APPENDIX B

RELATIONS BETWEEN MAXIMUM HISTORIC EARTHQUAKE, PEAK ACCELERATIONS, EPICENTRAL INTENSITY, AND GEOLOGY

Several investigators have attempted to obtain a relation between ground motion and rock classification on a most general basis. Trifunac & Brady[4] defined three classifications, e.g., "soft," "intermediate," and "hard" local geologic conditions. Unfortunately they elected to combine shallow and deep alluvium into one group (0), the significance of which will become apparent later in this discussion. The results of this study indicate that, disregarding the large dispersion of the data, the accelerations are relatively highest on "intermediate" sites, of intermediate value on "hard rock" sites, and lowest on "soft" sites. The velocities indicate generally the exact opposite, i.e., lowest on hard rock sites, highest on soft rock sites. Murphy & O'Brien[5] arrived at similar conclusions from a study which utilized a slightly different approach, classifying crystalline rock under "hard rock," sedimentary rock, and thin alluvium under "intermediate" and deep alluvium under "alluvium." They observed that horizontal accelerations are considerably lower for "alluvium" than for either "intermediate" or "hard rock." Further spectral analysis performed by the above investigators present a much more qualitative picture of the earthquake phenomena. The results show that the peak accelerations and short-period spectral amplitudes at the "hard rock" sites and "intermediate" sites are significantly higher than those observed at a comparable "alluvium" site for short periods while the trend is reversed for long periods. It was also noted that significant short period amplification may occur on thin alluvium sites. The authors conclude that intensity may correlate much more strongly with response spectral amplitudes in a limited period band than with any single peak amplitude parameters. A study undertaken by Mohraz[7] shows similar results. Mohraz notes that "The maximum acceleration amplification for less than 30 feet of alluvium on rock is approximately 40 percent greater than that for alluvium and about 33 percent greater than that of rock," and that "Based on the statistical studies of a number of earthquake records, it is shown that for low- and intermediate-frequency regions [long and intermediate periods] the spectral bounds for rock deposits are substantially lower than those for alluvium deposits. This difference results partially from the slight differences in the amplifications, but mainly from the appreciable differences in the v/a and ad/v^2 ratios of the two sites." (Where a = acceleration, v = velocity, and d = displacement of the peak ground motion observed.)

It should be noted that the above relations between geologic conditions and v/a, ad/v^2 ratios are corroborated by the Trifunac-Brady[4] study when subjected to a similar analysis. Results of this study probably would have shown better agreement with both the Murphy & O'Brien[5] and the Mohraz[7] data had the authors chosen to differentiate between thin alluvium (less than 30 feet thick) and deep alluvium.

The fact that present interpretations still leave much to be desired is expressed by Evernden et al[3] in discussing the San Fernando earthquake data: "It is our opinion that there is a tendency to be overly influenced by the accelerometer above Pacoima Dam...while ignoring the fact that the house nearby suffered essentially no damage. In some ways, that house was a far more significant instrument for measuring ground motion than was the accelerometer." Similar statements are listed at the end of appendix A.

In order to define the earthquake induced ground motion for the SATP, Law Engineering Testing Company[8] and TVA have performed an evaluation of the MM intensity of the 1897 Giles County earthquake and concluded that the epicentral intensity was an MMI VII-VIII. A report issued by the USGS[11] on the same subject is not as conclusive in defining the MM intensity. For example J. L. Coffman and C. A. Von Hake summarize their findings by assigning an MMI VIII to the earthquake because of changes in springs in the epicentral areas and numerous reports of fallen chimneys; however, they state also that much of the chimney damage should be rated MMI VII. O. W. Nuttli concluded that he would classify the earthquake as an MM VII-VIII. R. J. Brazee classified the earthquake as an MM VIII and stated that he would categorize it as a weak eight. G. A. Bollinger, who has done extensive work on the Giles County quake, classifies the quake as an MM VII-VIII.

The epicentral area of the May 1897 Giles County earthquake is reported as being between Narrows, VA, and Pearisburg, VA. The New River runs between Narrows and Pearisburg and all transportation routes and development follow the river valley. Mountains rise abruptly on either side of the valley and even today have not been developed. Research disclosed that the town of Narrows occupied the lowland (flood plain) adjacent to the river.

Pearisburg, VA, is situated in a limestone valley. The rock depth in the valley varies over short distances as is typical of limestone areas. In order to evaluate the epicentral overburden thickness, seismic refraction surveys were performed and data from 450 borings along Interstate 81 in the same formations were reviewed. These borings showed that the minimum overburden thickness was in the order of 0-10 feet, the maximum overburden thickness was over 100 feet, and the average thickness was about 25-30 feet.

The geologic setting of the epicentral area of the May 1897 Giles County earthquake clearly shows that:

1. The development of the two towns was along the New River and in a limestone valley.
2. The intensities reported are representative of thin alluvium sites.

Similar geologic settings occur for the other towns which were assigned intensity ratings of VII due to the May 1897 Giles County earthquake. Radford is situated along a stretch of the New River where alluvium and terrace deposits extend laterally for about 2 miles away from the river and occur at elevations over 100 feet above the river level. Pulaski was situated along the low land adjacent to the Peak Creek and the town area has been filled to its present level. Christianburg is situated in a limestone valley similar to Pearisburg. An inspection by TVA revealed that in the center of town, adjacent to the city hall, a new structure is being founded on piles which extend in excess of 30 feet below the general street levels. This is in line with the estimated overburden thickness at Pearisburg.

A striking example of the difference in intensity for shallow rock and loose overburden towns for the Giles County earthquake is provided by comparing the towns of Fincastle and Bedford. Both towns are northeast of the epicentral area with Bedford 80 miles distant and Fincastle 60 miles distant. Both towns are rich in colonial heritage and were population centers before the turn of the century. Both towns still contain numerous similar structures that were built during the 19th century. Fincastle is situated on a limestone interbedded with sandstone. Rock is evident in outcrops over much of the old town area. A new town hall in Fincastle is founded on rock at a depth of 8 feet. Bedford is situated in Piedmont residuum with overburden thickness of approximately 30 feet. Fincastle was assigned intensity IV; Bedford was assigned intensity VII.

Summarizing the above observations:

1. Local historical intensity data is alluvium biased and the Giles County earthquake MM VIII is no exception.
2. The assignment of the epicentral intensity of the May 1897 Giles County earthquake as MM VIII intensity is conservative, and represents thin alluvium characteristics.
3. The Giles County earthquake reports indicate that the MM intensity is 2 to 3 units greater on thin alluvium than on rock which agrees with other earthquake intensity reports listed in appendix A.

Thus, when estimating peak accelerations associated with the reported intensity, the above observations should be taken into consideration.

APPENDIX C

SEISMIC DESIGN CRITERIA FOR THE SEQUOYAH, WATTS BAR, AND BELLEFONTE NUCLEAR POWER PLANTS

The three nuclear power plants in question are situated in the Southern Appalachian tectonic province. The largest earthquake recorded in this province is the 1897 Giles County, VA, earthquake. The maximum ground acceleration which could be expected from this earthquake was originally defined as 0.14 g. During the course of NRC's review process for Sequoyah the maximum ground acceleration was increased to 0.18 g in the high frequency range. Figures 5 through 11 show the manner in which this peak acceleration was translated into the SSE design response spectra used at the plants. A maximum ground acceleration of 0.18 g was used at all three plants as shown in the response spectra. The response spectra used at Sequoyah are based on artificial earthquakes which have a modified type Newmark spectra shape (pre-regulatory guide 1.60 spectra). The spectra used at Watts Bar are the Newmark type spectra (pre-regulatory guide 1.60 spectra). The spectra used at Bellefonte are based on the regulatory guide 1.60. Table 1 shows that the damping ratios used at Sequoyah and Watts Bar are more conservative than the regulatory guide 1.61 damping ratios. The damping values at Bellefonte are the same as the regulatory guide 1.61 values.

Examination of the response spectra shows that justification of the spectra used at Sequoyah will also demonstrate that Watts Bar and Bellefonte are justified since their spectra are more conservative than Sequoyah. All three plants are located on rock sites. The rock foundations are very competent (shear wave velocities of 6000 fps or greater). Considering the different damping ratios used at Sequoyah versus the regulatory guide, the response spectra at Sequoyah are about equivalent to a regulatory guide spectrum anchored at 0.15 g. Figure 12 is a comparison of the response spectrum used to arrive at the design specifications for concrete structures at Sequoyah and the NRC Regulatory Guide spectrum; the Sequoyah spectrum is based on 5% damping while the Regulatory Guide allows 7% damping. Figure 13 is a similar comparison for steel structures; the Sequoyah design spectrum being based on 1% damping while the Regulatory Guide calls for 4% damping.

This discussion is appropriate to sites which are sufficiently far from the earthquake fault such that the near source, very high frequency accelerations have dissipated. Little recorded data for the near-field is available; to our knowledge, pairs of acceleration in the near-field are not available at all.

Newmark[10] notes: "Peak values of ground motion may be assigned to the various magnitudes of earthquake, especially in the near vicinity of the surface expression of the fault or at the epicenter. However, these motions are in general considerably greater than smaller motions which occur many more times in an earthquake. Design Earthquake response spectra are based on "effective" values of the earthquake intensities of accelerations, velocities and displacements, which occur several times during the earthquake, rather than isolated peak values of instrumental reading. The earthquake hazards selected for design are about 1/2 to 1/3 the expected isolated peak instrument readings."

There have been very high accelerations recorded in the near-field, such as at Pacomia Dam in the San Fernando earthquake of 1971. These high accelerations have been associated with high frequency motion, and since rock is more capable of transmitting high frequencies, one could surmise that maximum accelerations would be higher on rock than soil in the near-field. Examination of the near-field motions show that these high accelerations are associated with one or a few high frequency spikes which dissipate rapidly with distance from the fault, reference 5, 15. These high frequency spikes have not caused damage and are not of a long enough duration to cause damage.

Reexamination of past practices to convert intensity to design spectra is a complex issue because of the high level of activity in academic research which has been generated by the advent of nuclear power.

Figure 1 is a graphic representation of the relationships which have been suggested by diverse researchers on the subject. Cursory examination tends to indicate that both the Trifunac-Brady[4] and the Neumann[9] relationships follow a mean trend among relationships plotted. However, when comparing the relationships to available strong motion data, it is the Murphy-O'Brien relationship which deserves the designation of most likely estimate for the following reasons:

a. To assign a certain level of confidence to empirical formulae a statistical analysis of the data is necessary. If the distribution of the data cannot be ascertained, little can be said about the fit of the formula. Trifunac-Brady[4] chose to compute an arithmetic mean of the data thus rendering the significance of the standard deviation useless. Murphy & O'Brien[6] noted that the logarithm of the data fits a normal distribution, thus the use of their proposed relationship between intensity and acceleration can be assigned a specific confidence level.

b. The use of the Murphy-O'Brien[5] formula appears to agree with the mean acceleration levels tabulated by Trifunac-Brady. The use of the Trifunac-Brady[4] relationship appears to fit the "mean plus one sigma" value tabulated by the authors.

However, both the above discussed relationships would apply if appropriate constraints are applied, i.e., to an intensity MM VIII the Murphy-O'Brien[5] equation assigns a horizontal peak acceleration of 0.15 g. Since Trifunac & Brady chose to relate upper bound values of peak acceleration to intensity ratings, it would be reasonable to assign the lower estimate of intensity to the 1897 Giles County earthquake. Thus to an intensity MM VII the Trifunac-Brady[4] equation (1) assigns a horizontal peak acceleration of 0.13 g. To demonstrate that these values are reasonable estimates of the peak acceleration which can be expected at the sites, it will be shown that similar values can be arrived at by using the upper bound peak acceleration which caused the assignment of intensity MM VIII at the epicenter and relate those to the nuclear power plant site characteristics. According to Trifunac-Brady[4] the intensity MM VIII was the result of an earthquake with a horizontal peak acceleration of 0.26 g. Noting that this acceleration is anchored to thin alluvium the same earthquake would cause a peak acceleration of 0.17 g at a hard rock site according to Mohraz[7].

The fact that accelerations at depth on solid rock are less than those experienced at ground level is a fairly well accepted fact although the exact characteristics of this phenomenon are not well known. The seismology department of the University of California, Berkeley, has embarked on a data acquisition program using deep borings to measure acceleration at different depths to study the attenuation/amplification characteristics of geologic formations. Figure 14 is a preliminary release of signals obtained from one of these borings which shows conclusively how the amplitude diminishes with depth.

In discussing whether the acceleration is higher on rock or on soil as it applies to this particular site, the discussion should be restricted to pairs of accelerations (accelerations on rock and soil near each other during a given earthquake or accelerations measured with depth at a given site during a given earthquake). If the accelerations are taken in pairs, the influences of travel path, local geology, and local topography can be minimized.

The first pair of measured peak accelerations were obtained from the Humbolt Bay Nuclear Power Station (Figure 15). The horizontal components of the free field surface accelerations were recorded as .25 g and .36 g (or an average of .3 g), reference 16. The corresponding peak acceleration components recorded on the base slab of the refueling building were .12 g and .16 g (or an average of .14 g). There was a soil-structure interaction study done for this site prior to the earthquake and the recorded values compare well with the calculated values (reference 17). The soil-structure interaction study also showed that the free field acceleration in the dense sand at the elevation of the reactor build base slab was approximately the same as that of the base slab. This indicates soil-structure interaction was only a minor influence in the attenuation of the peak acceleration.

The site of the Joseph Jensen filtration plant, at the Balboa Water Treatment Plant (BWTP), experienced a similar response during the San Fernando earthquake in 1971. During major shock, instruments were not available to record accelerations. Instruments were, however, set up for recording aftershock. One instrument was located on the Saugus formation and the other on soil. The Saugus formation is not rock since it has a shear wave velocity of approximately 1550 ft/sec, it is, however, stiffer than the soil. The soil is made up of insitu material and compacted backfill. The instruments are shown schematically in Figure 16 and are separated approximately 1200 feet.

The instruments recorded eleven aftershocks ranging in magnitude from 3.2 to 4.9. For the aftershocks, where sufficient data was available, amplification factors were determined by taking the ratio between the soil and Saugus accelerations. These amplification factors are shown in Figure 17a and range from .98 to 4.15 as indicated in Table 2. The average value of the amplification factors, considering the E-W and N-S components of the aftershocks, are shown in Figure 17b.

The acceleration at the top of the Saugus directly below the instrument located on the soil can be expected to be less than or equal to the acceleration recorded at the Saugus surface.

The San Fernando earthquake of February 9, 1971, has been assigned a magnitude of 6.5 or 6.6. The distance from the zone of maximum energy release to BWTP has been estimated to be five miles. (Because the earthquake occurred on a thrust fault, at an angle of approximately 45 degrees, distance to nearby sites is difficult to assess.) In contrast, the distance of BWTP to the instrumental epicenter is approximately 8 miles.

Using the relationships summarized in reference 18 indicates that the predominant period of motions arriving in rock at the site is approximately 0.3 second. The maximum acceleration in rock is approximately 35 percent g.

The maximum acceleration in the Saugus formation (such as at the location of Instrument No. 1) would be expected to be somewhat higher than that estimated for rock. The near-surface Saugus at BWTP does not correspond to what would normally be classified as rock. The maximum acceleration in Saugus during the February 9 earthquake isestimated to be approximately 40 percent g.

A ground response analysis of the soil profile in the vicinity of Instrument No. 2 was conducted assuming a maximum acceleration of 40 percent g in Saugus. The variations of modulus and damping values with strain utilized in the analyses of aftershocks were also used in this analysis. The soil conditions in the vicinity of Instrument No. 2 and the computed response values are shown in Figure 18 which indicates a computed maximum ground surface acceleration of approximately 49 percent g.

Again, the recorded and calculated results indicate an attenuation of acceleration with depth.

The same type of response is observed due to underground explosions (reference 15). Figure 19 shows a pair of stations 183 m apart and sited respectively on dacite (an igneous rock) and 13.1 m of mine tailings (fill). The stations have recorded input ground motion from more than twenty individual nuclear detonations located about 100 km away. The peak ground acceleration levels vary by a factor of about 2 at the two recording stations with the station on fill recording the higher values.

Observations from Japan show the same general trend. Some of these observations have been obtained from recordings with depth at a site (reference 19) where one instrument is located on the surface and the other instruments are located in a bore hole. The acceleration time histories shown in Figure 20 were obtained under these conditions at Urayasu, Chiba Prefecture. The ground at this site consists of a silt stratum about 30 m thick, under which is a hard sand stratum. This recording is said to be typical.

The ratio of earthquake acceleration obtained at the ground surface to that underground was between 2 and 4 at Urayasu, and observations carried out subsequently at various locations have given about the same results. Thus it has been confirmed that there are predominant periods and amplifying effects in alluvial strata, so that acceleration underground is generally smaller than acceleration at the surface, with the ratio being more or less in the range previously mentioned.

Another example of acceleration attenuation with depth is shown in Figure 21. This record was obtained at Sadagai, located 150 km northeast of Tokyo.

The rock in this area is liparite and the surface portion is somewhat weathered. The record shown in this figure is that of an earthquake with an epicenter in Chiba Prefecture. It was taken at the ground surface and 38 m below in the underground powerhouse there. The waveforms of both records contain components with periods of 0.4 second, while the acceleration underground is reduced to 45 to 40 percent of that at the ground surface for the components associated with period of 0.3 to 0.5 second. The diminution of amplitude with depth is similar to that in an alluvial stratum, but the point which differs from the records of alluvial layers is that the waveforms above and below ground are very similar and the characteristic effects of a surface layer can scarcely be recognized. Therefore, the amplification in this case is not considered to be due to a multi reflection phenomenon of the surface layer type.

The maximum accelerations recorded at various locations in Tokyo City (reference 15) due to the Higashi-Matsuyama earthquake are shown in Figure 20. The numbers at the base of each building indicate the maximum recorded accelerations, in gallons, at the base of each structure. The average accelerations of the buildings founded on Tokyo gravel layer, upper

Tokyo layer, and alluvium show a consistent increase going from the lower stiffer layers to the upper softer layers. The same trend is shown on the upper portion of the city where the buildings are founded on upper Tokyo layer and Kanto-loan.

Similar recordings were obtained during the February 4, 1975, Haicheng, China earthquake, reference 16.

"Recorded accelerations on soil were greater than those on rock at a similar distance by a factor of about 2.3 for horizontal motion, and 2.4 for vertical."

From the above comments we may conclude that when pairs of acceleration records of a singular event are examined, the data of a particular site indicates that, generally, the amplitudes are less on rock than on soil.

TABLE 1

DESIGN DAMPING RATIOS FOR SAFE SHUTDOWN EARTHQUAKE

Component	Damping in Percent SQN	WBN	Reg Guide
Steel Containment Vessel	1	1	4
Concrete Shield Building and Internal Concrete Structure	5	5	7
Other Welded Steel Structures	1	2	4
Bolted Steel Structures	2	5	7
Other Reinforced Concrete Structures	5	5	7
Vital Piping Systems	1/2	1/2	2&3

TABLE 2

ACCELERATION VALUES OBTAINED FROM AFTERSHOCKS

Date	Magnitude	Distance to Site, Miles	E-W Component: Acceleration in Saugus	E-W Component: Acceleration in Fill	E-W Component: Amplification Factor	N-S Component: Acceleration in Saugus	N-S Component: Acceleration in Fill	N-S Component: Amplification Factor	Average E-W & N-S Components: Acceleration in Saugus	Average E-W & N-S Components: Acceleration in Fill	Average E-W & N-S Components: Amplification Factor
3/6/71	4.3	2.25	---	7.1	--	---	9.4	--	---	8.25	---
3/6/71	3.4	3.50	1.6	2.1	1.31	1.1	2.4	2.18	1.35	2.25	1.67
3/25/71	3.9	1.50	5.8	6.2	1.07	6.4	6.5	1.02	6.1	6.35	1.04
3/26/71	2.9	1.50	---	1.5	--	---	2.0	--	---	1.75	---
3/28/71	3.4	0.25	3.2	3.4	1.06	3.6	3.5	0.98	3.4	3.45	1.02
3/30/71	3.7	3.25	5.3	7.4	1.40	5.6	11.8	2.11	5.45	9.6	1.76
3/31/71	4.9	4.50	9.5	11.8	1.24	8.0	13.8	1.73	8.75	12.8	1.46
3/31/71	3.2	6.50	0.8	2.1	2.62	0.7	2.9	4.15	0.75	2.5	3.34
4/1/71	3.7	7.50	---	2.9	--	---	1.8	--	---	2.35	---
4/1/71	4.0	6.40	---	2.4	--	---	3.5	--	---	2.95	---
4/15/71	4.1	7.10	2.5	3.7	1.48	1.4	2.9	2.07	1.95	3.3	1.69

Notes: Acceleration values in percent of gravity.
Amplification factor designates ratio of acceleration in fill divided by acceleration in Saugus.

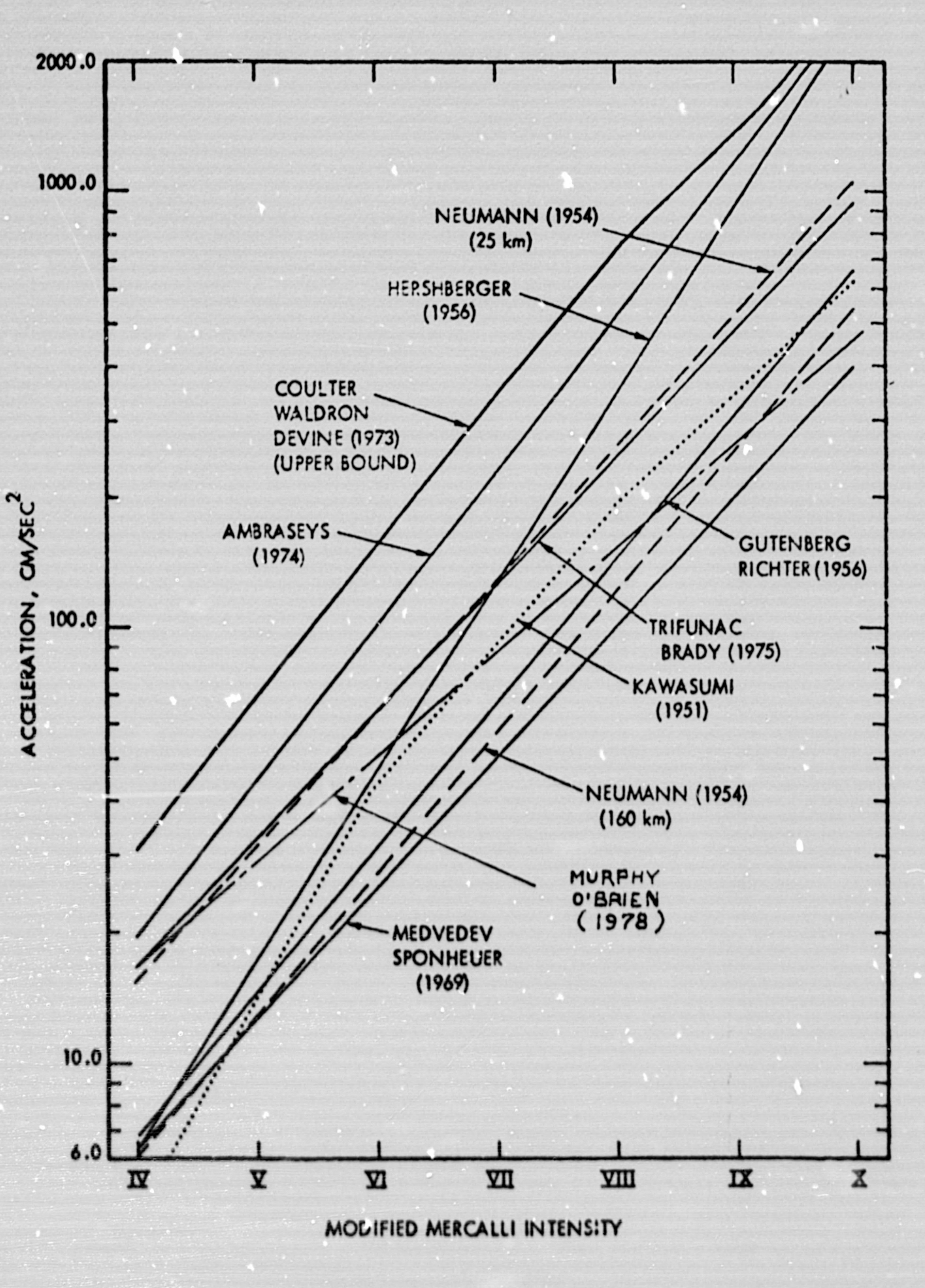


Figure 1 Graphic Representation of Selected Intensity/Acceleration Correlations

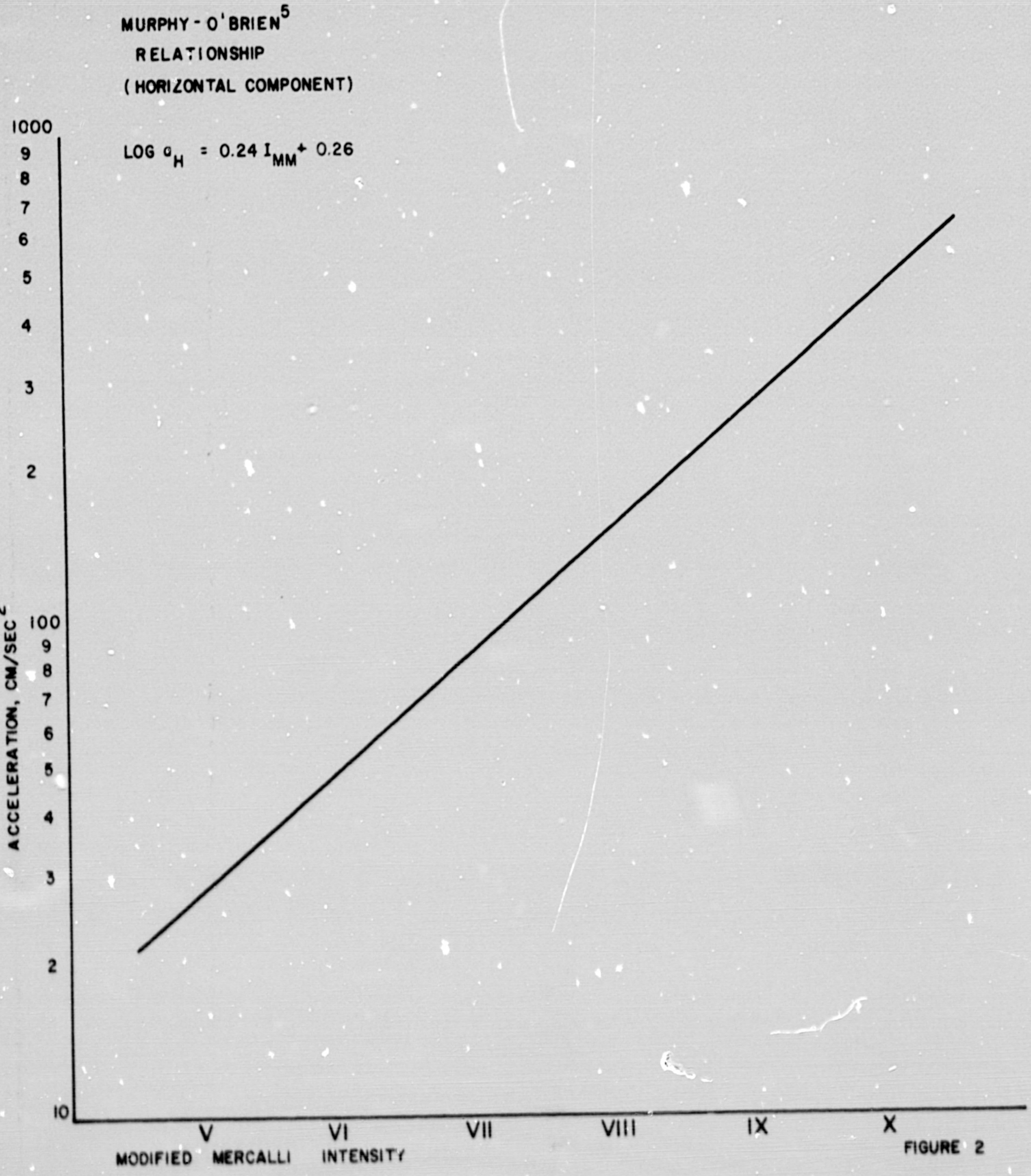

MURPHY - O'BRIEN[5]
RELATIONSHIP
(HORIZONTAL COMPONENT)
LOG a_H = 0.24 I_{MM} + 0.26
1000
9
8
7
6
5
4
3
2
100
9
8
7
6
5
4
3
2
10
ACCELERATION, CM/SEC^2
V
VI
VII
VIII
IX
X
MODIFIED MERCALLI INTENSITY

FIGURE 2

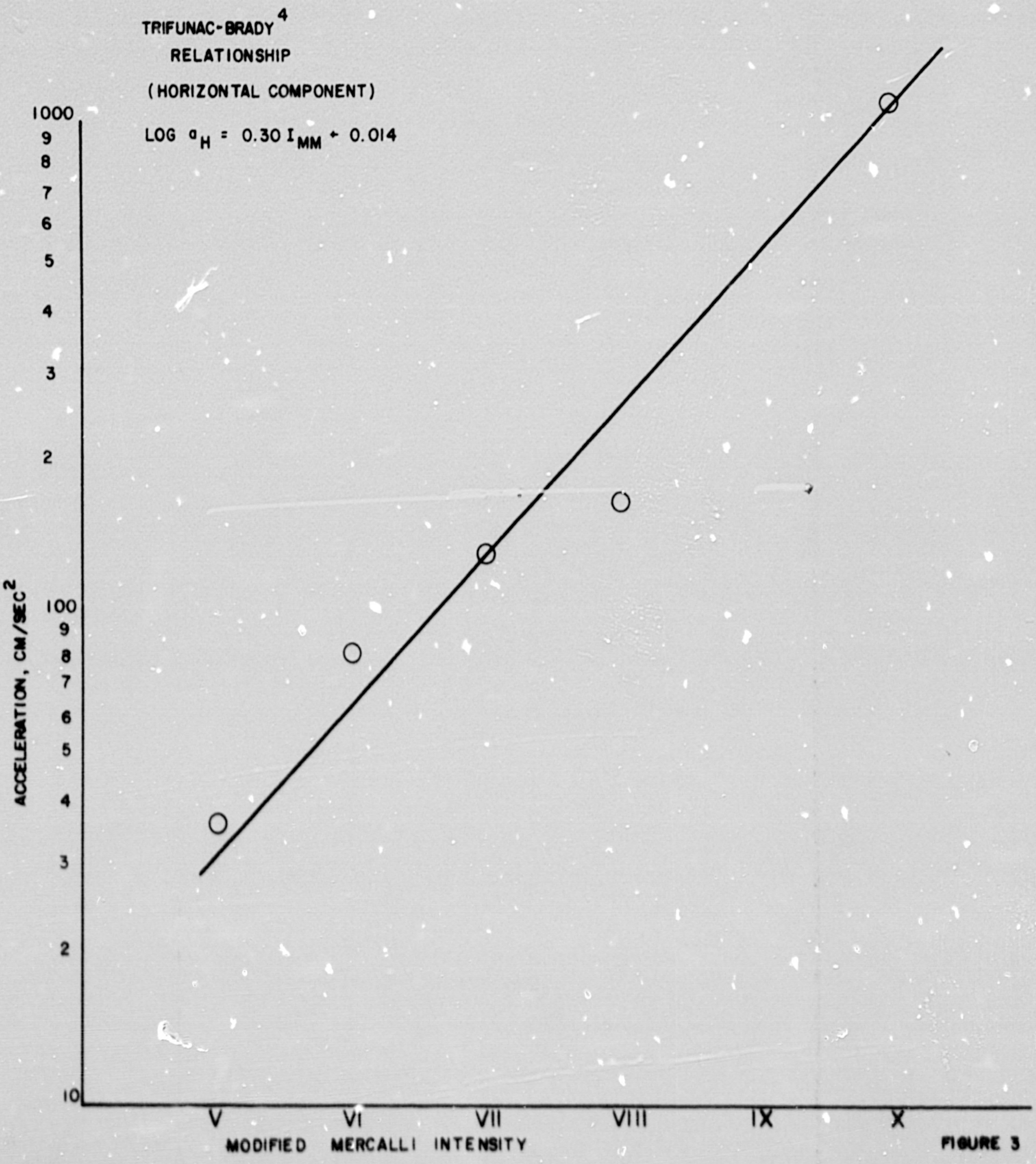

TRIFUNAC-BRADY 4
RELATIONSHIP
(HORIZONTAL COMPONENT)
LOG aH = 0.30 IMM + 0.014
1000
9
8
7
6
5
4
3
2
100
9
8
7
6
5
4
3
2
10
ACCELERATION, CM/SEC2
V
VI
VII
VIII
IX
X
MODIFIED MERCALLI INTENSITY

FIGURE 3

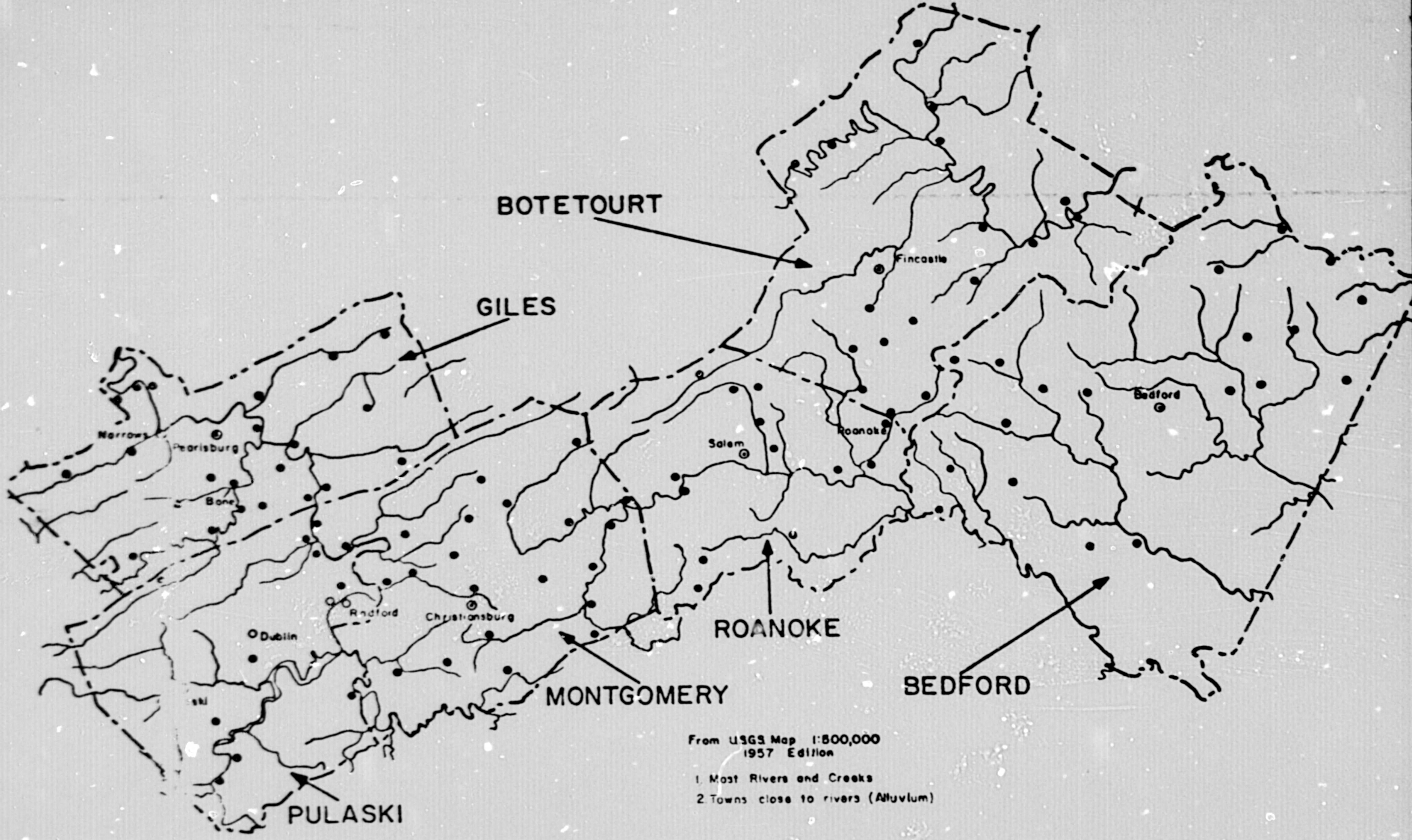
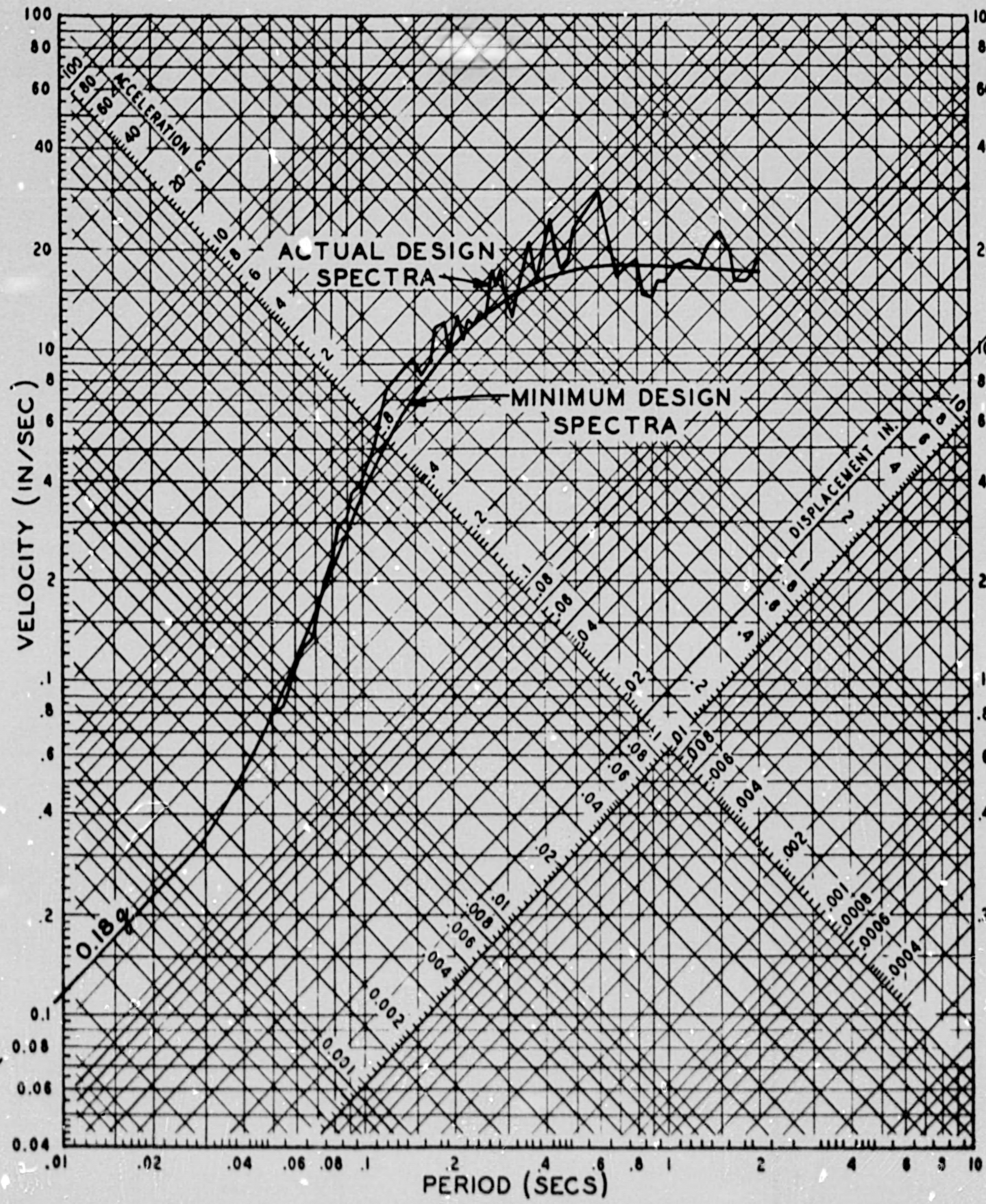
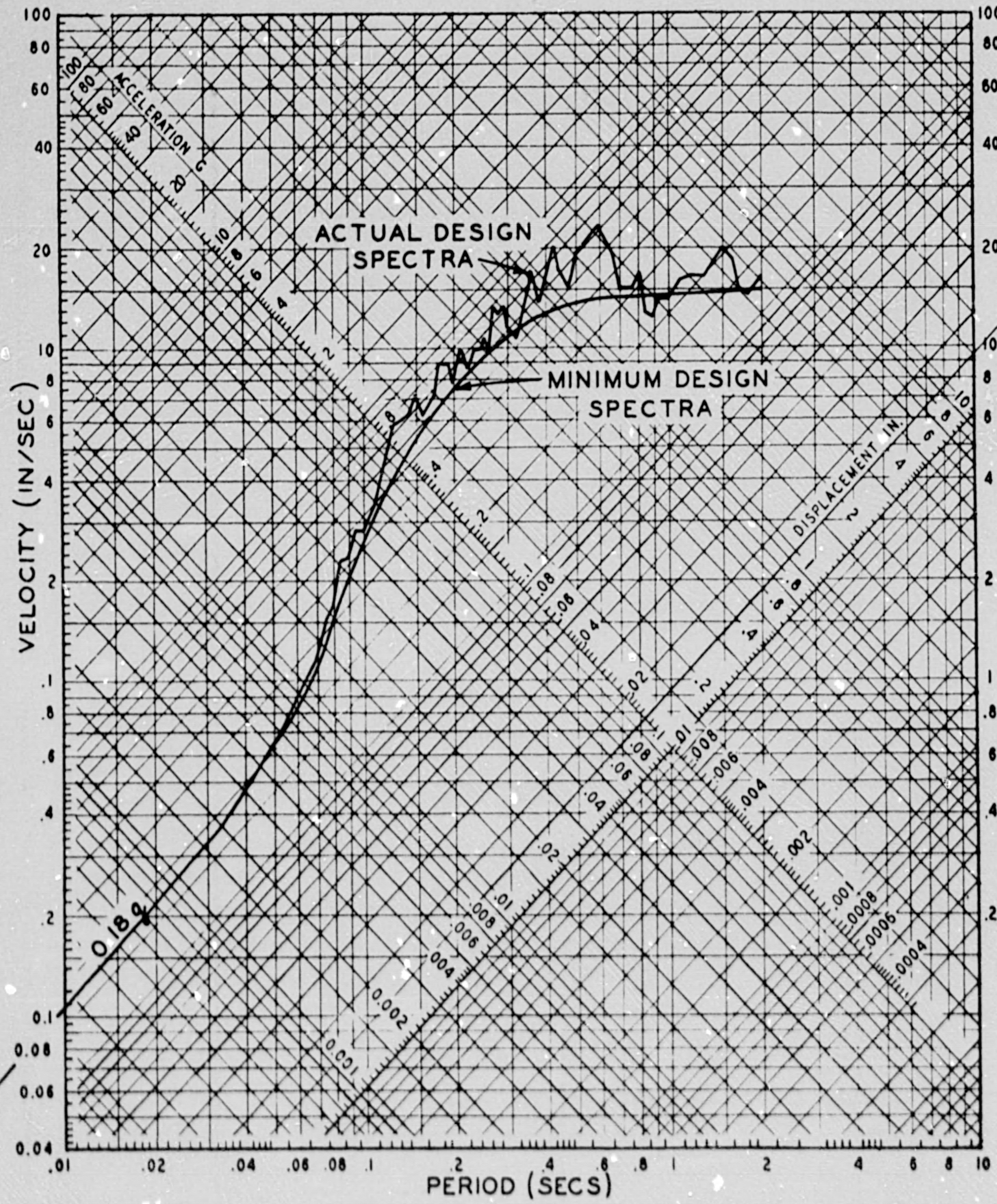

BOTETOURT
GILES
Narrows
Pearisburg
Bane
Fincastle
Salem
Roanoke
Bedford
Radford
Christiansburg
Dublin
ROANOKE
MONTGOMERY
BEDFORD
PULASKI
From USGS Map 1:500,000
1957 Edition
1. Most Rivers and Creeks
2. Towns close to rivers (Alluvium)

Figure 4

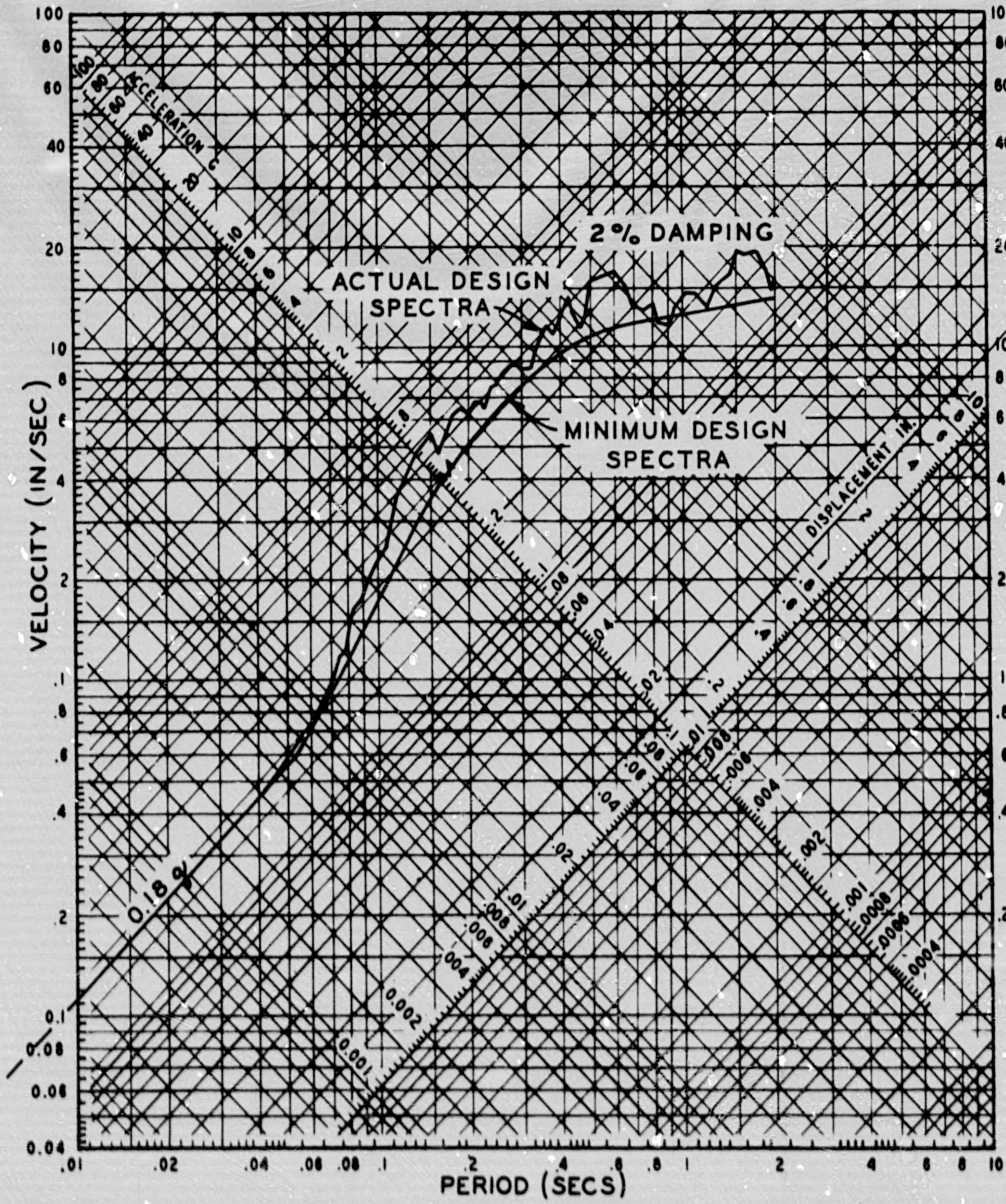


COMPARISON OF RESPONSE SPECTRA
FOR SAFE SHUTDOWN EARTHQUAKE
1/2 % DAMPING

FIGURE 5

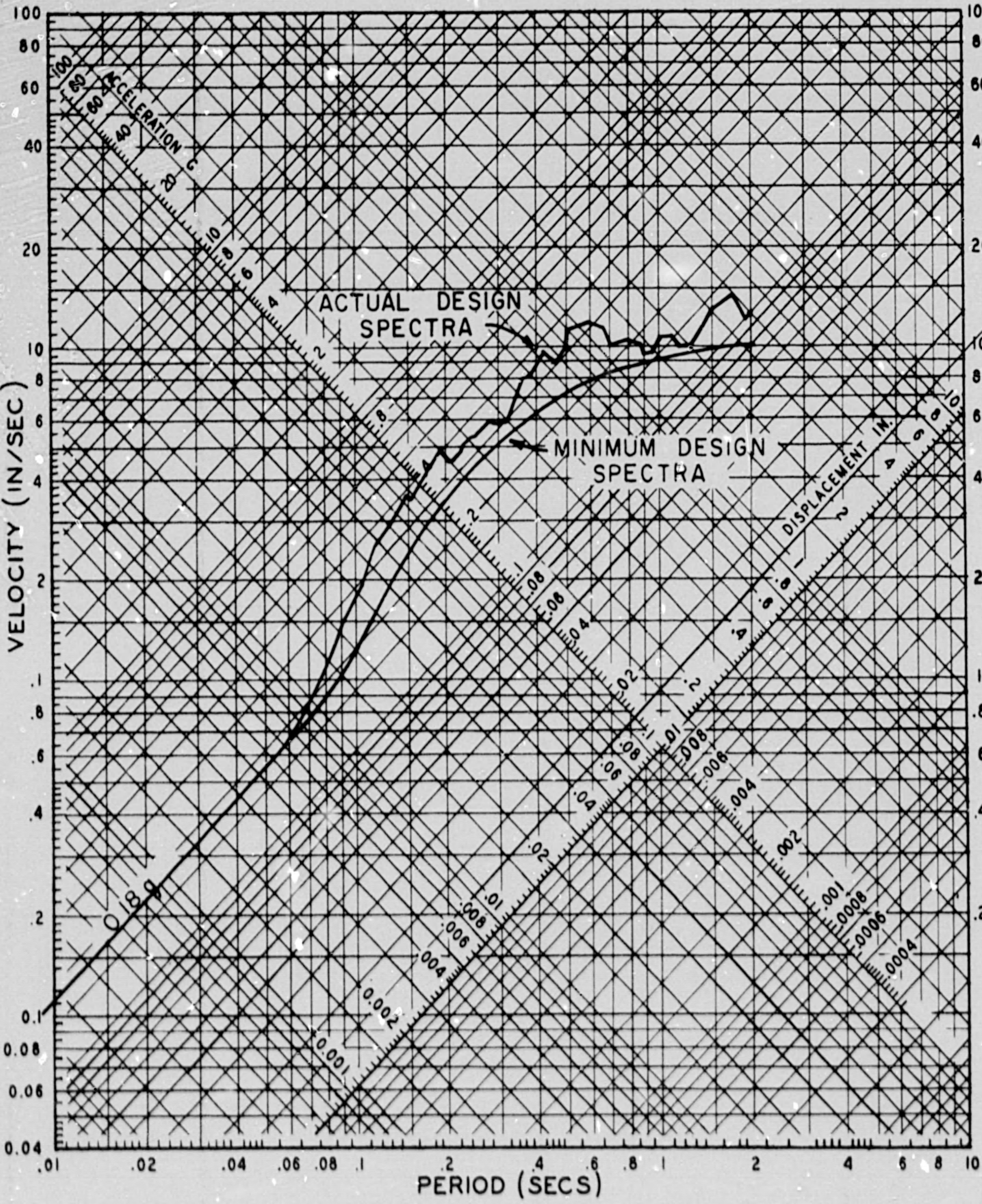


COMPARISON OF RESPONSE SPECTRA
FOR SAFE SHUTDOWN EARTHQUAKE
1% DAMPING
FIGURE 6

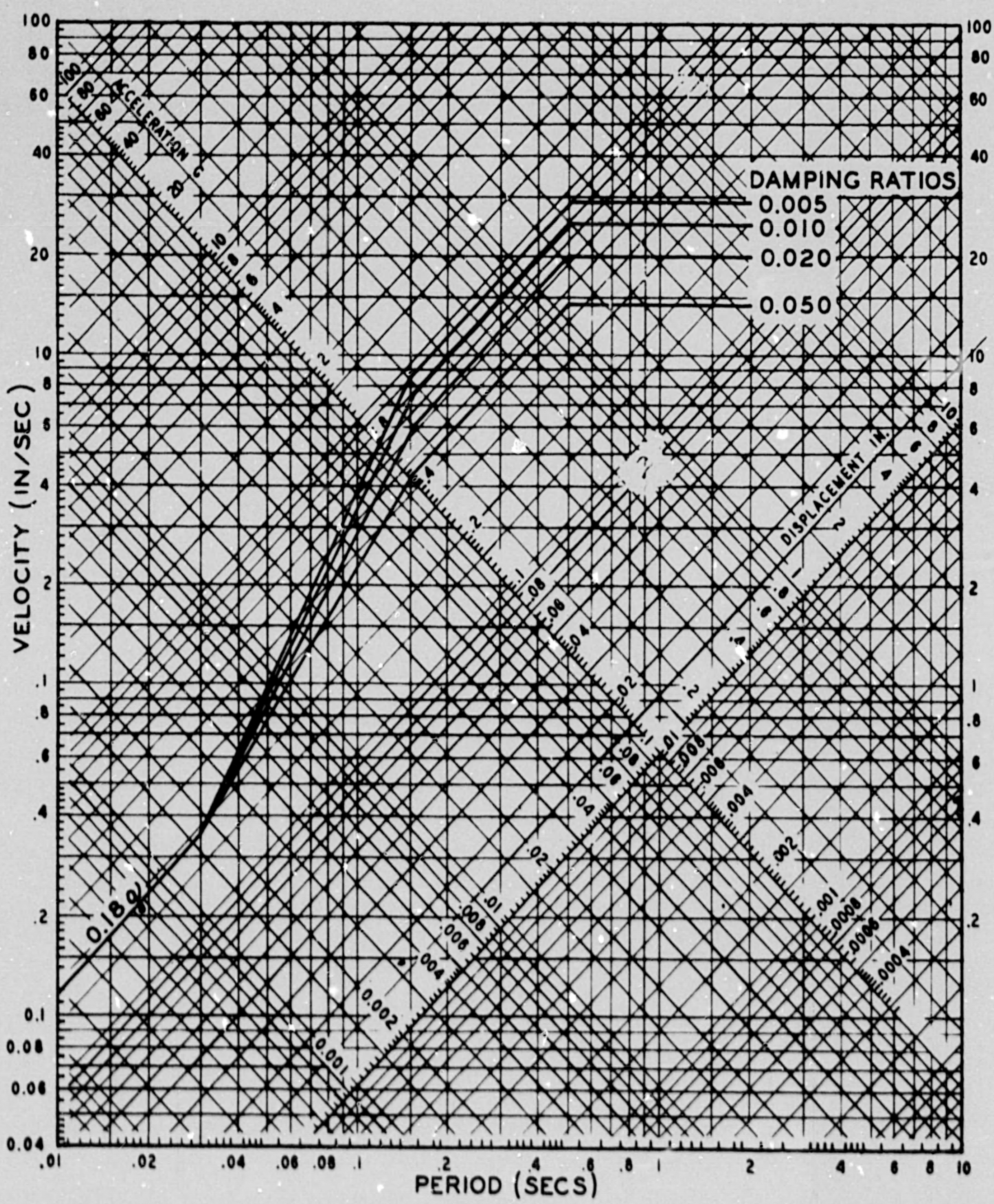


COMPARISON OF RESPONSE SPECTRA
FOR SAFE SHUTDOWN EARTHQUAKE
2% DAMPING

FIGURE 7



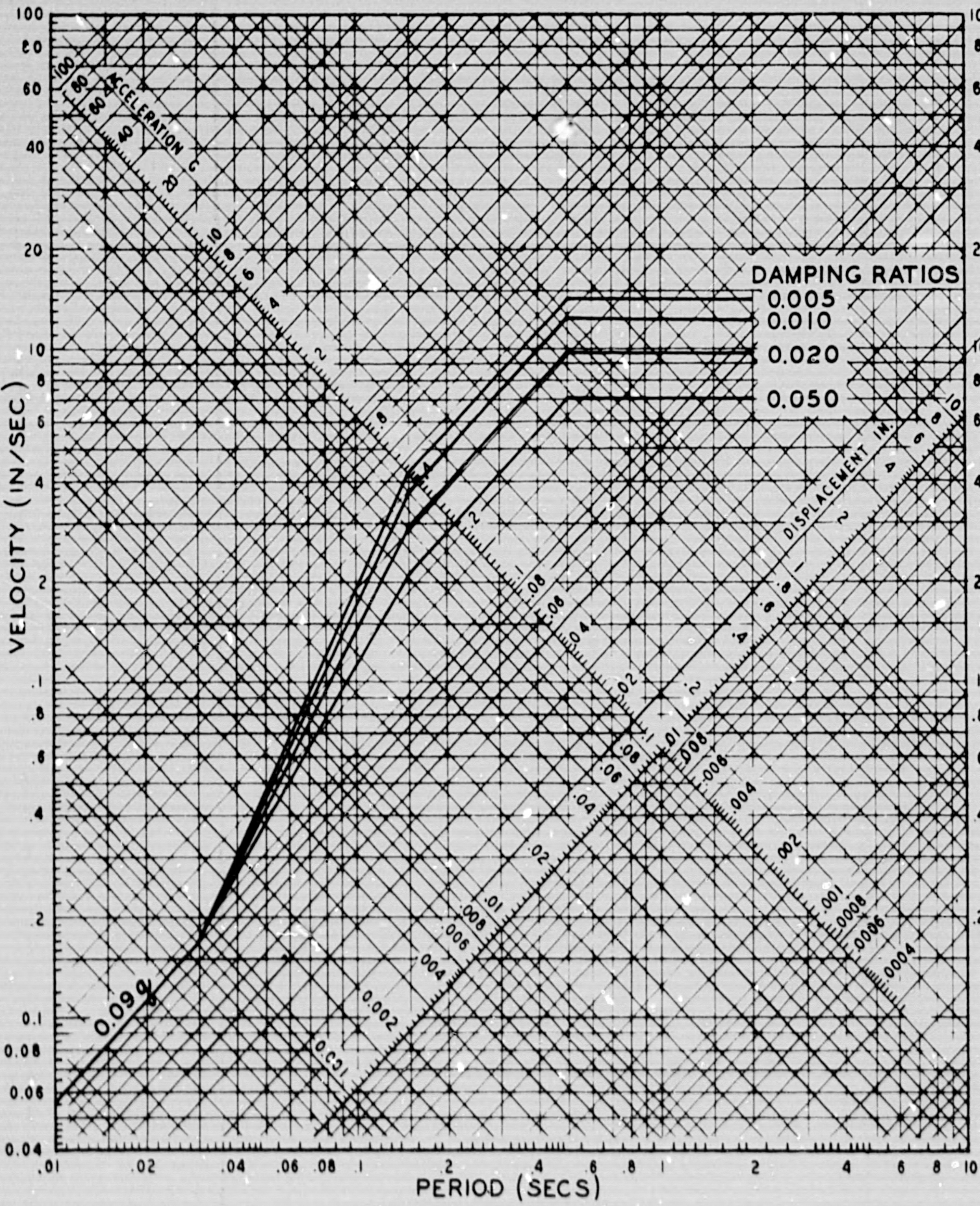
COMPARISON OF RESPONSE SPECTRA
FOR SAFE SHUTDOWN EARTHQUAKE
5% DAMPING
FIGURE 8



SAFE SHUTDOWN EARTHQUAKE

RESPONSE SPECTRA FOR ROCK SUPPORTED STRUCTURES

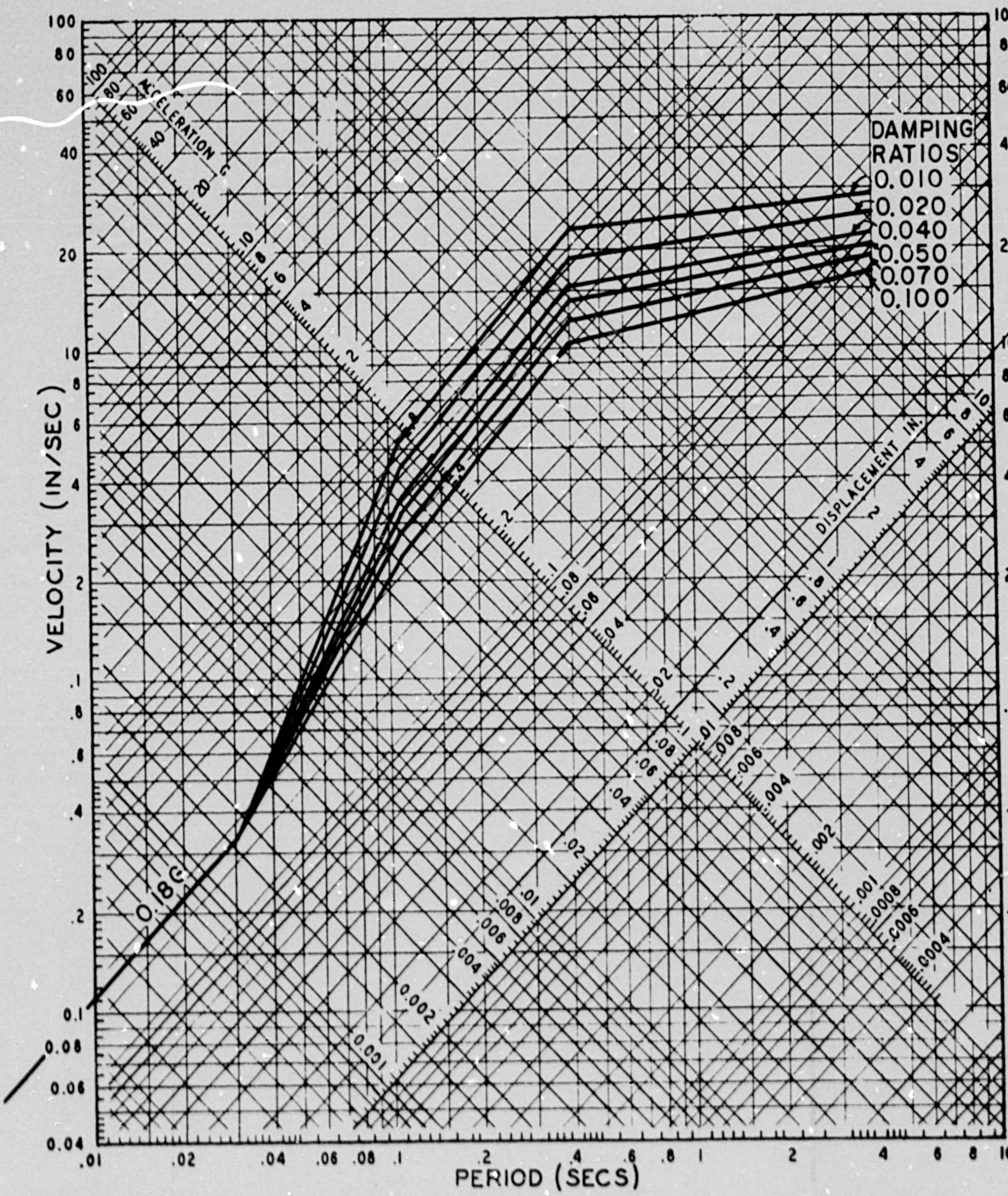
FIGURE 9



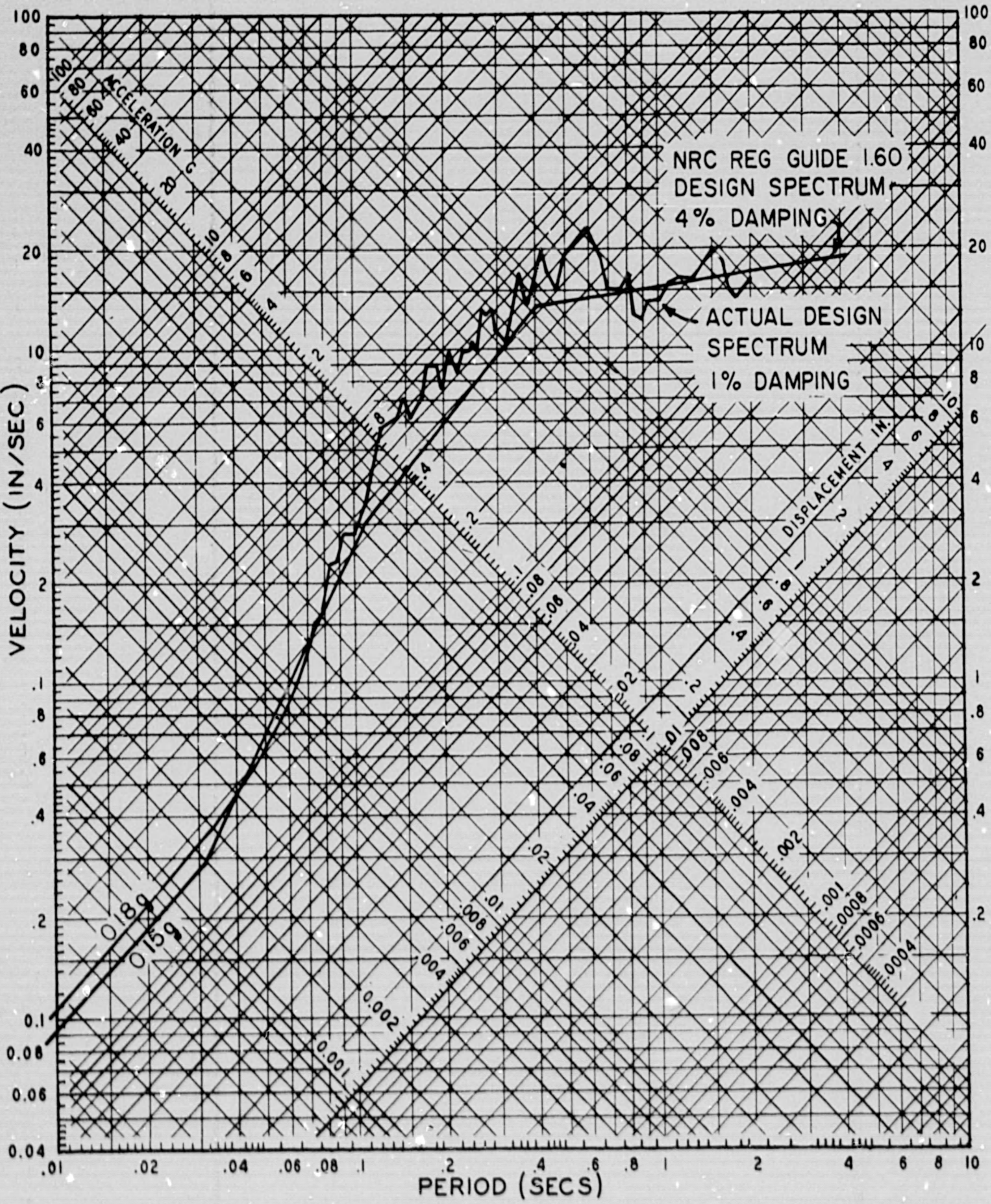
OPERATING BASIS EARTHQUAKE

RESPONSE SPECTRA FOR ROCK SUPPORTED STRUCTURES

FIGURE 10

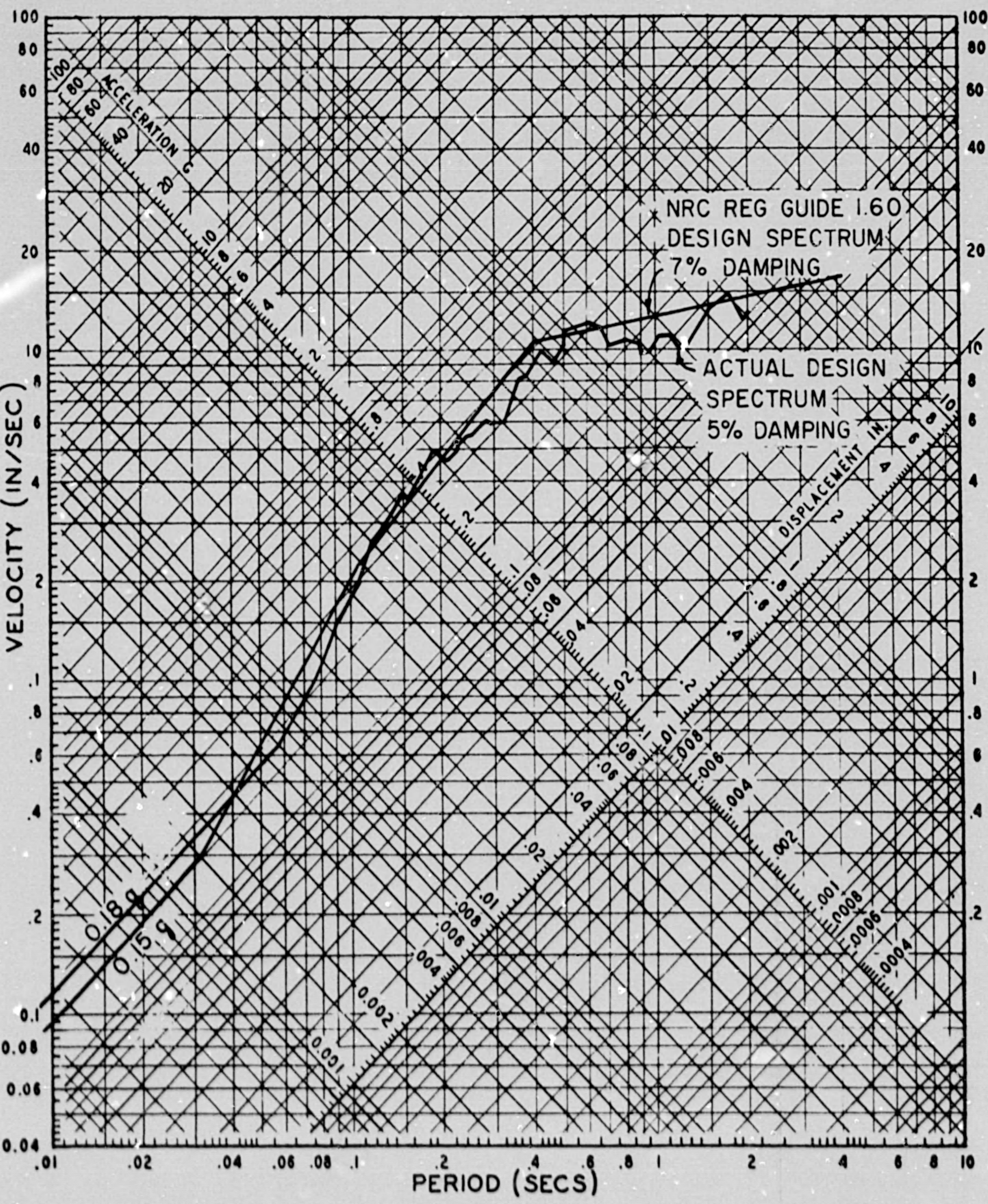


SAFE SHUTDOWN EARTHQUAKE
DESIGN RESPONSE SPECTRA
HORIZONTAL MOTION
ROCK-SUPPORTED STRUCTURES
FIGURE 11



COMPARISON OF SEQUOYAH SSE DESIGN SPECTRUM (1% DAMPING) WITH NRC REGULATORY GUIDE 1.60 STANDARD SPECTRUM (4% DAMPING)

FIGURE 12



COMPARISON OF SEQUOYAH SSE DESIGN SPECTRUM (5% DAMPING) WITH NRC REGULATORY GUIDE 1.60 STANDARD SPECTRUM (7% DAMPING)

FIGURE 13

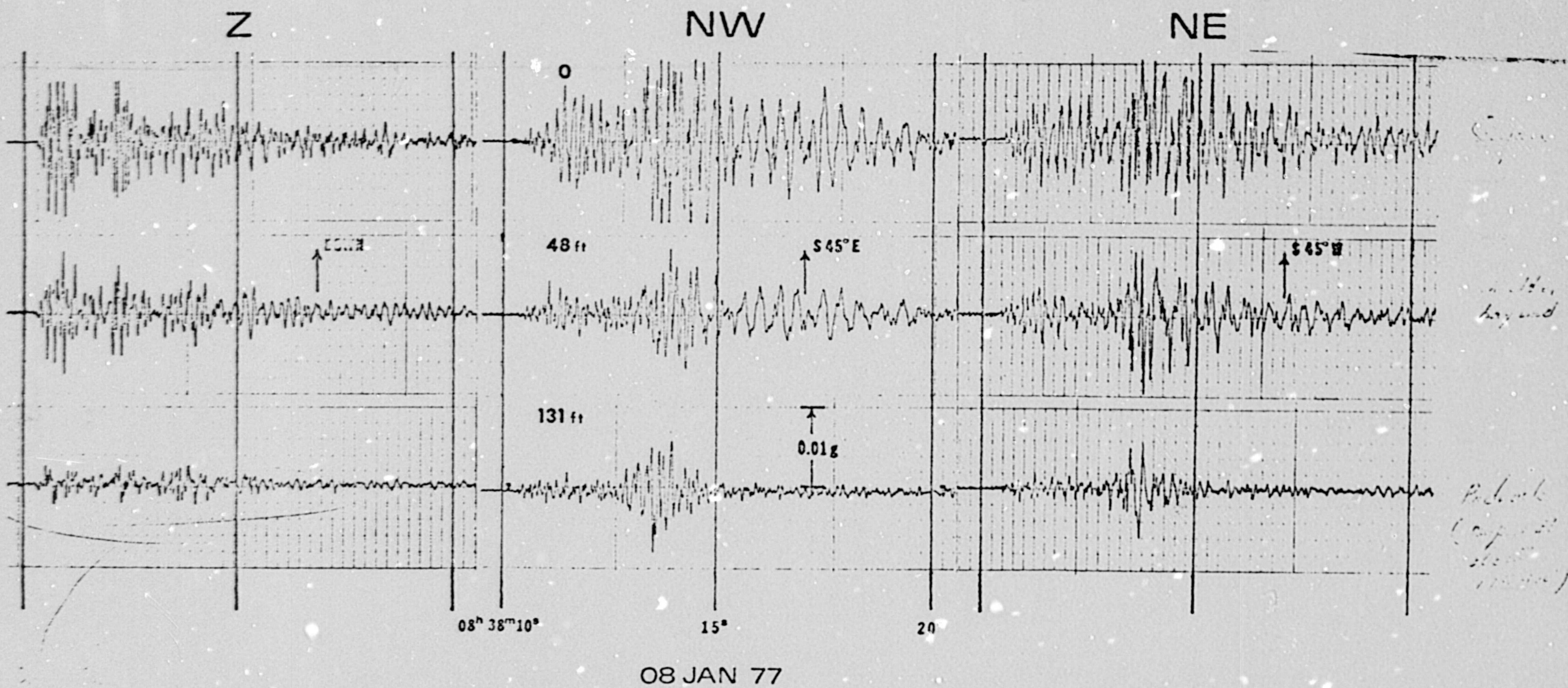
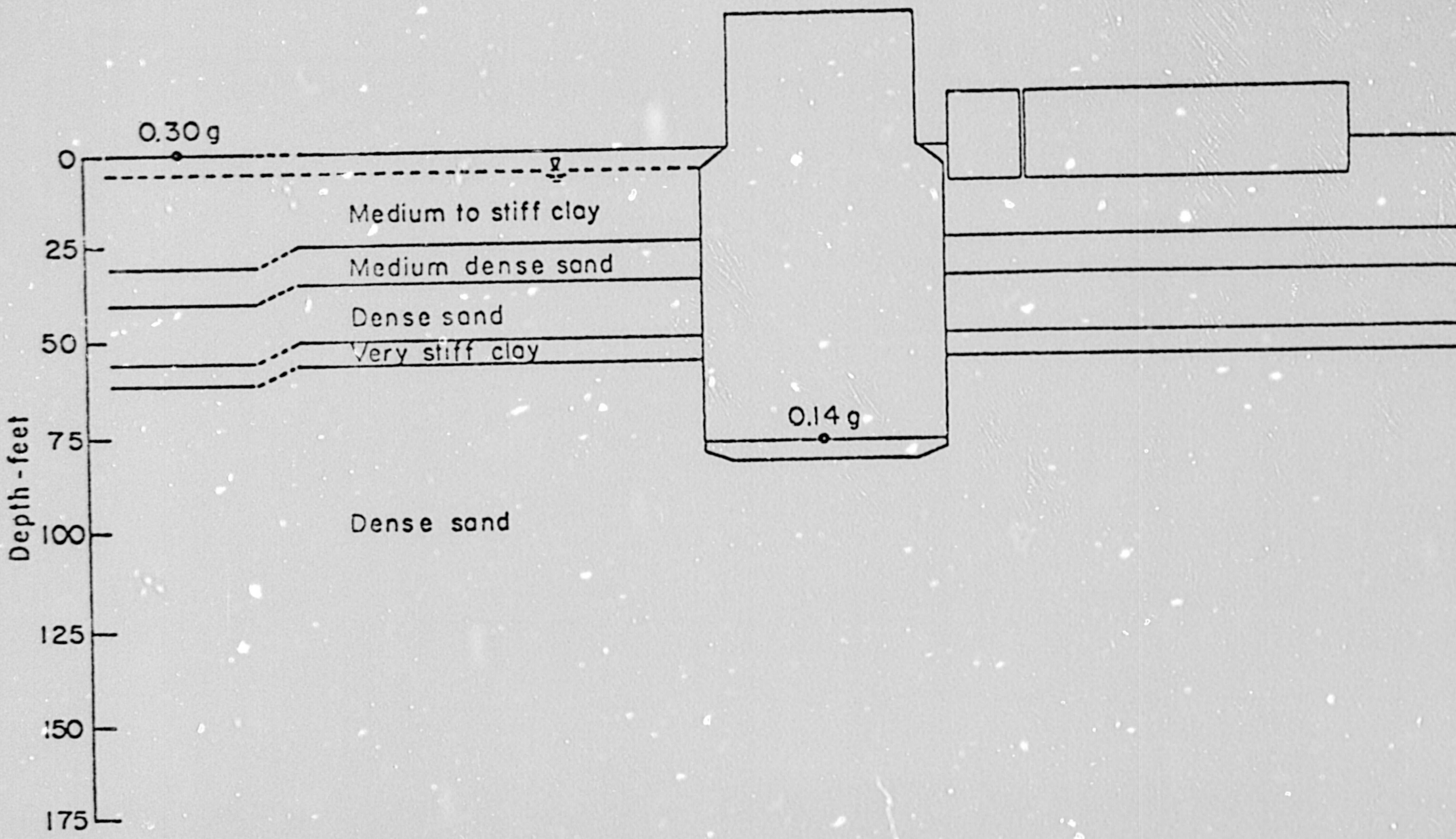


Figure 14



MAXIMUM ACCELERATIONS RECORDED AT HUMBOLDT BAY NPS - FERNDALE EARTHQUAKE, JUNE 7, 1975

Figure 15

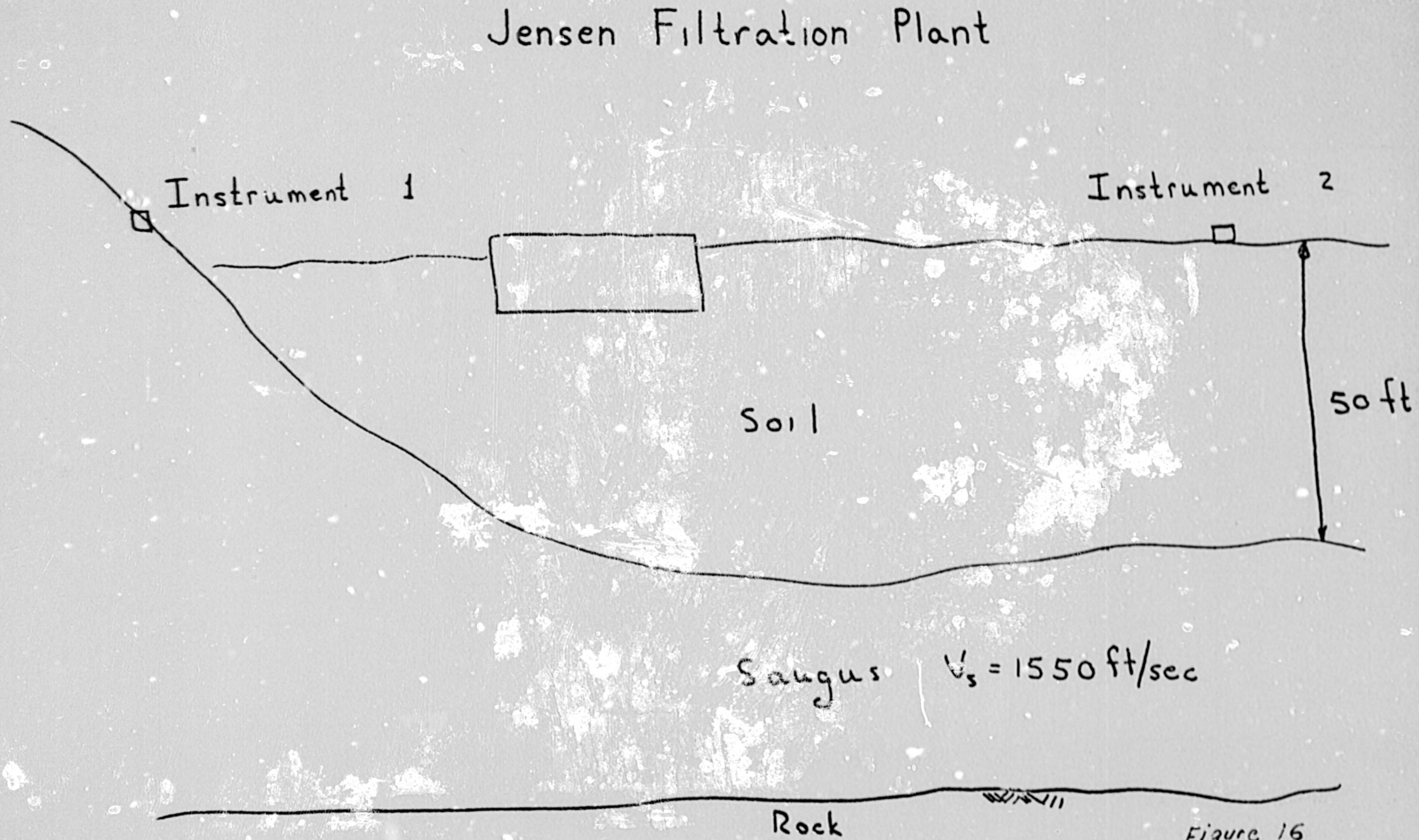
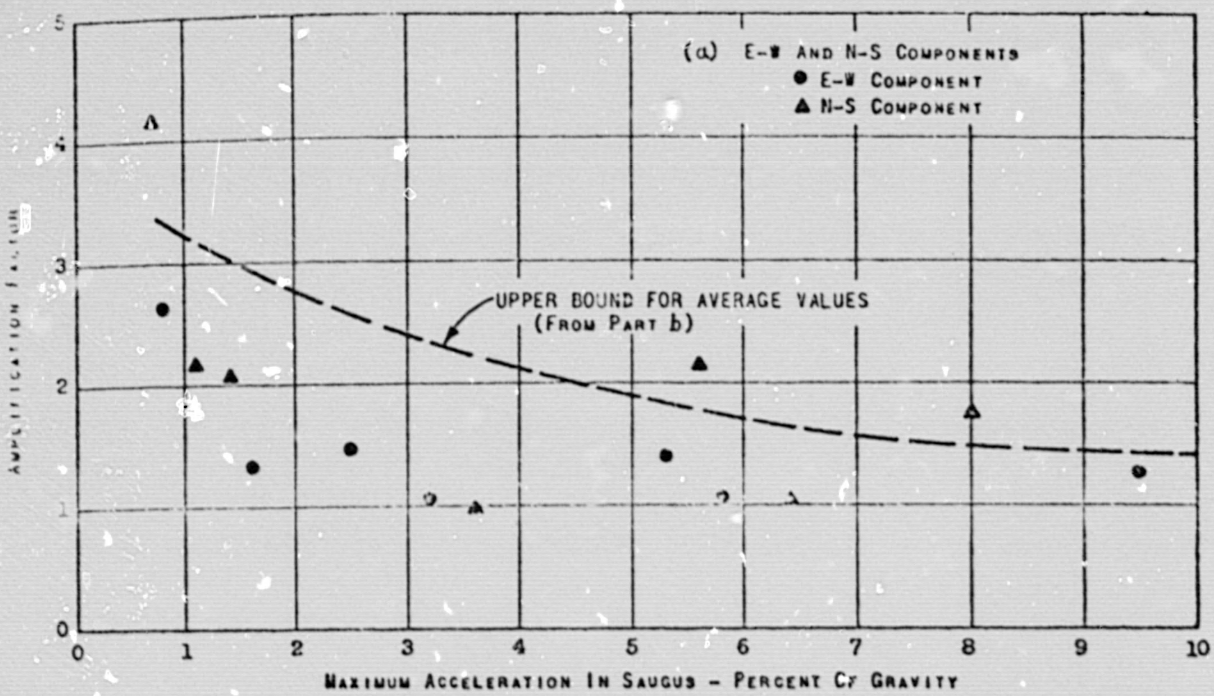
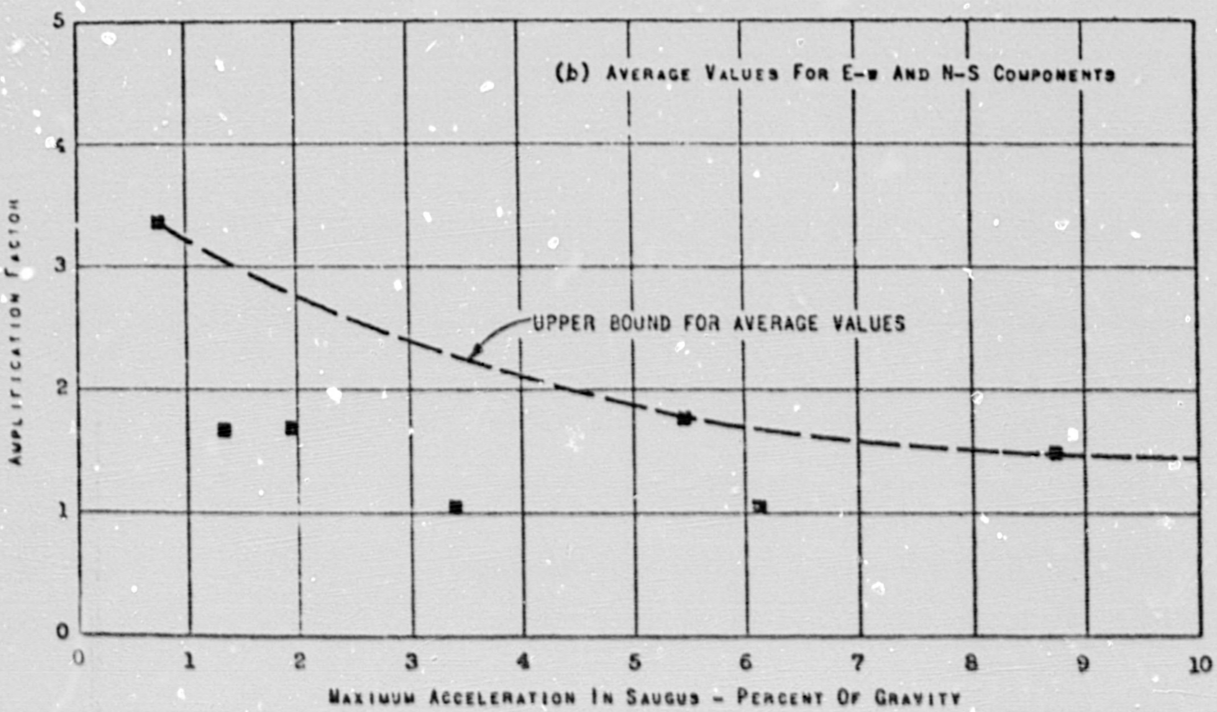

Jensen Filtration Plant
Instrument 1
Instrument 2
50 ft
Soil
Saugus $V_s = 1550$ ft/sec
Rock

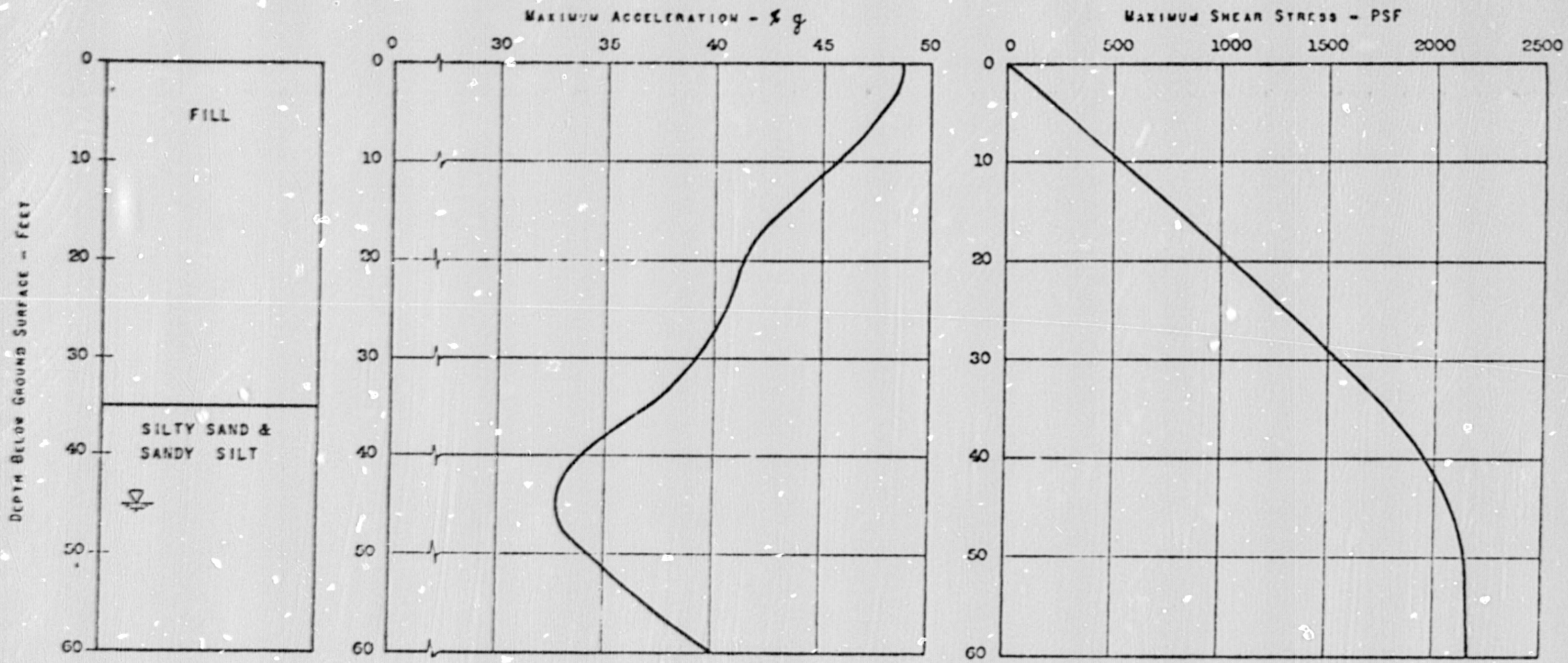
Figure 16





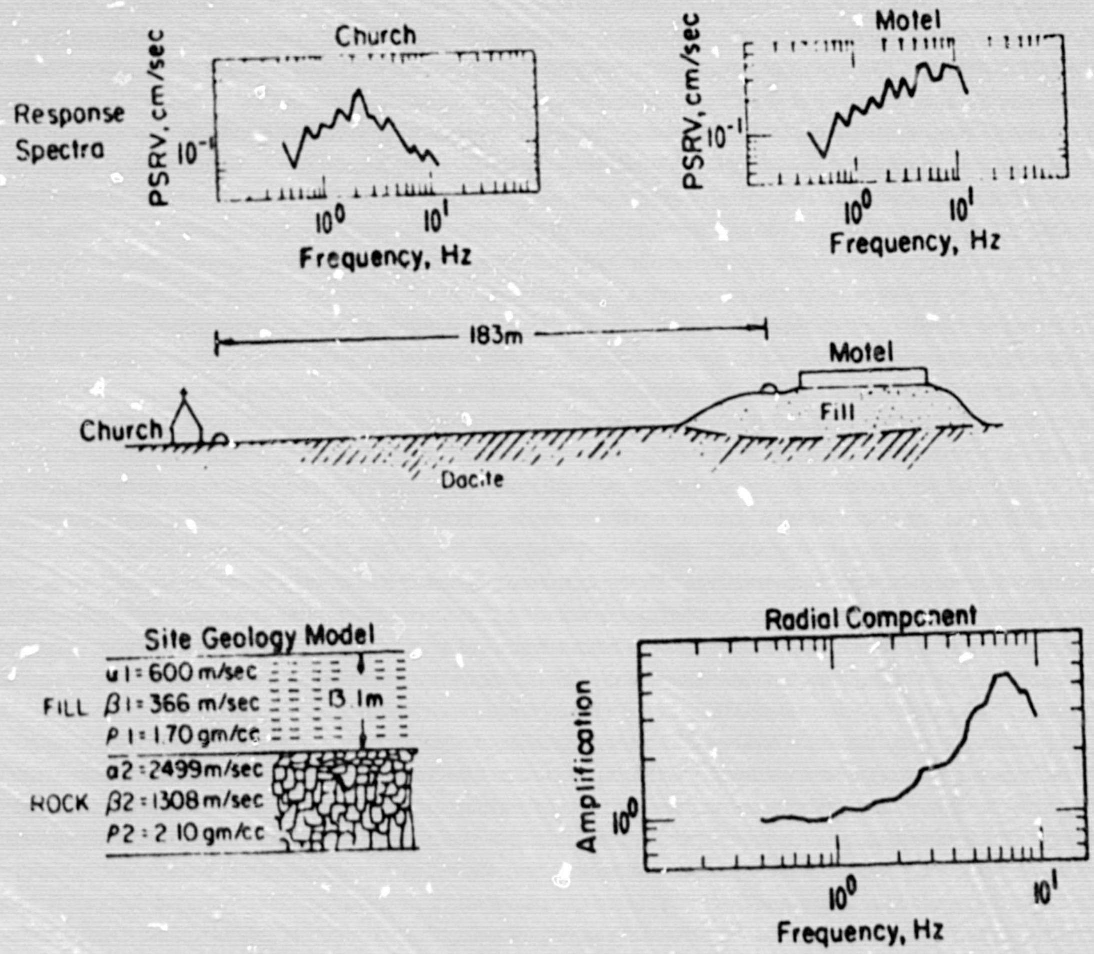
AMPLIFICATION FACTORS FOR ACCELERATION VALUES RECORDED DURING AFTERSHOCKS

Figure 17



RESPONSE EVALUATION — VICINITY OF SEISMOGRAPH NO. 2 DURING MOTION REPRESENTING FEB. 9, 1971 EARTHQUAKE

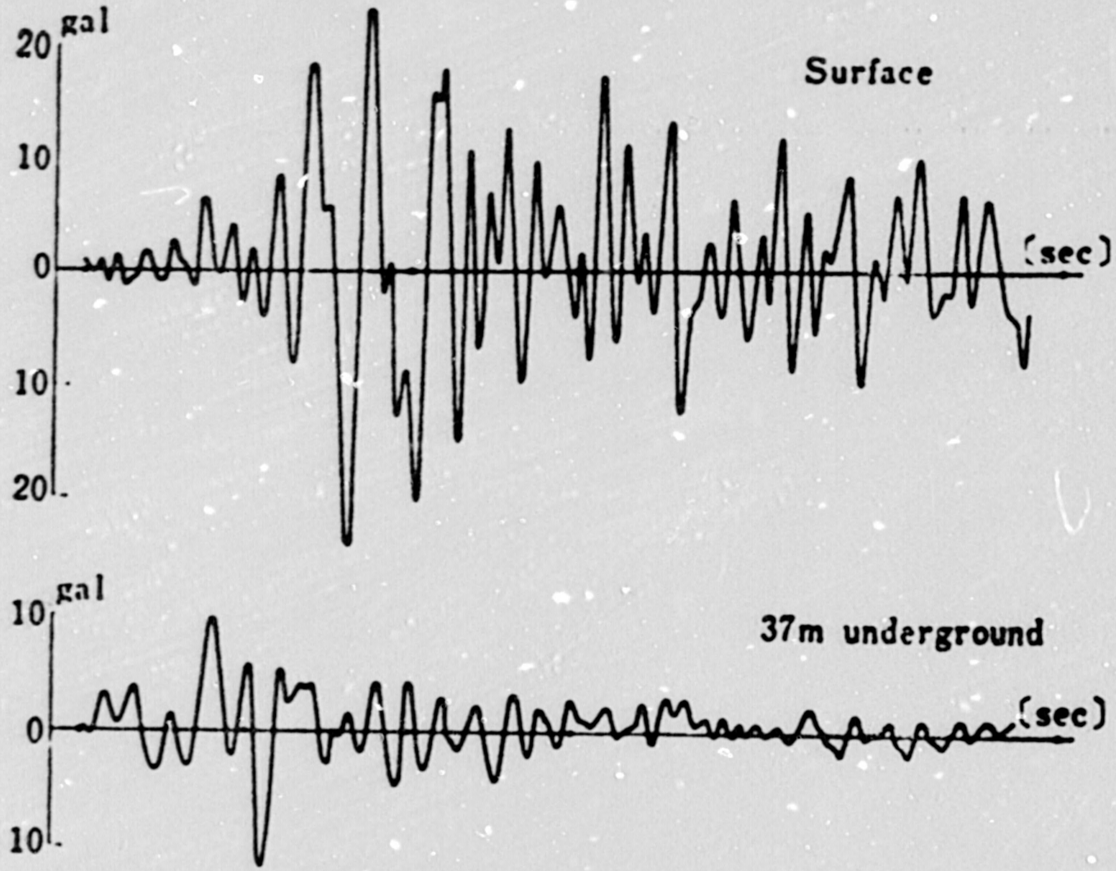
Figure 18



Soil amplification effects at Tonopah, Nevada

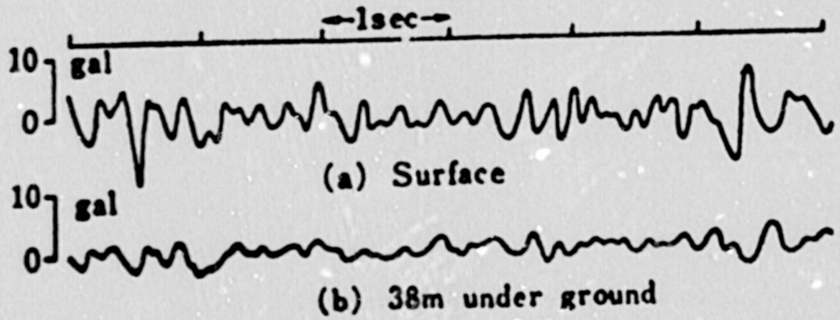
"The peak ground acceleration levels vary by a factor of about 2 at the sites."

Figure 19



Surface and underground acceleration records obtained at Urayasu, Chiba Prefecture.

Figure 20



Acceleration records taken on the surface and 38 meters underground at Sudagai, northern umma Prefecture.

Figure 21