure of the level of expertise of the experts, the combined best estimate hazard curve is

$$\hat{P}(A_t > a) = \left\{\sum_s W_s \hat{P}_s(A_t > a)\right\} / \sum_s W_s$$

$$= \left\{\sum_s \sum_u W_s W_{Au} \hat{P}_{su}(A_t > a)\right\} / \sum_s \sum_u W_s W_{Au}$$

C.5.3 Uncertainty Analysis

In addition to their best estimate of the parameters used to evaluate the seismic hazard at a site, the experts also provided a measure of their confidence in the data, available information, and any other resources used to formulate their opinions. Quantification of confidence in the basis for the experts' opinions took several forms depending on the parameter:

- Uncertainty in identifying seismic sources (zones)

  A collection of alternative maps with associated "confidence" or degree of belief reflecting

  - Confidence that a zone is seismically distinct from the surrounding region.
  - Confidence in alternative boundary shapes for a zone or cluster of zones.

  The collection of maps for each seismicity expert was treated as a finite population, the probability associated with each map being the confidence assigned it by the expert.

- Uncertainty in seismicity parameters

  - For the occurrence rate λ_0, the bounds were treated as the 2.5th and 97.5th percentiles of a triangular distribution with mode equal to the best estimate of the parameter.
  - For the upper magnitude cutoff, the bounds were treated as the range of a triangular distribution with mode equal to the best estimate $\hat{M}_U$.
  - For the coefficients in the magnitude recurrence model, three models for the estimates (a, b) of the coefficients were considered:

    1. (a, b) are independent
    2. (a, b) are 'moderately' negatively correlated
    3. (a, b) are perfectly negatively correlated

    For 1. and 2. the bounds were treated as the 2.5th and 97.5th percentiles of a triangular distribution and the mode of the distribution of a is equal to the best estimate $\hat{a}$. In

1. the mode of the distribution of b is the best estimate $\hat{b}$

2. the distribution of b is conditional on a; specifically if a = a_o, the mode of the distribution of b, given a = a_o, is

$$\hat{b}_{a_o} = \frac{\hat{a} + \hat{b}M_{UB} - a_o}{M_{UB}}$$

under the restrictions that

$$\hat{b}_{ao} = \begin{cases} b_L \text{ (the lower bound for b), if } \hat{b}_{a_o} < b_L \\ b_U \text{ (the upper bound for b), if } \hat{b}_{a_o} > b_U \end{cases}$$

For 3. the bounds for a were treated as the 2.5th and 97.5th percentiles of a triangular distribution with mode a; the distribution of b, given a, is degenerate, i.e., if a = a_o,

$$b_{a_o} = - \frac{(a_o - a_L) - b_U m^*}{m^*}$$

where b_U is the upper bound for b, a_L is the lower bound for a, and

$$m^* = \frac{a_U - a_L}{b_U - b_L}$$

- Uncertainty in attenuation models

  As for the zonation maps, the collection of attenuation models with their associated confidences (probabilities) were treated as a discrete probability distribution.

- Uncertainty in random variation in PGA

  The uncertainty in σ_R was treated the same as λ_o.

The purpose of the uncertainty analysis is to produce a set of curves which reflect the variability in estimates of hazard at a site due to the uncertainties associated with the experts' opinions. The curves so produced describe the possible range of hazard, i.e., the range of values of P(A > a) for each a, at the site along with a measure of the experts' "confidence" in the values within the range. That is, for each pair of experts (seismicity-ground motion pair) it quantifies the variation in the estimates of hazard due to the uncertainties in the opinions of the individual experts. When combined over several experts, the variation in the hazard also reflects the variation in opinions about the input parameters between experts.

Propagation of the uncertainties in the inputs through the evaluation process is based on simulation methods. That is, each input parameter is treated as a random variable with the appropriate continuous or discrete probability distribution, e.g., λ_o is treated as a triangular random variable and the maps and ground motion models have discrete distributions.

For each pair of experts (seismicity-ground motion pair) a random sample of each of the parameters, maps and ground motion models is selected from the appropriate distributions. Then,

- o Given a set of inputs, the hazard, $P_{su}(A_t > a | \text{inputs})$, $a = a_1, \ldots a_I$, is evaluated based on the inputs.

- o The sample $P_{su\ell}(A_t > a)$, $\ell = 1, \ldots L$ represents a sample from the "uncertainty" distribution for $P(A_t > a)$ for each $a = a_1, \ldots a_I$.

- o For each a_i, the empirical cumulative distribution function (CDF) is used to estimate the distribution for $P(A_t > a_i)$. This is illustrated in Fig. C.7. An approximation to the continuous CDF is also included in the illustration. $Q_{su}(\cdot)$ is an estimate of the uncertainty CDF for $P(A > a_i)$ given the uncertainties expressed by the (s, u)th pair of experts.

- o Using the percentiles, e.g., 15th, 50th, 85th, from $Q_{su}(\cdot)$ for each a_i, $i = 1, \ldots I$, a series of curves, reflecting the variation in hazard due to the uncertainties expressed by the (s, u)th pair of experts, can be produced.

- o Optional 'point' estimates of the hazard curve are based on

  - the arithmetic mean estimate, for each a

$$P^{*}_{su}(A_t > a) = \{ \sum_{\ell=1}^{L} P_{su\ell}(A_t > a)\}/L$$

  the geometric mean estimate, for each a,

$$P^{**}_{su}(A_t > a) = \{ \prod_{\ell=1}^{L} P_{su\ell}(A_t > a)\}^{1/L}$$

To combine the uncertainty results over several experts, we estimate the uncertainty CDF for $P(A > a)$ which reflects the uncertainties of individual experts as well as the variation in opinions between experts. $Q_{su}(\cdot)$ is an estimate of this CDF if there were only the two experts. Using the weights W_{Au}, W_s as a measure of the level of expertise of the experts, the uncertainty

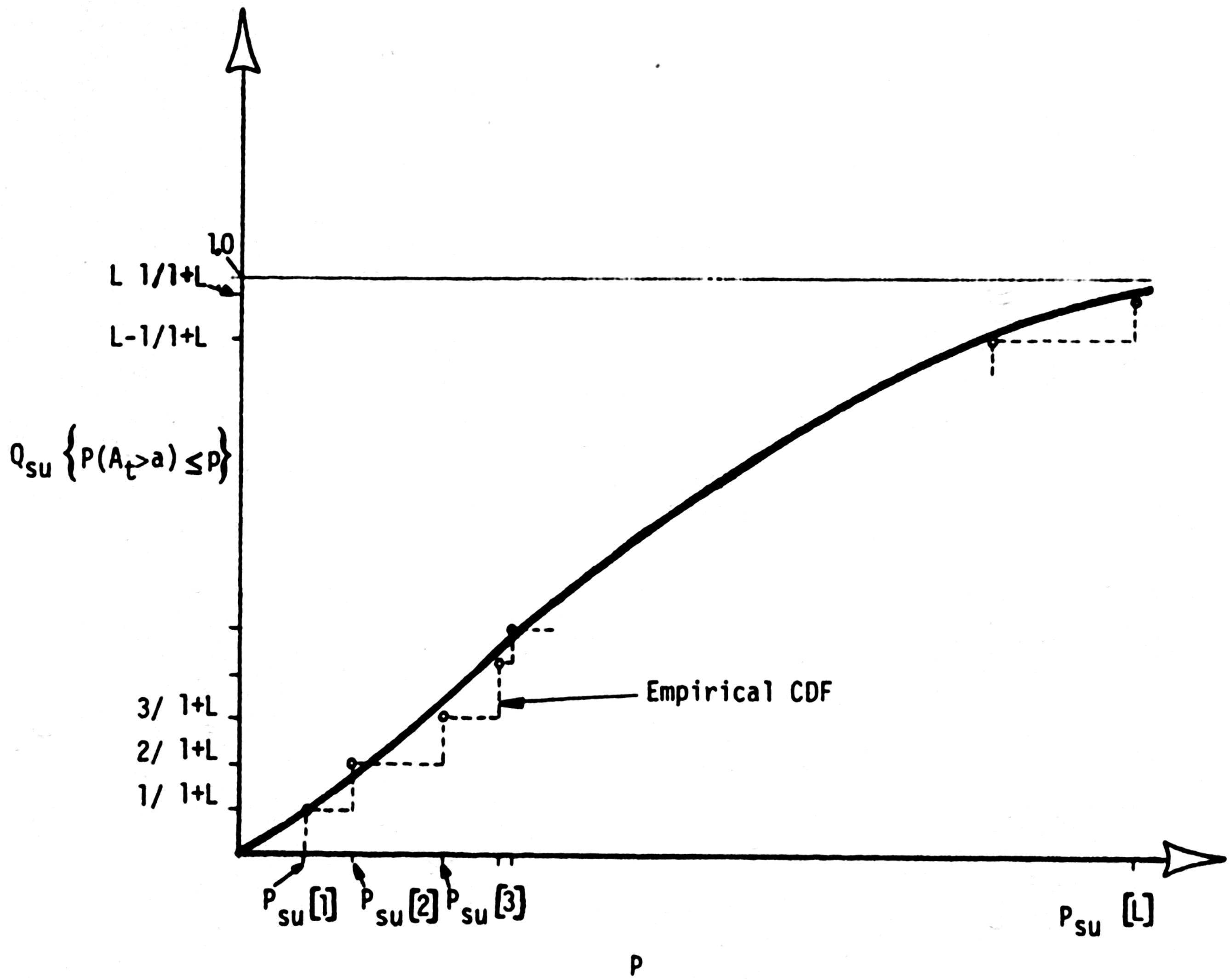


Fig. C.7. Illustration of the empirical CDF for $P(A_t > a)$.

CDF for $P(A > a)$ is estimated by taking a weighted average of the $Q_{su}(\cdot)$'s. That is, for each p

$$Q\{P(A > a) \leq p\} = [\sum_s \sum_u W_s W_{Au} Q_{su}\{P(A > a) \leq p\}]/\sum_s \sum_u W_s W_{Au}$$

This is illustrated in Fig. C.8 for three pairs of experts.

For each value a individually, the $Q_{su}(\cdot)$ for that value a is an estimate of the uncertainty associated with estimating $P(A > a)$. The combined CDF, $Q(\cdot)$ reflects a level of uncertainty consistent with the weights associated with the experts.

The combined CDF's for $P(A > a)$, for $a = a_1, \ldots, a_I$, are used to determine bounds for $P(A > a)$ for each a_i. For example, the 15th percentile $p_{.15}(a)$ is the value of p such that

$$Q\{P(A > a) \leq p\} = 0.15$$

Similarly for the 85th percentile.

The 15th and 85th curves, which reflect the potential variation in the hazard curve at a site, are the loci of the points $p_{.15}(a_i)$ and $p_{.85}(a_i)$, $i = 1, \ldots I$.

One must be careful in interpreting the bounds as hazard curves which correspond to a specific set of input parameters. The bounds are analogous to the bounds which are used to define Uniform Hazard Spectra (UHS). The UHS is the locus of points each corresponding to the same probability of exceedance and does not represent a distinct spectrum since the inherent physical correlation between the values at different frequencies has been lost in the calculations. However, it can be interpreted as an envelope of all possible spectra. Similarly the 85th and 15th percentile hazard curves do not represent the hazard curve corresponding to a specific set of input parameters. Rather they are the loci of probabilities such that the "Probability" (due to the uncertainty of the experts in their inputs) that $P(A > a)$ is less than the bound is .15 (.85) respectively for each a. It can be interpreted as an envelope of all possible hazard curves. It is not correct to interpret the 85th percentile curve as a hazard curve which will not be exceeded by 85 percent of the hazard curves produced by the uncertain parameters. It is true, however, that for a fixed value a the value $P_{.85}(A > a)$, taken from the 85th percentile curve at a, is an estimate of the value of $P(A > a)$ which has "degree of belief" or "confidence" 0.85 that it will not be exceeded, where the "confidence" is a weighted average of the levels of confidence of the individual experts.

To combine the optional point estimates of the hazard over all experts, the appropriate weights are applied. Specifically,

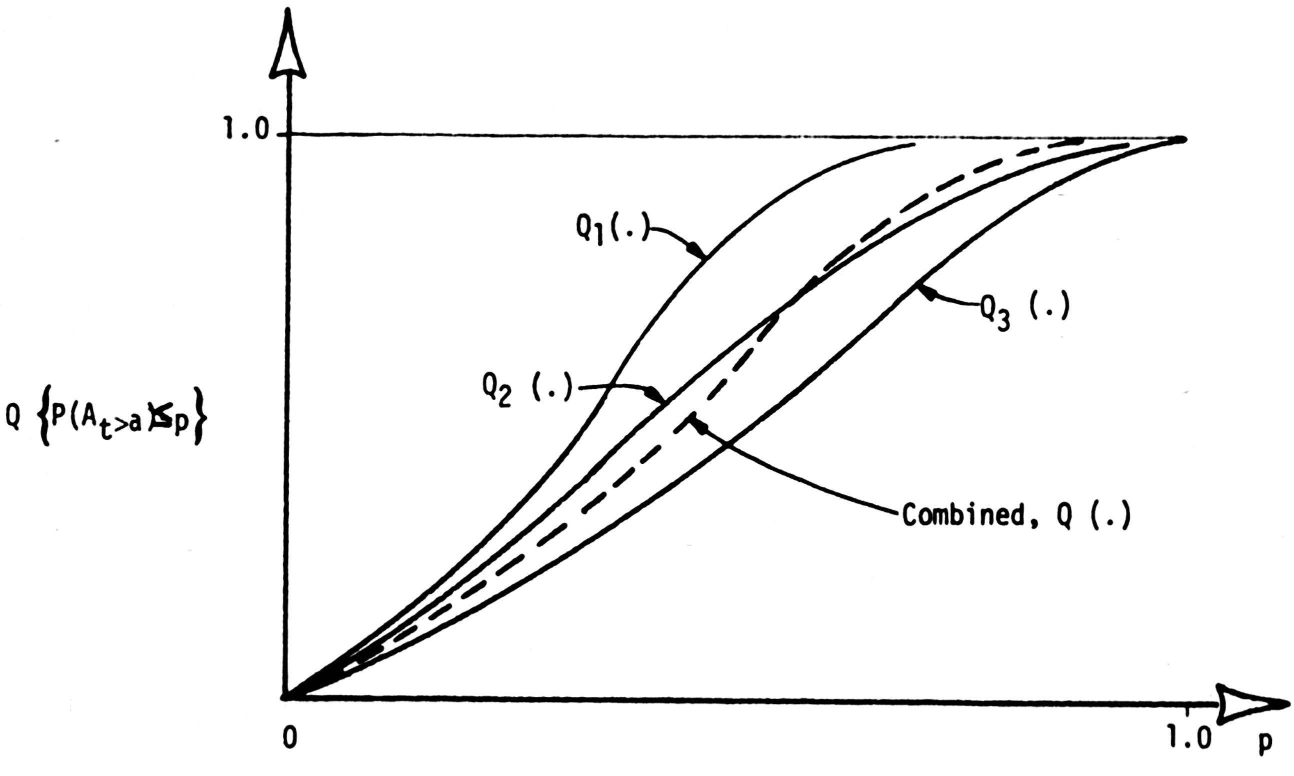


Fig. C.8. Illustration of uncertainty distribution for P(A > a) for fixed a.

- The arithmetic mean estimate, for each a,

$$P^{*}(A_t > a) = \left\{ \sum_s \sum_u \sum_{\ell=1}^{L} W_s W_{Au} P_{su\ell}(A_t > a) \right\} / L \sum_s \sum_u W_s W_{Au}$$

- The geometric mean estimate, for each a,

$$P^{**}(A_t > a) = \left\{ \prod_s \prod_u \left[\prod_{\ell=1}^{L} P_{su\ell}(A_t > a) \right]^{W_s W_{Au}} \right\}^{1/L \sum_s \sum_u W_s W_{Au}}$$

The estimated hazard curves are an envelope of the individual estimates over all accelerations.

C.6 References

[1.] Bernreuter, D. L., "Seismic Hazard Analysis, A Methodology for the Eastern United States," NUREG/CR-1582, Vol. 2, August 1980.