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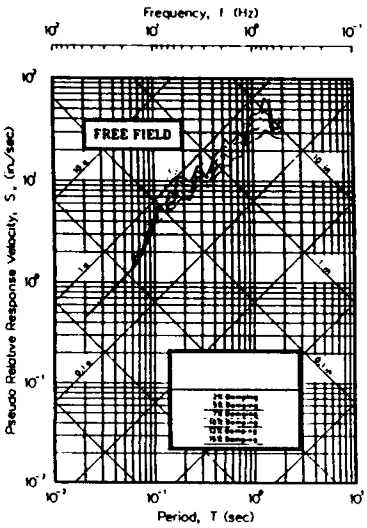

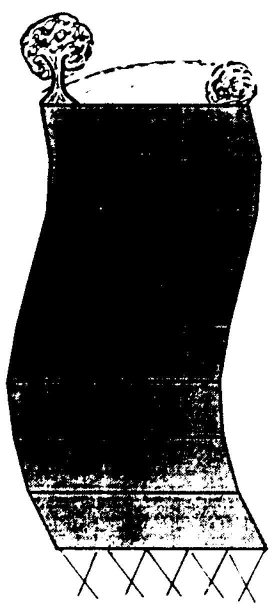

GEOTECHNICAL LABORATORY

INSTRUCTION REPORT GL-92-4

(2)

USACE GEOTECHNICAL EARTHQUAKE ENGINEERING SOFTWARE

Report 1

WESHAKE FOR PERSONAL COMPUTERS (Version 1.0)

by

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13. ABSTRACT *(Maximum 200 words)* One of the basic problems to be solved by geotechnical engineers in regions where earthquake hazards exist is to estimate the site-specific dynamic response of a layered soil deposit under a level ground surface. This problem is commonly referred to as a site-specific response analysis or soil amplification study (although motions may be deamplified). The solution of this problem allows the geotechnical engineer to evaluate the potential for liquefaction, to conduct the first analytical phase of seismic stability evaluations for slopes and embankments, to calculate site natural periods, to assess ground motion amplification, and to provide structural engineers with various parameters, primarily response spectra, for design and safety evaluations of structures.

The computer program described and provided in this report, *WESHAKE*, may be used to accomplish this task. *WESHAKE* is an adaptation of the original computer program, *SHAKE*, written at the University of California at Berkeley by Schnabel, Lysmer, and Seed (1972). *WESHAKE* was created and has been continually modified by WES to keep pace with state-of-the-art technology and provide a user-friendly interface.

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EXECUTIVE SUMMARY

One of the basic problems to be solved by geotechnical engineers in regions where earthquake hazards exist is to estimate the site-specific dynamic response of a layered soil deposit for level-ground conditions. The computer program described and provided in this report, *WESHAKE*, may be used to accomplish this task. *WESHAKE* is an adaptation of the original computer program, *SHAKE*, written at the University of California at Berkeley by Schnabel, Lysmer, and Seed (1972). *WESHAKE* was created and has been continually modified by WES to keep pace with state-of-the-art technology and provide a user-friendly interface.

The *WESHAKE* package consists of this report and a single floppy disk that contains the executable program, data base files, a plotting program, and example input and output files. It is imperative that the user of this program have a competent understanding of the problem statement, basic assumptions, and mathematical formulation used by the original authors of *SHAKE*. Documentation of the original program, *SHAKE*, is not duplicated herein nor is this report intended to be a primer on dynamic site response analysis.

PREFACE

This study is sponsored by the Headquarters, US Army Corps of Engineers (USACE) under the Numerical Model Maintenance Program (NMMP). This program provides for the maintenance, documentation, and corrections of existing computer models (programs) that have existing, or the potential for, widespread usage among Corps personnel. The program also provides for user consultation with WES authors. Mr. Richard Davidson, USACE, is the Technical Monitor for this particular model.

This report and accompanying software, the first in the report series on Geotechnical Earthquake Engineering Software (GEES), contains the information necessary to run the program *WESHAKE*. *WESHAKE* is a wave equation solver for one-dimensional problems and has been widely used to solve problems in earthquake engineering for USACE projects.

The purpose of establishing GEES is to provide a set of easy to use and understandable tools that can support the needs of the district and division engineers in evaluating the dynamic response effects of earthquakes on foundations, earth structures, and soil-structure systems at specific sites throughout the world. GEES will also allow USACE to establish and maintain consistency of programs among offices and a center for validation studies.

The WES Principal Investigator was Mr. David W. Sykora, Earthquake Engineering and Seismology Branch (EESB), Earthquake Engineering and Geosciences Division (EEGD), Geotechnical Laboratory (GL), WES. Mr. Ronald E. Wahl, Soil and Rock Mechanics Division (SRMD), GL, initiated the study and provided technical assistance. Mr. Michael K. Sharp, Engineering Geophysics Branch (EGB), EEGD, GL, has provided useful additions and suggestions to the core computer program over the past four years. Dr. David C. Wallace, Illinois State University, performed most of the programming for this study while at WES during the summers of 1991 and 1992 under the US Army Summer Faculty Research and Engineering Program (SFREP) provided through the US Army Research Office. Messrs. Willie McGeehee and Daniel Habeeb and Ms. Jennifer Davis, EESB, drafted figures, made copies, and helped to prepare the final report. Dr. Mary Ellen Hynes was Chief, EESB, during the course of this study and provided direct technical oversight.

Overall direction at WES was provided by Dr. A. G. Franklin, Chief, EEGD, and Dr. William F. Marcuson III, Chief, GL. Ms. Mary K. Vincent,

Chief, Office of Technical Programs and Plans, was the overall WES program manager of the NMMP.

At the time of publication of this report, Director of WES was Dr. Robert W. Whalin. Commander and Deputy Director was COL Leonard G. Hassel, EN.

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CONVERSION FACTORS, NON-SI to SI (METRIC) UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	Abbreviation	By	To Obtain
feet per second	fps	0.3048	metres per second
kips per cubic foot	kcf	16.03	megagrams per cubic metre

USACE GEOTECHNICAL EARTHQUAKE ENGINEERING SOFTWARE

WESHAKE FOR PERSONAL COMPUTERS

PART I: INTRODUCTION

Background

1. One of the basic problems to be solved by geotechnical engineers in regions where earthquake hazards exist is to estimate the site-specific dynamic response of a layered soil deposit under a level ground surface. This problem is commonly referred to as a site-specific response analysis or soil amplification study (although motions may be deamplified). The solution of this problem allows the geotechnical engineer to evaluate the potential for liquefaction, to conduct the first analytical phase of seismic stability evaluations for slopes and embankments, to calculate site natural periods, to assess ground motion amplification, and to provide structural engineers with various parameters, primarily response spectra, for design and safety evaluations of structures.

2. A site-specific response analysis is critical to US Army projects, both Civil Works and Military. Department of the Army, Engineering Regulation 1110-2-1906 (1983) provides guidance for US Army Corps of Engineers (USACE) Civil Works projects. For "Embankments and Soil Foundations" projects located within seismic zones 2, 3, and 4 (refer to Figures I-1 through I-4), the pseudo-static method of analysis is superseded. Rather:

> ...appropriate analytical techniques [shall be used] to evaluate liquefaction potential and/or to estimate deformations, beginning with the more simplified methods, and progressing as necessary to more rigorous, sophisticated procedures.

US Army Technical Manual TM 5-809-10-1 (1986) provides seismic design guidelines for essential buildings (Military projects). The "analytical soil-column response" method represents one of three methods that can be used to develop site-specific response spectra (refer to section 3-6 and Appendix C, section C-3 of TM 5-809-10-1).

3. The computer program *SHAKE* was written in the early 1970's by Schnabel, Lysmer, and Seed (1972) to conduct analytical site response analyses via solution of the wave equation. This program has been distributed freely and is still widely used by the profession although many versions of the

program have been modified by different organizations (e.g., GeoTech International, Ltd. 1985). This program has been, and continues to be, successfully validated with measured earthquake motions and site response. The US Army Waterways Experiment Station (WES) has been using the computer program *SHAKE* to calculate site response for level-ground soil sites for more than 15 years, including use on a number of USACE projects. A partial list of projects are provided in a supplemental Bibliography at the end of this report.

4. WES has continually made adaptations to *SHAKE* as the use for each new project required. The original version for use on a personal computer was obtained from the University of California at Berkeley (UCB) around 1985. This program at WES is now called *WESHAKE* to reflect the numerous changes that have been made to keep pace with state-of-the-art technology, to provide for needs of USACE users, and to provide a user-friendly interface. These adaptations facilitate transfer technology to, and wide-spread use among, USACE personnel.

Purpose

5. The purpose of this report and software is to provide USACE district and division engineers a means to calculate the horizontal site response of level-ground soil sites caused by vertically-propagating, horizontally-polarized shear waves that can be used to solve a variety of site response problems. Data bases have also been created to attempt to reduce the amount of effort in preparing an input file to solve a particular problem. It is the intention of the authors to create a user interface that is convenient to use and requires little, if any, guidance from the user's manual.

6. *WESHAKE* is part of the Geotechnical Earthquake Engineering Software (GEES) library that was established to prepare, validate, and maintain programs used to evaluate the dynamic response effects of earthquakes on foundations, earth structures, and soil-structure systems and establish a center for free distribution and support. Three programs in the GEES library are currently being supported, all by the Numerical Model Maintenance Program (NMMP): *WESHAKE*, *WESRISK*, and *WESFLUSH*.

Intended Users

7. It is imperative that the user of *WESHAKE* have a competent understanding of the problem statement, basic assumptions, and mathematical formulation used by the authors of *SHAKE*. The simplicity of the user interface should not be associated with the minimum level of capability of the user. The interface is designed to allow the first-time or occasional user with a rapid and easy means to run the program. Documentation of the original program, *SHAKE*, is not duplicated herein.

Merits of *WESHAKE*

8. *WESHAKE* is considered to be an improvement over *SHAKE* for all users for the following reasons:

a. Shear modulus can be defined by shear wave velocity or K_2 individually for each layer.

b. Recent sets of shear modulus degradation and damping curves are available in a data base.

c. The relationships for normalized shear moduli and damping ratio can be specified separately for each material.

d. The experience of WES engineers has been interjected into the data input requirements and in the discussions of the report.

e. An option for interactive plotting of earthquake motions is included.

WESHAKE should benefit the first-time or occasional user for the following reasons:

a. The menus and displays allow the user to create an input file and conduct the analysis without need to reference the user's manual or have knowledge of the format of input fields.

b. Some parameters that take on typical values have been assumed for the initial runs.

c. Only parameters required for analysis are part of the query sequences.

d. Several error checks have been incorporated including the establishment of reasonable bounds for some data values.

9. Despite the many cosmetic changes made as part of the study, the core structure of subroutines, algorithms, and data flow have not changed

significantly. Only minor differences exist between formats used for *SHAKE* and *WESHAKE*. These differences are documented in this report.

Report Organization and Suggested Use

10. This report is intended to serve as a guide to the first-time or occasional user of *WESHAKE*. Information for the data files are collected in an interactive mode with the computer providing menus and information requests. Example input screens and responses are provided in this manual to give the user a clearer understanding of the basic requirements. Output screens, files, and reports are also provided to illustrate the relationship between the inputs and the outputs as well as the interpretation of the results. Instructions for installation, hardware requirements, listings of data bases and example files, and file formats are provided in appendices to this report.

11. Some basic background information about the analytical solution to site response analysis and aspects of *WESHAKE* that are different from *SHAKE* are presented in Part II of this report. The salient features of *WESHAKE* and validation are presented in Part III of this report. The use and execution of *WESHAKE* are described in Part IV of this report. The first section of Part IV focuses on the preprocessing stage of collecting information. The preprocessing stage is divided into two primary sections: mandatory actions and user options. The mandatory actions are used to define the soil column, identify an earthquake motion, and assign the location of object motion. User options allow for variations in input parameters and the calculation and preparation of specialized forms of output. Other sections of Part IV describe the analysis stage (execution) of *WESHAKE* and error checks. An example problem is used throughout this report to assist the user.

12. Part V of this report presents discussion on how to model and solve more difficult problems that may not have been addressed previously. It is considered to be a supplement to the other sections and is not a necessary part of learning how to use *WESHAKE* to solve basic problems. The reader should be familiar with the topics discussed in Part V and refer to the appropriate discussions as needed.

13. The complete package for *WESHAKE* includes this report and a floppy disk with the following files:

WESHAKE.EXE	--	Executable shell containing wave propagation code
SHEARDB	--	Data base of shear modulus relationships
DAMPDB	--	Data base of damping relationships
EARTHQ	--	Data base of accelerograms
MOTION.EXE	--	Executable accelerogram plotting program
EXAMPLE.DAT	--	Example specification file
EXAMPLE.EXT	--	Companion to specification file
EXAMPLE.SPF	--	Soil profile file
READ_ME.TXT	--	List of files and file sizes

Questions, comments, and requests for updates should be directed to:

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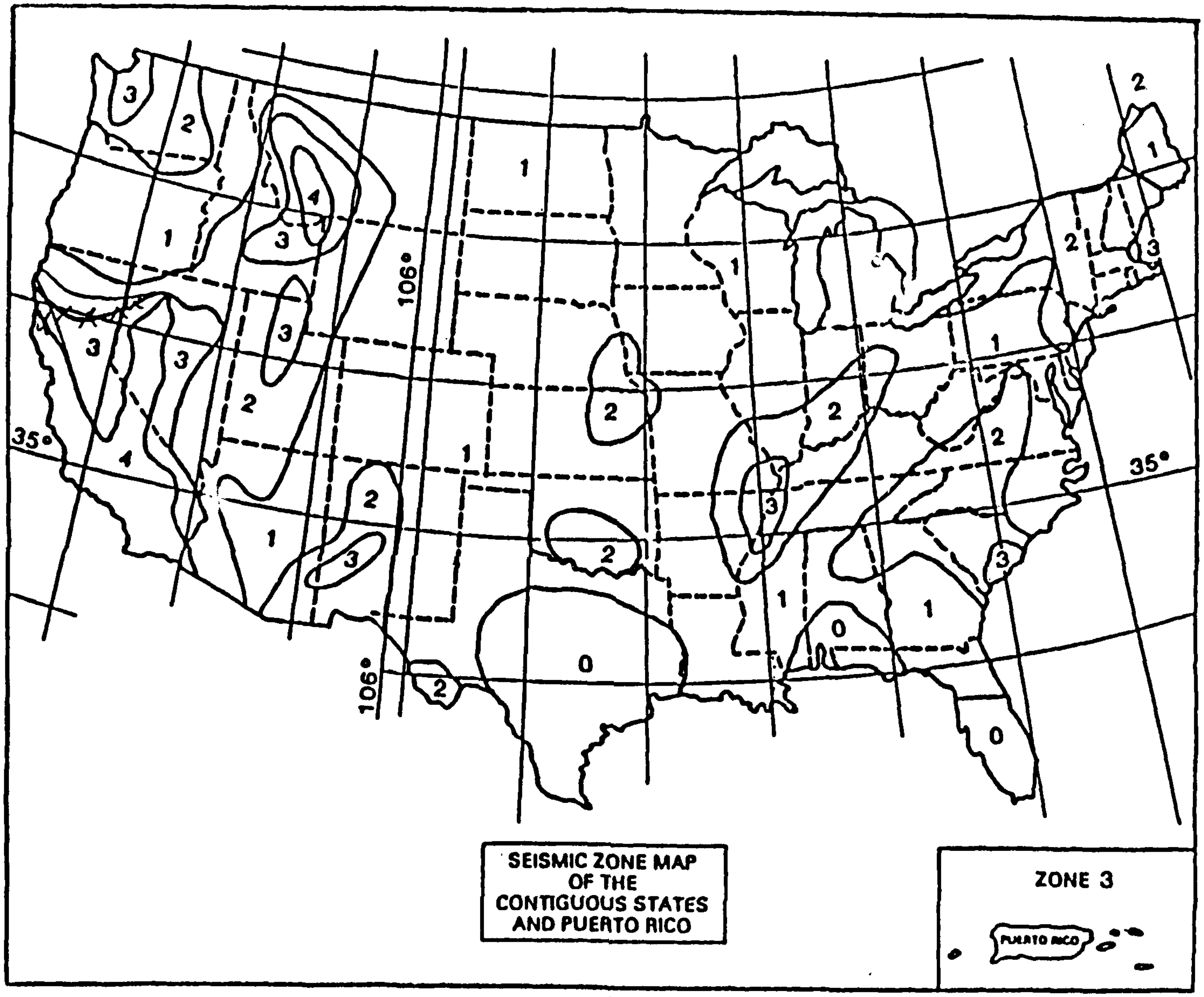

Figure I-1. Seismic zones within contiguous 48 United States (Department of the Army 1983; adapted from Algermissen et al. 1982)

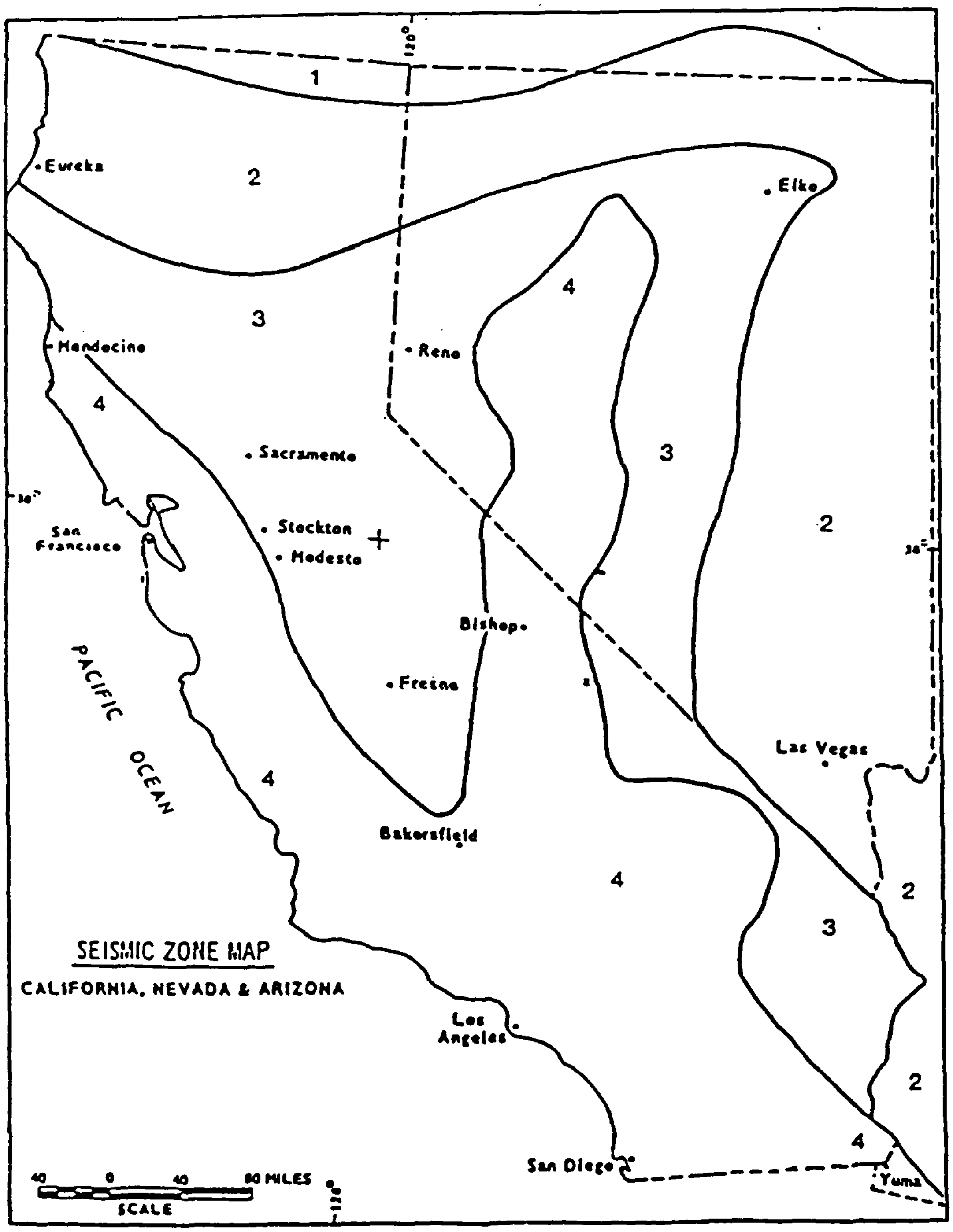

Figure I-2. Seismic zones within California (Department of the Army 1983; adapted from Algermissen et al. 1982)

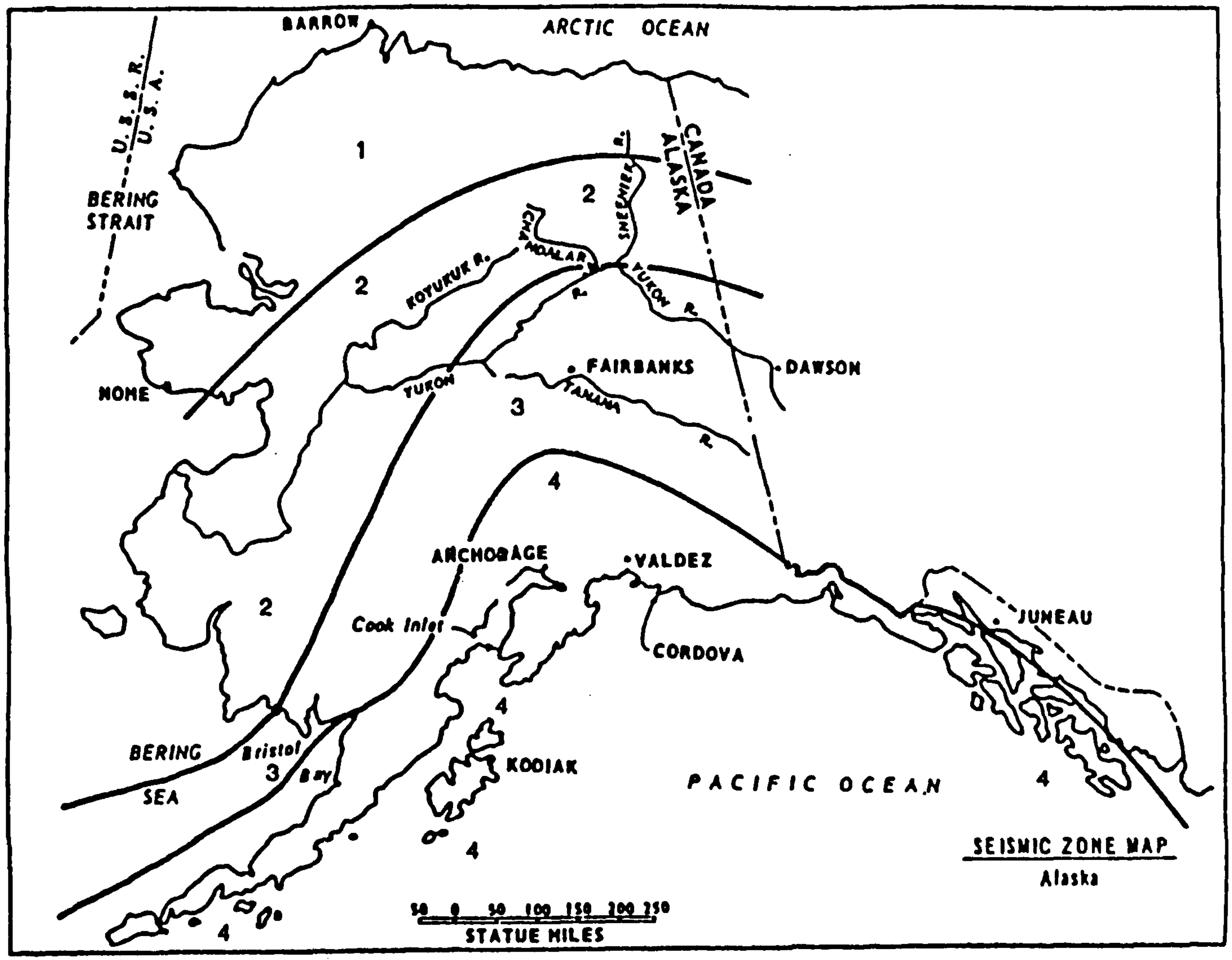

Figure I-3. Seismic zones within Alaska (Department of the Army 1983; adapted from Algermissen et al. 1982)

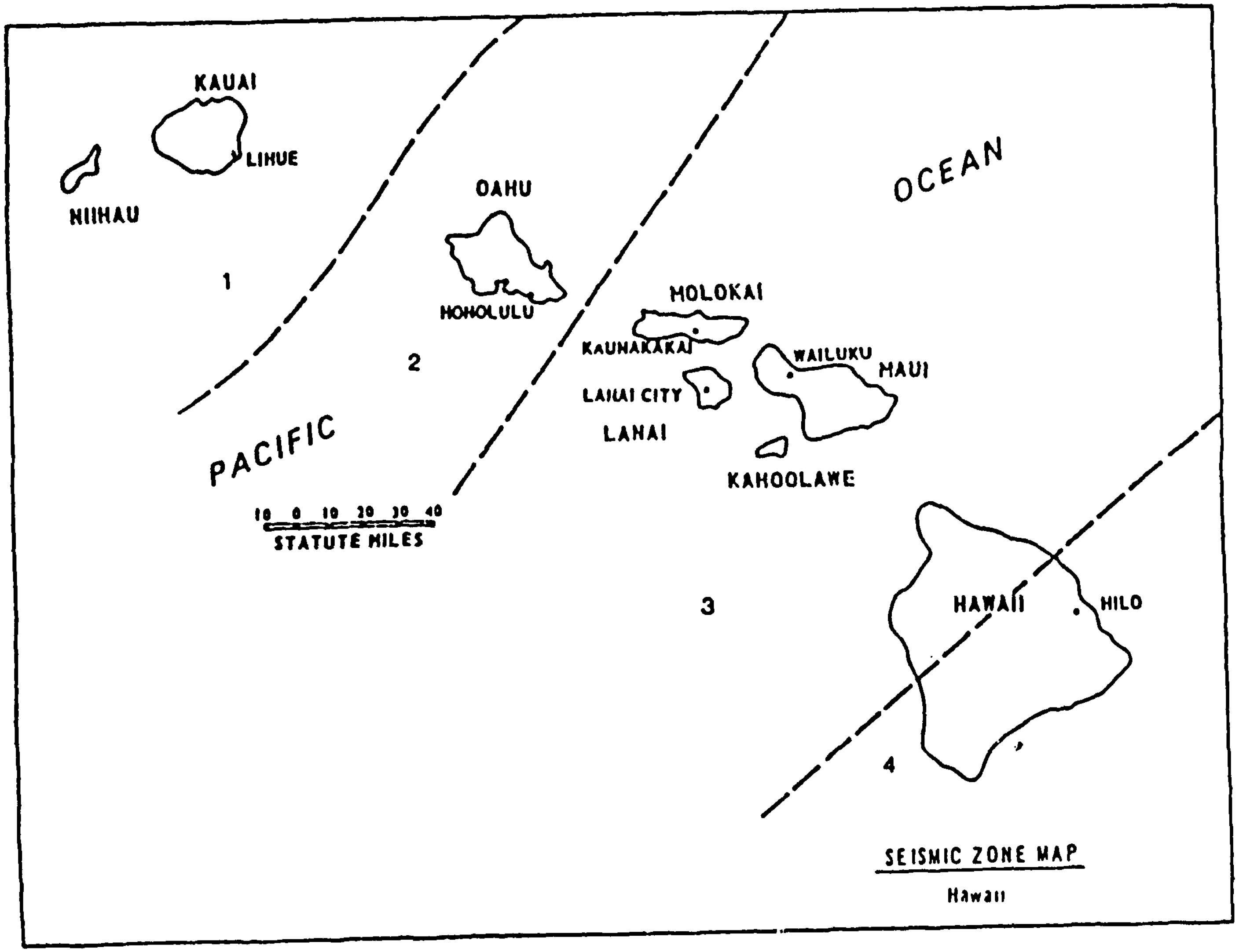

Figure I-4. Seismic zones within Hawaii (Department of the Army 1983; adapted from Algermissen et al. 1982)

PART II: *WESHAKE* BACKGROUND AND THEORY

Procedure of Site Response Analysis

14. A site response analysis, sometimes referred to as a soil amplification analysis, involves the determination of components of ground motion for design or seismic evaluation. Typically, as in this study, that determination is made for a "free-field" response -- the response at the ground surface of an ideal soil deposit (horizontal layers extending to infinity) to a spatially-uniform motion applied at the base. The conceptual relationship between free-field response with respect to two primary control points -- rock outcrop and base rock -- in a site response analysis is shown in Figure II-1. The motions at these three points, as well as any other point in the vertical profile, are unique. Design earthquakes are frequently specified as corresponding to a rock outcrop. Mathematical expressions (transfer functions) are then used to find the equivalent motion for the base rock and then the seismic waves are propagated through the soil column to determine the free-field motion.

15. The determination of site-specific earthquake response of soil deposits, then, generally involves three basic steps:

- a. Selection of earthquake motions, usually corresponding to rock outcrop.
- b. Idealization of stratigraphy and selection of material properties.
- c. Calculation and evaluation of site response.

The third, and final, step of a site-specific earthquake response analysis is the subject of this study.

16. Different techniques are available to determine site-specific response of soil sites to earthquake motions. Analytical formulations include the wave equation and shear beam analogies (both continuous formulations) and a lumped mass model analysis (discrete formulation). Initial formulations for site specific calculations using the wave equation were reported in the U.S. by Roesset and Whitman (1969) and Roesset (1970) and have been enhanced since. A number of computer codes are available to solve the wave equation in one, two, or three dimensions. This report summarizes the code *WESHAKE* which evolved from the code *SHAKE*, described in the next section.

SHAKE

17. *SHAKE* was developed at the University of California at Berkeley (Schnabel, Lysmer, and Seed 1972) and written in FORTRAN IV to run on a CDC 6400 computer. It has since been adapted to run on a number of computer platforms including personal computers by various sources. *SHAKE* is widely used by the geotechnical earthquake engineering profession for the calculation of site response for horizontal motions.

18. Several investigators have reported close comparisons between the results using *SHAKE* and the measured horizontal response from strong-motion instruments triggered during earthquakes at site periods less than 2 sec (e.g., Seed et al. 1987, Idriss 1990, and Seed, Dickenson, and Idriss 1991). The experience of these investigators suggest that for calculated site periods greater than 4 sec, motions are likely to be significantly affected by two-dimensional effects and surface wave energy and are not well represented with *SHAKE*.* The user should be cautious when using values at periods greater than 2 sec.

19. *SHAKE* was developed to calculate the horizontal response caused by an earthquake at any depth of a soil profile. The approach and algorithms incorporated in the program are simple, straight forward, and adequate for the purpose intended as clearly evident through the prolific publication of results and favorable comparisons with measured response (e.g., Seed et al. 1987, Idriss 1990, and Seed, Dickenson, and Idriss 1991). The simplicity associated with *SHAKE* is attributed to some basic assumptions regarding the cyclic behavior of materials and geometry of the problem. The basic assumptions used in the formulation of are:

- a. The soil layers are horizontal and extend to infinity.
- b. The ground surface is level.
- c. Each soil layer is completely defined by the shear modulus and damping as a function of strain, the thickness, and unit weight.
- d. The non-linear cyclic material behavior is adequately represented by the linear visco-elastic (Voigt) constitutive model and implemented with the equivalent-linear method.
- e. The incident earthquake motions are spatially-uniform, horizontally-polarized shear waves, and propagate vertically.

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* Personal communication, Prof. Raymond Seed, University of California at Berkeley, 23 September 1991.

In general, assumptions (a), (b), and (c) used to derive this model would seem to significantly limit the applicability of this method. Past studies have shown, however, that reasonable results are obtained for a much broader spectrum of in situ conditions. The equivalent-linear constitutive model, assumption (d), is described later in this section. The last assumption, (e) above, narrows the focus to a simple class of problems, but, is a common assumption for this type of problem.

20. It is important to realize that the formulation of *SHAKE* for wave propagation is based on a total stress analysis. The materials are considered to be continua and pore water pressures are non-existent. The calculation of shear modulus using values of K_2 does involve the determination of mean effective stress using the depth of the water table and the unit weight of water.

<u>Formulation and iteration scheme</u>

21. The one-dimensional wave equation model (Kanai 1951) was used to develop *SHAKE*. This model has proven to be effective despite the simplicity and number of assumptions involved. The solution algorithm involves the complex response technique and the Fast Fourier Transform (Cooley and Tukey 1965). The general formulation of the wave equation is not unique to horizontally-polarized shear wave motion; the equation can also be solved for the vertical propagation of compression waves.

22. In general, soil is a non-linear material that exhibits hysteretic behavior under cyclic loading. An example of the stress-strain behavior is shown in Figure II-2a. Soil is difficult to model accurately for cyclic response; exact representations are unavailable. The constitutive model incorporated into *SHAKE* is linear with simulated nonlinear effects to account for dependency of moduli on shear strain. The method used to implement the linear visco-elastic model, called the equivalent-linear method, was proposed by Seed and Idriss (1970) and is widely used in geotechnical earthquake engineering studies.

23. The basic components of the equivalent-linear method are the maximum shear modulus, G_{max} , moist unit weight, γ , and ratio of critical damping, β . The property G_{max} , which corresponds to the linear-elastic, continuum material property (Lamé 1852), can be calculated from low-strain seismic shear wave velocity using:

$$G_{max} = \frac{\gamma}{g} V_s^2 \qquad (1)$$

where

g - gravitational constant of earth
V_s - shear wave velocity

When using the shear modulus coefficient in lieu of V_s, the following equation is used (Seed and Idriss 1970):

$$G_{max} = 1000 \ (K_2)_{max} \ (\sigma_m')^{0.5} \qquad (2)$$

where

σ_m' - mean effective stress, in psf
G_{max} is in psf

The shear modulus, G, of a soil remains constant during cyclic loading at very small shear strains (defined as G_{max}). As the shear strains increase above some threshold value, generally accepted to be about 10^{-4} percent or less, G decreases. The equivalent-linear method uses secant shear moduli that are adjusted during each iteration to account for this degradation of shear modulus. Damping is input by using complex moduli, G^* , and hysteretic damping (which is independent of frequency) as reported by *Udaka and Lysmer* (1973):

$$G^* = G \ (1-2\beta^2+2i\beta\sqrt{1-\beta^2}) \qquad (3)$$

where

$i = \sqrt{-1}$

Damping increases as shear strain increases.

24. The character of the relationships between normalized shear modulus versus shear strain and damping ratio versus shear strain was addressed in studies at the University of Kentucky in the late 1960's (Hardin and Drnevich 1972a; 1972b). Seed and Idriss (1970) and Schnabel (1973) used the results of these studies to derive the equivalent linear model and the first set of relationships provided with *SHAKE*. The general shapes of these relationships are shown in Figure II-3. Relationships provided with *WESHAKE* are presented in Part III of this report.

25. An example of the iterative procedure for the equivalent-linear method is shown in Figure II-2b and described below. Assuming shear wave

propagation, the model is initiated with an arbitrary value of shear modulus, G_1 , chosen to be less than, or equal to, G_{max} . For the first cycle of loading, the stress-strain relation is linear between the two levels of shear strain, $\pm \tau_1$, with a slope of G_1 . The ordered pair (G_1 , τ_1) comes from the appropriate modulus degradation curve as discussed in Part III of this report and shown schematically in Figure II-2b. Maximum shear strains are obtained from the solution of the wave equation. The ratio of effective shear strain to maximum shear strain, PRMUL, (assumed to be 0.65) is used to obtain a new value of shear modulus, G_2 , from the appropriate modulus curve. A new value of β is also obtained.

26. This process is repeated until the difference in moduli and damping for two successive iterations are within a prescribed tolerance, ERR (5 percent is assumed). The number of iterations required by the computer to solve the problem is a function of how close the initial estimates are to the final results; the closer the two sets of values, the fewer the number of iterations required (and proportionally, more time to solve).

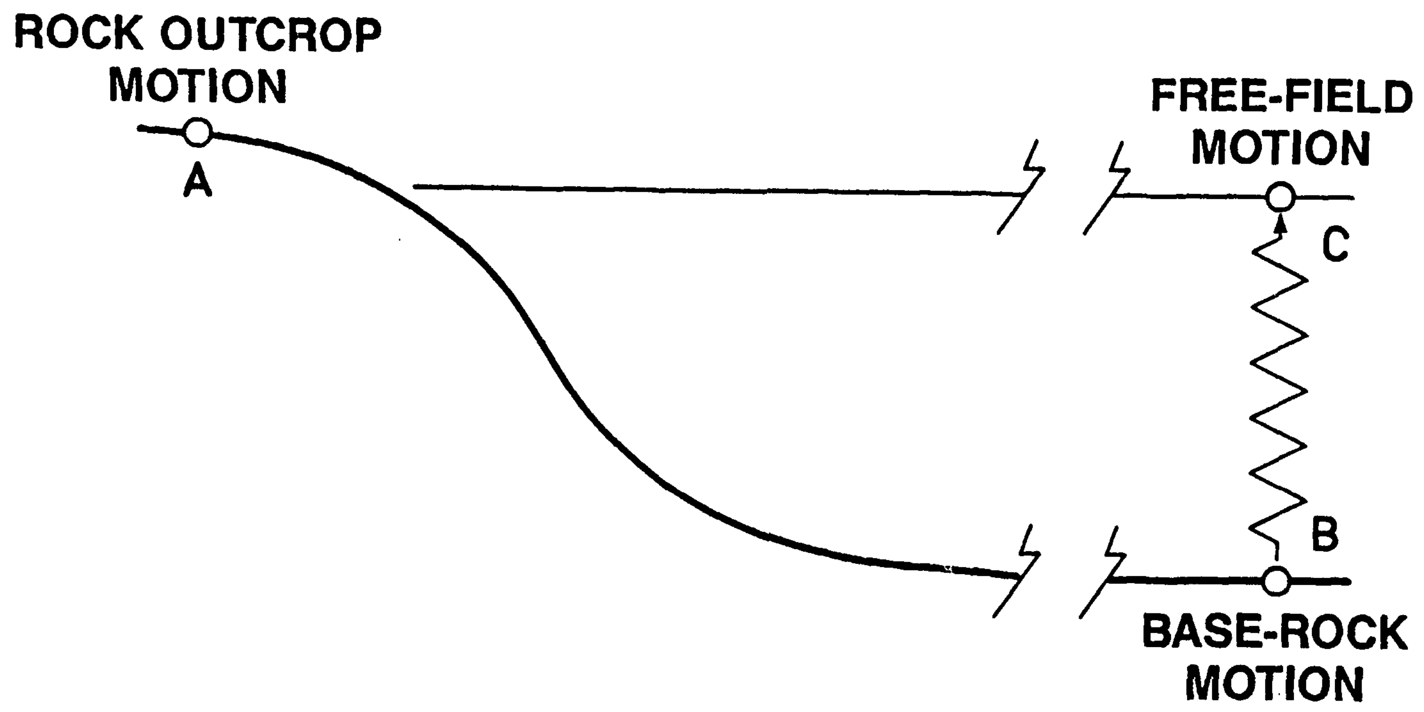
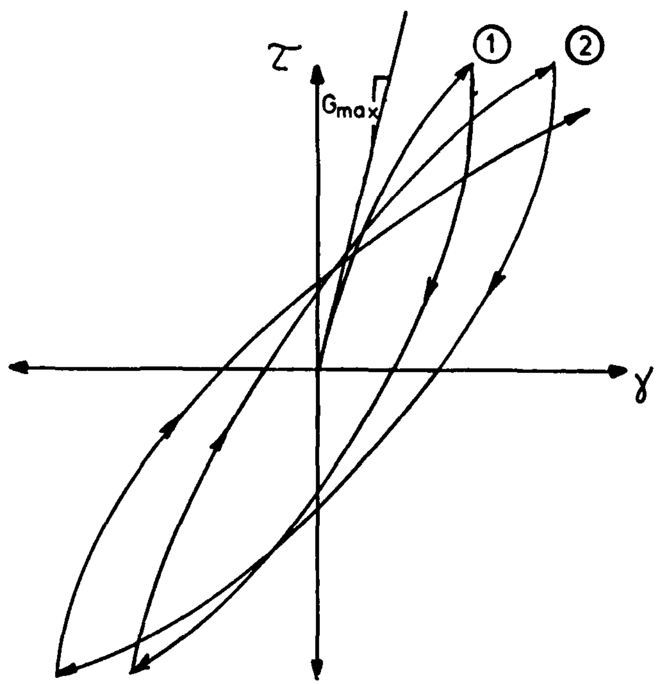
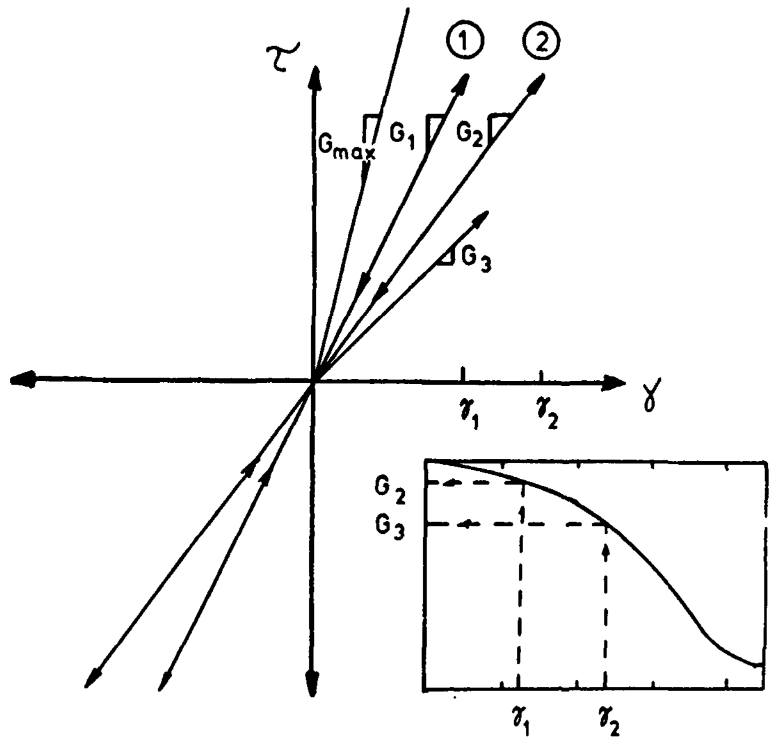


Figure II-1. Three primary control points for site response analysis



a. General hysteretic soil behavior



b. Equivalent-linear method representation

Figure II-2. Generalized comparison between hysteretic soil behavior and the equivalent-linear soil model for a constant stress state

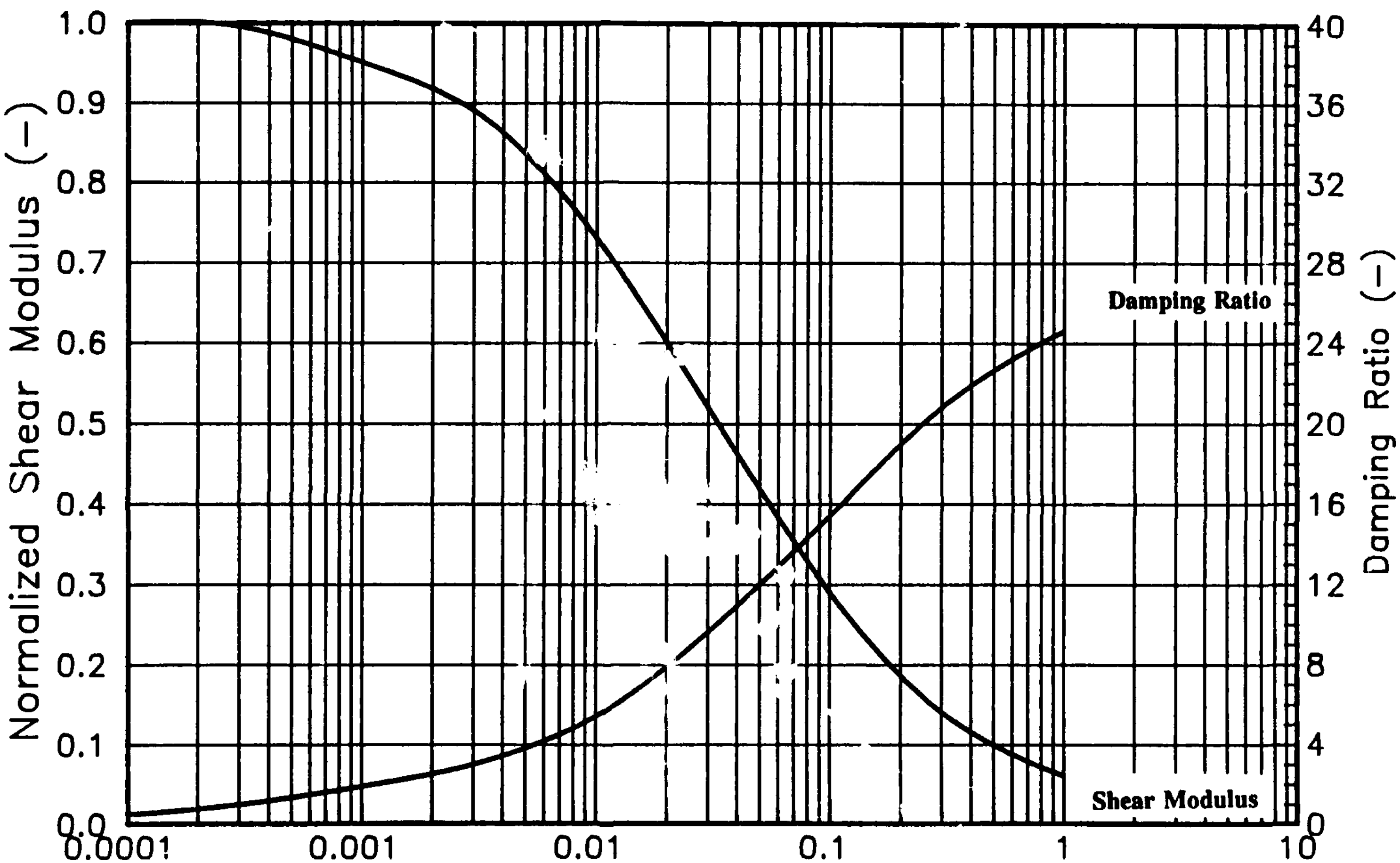


Figure II-3. Standard relationships between normalized shear modulus and damping ratio versus shear strain

PART III: PERSONAL COMPUTER IMPLEMENTATION

27. The computer program *WESHAKE* is primarily a menu driven shell system with various other requests for information from the user to quickly and conveniently guide the user to execution of the core computer code. This program is linked with overlays and external data bases to reduce memory size during execution. Information about loading the program and companion files is presented in Appendix A along with discussions about hardware requirements, array limitations, memory requirements, and program run times.

Changes from *SHAKE*

28. Over the 20 years that *SHAKE* has been used, more knowledge has become available with regard to the specification of inputs to the program and significant advances have been made in computer technology. As these findings and advances have been made, WES has refined and adapted *SHAKE*. *WESHAKE* can best be described as a program that performs pre- and post-processing functions and uses the original program, called *SHAKE1*, as a core for calculations. *SHAKE*, then, is essentially embedded in *WESHAKE* which facilitates the implementation of newer versions or formulations of *SHAKE*.

29. The pre- and post-processing routines were written from scratch during FY91 and version 1.0 was finalized and distributed in FY92. Only a few minor changes were made to *SHAKE1* to reflect changes in the state-of-the-art. The changes made to *SHAKE1* were purposely kept to a minimum to retain the intent of that program's authors and minimize the amount of re-validation required. The options to *SHAKE* are also numbered differently in the interface to reduce the size of user menus. The cross reference between option numbers is provided in Table III-1.

30. The most significant change made to *SHAKE1* was in the subroutine SOILIN which is used to read, calculate, and store the initial values of shear wave velocity and shear modulus. First, the initial value of shear modulus for each layer used in the iteration scheme for the equivalent linear constitutive model is fixed to equal G_{max}. Fixing the initial value corresponding to G_{max} will increase the time to iterate to the solution but not significantly when using personal computers with processor speeds greater than about 20 MHz. Then, rather than having fixed variable inputs of S_u and

K_2 for clay and sand, respectively, *SHAKE1* allows the user to input K_2 OR V_s for any soil; S_u is no longer used. V_s input is still required for rock, however.

31. Other significant changes include the separation of shear modulus and damping relationships for soil types. Previously, a set of shear modulus and damping relationships was selected. Now, each relationship can be chosen separately. This is described in more detail in the next section. *WESHAKE* has no provisions for the use of sublayers. This original option does not appear to be useful. In addition, error checks were added and will be described later.

Shear Modulus and Damping Ratio Data Bases

32. Two separate data bases are used to contain options for specifying the variation of normalized shear modulus and damping ratio with effective shear strain -- **SHEARDB** and **DAMPDB**, respectively. Both data bases are used independently to specify material relationships for each layer allowing versatility. (In previous versions of *SHAKE* and *WESHAKE* the selection of one material relationship required the use of a specific damping ratio relationship.) A description of the data bases, including format, are presented in Appendix B.

33. Eleven relationships for normalized shear modulus and damping ratio exist in the two data bases -- one for rock, one for gravel, three for sand, and six relations for cohesive soils. These relationships are shown in Figures III-1 and III-2 for normalized shear modulus and Figures III-3 and III-4 for damping ratio. The sources of the relationships are summarized in Table III-2. The criteria for selection of appropriate relationships from the data bases are based on the general soil classification and plasticity index (for fine-grained soils).

34. Three different relationships are available in each of the data bases for sands -- average, lower bound, and upper bound (refer to Figures III-1 and III-3). These relationships are based on the results of laboratory studies (e.g., Hardin and Drnevich 1972a; Seed and Idriss 1970, Wong et al. 1974; Seed et al. 1986; and Hynes 1988) Some investigators (e.g. Idriss 1990) tend to use the upper bound relationship for sands. The general recommendation of WES is to use the lower bound sand relationship for gravelly

sands or sandy gravel (rather than the "gravel" curve), use the average relationship for clean sands, and use the upper bound relationship for clayey and silty sands.

35. The results of independent laboratory studies by Sun, Golesorkhi, and Seed (1988), Zen and Higuchi (1984), and Vucetic and Dobry (1991) have shown that for cohesive soils, the selection on an appropriate shear modulus curve should be based on the plasticity index. The set of relationships proposed by Sun, Golesorkhi, & Seed (1988) are included in the data base. A discussion related to the choice of this set is contained in Part V of this report. Note that the range of relationships for cohesive soils overlaps the range of relationships for sands.

Earthquake Record Data Base

36. Lists of earthquake records (accelerograms) in the *WESHAKE* data base are separated into measured records and synthetic records and are presented in Tables III-3 and III-4, respectively. More information on the data base is provided in Appendix C, including data base syntax and plots of the variations of acceleration with time and velocity spectra for all of the records.

37. The data base used in *WESHAKE* has been limited initially to 22 records representing both measured and synthetic earthquake records. Most importantly, this data base purposely includes only records corresponding to rock outcrop (refer to Figure II-1). The user may define an earthquake not contained in the data base, preferably a project-specific record.

38. A number of (measured) earthquake records are available to the user, particularly with the establishment of national data bases for strong motion (e.g., Row 1990; Friberg and Jacob 1990). The user should be aware that the vast majority of earthquake records have been measured at points other than rock outcrop, the most desired point for *WESHAKE*. Most of the U.S. records, for instance, have been measured by instruments housed in buildings, primarily the basements, and at the top of free-field soil sites (well above the top of rock). The presence of the building and soil overlying bedrock can greatly affect the recorded motion (e.g., refer to the presentation under the previous sub-heading). In fact, this is the purpose of conducting an analytic site response study. Free-field rock outcrop records (or base rock records,

when they become available) should be used to properly evaluate site response and maintain consistency in approach.

39. The variation of acceleration with time for each earthquake can be viewed on the computer monitor by enabling the computer program *MOTION* (outside of the *WESHAKE* shell). The plots represent unscaled (measured accelerations) records as they are contained in the database. Details concerning its procedures and operations are included in Appendix D.

Input and Output Files

40. *WESHAKE* creates and manages a number of different files as needed. The use of input files may go relatively unnoticed to the user. Output files are created to be easily read by commercial plotting software. Both input and output files are described below.

Input files

41. *WESHAKE* makes use of three different files for input to the core program *SHAKE1*: a specification file (with *.DAT filename extension), a soil profile file (with *.SPF filename extension), and a companion file (with *.EXT filename extension). The specification file is the complete input file to *SHAKE1*. A soil profile file contains information regarding the stratigraphy and material properties and is a subset of the specification file. Its use is optional but useful when a number of specification files are to be created with the same soil profile. For instance, an engineer may be interested in subjecting a particular soil column to a number of different earthquake records scaled to the same value of a_{max} . The companion file is merely a storage area for descriptions of the soil types and is created by *WESHAKE* along with the specification or soil profile file. The manipulation of these three files is relatively transparent to the user. Options within *WESHAKE* allow the user to list existing files in the working directory to avoid confusion.

42. Old input files (from *SHAKE* or *WESHAKE*) can be modified with minimal effort using a DOS editor and used with *WESHAKE* as described in Part IV and Appendix E. These changes include adding a line to the option defining the earthquake motion and deleting the end of input option and any existing end-of-file markers. Differences in format for input files to *SHAKE1* and

WESHAKE are marked for easy identification in Appendix E to facilitate changing of existing input files.

Output files

43. Several different files are created as a result of running *WESHAKE*. Some of these files are created as a consequence of mandatory actions (i.e., always created) whereas other files are specific to different options selected. A summary table of output files is shown in Table III-5. Output files are in ASCII format so they may be read by a DOS editor, word processing software, or sent directly to a printer.

44. Five of the output files are automatically created whenever *WESHAKE* is run: GMOD, DAMP, EQIN, STRESS, and OUTPUT. The first three of these present some of the input parameters into a convenient form for plotting using programs such as *GRAPHER*. The format used for these files is comma-separated variables. The primary output file and typically the largest in size is named OUTPUT. This file summarizes the inputs contained in the specifications file and all of the results of the various actions and options. The file STRESS also has a comma-separated form of peak effective shear stresses and shear strains for the top of each layer.

Error Checks

45. Some error checks have been implemented into version 1.0 of *WESHAKE* in an attempt to assist the user and preclude the calculation of erroneous results. On the most basic level, a system of recognizing valid responses to the menu queries is used so that many unintentional entries made will not be accepted and the user is allowed to re-enter the value. This system is intended to prevent the pre-processing portion of the program from exiting abruptly and consequently losing all entries made up to that point.

46. The implementation of *WESHAKE* also has established bounds for some entries. This includes parameters like the coefficient of lateral earth pressure, unit weight of soil and pore fluid (including units of kcf), and shear wave velocity. These checks are intended to help the user find typing errors and help operators unfamiliar with typical values for some geotechnical parameters.

47. The final, and most important, set of error checks involve the detection of potential calculation errors. Two primary checks are now in

place: checks on comparisons between the lengths of earthquake records and size of FFT arrays and the level of effective shear strain used to calculate new moduli and damping ratios (must be less than 1.0 percent -- the extent of definition of the curves). In both cases, the user is warned immediately on the computer screen.

Validation of *WESHAKE*

48. Although only minor changes have been made to the core program (original version of *SHAKE*) the validation of *WESHAKE* was considered to be necessary. One good source of validation is a comparison of results with the example problem used by Schnabel, Lysmer, and Seed (1972) in chapter 6 of the original *SHAKE* manual. Minor interpretations were required to accommodate the parameters used by *WESHAKE* (e.g., shear wave velocity in lieu of S_u for clays). A summary of this comparison is presented in Appendix F including a soil column representing the example problem. Note that this example contained an error in the definition of the normalized shear modulus relationship for sands. A discontinuity exists at a shear strain of 0.3316 percent (shear strain should have been defined as 0.0316). This error was repeated for validation to maintain consistency.

49. In general, the results between the two are consistent. A few comparisons are made within the output file presented in Appendix F. Small differences may be the consequence of differences in machine accuracy. Other favorable comparisons have been made with other problems previously analyzed at WES.

Table III-1

Correlation Between Option Numbers Used in *SHAKE* and *WESHAKE*

INPUT/ACTION	*WESHAKE*	*SHAKE*
General information	"Project Information"	"Initialization"
Soil column/soil properties	Mandatory Action 1	Options 2 and 8
Earthquake motion	Mandatory Action 2	Option 1
Point of excitation	Mandatory Action 3	Option 3
Compute motions	Mandatory Action 3	Option 4
Compute motions in sublayers	User Option 1	Option 5
Print object motion	User Option 2	Option 6
Change object motion	"	Option 7
Compute response spectra	User Option 3	Option 9
Increase time interval	User Option 4	Option 10
Decrease time interval	"	Option 11
Plot Fourier spectra of object motion	User Option 5	Option 12
Plot Fourier spectra of computed motion	"	Option 13
Plot time history of object motion	User Option 6	Option 14
Compute amplification spectra	User Option 7	Option 15
Compute stress or strain history	User Option 8	Option 16
Close input file	User Option 10 Analysis Option 1	Option 0

Table III-2

References for Material Property Data Bases

Material Type	References
Rock	Schnabel (1973)
Gravel	Seed et al (1986)
Sand (upper bound, average and lower bound)	Seed & Idriss (1970)*
Clay & Silt: PI = 5-10 PI = 10-20 PI = 20-40 PI = 40-80 PI > 80 Mexico City Clay	Sun, Golesorkhi, & Seed (1988) Seed and Idriss (1970)

* Confirmed by Seed et al (1986)

Table III-3

Measured Earthquake Records in WESHAKE Data Base

No.	Date	Earthquake Name	Instrument Location	Point Type*	Component	Magnitude	Distance (km)	a_{max} (g)
1	3/22/57	San Francisco, CA**	Golden Gate Park	R	S 80° E	5.3	11	0.10
2	6/28/66	Parkfield, CA	Cholame-Shandon, Temblor	R	N 65° W	5.5	27	0.27
3	2/9/71	San Fernando, CA	Castaic, Old Ridge Route	R	N 21° E	6.5	30	0.32
4	"	"	Lake Hughes, Array Sta. 4	R	S 21° W	6.5	28	0.14
5	7/30/72	Sitka, AK	Magnetic Obs.	R	N 90° E	7.6	48	0.09
6	11/28/74	Hollister, CA	Gilroy #1, Gavilan Coll.	R	N 90° E	5.2	22	0.14
7	8/6/79	Coyote Lake, CA	"	R	S 67° W	5.8	16	0.11
8	10/15/79	Imperial Valley, CA	Superstition Mountain	R	320°	6.6	58	0.19
9	4/26/81	El Centro, CA	"	R	135°	5.6	22	0.10
10	4/24/84	Morgan Hill, CA	Gilroy #1, Gavilan Coll.	R	S 67° W	6.2	39	0.10
11	12/23/85	Nahanni, Canada**	Iverson site	?	10°	5.4	7	0.23
12	"	"**	Slide Mtn. site	?	330°	4.8	6	0.39
13	10/18/89	Hollister Airport	Loma Prieta	R	°	7.0	45	0.28

* R = free field rock outcrop

** Aftershock (all others main shock)

Table III-4

Synthetic Earthquake Records in WESHAKE Data Base

No.	Project/Event*	Method of Derivation	Record Name	Point Type	Magnitude	Distance (km)	a_{max} (g)
14	Folsom Dam MCE	Deterministic	Record "A"	Rock outcrop	6.5	15	0.35
15	Folsom Dam MCE	"	Record "B"	"	6.5	15	0.43
16	New Madrid DBE	Probabilistic	500-yr H1	"	7.1	65	0.
17	"	"	500-yr H2	"	7.1	65	0.
18	"	"	1000-yr H1	"	7.3	52	0.
19	"	"	1000-yr H2	"	7.3	52	0.
20	"	"	5000-yr H1	"	7.3	38	0.
21			5000-yr H2	"	7.3	38	0.
22	Ririe Dam MCE	Deterministic	-	"	7.5	8	1.17

* MCE - Maximum credible event
DBE - Design basis earthquake

Table III-5

Summary of Output Files

File Name	Source	Description
GMOD	Mandatory actions	Table of points defining the variations of shear modulus with shear strain representing soils in soil column
DAMP	Mandatory actions	Table of points defining the variations of damping ratio with shear strain representing soils in soil column
EQIN	Mandatory actions	Two-column table of time and acceleration defining input earthquake record
OUTPUT	Mandatory actions	Primary output file; contains all pertinent information; printing of earthquake record is option [OUTKEY]
STRESS	Mandatory actions	Two-column table of (top-of-layer) depth and corresponding shear stress and shear strain
AMAX	User option 1	Two-column table of (top-of-layer) depth and corresponding maximum accelerations
VELSPEC	User option 3 Sub-option 0 or 2	Table of pseudo velocity spectra showing periods and velocities at specified levels of damping (columns)
ACCSPEC	User option 3 Sub-option 1 or 2	Table of pseudo acceleration spectra showing periods and velocities at specified levels of damping (columns)

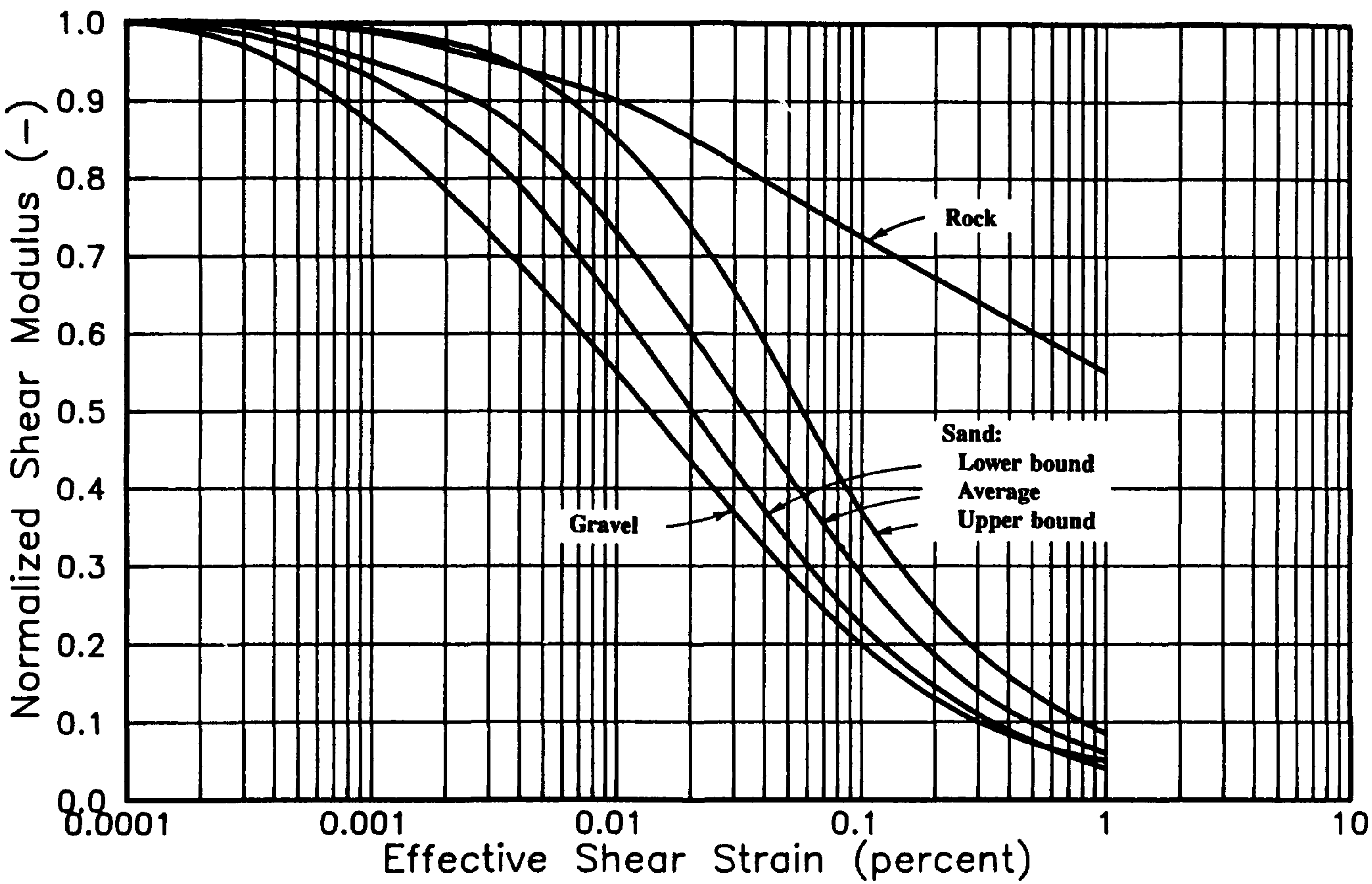


Figure III-1. Standard relationships between normalized shear modulus and shear strain for granular soils and rock

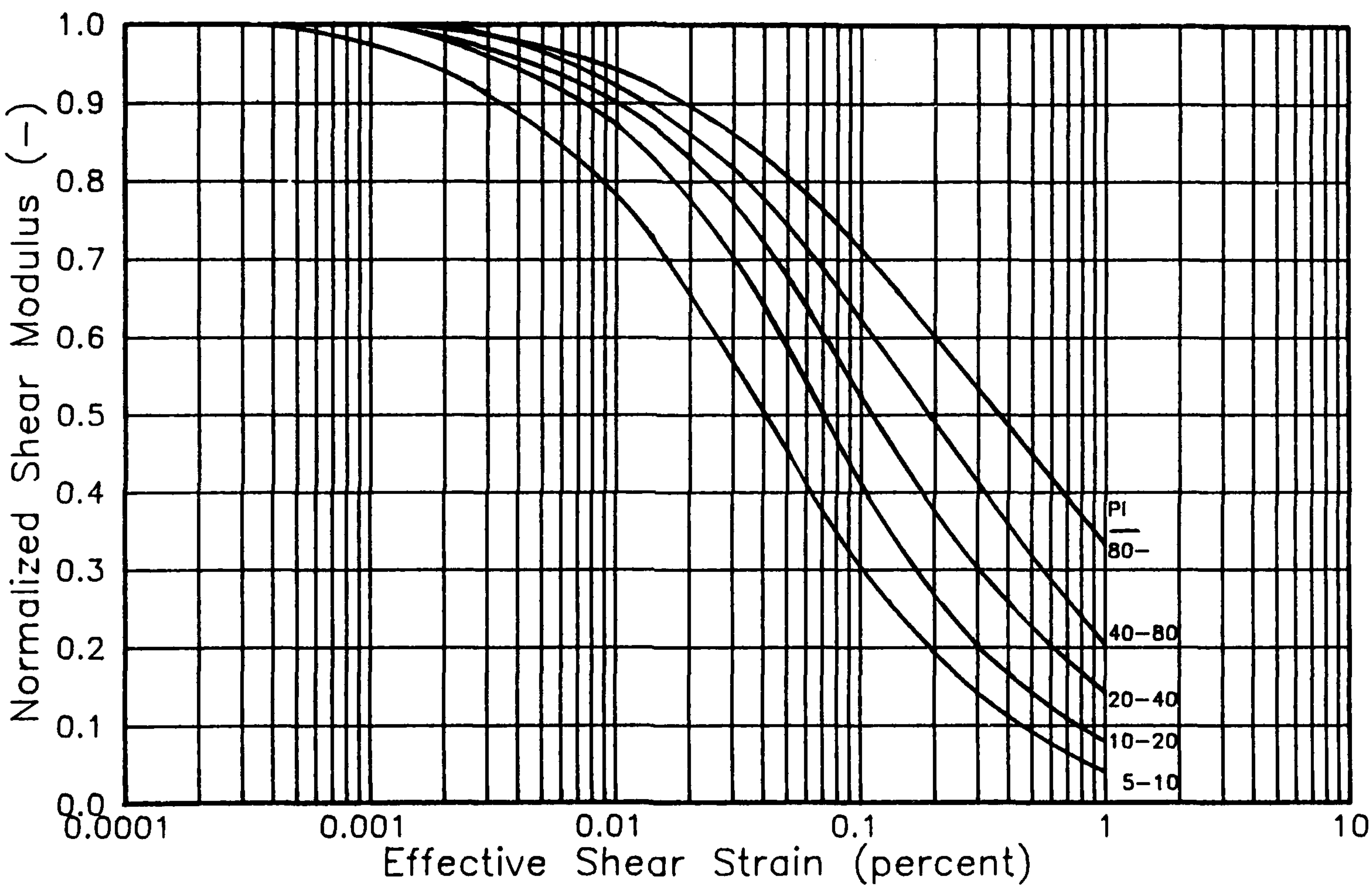


Figure III-2. Standard relationships between normalized shear modulus and shear strain for cohesive soils (Sun, Golesorhki, and Seed 1988)

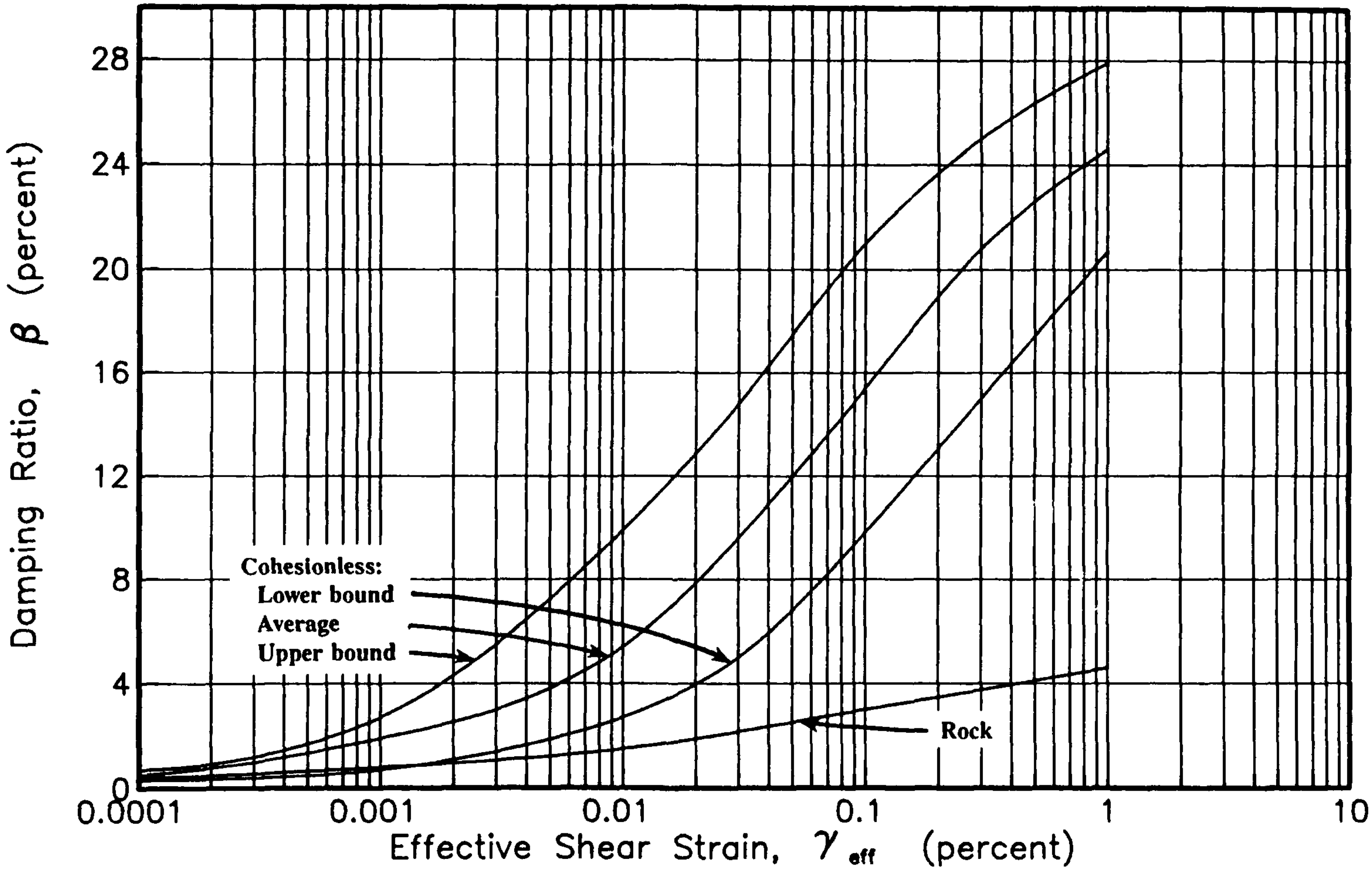


Figure III-3. Standard relationships between damping ratio and shear strain for granular soils and rock

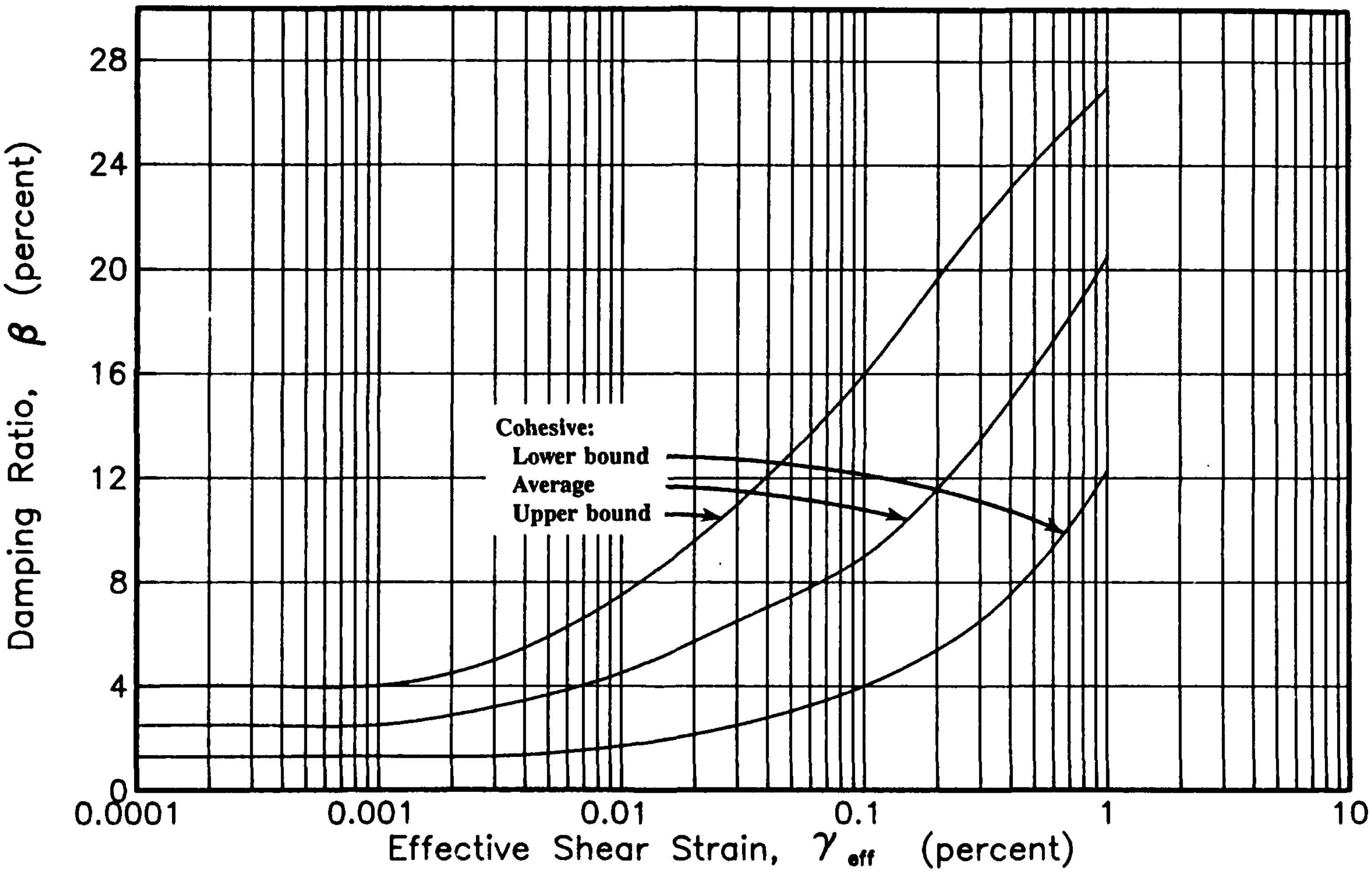


Figure III-4. Standard relationships between damping ratio and shear strain for cohesive soils (Sun, Golesorkhi, and Seed 1988)

PART IV: RUNNING *WESHAKE*

50. The execution of *WESHAKE* basically two stages: preprocessing and analysis. In the preprocessing stage, the computer prompts the user for various mandatory information -- the type of earthquake motion, the number of soil layers, the type of soil layers, and certain parameters needed for the analysis -- and user options for additional analysis. Output files containing results from the analysis are generated by the mandatory actions and the various options. These output files are in ASCII format and, therefore, can be viewed on a DOS editor or converted into a word processing document. The final action posed in the analysis stage is to allow the user to generate printed files of the various output documents. Figure IV-1 illustrates the processing cycle for *WESHAKE*. A flowchart of subroutines defining these two stages is shown in Appendix G.

51. The format for the various user responses in Part IV will be menus and user response screens. Example responses are shown in bold type; variable names are enclosed in square brackets. To start *WESHAKE*, type **WESHAKE** at the DOS prompt. An example problem used throughout this Part is shown in Figure III-2. The first screen is:

```
                 U.S. ARMY WATERWAYS EXPERIMENT STATION
                        GEOTECHNICAL LABORATORY
              EARTHQUAKE ENGINEERING AND SEISMOLOGY BRANCH
                         Vicksburg, Mississippi

                           ******************
                           W E S H A K E 1.0
                           ******************

                          OPTIMIZED FOR USE ON
                   DOS-COMPATIBLE PERSONAL COMPUTERS

                                   by
               David W. Sykora and Dr. David C. Wallace

                              SUMMER 1992

                For consultation and recent updates, call:

                            (601) 634-3551

 PRESS <ENTER> TO CONTINUE
<ENTER>
                                              (CONTINUE NEXT SCREEN)
```

Pre-Processing Stage

52. The user provides with information that will be required for the analysis in the pre-processing stage. This information is divided into two parts -- mandatory actions and user options and is stored in files read by the core program, SHAKE1. Once the files are created, they can be used repeatedly. As described in Part III, *WESHAKE* creates up to three files: a specification file, a soil profile file, and a companion file. The primary files of interest are the specifications file and the soil profile file. After the initial screen, the user will be prompted:

```
          SPECIFICATION FILE DESIGNATION
          ******************************

 TO CREATE A NEW SOIL PROFILE FILE,                    ENTER  1
 TO USE AN EXISTING SOIL PROFILE FILE,                 ENTER  2
 TO CREATE A NEW SPECIFICATION FILE,                   ENTER  3
 TO USE AN EXISTING SPECIFICATION FILE,                ENTER  4

 TO DELETE A FILE,                                     ENTER  5
 TO DISPLAY FILES,                                     ENTER  6
4

 ENTER THE FILE NAME (EIGHT OR LESS ALPHANUMERIC
 CHARACTERS WITH NO PERIODS OR EXTENSIONS):
EXAMPLE
                                             (CONTINUE NEXT SCREEN)
```

If one soil profile will be used repeatedly with different earthquake motions, a soil profile file is preferred. If only one earthquake will be used, the soil profile file is unnecessary and only a specification file is needed. No matter which selection is made, the computer will search the current directories for file name specified. If a new file is desired, the file may not already exist. If an existing file is desired, the file must already exist. For convenience, options are provided to obtain a listing of the existing files contained in the working directory and delete unwanted files. If an existing specification file is used, the screen will look like this:

```
 THIS SPECIFICATION FILE WAS CREATED USING:
   WESHAKE,     ENTER 1
   OTHER MEANS, ENTER 2
1
                                          (CONTINUE NEXT SCREEN)
```

This designation is necessary to indicate whether a companion file should be sought (If "USING *WESHAKE*" is selected, the companion file must exist).

Mandatory Actions

53. The pre-processing stage now follows with mandatory actions which are listed in the **SUMMARY OF MANDATORY ACTIONS** screen:

```
                SUMMARY OF MANDATORY ACTIONS
                ****************************

*********************************************************
**  FOLLOWING THE INPUT OF SOME INITIAL INFORMATION,   **
**  THE FOLLOWING MANDATORY ACTIONS WILL BE UNDERTAKEN **
**  IN THE SPECIFIED ORDER:                            **
**  -------------------------------------------------- **
**  1  CREATE SOIL COLUMN                              **
**  2  SELECT EARTHQUAKE RECORD                        **
**  3  SPECIFY POINT OF EARTHQUAKE EXCITATION          **
*********************************************************
 PRESS <ENTER> TO CONTINUE
<ENTER>
                                  (CONTINUE NEXT SCREEN)
```

These actions are automatically enacted by the program through the use of additional menus and screens as shown below. A project title may be entered on the following screen:

```
                      PROJECT INFORMATION
                      *******************

 ENTER A PROJECT TITLE [PTITLE]:
   - MAXIMUM OF 74 CHARACTERS IN LENGTH
TITLE OF EXAMPLE PROBLEM
                                  (CONTINUE NEXT SCREEN)
```

Next, mandatory action 1 is summarized:

```
          MANDATORY ACTION 1:  CREATE SOIL COLUMN
          ***************************************

 INFORMATION AND PROPERTIES DEFINING EACH SOIL
 LAYER WILL NOW BE REQUESTED BEGINNING AT THE
 TOP LAYER AND WORKING DOWN TO ROCK (BASE).

 A MENU OF SOIL TYPES WILL BE DISPLAYED FOR
 EACH SOIL LAYER TO SELECT REPRESENTATIVE RELATIONSHIPS
 FOR SHEAR MODULUS AND DAMPING RATIO.
```

(continued next page)

```
ONCE THE COLUMN HAS BEEN CREATED, A SUMMARY
TABLE WILL BE DISPLAYED FOR REVIEW.  ERRORS
MAY BE CORRECTED AT THAT TIME BY RE-ENTERING
ALL VALUES FOR THAT LAYER.
*****************************************************
PRESS <ENTER> TO CONTINUE
<ENTER>
                                  (CONTINUE NEXT SCREEN)
```

54. The next screen will ask general information about the soil column to prepare for input of properties for each layer. Note that the unit of measurement for the total unit weight of soil is kips per cubic foot. The entry corresponding to the layer number for the water table is required input to proceed but is only used for the calculation of G_{max} when values of K_2 are used. A unit weight of pore fluid corresponding to water (0.0624 kcf) is assumed for this calculation.

```
 ENTER THE NUMBER OF SOIL LAYERS FOR THE COLUMN
 INCLUDING ROCK  [ML]:
5

 ENTER THE LAYER NUMBER AT THE TOP OF WHICH LIES
 THE WATER TABLE [MWL]:
5

 ENTER THE IDENTIFICATION FOR THE SOIL PROFILE:
   - MAXIMUM OF 43 CHARACTERS IN LENGTH
IDENTIFICATION OF EXAMPLE SOIL PROFILE

                                  (CONTINUE NEXT SCREEN)
```

55. The next three screens query the user for specific information about each soil layer. The first two screens have menus that summarize the shear modulus and damping ratio data bases, respectively.

```
 DATA BASE OF NORMALIZED SHEAR MODULUS CURVES
*****************************************************
** NUMBER            DESCRIPTION                      **
** ------ --------------------------------------------- **
**   1    ROCK, AVERAGE          (SCHNABEL 1973)      **
**   2    GRAVEL, AVERAGE        (SEED ET AL 1986)    **
**   3    SAND, LOWER BOUND      (SEED & IDRISS 1970) **
**   4    SAND, AVERAGE          (SEED & IDRISS 1970) **
**   5    SAND, UPPER BOUND      (SEED & IDRISS 1970) **
**   6    CLAY/SILT, PI=5-10     (SUN et al 1988)     **
**   7    CLAY/SILT, PI=10-20    (SUN et al 1988)     **
**   8    CLAY/SILT, PI=20-40    (SUN et al 1988)     **
**   9    CLAY/SILT, PI=40-80    (SUN et al 1988)     **
**  10    CLAY/SILT, PI>80       (SUN et al 1988)     **
**  11    MEXICO CITY CLAY       (SUN et al 1988)     **
```

(continued next page)

```
*******************************************************
ENTER THE NUMBER FOR LAYER  1 OF  5 LAYERS [TYPE]:
7
                                  (CONTINUE NEXT SCREEN)
```

and

```
 DATA BASE OF DAMPING RATIO CURVES
*******************************************************
** NUMBER             DESCRIPTION                    **
** ------ ---------------------------------------- **
**   1    ROCK, AVERAGE         (SCHNABEL 1973)       **
**   2    GRAVEL, AVERAGE       (SEED ET AL 1986)     **
**   3    SAND, LOWER BOUND     (SEED & IDRISS 1970)  **
**   4    SAND, AVERAGE         (SEED & IDRISS 1970)  **
**   5    SAND, UPPER BOUND     (SEED & IDRISS 1970)  **
**   6    CLAY/SILT,LOWER BOUND (SEED & IDRISS 1970)  **
**   7    CLAY/SILT,AVERAGE     (SEED & IDRISS 1970)  **
**   8    CLAY/SILT,UPPER BOUND (SEED & IDRISS 1970)  **
*******************************************************
ENTER THE NUMBER FOR LAYER  1  OF  5 LAYERS [TYPE]:
7
                                  (CONTINUE NEXT SCREEN)
```

Site-specific shear modulus and damping relations can be added (or deleted) from the soil property data bases (**SHEARDB** and **DAMPDB**) using a DOS editor. There are two requirements for customizing the data bases: use the exact format as documented in Appendix B and provide a unique identification number for the curve, INUM. Note that any new entries to the data base will not be displayed on the computer screen even though they can be accessed.

56. The third screen is used to query the user about properties for each layer. The use of K_2 or V_s to calculate shear modulus was described in Part II of this report. The example shown is for V_s input. If K_2 input is specified, the appropriate prompts for initial and maximum K_2 , $(K_2)_{max}$, will be displayed and a value of coefficient of lateral earth pressure will be requested. Only shear wave velocities are allowed to define shear modulus for rock.

```
 ENTER THE THICKNESS (ft) OF LAYER   1 [HL]:
5

 THE INITIAL ESTIMATES FOR DAMPING RATIO [B] WILL BE
 5 PERCENT FOR SOIL AND 2 PERCENT FOR ROCK.

 ENTER THE TOTAL UNIT WEIGHT (kcf) OF LAYER   1 [W]:
0.110
```

(continued next page)

```
 DESIGNATE '  ~HOD OF MODULUS CALCULATION
   FOR SHEAR vELOCITY,   ENTER VS
   FOR K2,               ENTER K2
VS

 ENTER THE SHEAR WAVE VELOCITY (fps)
 FOR LAYER   1:
425

                                   (CONTINUE NEXT SCREEN)
```

57. Once the soil column has been created a summary table is displayed to allow the user to check the information. The summary table for the example problem is:

```
LAYER SOIL  SOIL    S: SHEAR     LAYER  EARTH  UNIT
 NUM  NUM    ID     D: DAMPING   THICK  PRESS WEIGHT STIFFNESS
                                 (ft)          (kcf)

  1    9  S: CLAY/SILT,PI=40-80  5.0           .110  Vs =  425.
       7  D: CLAY/SILT, Average
  2    6  S: CLAY/SILT,PI= 5-10  8.0           .115  Vs =  575.
       7  D: CLAY/SILT, Average
  3    4  S: SAND, Average      10.0     .38   .125  K2 =   35.
       4  D: SAND, Average
  4    3  S: SAND, Lower Bound  15.0           .130  Vs = 1100.
       4  D: SAND, Average
  5    1  S: ROCK, Average                     .150  Vs = 5000.
       1  D: ROCK, Average

 IS THIS SOIL COLUMN CORRECT?
   ENTER 0 FOR NO
   ENTER 1 FOR YES
1

 TO CONTINUE ON TO MANDATORY ACTION 2, PRESS <ENTER>
<ENTER>
                                      (CONTINUE NEXT SCREEN)
```

If a correction is required, the user may enter the layer number at the prompt and then all information for the designated layer number must be input again via computer prompt. Once the correction(s) has been made the computer will again display the soil profile and ask the user if the soil profile is correct. The process will repeat until the column is accepted by the user (indicated by entering 1).

58. This marks the end of defining soil stratigraphy and soil properties. If the user specified the option for creation of a specification file, the program continues directly to the next mandatory action which is the selection of an earthquake record. If the user specified the option for

creation of a soil profile, the information collected up to this point is saved first before proceeding to the next mandatory action.

59. The following menu is used to initiate mandatory action 2. Earthquake records in the data base (EARTHQ) are displayed for selection:

```
          MANDATORY ACTION 2: SELECT EARTHQUAKE RECORD
          ********************************************
                   EARTHQUAKE DATA BASE
 **********************************************************
 ** NO.  MEASURED RECORD        NO.  SYNTHETIC RECORD     **
 ** ---  ----------------       ---  -----------------    **
 **  1  GOLDEN GATE 1957        14  FOLSOM RECORD "A"     **
 **  2  PARKFIELD 1966          15  FOLSOM RECORD "B"     **
 **  3  CASTAIC RIDGE 1971      16  NEW MADRID 500-YR H1  **
 **  4  LAKE HUGHES # 4 1971    17  NEW MADRID 500-YR H2  **
 **  5  SITKA 1972              18  NEW MADRID 1000-YR H1 **
 **  6  GILROY #1 1974          19  NEW MADRID 1000-YR H2 **
 **  7  GILROY #1 1979          20  NEW MADRID 5000-YR H1 **
 **  8  SUPERSTITION 1979       21  NEW MADRID 5000-YR H2 **
 **  9  SUPERSTITION 1981       22  RIRIE DAM             **
 ** 10  GILROY #1 1984                                    **
 ** 11  IVERSON 1985                                      **
 ** 12  SLIDE MT 1985                                     **
 ** 13  HOLLISTER AIRPORT 1989                            **
 **                                                       **
 ** Other:                                                **
 ** 25  STOP AT THIS POINT AND SAVE SOIL PROFILE FILE     **
 ** 26  PICK YOUR OWN EARTHQUAKE MOTION                   **
 **********************************************************
 ENTER EARTHQUAKE NUMBER:
1                                 (CONTINUE ON NEXT SCREEN)
```

Specific parameters describing these earthquakes are listed in Tables III-3 and III-4. Listings of the data files and plots of the records and velocity spectra are provided in Appendix C. If a record is selected (i.e., option 25 is not selected) then specify if the values of acceleration should be echoed (printed) in the OUTPUT file:

```
 SPECIFY WHETHER RECORD DATA ARE TO BE PRINTED
 IN OUTPUT FILE [OUTKEY]:
   ENTER 0 FOR NO
   ENTER 1 FOR YES
0
                                  (CONTINUE ON NEXT SCREEN)
```

60. Earthquake records not in the data base may be selected by entering 30 and then entering the name of the file (which must reside in the current working directory). The format for the earthquake record must follow the syntax for the earthquake data base which is specified in Appendix C. This

format has as a second line "earthquake characteristics." This may be left blank, but the line must exist. Also, make sure that no end-of-file markers exist (typically ^Z).

61. After the earthquake record has been selected, the earthquake characteristics and the maximum acceleration are displayed for convenience and options for scaling the record are posed. The accelerogram can be scaled linearly by specifying a scaling factor (all values of acceleration are multiplied by this constant) or a maximum value of acceleration, a_{max} (all values of acceleration are multiplied by the ratio: $(a_{max})_{new}$ / $(a_{max})_{old}$). The screen for this option is:

```
 EARTHQUAKE MOTION CHARACTERISTICS:
 ***************************************************
 "Mag-7.1, Dis-69 km, Amax-.63 g., Rock Outcrop"

 MAXIMUM CUT-OFF FREQUENCY: 50.0
 ***************************************************
 DO YOU WANT TO SCALE THE RECORD?
      ENTER  0  NO
      ENTER  1  YES
1

 SCALING RECORD OPTION:
    ENTER  0  TO USE SCALING FACTOR
    ENTER  1  TO SET NEW MAXIMUM ACCELERATION
0

 ENTER THE SCALING FACTOR [XF]:
2.0

 TO CONTINUE ON TO MANDATORY ACTION 3, PRESS <ENTER>
<ENTER>
                                     (CONTINUE NEXT SCREEN)
```

The default scaling factor on the earthquake motion record is set to 1.00 and the default maximum acceleration is set equal to the peak measured value (also accomplished by setting XMAX - 0.0). The complete accelerogram can be altered by selecting option 1 (YES). If option 2 (NO) is selected, then the parameters are set to the earthquake motion record.

62. The final mandatory action is used to define the point in the soil profile at which the input motion corresponds. The previous screen and Tables III-3 and III-4 list where the motion corresponds (typically rock outcrop). In most cases, particularly for design or seismic stability analysis, rock outcrop motions are used. To use the motion as an outcrop motion, select the layer number corresponding to the base rock (last layer) and specify an

outcropping layer (type 0). For base rock motions (refer to Figure II-1), again use the base rock layer number and then type a 1 for the motion type. If the motion corresponds to some other layer, for example ground surface (free field), use the layer number (which corresponds to the top of the layer) and a 1. The screen for these actions is:

```
        MANDATORY ACTION 3: SPECIFY OBJECT MOTION
        *****************************************

 *******************************************************
 SPECIFY A LAYER FOR THE OBJECT MOTION [IN]:
 (ROCK IS LAYER 5)
5

 ENTER THE MOTION TYPE [INT]:
    0 - FOR OUTCROPPING LAYER
    1 - FOR LAYER WITHIN SOIL PROFILE
0
                                (CONTINUE ON NEXT SCREEN)
```

63. Parameters defining the convergence criteria have been preset in *WESHAKE* for the convenience of the user. These values are displayed, as shown below, to remind the user:

```
 THE FOLLOWING VALUES HAVE BEEN ASSUMED:

   THE MAXIMUM NUMBER OF ITERATIONS [ITMAX] - 20

   THE ACCEPTABLE DIFFERENCE BETWEEN THE
   LAST-USED MODULUS AND DAMPING VALUES, AND THE
   STRAIN COMPATIBLE VALUES [ERR] - 5 PERCENT

   THE RATIO BETWEEN EFFECTIVE STRAIN AND
   MAXIMUM STRAIN [PRMUL] - 65 PERCENT

 TO CONTINUE ON TO USER OPTION MENU, PRESS <ENTER>
<ENTER>
                                     (CONTINUE NEXT SCREEN)
```

The user may change these values once the specifications file has been completed (see **USER OPTIONS MAIN MENU** in next section) by exiting *WESHAKE*, editing the specific file using a DOS editor, and restarting *WESHAKE* (and using an existing specification file).

64. Once these steps have been completed, the first component of the specifications file required to run *WESHAKE* has been created. This file can be used as often as necessary. The format of the specifications file for all of these responses is provided in Appendix E. An example specifications file

is shown in Appendix H corresponding to the example problem shown in Figure IV-3. ***WESHAKE*** continues by proceeding to the **USER OPTIONS MAIN MENU** which is described below.

User Options

65. The **USER OPTIONS MAIN MENU** is encountered following mandatory actions for new specifications files or immediately following selection of an existing specifications file. This menu is still part of the pre-processing stage and is used to identify various options and outputs available to the user. It is also used to save the specifications file and exit ***WESHAKE*** or proceed to the analysis stage. Each option on the menu will have its own set of screens that will prompt the user for information needed to implement that option. The menu is:

```
                    USER OPTION MAIN MENU
                    *********************

 *******************************************************
 ** OPTION           DESCRIPTION                      **
 ** ------   -------------------------------------    **
 **    1     COMPUTE MOTION IN SPECIFIED SUBLAYERS    **
 **    2     PRINT OR CHANGE OBJECT MOTION            **
 **    3     COMPUTE RESPONSE SPECTRA                 **
 **    4     INCREASE OR DECREASE TIME INTERVAL       **
 **    5     PLOT FOURIER SPECTRUM OF OBJECT OR       **
 **            COMPUTED MOTION                        **
 **    6     PLOT TIME HISTORY OF OBJECT MOTION       **
 **    7     COMPUTE AMPLIFICATION SPECTRUM           **
 **    8     COMPUTE STRESS/STRAIN HISTORY            **
 *******************************************************
 **    9     SAVE FILE AND RETURN TO DOS              **
 **   10     SAVE FILE AND PROCEED TO ANALYSIS STAGE  **
 *******************************************************
 ENTER ONE OPTION NUMBER:
1                                  (CONTINUE NEXT SCREEN)
```

66. The first eight options listed in the **USER OPTIONS MAIN MENU** are described briefly with user menus in the following subsections. These options may be used in any order (although order of options 2 and 4 will affect subsequent results) and repeated as often as desired. Theoretical details about these options may be found in the manual for ***SHAKE*** (Schnabel, Lysmer, and Seed 1972) and in textbooks on soil and structural dynamics. The correspondence between ***WESHAKE*** and ***SHAKE*** option numbers is presented in Table III-1.

67. The last two selections in the **USER OPTIONS MAIN MENU** pertain to actions once all of the program options have been chosen. Option 9, is used

to save the current specifications file and exit *WESHAKE* (without placing the file termination statement). Option 10 is used to save the file and continue on for execution (adding termination statement: **OPTION 0: END OF INPUT**). Specification files that are reused (Option 4 in **SPECIFICATION FILE DESIGNATION** menu) are automatically stripped of the termination statement.

68. Compute Motions in Sublayers. Option 1 provides for information regarding the horizontal accelerations at layers of interest. Either tables of peak values or the complete time record of acceleration may be chosen. The screen for the **OPTION 1 MENU** is shown on the next page.

```
                         OPTION 1 MENU
                         *************

 THIS OPTION IS USED TO SPECIFY THE EXTENT
 OF OUTPUT FOR ACCELERATIONS AT THE TOP OF
 SPECIFIED LAYERS
 *******************************************************
 ENTER 0 TO GET MAXIMUM ACCELERATION ONLY
 ENTER 1 TO GET VARIATION OF ACCELERATION WITH
         TIME AND PEAK ACCELERATIONS
0

 THE PRESENT SOIL COLUMN HAS    5 LAYERS

 THE OBJECT MOTION HAS BEEN ASSIGNED TO LAYER    5

 SPECIFY AT WHICH LAYERS OF THE SOIL COLUMN THE
 ACCELERATIONS SHOULD BE CALCULATED:
   - ONE AT A TIME
   - MAXIMUM OF 15

 ENTER THE LAYER NUMBER [LL5(1)]:
1

 SPECIFY THE MOTION TYPE [LT5(1)]:
   ENTER 0 FOR OUTCROPPING
   ENTER 1 FOR WITHIN SOIL PROFILE
1

 TO COMPUTE ACCELERATIONS AT MORE LAYERS,
   ENTER 0 FOR NO
   ENTER 1 FOR YES
0
                          (RETURN TO USER OPTIONS MAIN MENU)
```

69. Print/Change Motion in Sublayer Options. Option 2 allows the user to print the object motion in the OUTPUT file or change the object motion for recalculation of *WESHAKE*. (Note that the option for printing the input motion is also contained in Mandatory Action 2 [OUTKEY].) The initial screen for this option is (next page):

```
                  OPTION 2 MENU
                  *************

 THIS OPTION IS USED TO PRINT OR CHANGE THE OBJECT
 (EARTHQUAKE) MOTION
 ********************************************************
 ENTER 1 TO PRINT OBJECT MOTION
 ENTER 2 TO CHANGE OBJECT MOTION
1
                               (CONTINUE NEXT SCREEN)
```

If the print motion option is selected, the following screen is shown:

```
            OPTION 2 SUBMENU (PRINT MOTION)
            *******************************

 ENTER 0 TO PRINT MAXIMUM ACCELERATION IN OUTPUT FILE
 ENTER 1 TO PUT OBJECT MOTION IN PUNCH FILE
 ENTER 2 TO DO BOTH
0
                       (RETURN TO USER OPTIONS MAIN MENU)
```

The PUNCH file contains output data without annotation (as compared with the OUTPUT file). Notice that in *WESHAKE*, the option of printing the object motion in the OUTPUT file is also provided in Mandatory Action 2. If the change motion option is selected, the following screen:

```
            OPTION 2 SUBMENU (CHANGE MOTION)
            ********************************

 THIS IS USED TO CHANGE PARAMETERS SET
 IN MANDATORY ACTION 2: SELECT EARTHQUAKE RECORD
 *******************************************************
 THERE ARE  5 LAYERS IN THE SOIL COLUMN.
 LAYER  5 IS CURRENTLY THE POINT OF OBJECT MOTION

 SPECIFY THE LAYER FOR OBJECT MOTION [LL1]:
   ENTER  0  TO KEEP THE MOTION AT THE SAME LAYER
   OTHERWISE ENTER NEW LAYER NUMBER
0
 IDENTIFY THE TYPE OF ABOVE LAYER [LT1]:
   ENTER 0 FOR OUTCROPPING
   ENTER 1 FOR WITHIN SOIL PROFILE
0

 ENTER THE TIME STEP OF OBJECT MOTION [DTNEW]:
0.02

 SCALING OF ACCELERATIONS [XF]:
   ENTER 1. FOR MAXIMUM VALUE OF RECORD
   OTHERWISE ENTER SCALING FACTOR (DECIMAL)
1.
                       (RETURN TO USER OPTIONS MAIN MENU)
```

70. <u>Compute response spectrum.</u> Option 3 should be selected to calculate pseudo-velocity or acceleration response spectrum. A response spectrum is the response of an equivalent damped single-degree-of-freedom (SDOF) system to the free-field motion. The step-by-step method is used to calculate the response spectrum in *WESHAKE*. For response acceleration, absolute rather than relative values are preferred (Weigel 1970). The velocity spectrum typically is used for design and analysis by structural engineers.

71. The calculation of pseudo response spectrum for the input earthquake motion alone does not require execution of the program. This option can be inserted manually following the specification of the input motion and where the motion occurs (mandatory actions 2 & 3).

72. The ratio of the spectrum of free-field ground surface acceleration spectrum to rock outcrop acceleration spectrum is typically desired. The variation of this ratio with period at five levels of system damping will be used for design and seismic stability evaluations.

73. The OPTION 3 MENU is displayed on two screens below:

```
                         OPTION 3 MENU
                         *************

 THIS OPTION IS USED TO COMPUTE THE RESPONSE SPECTRUM.
 ACCELERATION OR VELOCITY SPECTRUM CAN BE CALCULATED,
 OR BOTH, FOR ANY OR ALL LAYERS.
 *******************************************************
 THERE ARE  5 LAYERS IN THE SOIL COLUMN
 LAYER  5 IS CURRENTLY THE POINT OF OBJECT MOTION

 ENTER THE LAYER NUMBER FOR ANALYSIS [LL1]:
1

 IDENTIFY THE TYPE OF ABOVE LAYER [LT1]:
   ENTER 0 FOR OUTCROPPING
   ENTER 1 FOR WITHIN THE SOIL PROFILE
1

 ENTER THE NUMBER OF DAMPING VALUES DESIRED [ND]:
   - MAXIMUM OF 5
2

 SELECT THE PARAMETER(S) OF INTEREST [KAV]:
   ENTER 0 FOR VELOCITY SPECTRUM
   ENTER 1 FOR ACCELERATION SPECTRUM
   ENTER 2 FOR BOTH
2
                                       (CONTINUE NEXT SCREEN)
```

and (next page):

```
                OPTION 3 MENU (continued)
********************************************************
SELECT TIME PERIODS FOR COMPUTATIONS
  KPER = 0
     9  STEPS FROM  .1 SEC TO 1. SEC
     5  STEPS FROM 1.  SEC TO 2. SEC
     4  STEPS FROM 2.  SEC TO 4. SEC
  KPER = 1
    18  STEPS FROM  .1 SEC TO 1. SEC
    10  STEPS FROM 1.  SEC TO 2. SEC
     8  STEPS FROM 2.  SEC TO 4. SEC
  KPER = 2
    38  STEPS FROM .05 SEC TO 1. SEC
    20  STEPS FROM 1.  SEC TO 2. SEC
    30  STEPS FROM 2.  SEC TO 5. SEC
  KPER = 3
    LOGARITHMIC INCREMENTS WITH 10
    STEPS IN EACH LOG. UNIT FROM
    .1 TO 5.
  KPER = 4
    LOGARITHMIC INCREMENTS WITH 25
    STEPS IN EACH LOG. UNIT FROM
    .05 TO 10.
********************************************************
ENTER VALUE OF KPER:
1

ENTER THE  2 VALUES OF DAMPING RATIO [ZLD]
ON SEPARATE LINES BELOW:
  - DECIMAL FORM
  - ASCENDING ORDER
0.02
0.05

                     (RETURN TO USER OPTIONS MAIN MENU)
```

74. <u>Increase/decrease time interval.</u> The time interval of the earthquake record can be increased or decreased and the analysis rerun. The first screen is:

```
                    OPTION 4 MENU
                    *************

 THIS OPTION IS USED TO INCREASE OR DECREASE
 THE TIME INTERVAL FOR THE OBJECT MOTION BY USING
 DIFFERENT NUMBERS OF POINTS IN THE FOURIER TRANSFORM
 ******************************************************
 ENTER 1 TO INCREASE THE TIME INTERVAL
 ENTER 2 TO DECREASE THE TIME INTERVAL
1
              (CONTINUE WITH APPROPRIATE SUBMENU SCREEN)
```

If an increase in time is selected, the following submenu appears (next page):

```
     OPTION 4 SUBMENU (INCREASE TIME INTERVAL)
     *****************************************

 ENTER THE MULTIPLE FOR TIME INCREASE [IFR]:
   -  MUST BE A POWER OF 2
2
                      (RETURN TO USER OPTIONS MAIN MENU)
```

If a decrease in time is selected, the following submenu appears:

```
     OPTION 4 SUBMENU (DECREASE TIME INTERVAL)
     *****************************************

 ENTER THE MULTIPLE FOR TIME DECREASE [IFR]:
   -  MUST BE A POWER OF 2
2
                      (RETURN TO USER OPTIONS MAIN MENU)
```

75. Plot Fourier spectrum of object or computed motion. The Fourier spectrum is calculated and plotted in the OUTPUT file using this option. The first screen for this option is:

```
                    OPTION 5 MENU
                    *************

  THIS OPTION IS USED TO CALCULATE AND PLOT THE
  FOURIER SPECTRUM OF THE OBJECT OR COMPUTED MOTION
  **************************************************
  ENTER 1 FOR OBJECT MOTION
  ENTER 2 FOR COMPUTED MOTION
 1

              (CONTINUE WITH APPROPRIATE SUBMENU SCREEN)
```

If the object motion is selected, the following submenu is shown:

```
          OPTION 5 SUBMENU (OBJECT MOTION)
          ********************************

 ENTER 0 TO STORE SPECTRUM FOR LATER PLOTTING:
   - LIMIT 2 SPECTRA
 ENTER 1 TO PLOT ALL STORED SPECTRA
1

 ENTER THE NUMBER OF TIMES SPECTRUM IS TO BE
 SMOOTHED [LNSW]:
2

 ENTER THE NUMBER OF VALUES TO BE PLOTTED [N]:
   - MAXIMUM OF 2049
100
                     (RETURN TO USER OPTIONS MAIN MENU)
```

The plot is character-style plot with limited resolution. The number of plotted values corresponds to the first N values in the array. If the computed motion is selected, the following submenu is shown:

```
              OPTION 5 SUBMENU (COMPUTED MOTION)
              **********************************

 ENTER THE SUBLAYER NUMBER [LL]:
 (ROCK IS LAYER 5)
1

 SPECIFY THE TYPE OF MOTION [LT]:
   ENTER 0 FOR OUTCROPPING
   ENTER 1 FOR WITHIN THE SOIL PROFILE
1

 ENTER 0 TO STORE SPECTRUM FOR LATER PLOTTING
   - LIMIT 2  SPECTRA
 ENTER 1 TO PLOT ALL STORED SPECTRA
1

 ENTER THE NUMBER OF TIMES SPECTRUM IS TO BE
 SMOOTHED [NSW]:
2

 ENTER THE VALUES TO BE PLOTTED [LLL]
   - MAXIMUM OF 2049
100
                        (RETURN TO USER OPTIONS MAIN MENU)
```

76. <u>Plot time history of object motion.</u> This option plots the variation of accelerations with time for specified sublayers in the OUTPUT file. The plot is character-style plot with limited resolution. The screen for this option is:

```
                     OPTION 6 MENU
                     *************

 THIS OPTION IS USED TO COMPUTE AND PLOT THE
 VARIATION OF ACCELERATION WITH TIME OF THE
 OBJECT MOTION
 *******************************************************
 SPECIFY THE CODE FOR VALUES TO BE PLOTTED [NSKIP]:
   ENTER 0 TO PLOT EVERY VALUE
   ENTER 1 TO PLOT EVERY SECOND VALUE
   ENTER 2 TO PLOT EVERY THIRD VALUE
   ENTER 3 TO PLOT EVERY FOURTH VALUE
   ETC.
1

 ENTER THE NUMBER OF VALUES TO BE PLOTTED [NN]:
   - MAXIMUM OF 2049
2049
                        (RETURN TO USER OPTIONS MAIN MENU)
```

77. Amplification spectrum. The amplification spectrum between the motions at two layers can be calculated and plotted with this option. The plot is character-style plot with limited resolution. The screen is:

```
                    OPTION 7 MENU
                    *************

 THIS OPTION IS USED TO COMPUTE THE AMPLIFICATION
 SPECTRUM BETWEEN ANY TWO LAYERS.
 THERE ARE 5 LAYERS IN THE PRESENT COLUMN.
 *****************************************************
 ENTER THE NUMBER OF THE FIRST LAYER [LIN]:
1

 SPECIFY THE TYPE OF MOTION FOR THIS LAYER [LINT]:
   ENTER 0 FOR OUTCROPPING
   ENTER 1 FOR LAYER WITHIN SOIL PROFILE
1

 ENTER THE NUMBER OF THE SECOND LAYER [LOUT]:
5

 SPECIFY THE TYPE OF MOTION FOR THIS LAYER [LOTP]:
   ENTER 0 FOR OUTCROPPING
   ENTER 1 FOR LAYER WITHIN SOIL PROFILE
0

 SELECT THE TYPE OF PLOTTING [KP]:
   ENTER 0 TO STORE SPECTRUM FOR LATER PLOTTING
     - LIMIT 2
   ENTER 1 TO PLOT ALL SPECTRA STORED SINCE LAST
   PLOTTING
1

 THE AMPLIFICATION FACTOR IS COMPUTED FOR THE
 FIRST 200 FREQUENCIES WITH INTERVAL DFA (Hz)
 BEGINNING AT 0.
   ENTER THE FREQUENCY STEPS [DFA]:
0.050

 ENTER AN IDENTIFICATION - LIMIT 40 CHARACTERS:
SITE 1
                      (RETURN TO USER OPTIONS MAIN MENU)
```

78. Compute stress/strain history. The variation of peak shear stress or peak shear strain with time at the top of a layer may be calculated with Option 8. This option allows for the specification of two layers at once. If the calculation is desired for more than two layers, the option must be called again. The results of this option are sent to the **OUTPUT** file. The variation of effective shear stress or strain may be determined by multiplying these peak values by **PRMUL**. Note that effective shear strains at the mid-height of layers are used to adjust shear modulus and damping values in the iterative process. The **OPTION 8 MENU** is (next page):

```
                      OPTION 8 MENU
                      *************

 THIS OPTION IS USED TO COMPUTE THE VARIATION OF
 SHEAR STRESS OR SHEAR STRAIN AT THE TOP OF
 EITHER ONE OR TWO LAYERS
 *******************************************************
 ENTER THE LAYER NUMBER CORRESPONDING TO THE
 FIRST LAYER [LLL]:
2

 SPECIFY THE PARAMETER OF INTEREST [LLGS]:
   ENTER 0 FOR SHEAR STRAIN
   ENTER 1 FOR SHEAR STRESS
0

 ENTER THE NUMBER OF VALUES TO BE PLOTTED [LNV]:
   - LIMIT 2049
2049

 ENTER AN IDENTIFICATION FOR THIS PLOT
EXAMPLE PLOT

 SPECIFY THE SCALE FOR PLOTTING (i.e.,MAXIMUM
 VALUE OF ORDINATE) [SK]:
   ENTER 0 FOR MAXIMUM VALUE OF DATA
   ENTER 1 TO SPECIFY MAXIMUM VALUE
0

 ENTER THE LAYER NUMBER CORRESPONDING TO THE
 SECOND LAYER (OR LEAVE BLANK) [LLL]:
4
                         (RETURN TO USER OPTIONS MAIN MENU)
```

79. Summary of Options. After entering desired options from the **USER OPTIONS MAIN MENU** and option 9, a specifications file has been written and the pre-processing stage is complete. The latter options of the **USER OPTIONS MAIN MENU** are then used to proceed with steps to run the program (analysis stage, described in the next section). Although a user interface has been written for *WESHAKE* to allow easy selection of user options, the user may find that a DOS editor is more versatile and quicker.

Analysis Stage

80. The analysis stage consists of calculation of the solution through the execution of the modified *SHAKE1* subprogram within the *WESHAKE* package, creation of output files, and printing of output files from within the *WESHAKE* shell. The solution process is started by selecting option 10 from the **USER OPTIONS MAIN MENU**. The **ANALYSIS STAGE MAIN MENU** is then shown (next page):

```
                 ANALYSIS STAGE MAIN MENU
                 ************************

*****************************************************
**  OPTION    DESCRIPTION                          **
**  ------    -----------------------------------  **
**     1      CLOSE FILE AND RUN WESHAKE           **
**     2      EXIT WESHAKE AND RETURN TO DOS       **
*****************************************************
ENTER ONE OPTION NUMBER:
1
```

If execution is chosen (Option 1) the program begins running. The status of the program will be continually shown on the screen along with times of execution for each option and notification of completion.

81. The most important aspect of the use of this program is the evaluation of results. The results are contained in various output files that are automatically created as a consequence of using the various mandatory actions and user options. The various output files were described previously (Table III-5). The **OUTPUT** file corresponding to the example problem is shown in Appendix I.

Print menu

82. Once all operations have been completed, the **PRINT MENU** will be displayed. The output files created and summarized in Table IV-1 may be sent directly to a printer on the (first) parallel port (LPT1) from within the *WESHAKE* shell. The screen for the **PRINT MENU** is:

```
                        PRINT MENU
                        **********

 ***************************************************
 ** 1 - PRINT OUTPUT FILE                         **
 ** 2 - PRINT STRESS/STRAIN FILE                  **
 ** 3 - PRINT ACCELERATION FILE                   **
 ** 4 - PRINT PUNCH FILE                          **
 ** 5 - PRINT ACCELERATION TIME FILE              **
 ** 6 - PRINT VELOCITY SPECTRUM FILE              **
 ** 7 - PRINT ACCELERATION SPECTRUM FILE          **
 ** 8 - FUTURE USE                                **
 ** 9 - FUTURE USE                                **
 **10 - EXIT WESHAKE                              **
 ***************************************************
 ENTER ONE CHOICE:
1
                      (REPEAT UNTIL OPTION 10 SELECTED)
```

Portions of the OUTPUT file are greater than 80-characters wide so it is recommended that a 132-character printer be used or a small print font.

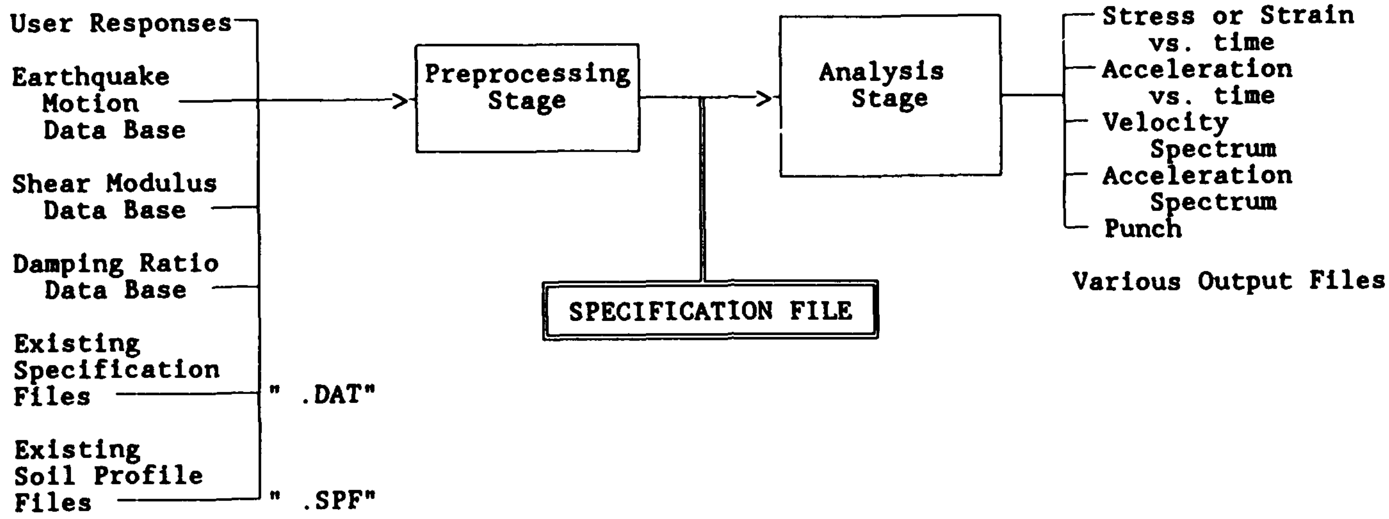


Figure IV-1. Program Organization of WESHAKE

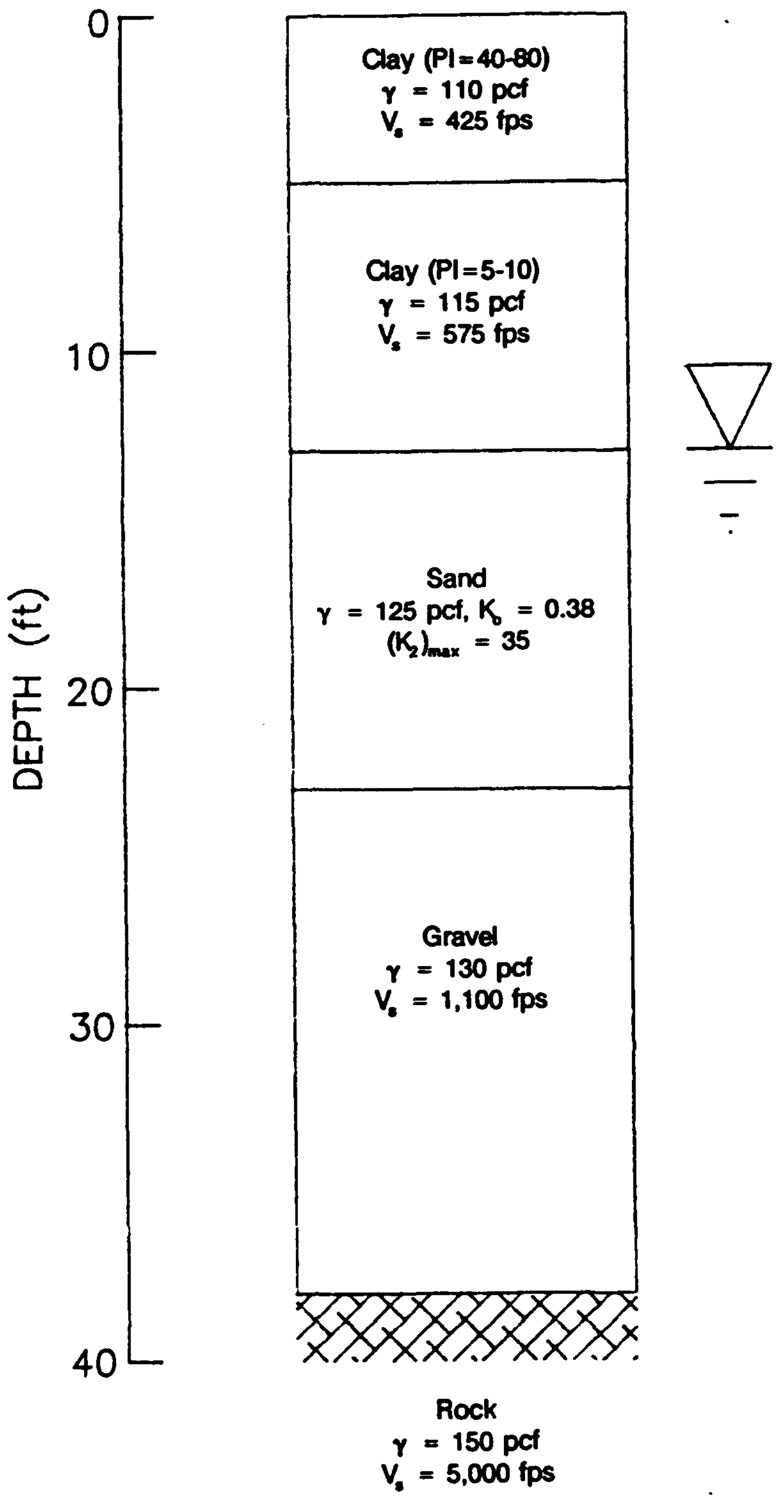
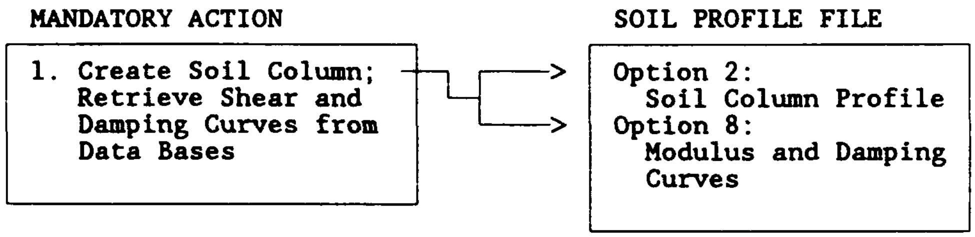
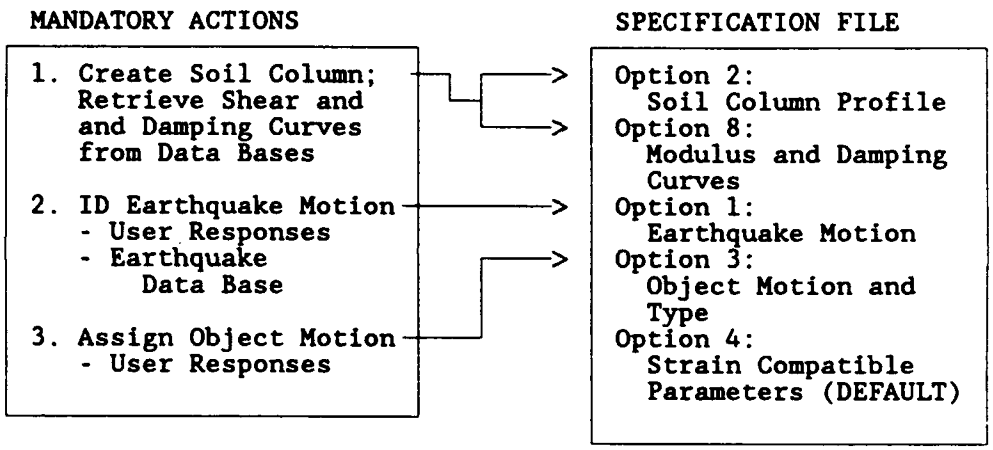


Figure IV-2. Example problem used for Part IV



a. For Option 3: Creating a Soil Profile File



b. For Option 4. Creating a Specification File

Figure IV-3. Components of mandatory actions for SPECIFICATION FILE DESIGNATION menu

PART V: ADVANCED TOPICS

83. In the course of using *SHAKE*, engineers have found ways of obtaining reasonable and meaningful results for more complicated problems than originally intended to solve. Some of these cases are described below to enlighten the user and spawn further creativity.

Application of Free-Field Results

84. It may not be appropriate to directly apply the free-field response to the base of the structure for a number of reasons, including:

- a. The depths of the footings most likely are not at the ground surface and motions will vary with depth.
- b. The weight of the structure acting on the footings will affect the motions beneath the footings.
- c. The friction acting on the sides of the footing will affect the motions acting on the footing.
- d. The impedance contrast between the soil and foundation is normally quite large.

The application of ground motions to the base of structures, i.e., the consideration of points such as those listed, is commonly referred to as dynamic soil-structure interaction (DSSI) and can be considered to be distinctly different from asynchronous effects produced with long period waves.

85. Basic design approaches for dynamic soil-structure interaction have recently been documented by Johnson (1980) and Veletsos, Prasad, and Tang (1988). Evaluation of simple foundation systems by Veletsos, Prasad, and Tang (1988) suggests the following rule of thumb: for a range of lower periods, DSSI will have no effect on the response; for a range of higher periods, DSSI will reduce the maximum response; for a range of intermediate periods, DSSI might increase or decrease the maximum response.

Estimation of Shear Wave Velocity

86. In some cases, all material properties necessary for the use of *WESHAKE* may not be available. This may be the case for sites with very deep soil deposits or projects with limited budgets. There is no substitute for measured properties in geotechnical engineering analysis, in this case the

primary variable being shear wave velocity. However, it may be possible to evaluate a range of site response based on estimated material properties.

87. A number of correlations exist in the literature that allow the user to derive shear wave velocities (refer to summary by Sykora and Koester 1988) or shear modulus coefficients (Seed et al. 1986) for an intended soil column. However, the variations among proposed correlations between shear wave velocity and Standard Penetration Test (SPT) N-value or depth are large (Sykora, 1987a; Sykora and Koester 1988). The correlation between $(K_2)_{max}$ and SPT N-value has been shown to produce poor results (Sykora 1989). The user, therefore, must exercise caution and good engineering judgement when using published relationships to determine shear wave velocity. The recommended procedure is to use a data base of shear wave velocities (e.g., Sykora 1987b, Sykora and Koester 1991) to establish a reasonable range of velocities using known site conditions and compare with published correlations.

Studies of Modulus and Damping Relationships

88. The variation of material properties, namely shear modulus and damping, with shear strain are continually under study. As described in Part II, the original investigations for this phenomenon were conducted in the 1960's and early 1970's. More recently in the 1980's and 1990's, studies have been completed to provide more information on the behavior of fine-grained soils and gravels.

89. Studies about fine-grained soils by investigators at different institutions have produced options for different sets of relationships. For instance, sets of shear modulus degradation relationships are proposed by Zen and Higuchi (1984), Sun, Golesorkhi, and Seed (1988), and Vucetic and Dobry (1991). The study by Vucetic and Dobry is intended to supersede that by Sun, Golesorkhi, and Seed in that new data were combined with data used in the Sun study. It appears as though the new modulus curves by Vucetic and Dobry (1991) are indeed more comprehensive. However, the new damping relationships are at issue.* Apparently some of the new damping data does not include large-strain determinations and serves to unduly weight the averaging

* Personal communication, Dr. Joseph Sun, Woodward-Clyde Consultants, Inc., Oakland, CA, 4 June 1992.

procedure. Until this issue is sufficiently resolved, the relationships by Sun, Golesorkhi, and Seed (1988) have been supplied in the data base.

High Effective Stresses

90. The relationships between shear modulus and shear strain for cohesionless soils may be significantly influenced by the effective confining pressure (Iwasaki, Tatsuoka, and Takagi 1976). The influence of confining stress on cohesive soils is not conclusive but is certainly less than that for cohesionless soils (Sun, Golesorkhi, and Seed 1988).

91. A simple means to evaluate the potential effect of high confining stresses is to select a modulus curve to the right of the "best estimate" curve. A rule of thumb based on the results by Seed and Idriss (1970) and Iwasaki, Tatsuoka, and Takagi (1976) is that if the effective vertical stress at the center of the layer is less than 500 psf, move one curve to the left. If the effective vertical stress is between 500 and 2,000 psf, use the best estimate curve. If the effective vertical stress is between 2,000 and 8,000 psf, move over one curve to the right. If the effective vertical stress is greater than 8,000 psf, move over two curves to the right.

92. The relationship between damping ratio and shear strain may also be affected by confining pressure (Seed et al. 1986 and Reeves and Castro 1991). This finding does not appear to be applied often in analyses by the profession, however, which may be the result of general uncertainties about normalized relationships for damping ratio. Limitations to the number of soil types allowed in the program used for this study do not normally facilitate involving stress adjusted relationships for damping ratio. Potential variations in damping ratio from stress effects are best addressed in the sensitivity analysis for damping ratio relationships.

Multiple Soil Columns

93. Recent standards by the US Nuclear Regulatory Commission (1989) and American Society of Civil Engineers, ASCE, (1987) provide recommendations for soil-structure interaction problems. They suggest that for sites that have not been "well investigated," a representative soil column should be derived for the site of interest using an average of stratigraphy and measured

properties, including shear wave velocities. The site response should then be calculated for the same column using an upper and lower bound of shear wave velocity determined by:

Lower bound: $$(G_{max})^{lb} = \frac{G_{max}}{(1+FACTOR)} \tag{4}$$

Upper bound: $$(G_{max})^{ub} = G_{max}\,(1 + FACTOR) \tag{5}$$

where

ASCE 4-36: FACTOR = coefficient of variation not to be less than 0.5
NRC 3.7.2: FACTOR = 1.0

to account for potential variations of material properties.

94. These standards are not recommended by WES for a site response analysis or liquefaction assessment (particularly the use of a single column to represent a site). The use of lower and upper bounds to determine a potential range in site response is recommended (refer to "Sensitivity Analysis" below). There are several reasons for this recommendation, including:

a. The "averaging" of stratigraphy, including the total column height, across a heterogeneous site may be too subjective;

b. Past experience has indicated that average columns may produce unconservative results compared to the range developed with the collection of individual columns;

c. The standards were derived primarily for soil-structure interaction studies.

In the end, the averaging of all the input parameters may have the effect of hiding resonance peaks produced by layers that are of limited extent both laterally and vertically.

Sensitivity Analysis

95. The sensitivity of various inputs to *WESHAKE* should be considered in most cases of site response analyses to evaluate the effects of potential variations across the site of interest. The range of parameters used should be a function of measured variations or perceived uncertainties. The primary

inputs to be considered are: depth to bedrock, shear modulus and damping ratio curves, and maximum shear modulus (function of V_s or $(K_2)_{max}$ and unit weight of soil).

Vertical Response

96. *SHAKE* has also been used by some investigators to estimate the vertical response of sites to earthquake excitations. The method used for this purpose only evaluates the vertical propagation of compression waves; it does not include the effect of shear waves. Details of the method are presented below.

97. Vertical response can be estimated using *SHAKE* by taking steps to match strains (and therefore matching percentage of modulus reduction and damping increase) from calculations for vertical response with calculations for horizontal response.* This may be accomplished by using some arbitrary value of the ratio of effective strain, PRMUL. Normally for the calculation of horizontal response, PRMUL is 0.65 (65 percent). The strains calculated for the vertical response and initial PRMUL are then compared with the strains calculated for horizontal response. The procedure is repeated by varying PRMUL until the variation of strain with depth for vertical response matched those for horizontal response as closely as possible. Values of PRMUL most likely will be greater than unity, and could be as large as 50. A factor greater that unity means that the constrained modulus degrades much faster than the shear modulus. The selection of an appropriate value of effective strain involves subjective decision making. Close matches should not be expected, especially for near-surface layers.

98. Inherent in the above procedure is the assumption that the variation of normalized constrained modulus is similar to that for normalized shear modulus. At large strains, this assumption may lead to considerable errors. Some laboratory tests conducted by WES for a particular project in the late 1970's included torsional and longitudinal vibration testing (Curro and Marcuson 1978). The results of these tests indicate that at longitudinal strains between about 10^{-4} and 10^{-3} percent, the maximum modulus decreased rapidly by about 50 percent. This characteristic "break" in the normalized

* Personal communication, Prof. John Lysmer, University of California at Berkeley, 1 November 1990.

curve differs greatly from the characteristic smooth shape and maximum slopes of the normalized shear modulus curves. Therefore, large differences are expected between calculated vertical response and actual site response.

99. For vertical response calculations, the constitutive model for stiffness is assumed to be the same except that the maximum constrained moduli, M_{max} , is used, calculated from compression waves:

$$M_{max} = \frac{\gamma}{g} V_P^2 \quad (6)$$

where

V_p = compression wave velocity

100. The comparison of calculations of motions using *SHAKE* with measured vertical response have not been reported in the literature. Consequently, validation of *SHAKE* for vertical response is considered to be inadequate. The calculation of vertical motions using this program are considered to merely provide qualitative insight into vertical site behavior.

Other Uses

101. Elton, Shie, and Hadj-Hamou (1991) showed that the shear stresses calculated using *SHAKE* and a computer program used to calculate the two-dimensional response, *FLUSH* (Lysmer et al. 1973), were in good agreement for both level-ground sites and sloped sites except near the surface. For embankments, the agreement improved as the period of excitation moved farther from the natural period of the embankment. Comparisons made of other ground motion parameters, however, such as the variation of acceleration with time and velocity or acceleration response spectrum showed much greater variation.*

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* Personal communication, Prof. David Elton, Auburn University, Auburn, AL, May 1992.

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APPENDIX A:

GETTING STARTED AND PERFORMANCE STATISTICS

Computer Hardware and Software Requirements

A1. The computer program will run on an IBM compatible personal computer, including an XT model using an 8086 processor. The size and power of the computer will serve to better enhance the performance of the program. The speed of execution is compared for an example problem with 15 layers and a few output options in Table A-1. These times may be used as a relative basis for comparison.

A2. Some minimum requirements exist to successfully execute *WESHAKE*. They include: 465 Kbyte RAM and version 3.1 of DOS. (The DOS 3.1 (and higher) commands **mem** and **ver** will determine the memory available and version, respectively.) If DOS 5.0 or greater is installed, some lower system memory can be transferred to upper memory thus freeing up more RAM. The math coprocessor option is mandatory for computers with 8086, 80286, and 80386 processors. No graphics requirements exist for *WESHAKE* version 1.0.

Installation

A3. All necessary components of *WESHAKE* are contained in one executable file, **WESHAKE.EXE**, and the shear modulus, damping ratio and earthquake data bases (**SHEARDB**, **DAMPDB**, and **EARTHQ**, respectively) that can be copied to a directory on a computer hard drive or run directly from the floppy disk drive. It is recommended that a directory be created on a hard disk specifically for this program file in addition to various files that may be created by the user as a consequence of running this program. To create a directory, for example WESHAKE, and load the software onto a hard disk, begin at the start-up prompt, (C:\>), then type:

C:\> **MD WESHAKE**

Recall that DOS commands are not case sensitive. Now change directories by typing:

C:\> **CD WESHAKE**

If the command **PROMPT pg** is in the **AUTOEXEC.BAT** file of your computer, the computer prompt will be:

C:\WESHAKE>

Read the files on the distribution disk by inserting the *WESHAKE* floppy disk into a floppy drive, say drive A, and typing:

C:\WESHAKE> **COPY A:*.***

To begin *WESHAKE*, type:

C:\WESHAKE> **WESHAKE**

The use of *WESHAKE* is described in the main text of this report.

Array Limitations

A4. Certain limitations exist within the program to minimize the overall size of the program. Limitations can be modified by WES to accomodate the needs of the users. The current list of more important limitations are summarized in Table A-2. Less important limitations, typically those pertaining to output options, are specified in the option menus shown in Part IV of the main text.

Run-Time Optimization

A5. Run times are highly machine dependent as might be expected and shown above. For a given machine, the run times can also vary considerably depending on the values of certain input parameters. Some of the more time-consuming parameters are: the number of FFT terms, the number of layers, and the convergence criterion (ERR). The number of FFT terms and number of layers may non-negotiable. ERR is easily adjusted; as ERR is decreased, the number of iterations required increases (and therefore time to solution increases). An optimal value of ERR is probably about 5 percent, the value used by default in *WESHAKE*.

Table A-1

Performance Statistics for *WESHAKE*

Example File for comparison with a 15 layer system

Computer Brand and model	Processor	Processor Speed (MHz)	Execution Time (Sec)	Ratio Time XT
IBM PC-XT	Intel 8086	8	1374	1
IBM PC-AT	Intel In-Board 386	16	209	.15
Compaq Deskpro	Intel 80386	16	258	.19
Compaq Deskpro	Intel 80386	20	193	.14
IBM PS/2, Model 70	Intel 80386	20	206	.15
Unisys	Intel 80386	20	160	.12
Compu Add	Intel 80386	25	161	.12
Gateway 2000	Intel 80486	25	41	.03
Gateway 2000	Intel 80486	33	21	.01

Table A-2

Array Limits for *WESHAKE*

Description	Program Variable	Limit
Maximum number of layers in soil column (including rock)	ML	20
Maximum number of modulus degradation/damping relationships	NSOILT	10
Maximum number of terms in Fast Fourier Transform (FFT)*	MAMAX	4096
Number of soil layers for acceleration output		15

* MAMAX must be at greater than or equal to the largest FFT used in the specifications file and at least twice as large as number of non-zero terms in the earthquake records. The array in **SHAKE1** has been fixed for a maximum of 4096 points to greatly reduce fixed memory size.

APPENDIX B:

SHEAR MODULUS AND DAMPING RATIO DATA BASES

The modulus and damping data bases have the following format:

Columns	Format	Parameter(s)
FIRST LINE		
1 5	I5	NUMBER OF VALUES PLOTTED ON RVE [NV] - maximum of 20 points per curve
6 - 10	I5	MULTIPLICATION FACTOR IN PLOTTING [NPL]
7 - 15	I5	CURVE IDENTIFICATION NUMBER [NUM][1]
16 - 75	A60	IDENTIFICATION OF SOIL PROFILE [ID]
SECOND LINE(S)		
1 - 80	8F10.4	NV VALUES OF SHEAR STRAIN (percent) IN INCREASING ORDER [R]: - Eight per line

The second line repeats until all values of shear strain have been specified

Columns	Format	Parameter(s)
THIRD LINE(S)		
1 - 80	8 F10.4	NV VALUES OF NORMALIZED SHEAR MODULUS (percent) OR DAMPING RATIO (percent), IN INCREASING ORDER, CORRRESPONDING TO VALUES OF SHEAR STRAIN IN SECOND LINE(S) [U]: - Eight per line

The third line repeats until all values of modulus or damping have been specified.

The second and third lines [illegible] a set and a set is created for each material type (i.e., these lines are repeated) in the respective data bases (unique to NUM).

[1] Deviation from syntax of specification file and OPTION 8 of SHAKE

Shear Modulus Data Base

```
8 100.     1 ROCK (Schnabel 1973)
0.0001     0.0003    0.0010    0.0030    0.0100    0.0300    0.1000    1.0000
1.00       1.00      0.99      0.95      0.90      0.81      0.725     0.55
9 100.     2 GRAVEL, Average (Seed et al. 1986)
0.0001     0.0003    0.0010    0.0030    0.0100    0.0300    0.1000    0.3000
1.000
1.00       0.97      0.87      0.73      0.55      0.37      0.20      0.10
0.050
9 100.     3 SAND, Lower Bound (Seed & Idriss 1970)
0.0001     0.0003    0.0010    0.0030    0.0100    0.0300    0.1000    0.3000
1.0000
1.000      0.985     0.93      0.83      0.635     0.425     0.225     0.11
0.04
9 100.     4 SAND, Average (Seed & Idriss 1970)
0.0001     0.0003    0.0010    0.0030    0.0100    0.0300    0.1000    0.3000
1.0000
1.00       0.98      0.95      0.89      0.73      0.52      0.29      0.14
0.06
9 100.     5 SAND, Upper Bound (Seed & Idriss 1970)
0.0001     0.0003    0.0010    0.0030    0.0100    0.0300    0.1000    0.3000
1.0000
1.00       1.00      0.99      0.96      0.85      0.655     0.37      0.19
0.085
9 100.     6 CLAY (PI=5-10, Sun et al. 1988)
0.0001     0.0003    0.0010    0.0030    0.0100    0.0300    0.1000    0.3000
1.0
1.00       1.00      0.975     0.91      0.78      0.565     0.305     0.14
0.04
9 100.     7 CLAY (PI=10-20, Sun et al. 1988)
0.0001     0.0003    0.0010    0.0030    0.0100    0.0300    0.1000    0.3000
0.0
1.00       1.00      1.00      0.96      0.87      0.70      0.41      0.20
0.08
9 100.     8 CLAY (PI=20-40, Sun et al. 1988)
0.0001     0.0003    0.0010    0.0030    0.0100    0.0300    0.1000    0.3000
1.0
1.00       1.00      1.00      0.97      0.90      0.77      0.52      0.30
0.14
9 100.     9 CLAY (PI=40-80, Sun et al. 1988)
0.0001     0.0003    0.0010    0.0030    0.0100    0.0300    0.1000    0.3000
1.0
1.00       1.00      1.00      0.985     0.92      0.815     0.62      0.41
0.20
9 100.     10 CLAY (PI>80, Sun et al. 1988)
0.0001     0.0003    0.0010    0.0030    0.0100    0.0300    0.1000    0.3000
1.0
1.00       1.00      1.00      0.985     0.94      0.86      0.71      0.53
0.33
9 100.     11 Mexico City Clay (Sun et al. 1988)
0.0001     0.0003    0.0010    0.0030    0.0100    0.0300    0.1000    0.3000
1.0
1.00       1.00      1.00      1.000     0.995     0.975     0.920     0.8000
0.46
```

Damping Ratio Data Base

```
 5   5.0     1 ROCK (Schnabel 1973)
 0.0001     0.0010    0.0100    0.1000    1.0000
 0.40       0.80      1.50      3.00      4.60
 9   5.0     2 GRAVEL (Average, Seed et al 1986)
 0.0001     0.0003    0.0010    0.0030    0.0100    0.0300    0.1000    0.3000
 1.0000
 0.8        1.0       1.9       3.0       5.4       9.6       15.4      20.8
24.6
 9   5.0     3 SAND (Average, Seed & Idriss 1970)
 0.0001     0.0003    0.0010    0.0030    0.0100    0.0300    0.1000    0.3000
 1.0000
 0.8        1.0       1.9       3.0       5.4       9.6       15.4      20.8
24.6
 9   5.0     4 SAND (Lower Bound, Seed & Idriss 1970)
 0.0001     0.0003     .0010    0.0030    0.0100    0.0300    0.1000    0.2780
 1.0000
 0.3        0.4       0.7       1.4       2.7       5.0       9.8       15.5
20.7
 9   5.0     5 SAND (Upper Bound, Seed & Idriss 1970)
 0.0001     0.0003    0.0010    0.0030    0.0100    0.0315    0.1000    0.3000
 1.0000
 0.7        1.2       2.7       5.5       9.9       14.8      21.0      25.5
27.9
 9   5.0     6 CLAY (Average, Seed & Idriss 1970)
 0.0001     0.0003    0.0010    0.0030    0.0100    0.0300    0.1000    0.4000
 1.0000
 2.5        2.5       2.5       3.5       4.5       6.5       9.0       13.5
20.5
 9   5.0     7 CLAY (Lower Bound, Seed & Idriss 1970)
 0.0001     0.0003    0.0010    0.0030    0.0100    0.0300    0.1000    0.4000
 1.0000
 1.3        1.3       1.3       1.5       1.7       3.5       4.0       6.5
12.3
 9   5.0     8 CLAY (Upper Bound, Seed & Idriss 1970)
 0.0001     0.0003    0.0010    0.0030    0.0100    0.0300    0.0780    0.3000
 1.0000
 4.0        4.0       4.0       5.0       7.5       11.0      16.0      21.8
27.0
```

APPENDIX C:

EARTHQUAKE DATA BASE

C1. The earthquake data base (**EARTHQ**) is described and characteristics of each earthquake motion is presented. Note that earthquake records to be used with *WESHAKE* that are not included in the data base need to comply with the specification file format (refer to Appendix E) and not the data base format. The differences between these two formats can be seen by comparing the format below with that presented beginning on page E4. The earthquake data base has the following format:

Columns	Format	Parameter(s)
FIRST LINE		
1 - 5	I5	NUMBER OF VALUES IN EARTHQUAKE MOTION [NV]
6 - 10	I5	NUMBER OF TERMS IN FFT [MA] - must be a power of 2 and ≤ MAMAX - should be ≥ 2 * NV
11 - 20	F10.3	TIME STEP FOR MEASUREMENT [DT]
21 - 25	I5	EARTHQUAKE DATA BASE NUMBER [INUME][1]
26 - 85	A60	EARTHQUAKE TITLE [EQTITLE]
SECOND LINE[1]		
1 - 80	A80	CHARACTERISTICS OF EARTHQUAKE
THIRD LINE		
1 - 10	F10.3	MULTIPLICATION FACTOR FOR ACCELERATION [XF]
11 - 20	F10.3	MAXIMUM ACCELERATION VALUE TO BE USED [XMAX]
21 - 30	F10.3	MAXIMUM (CUTOFF) FREQUENCY [FMAX]
FOURTH AND SUBSEQUENT LINES		
1 - 72	8(1X,F8.6)	NV VALUES OF ACCELERATION (g's) [XR] - eight per line
73 - 79	I7	LINE NUMBER [K]

C2. Note that the number of non-zero values in the earthquake record must be less than or equal to half of the maximum number of terms for the FFT (MA). The records in the data base all conform to this requirement. Users providing additional records must ensure that this requirement is met, however. The proper format is shown in Appendix C along with the existing data base and plots of records. Also, the maximum number of terms for the FFT can not exceed 4096. This value was fixed in *WESHAKE* and can be modified is necessary.

---

[1] Deviation from syntax of specification file and OPTION 1 of SHAKE

C3. At the present time, there are 22 earthquakes in the data base. Important information about earthquakes in the data base was presented in Tables III-1 and III-2 of the main text. The data for these records are presented on the following pages in the form of figures. Numerical values can be extracted from the data base. The first figure for each earthquake is a plot of the variation of acceleration with time. The second figure for each earhtquake is a plot of pseudo-response velocity spectra using a tripartite format (assuming 5 percent damping) at 6 levels of system damping (2, 5, 7, 10, 12 and 15 percent).

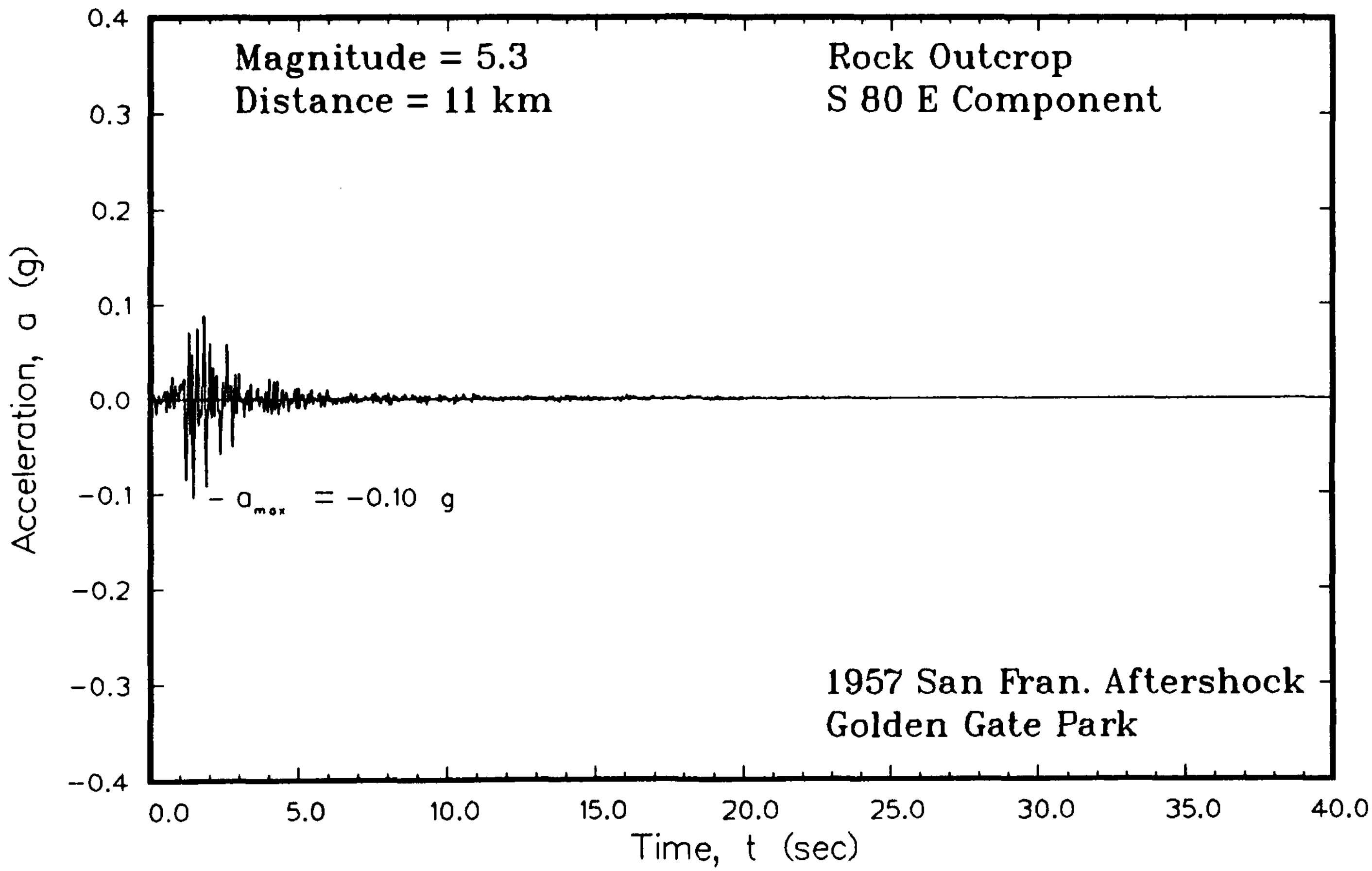

Figure C1. Golden Gate record of 1957 San Francisco, California, aftershock

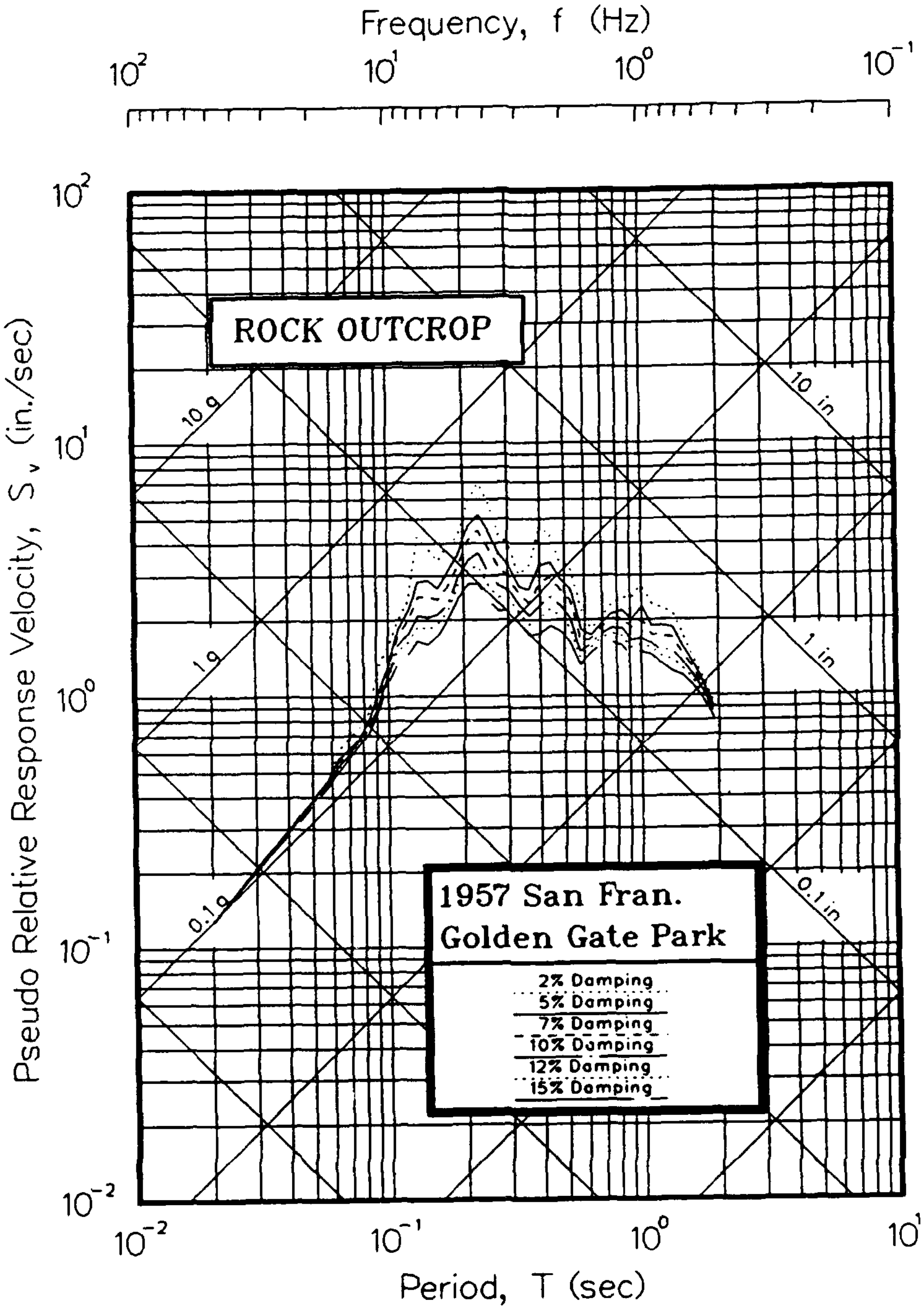

Figure C2. Tripartite presentation of pseudo-velocity spectra for Golden Gate record of 1957 San Francisco, California, aftershock

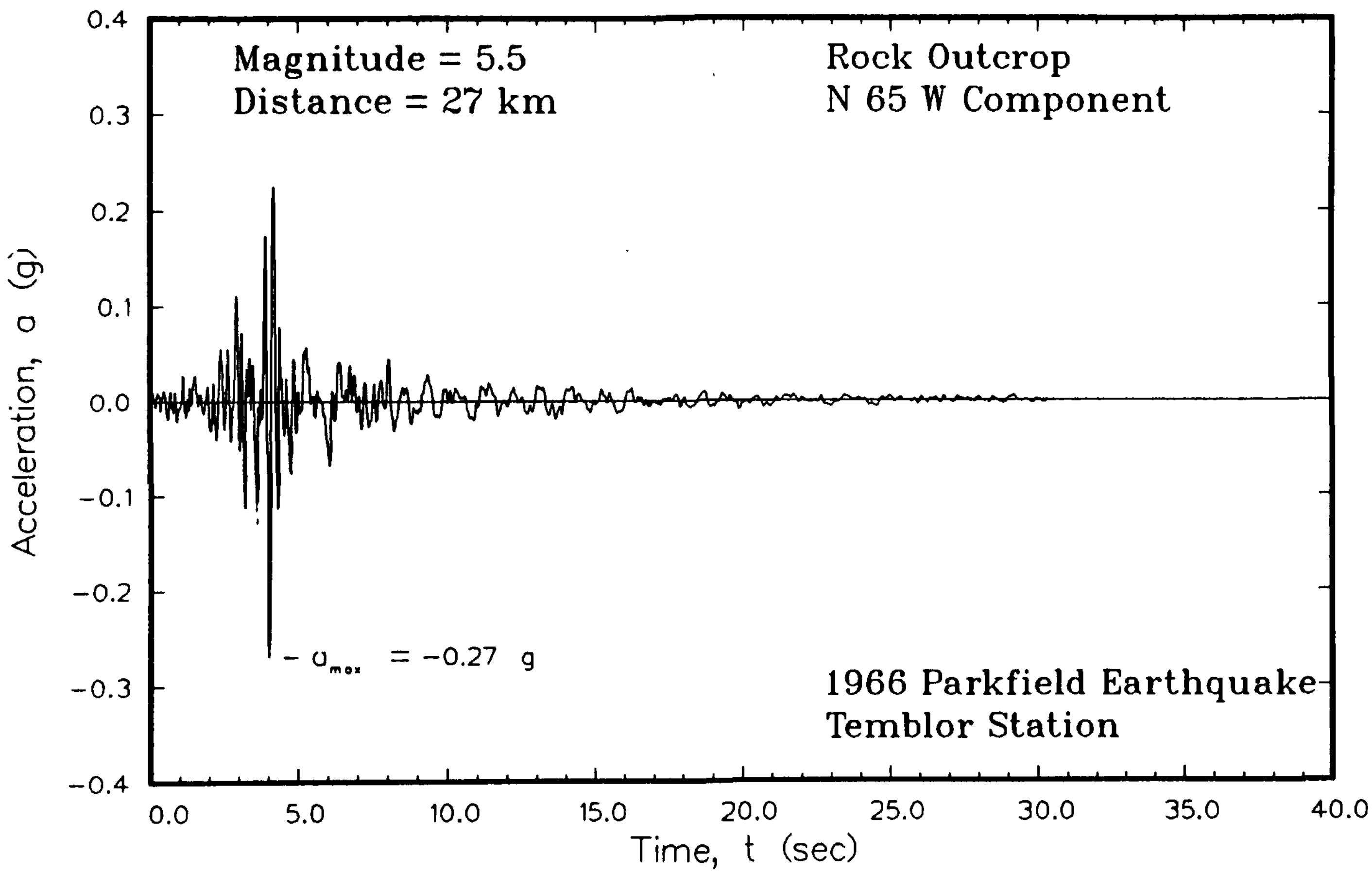

Figure C3. Cholame-Temblor record of 1966 Parkfield, California, earthquake

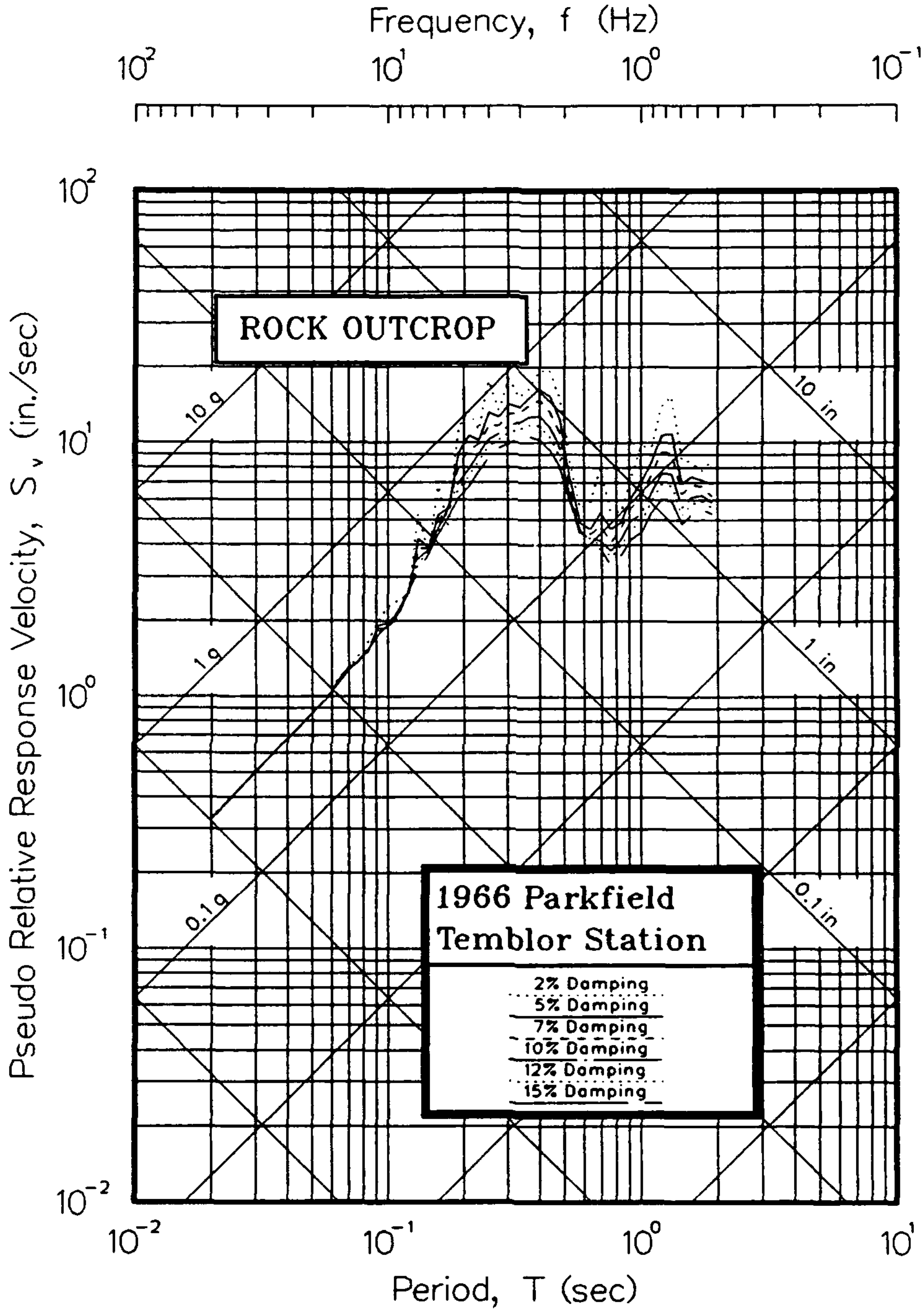

Figure C4. Tripartite presentation of pseudo-velocity spectra for Cholame-Temblor record of 1966 Parkfield, California, earthquake

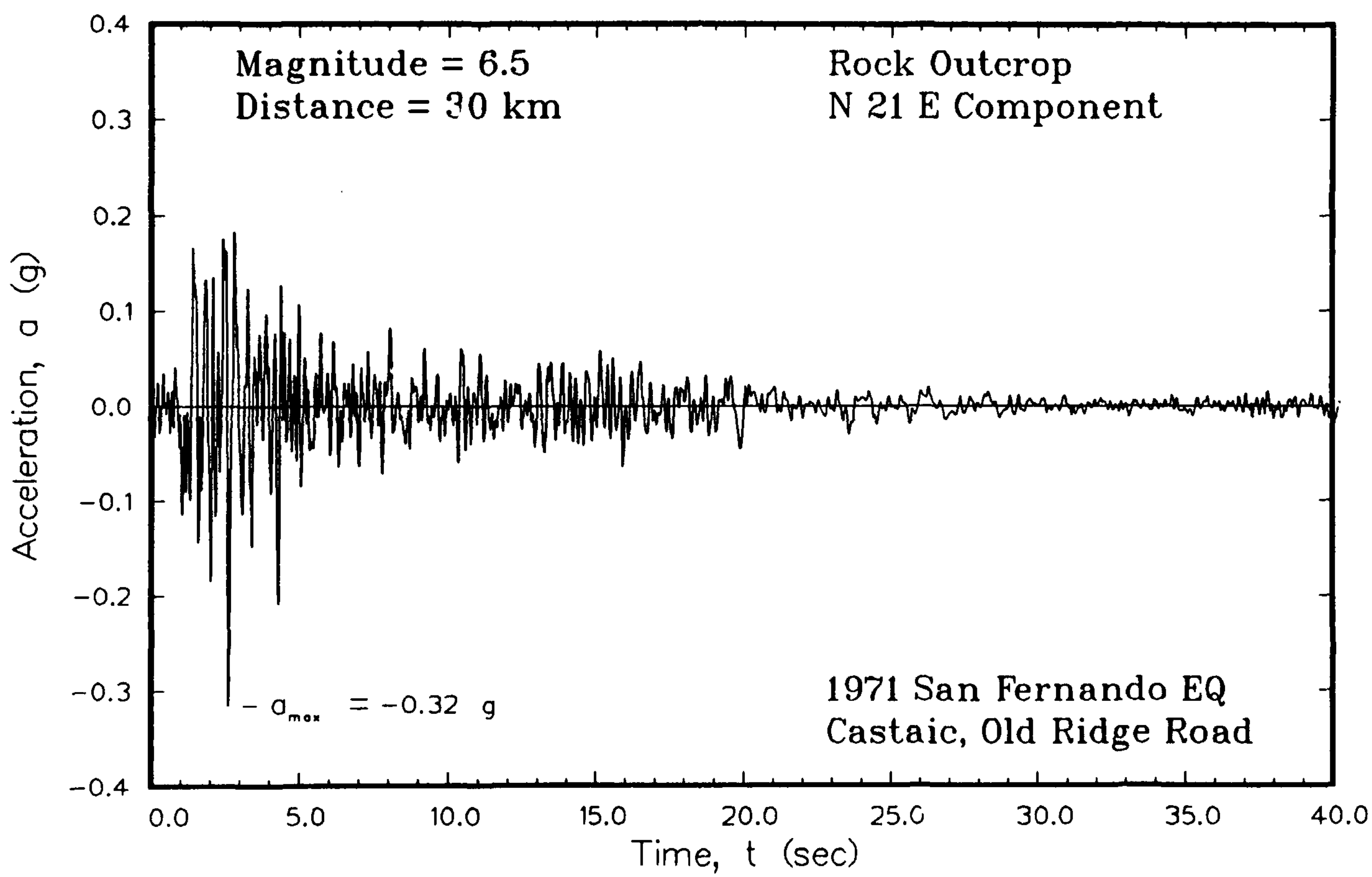

Figure C5. Castaic Ridge record of 1971 San Fernando, California, earthquake

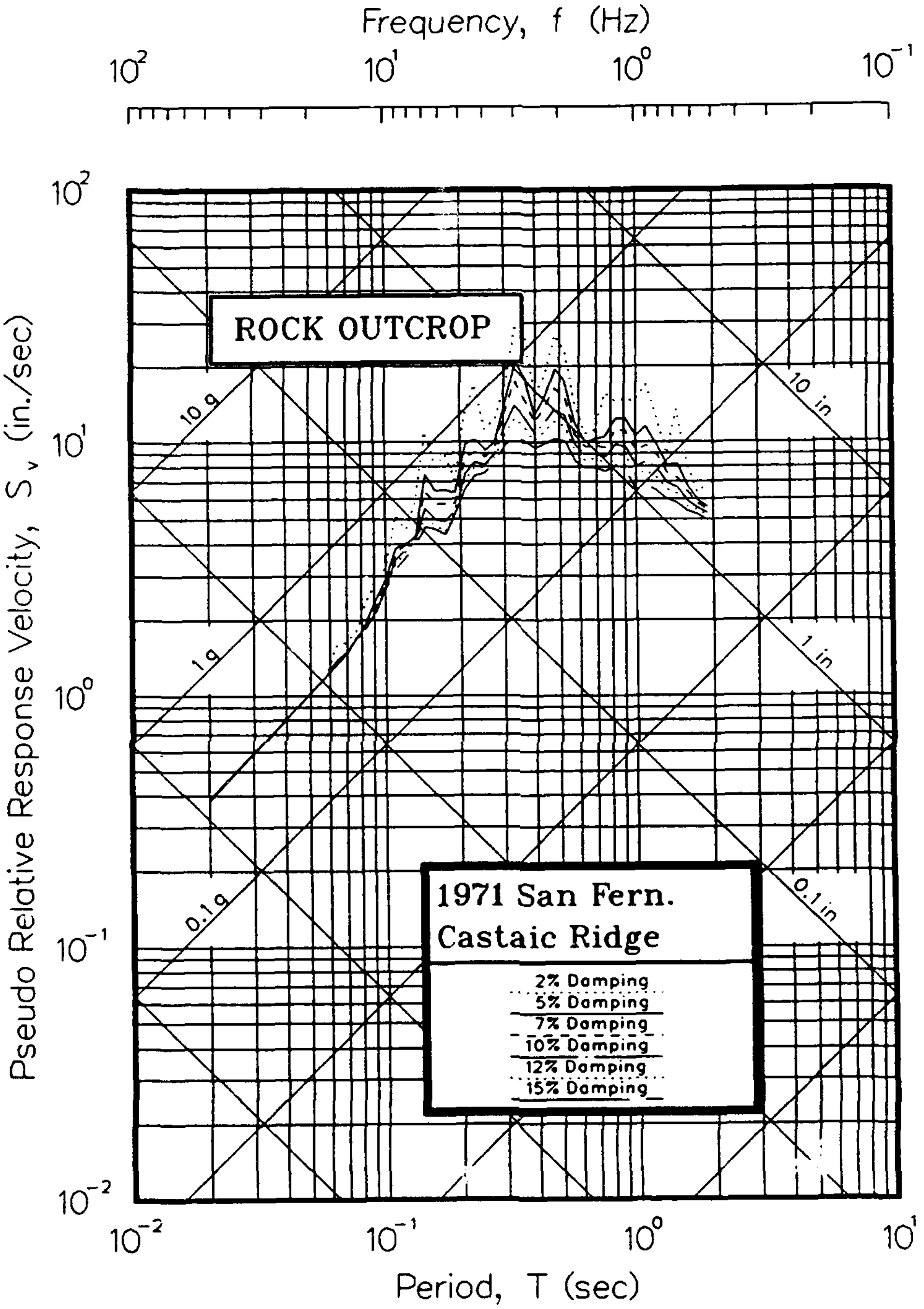

Figure C6. Tripartite presentation of pseudo-velocity spectra for Castaic Ridge record of 1971 San Fernando, California, earthquake

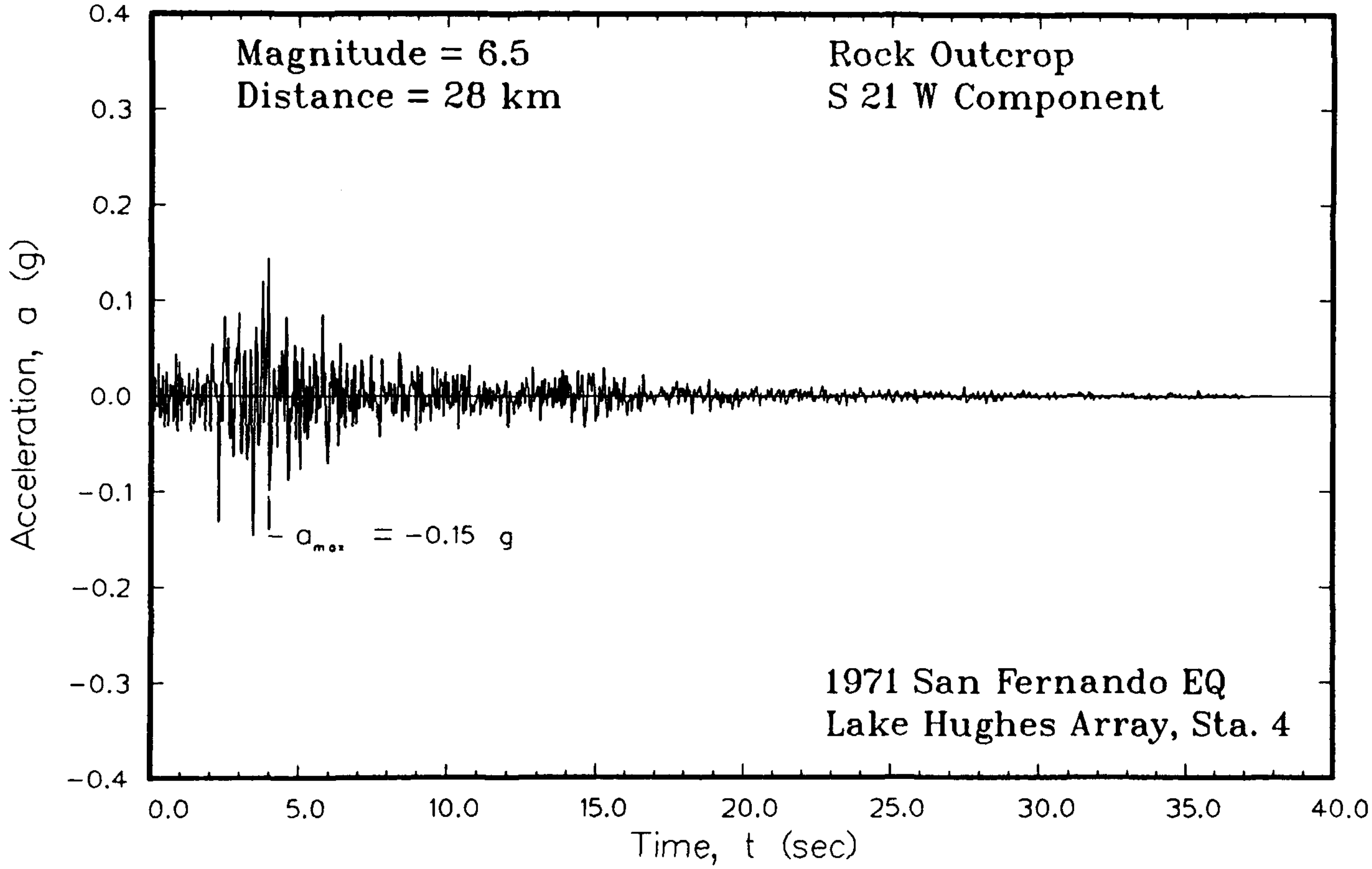

Figure C7. Lake Hughes Array No. 4 record of 1971 San Fernando, California, earthquake

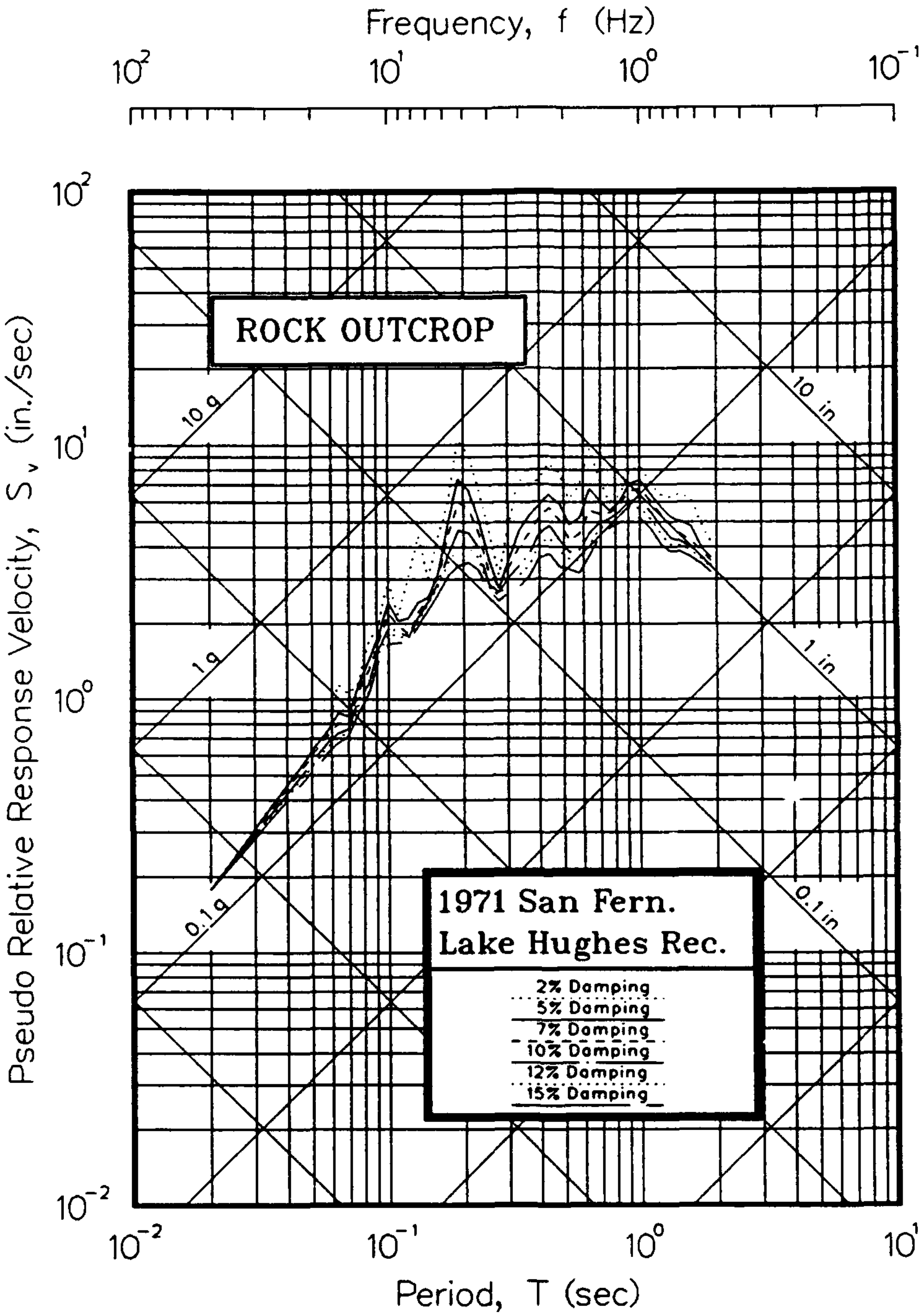

Figure C8. Tripartite presentation of pseudo-velocity spectra for for Lake Hughes Array No. 4 record of 1971 San Fernando, California, earthquake

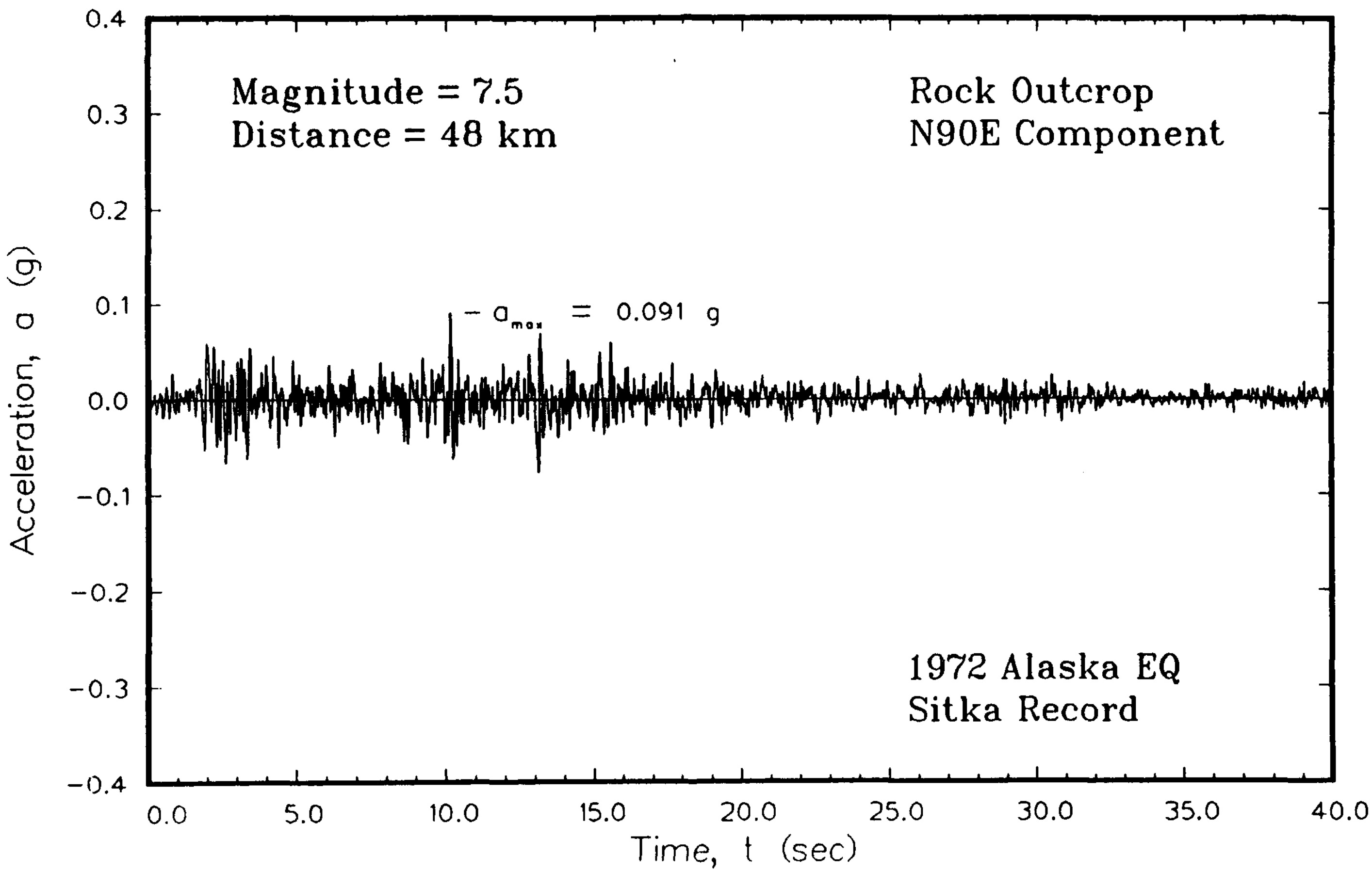

Figure C9. Sitka Magnetic Observatory record of 1972 Alaskan earthquake

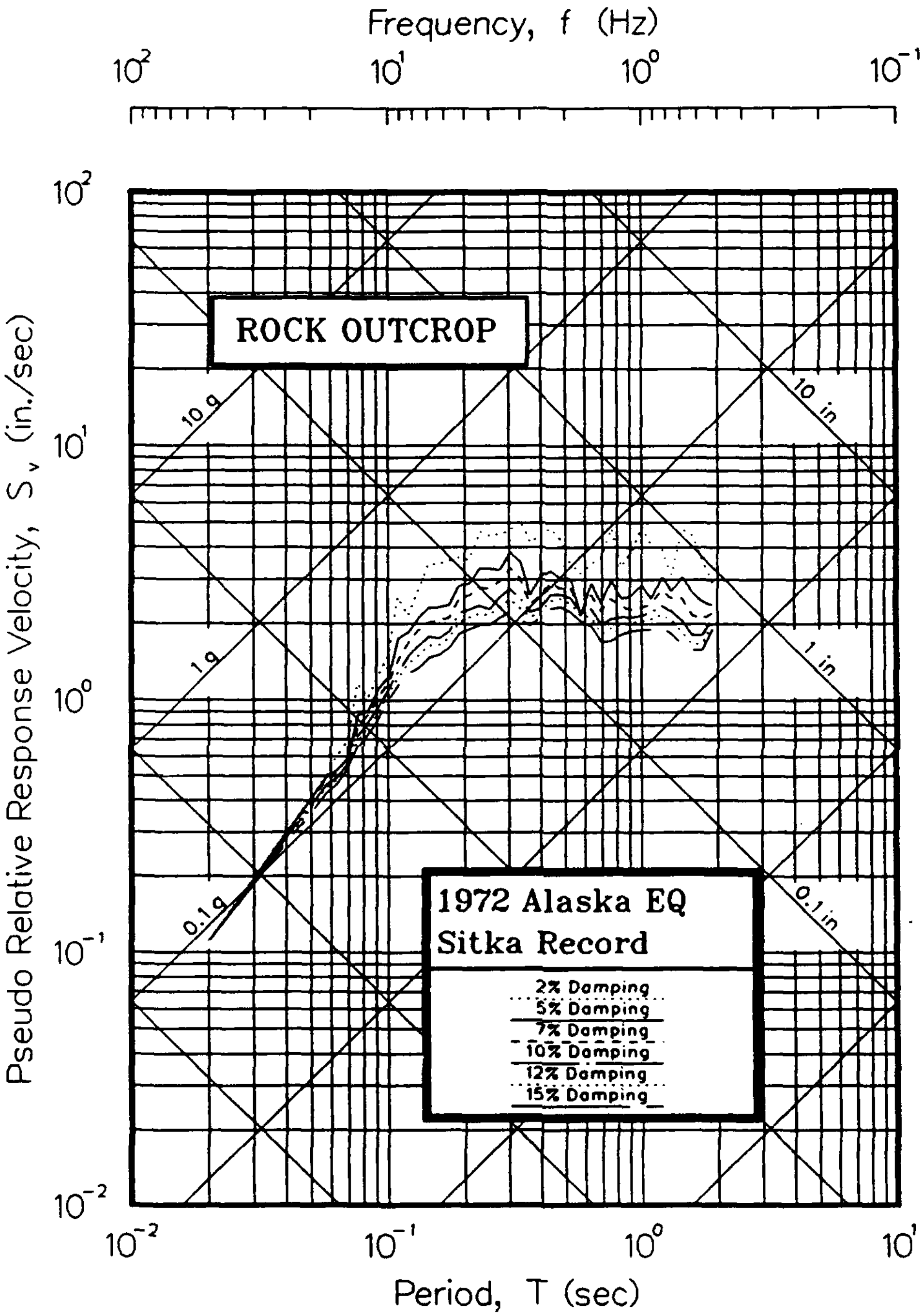

Figure C10. Tripartite presentation of pseudo-velocity spectra for Sitka Magnetic Observatory record of 1972 Alaskan earthquake

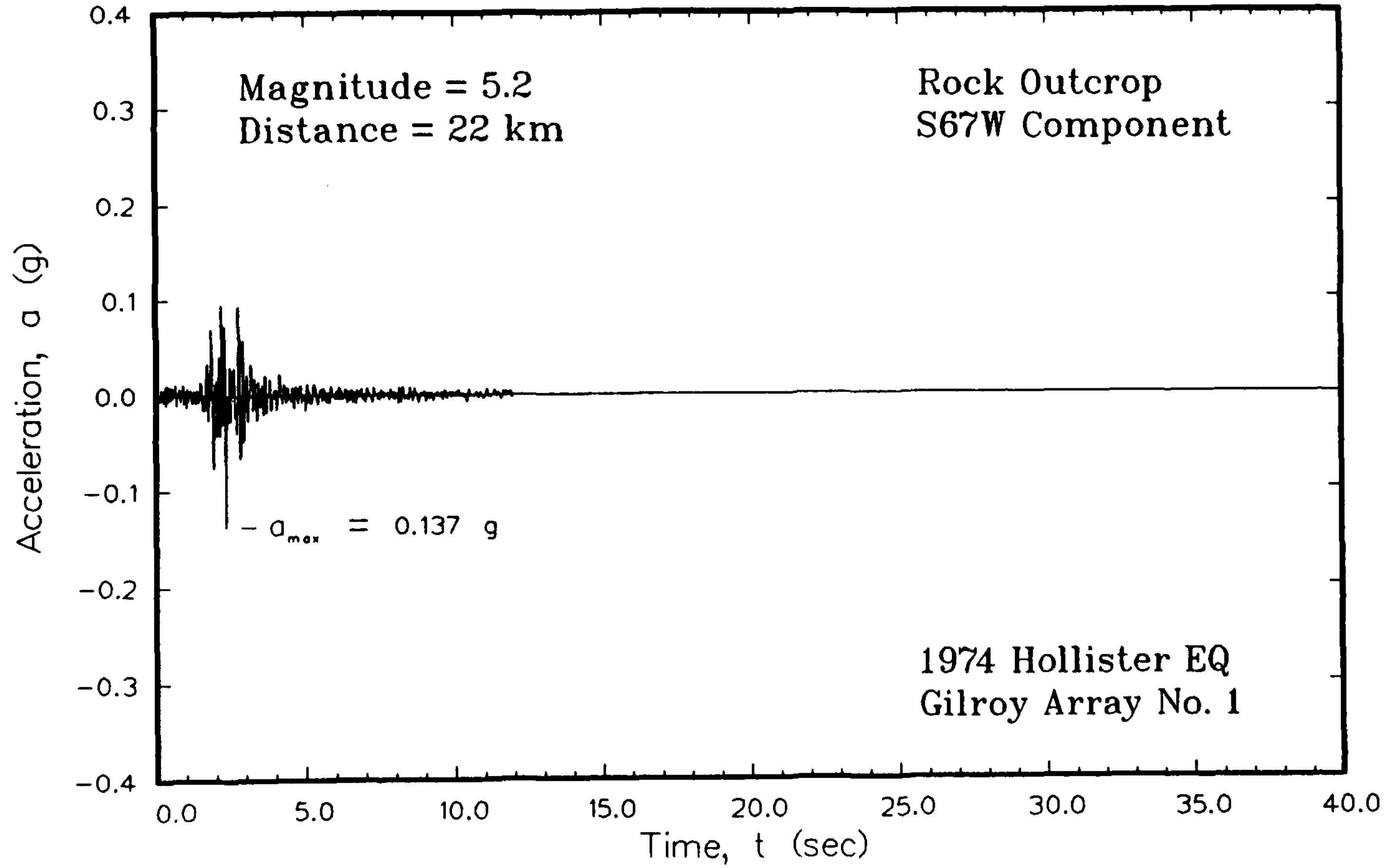

Figure C11. Gilroy No. 1 record of 1974 Hollister, California, earthquake

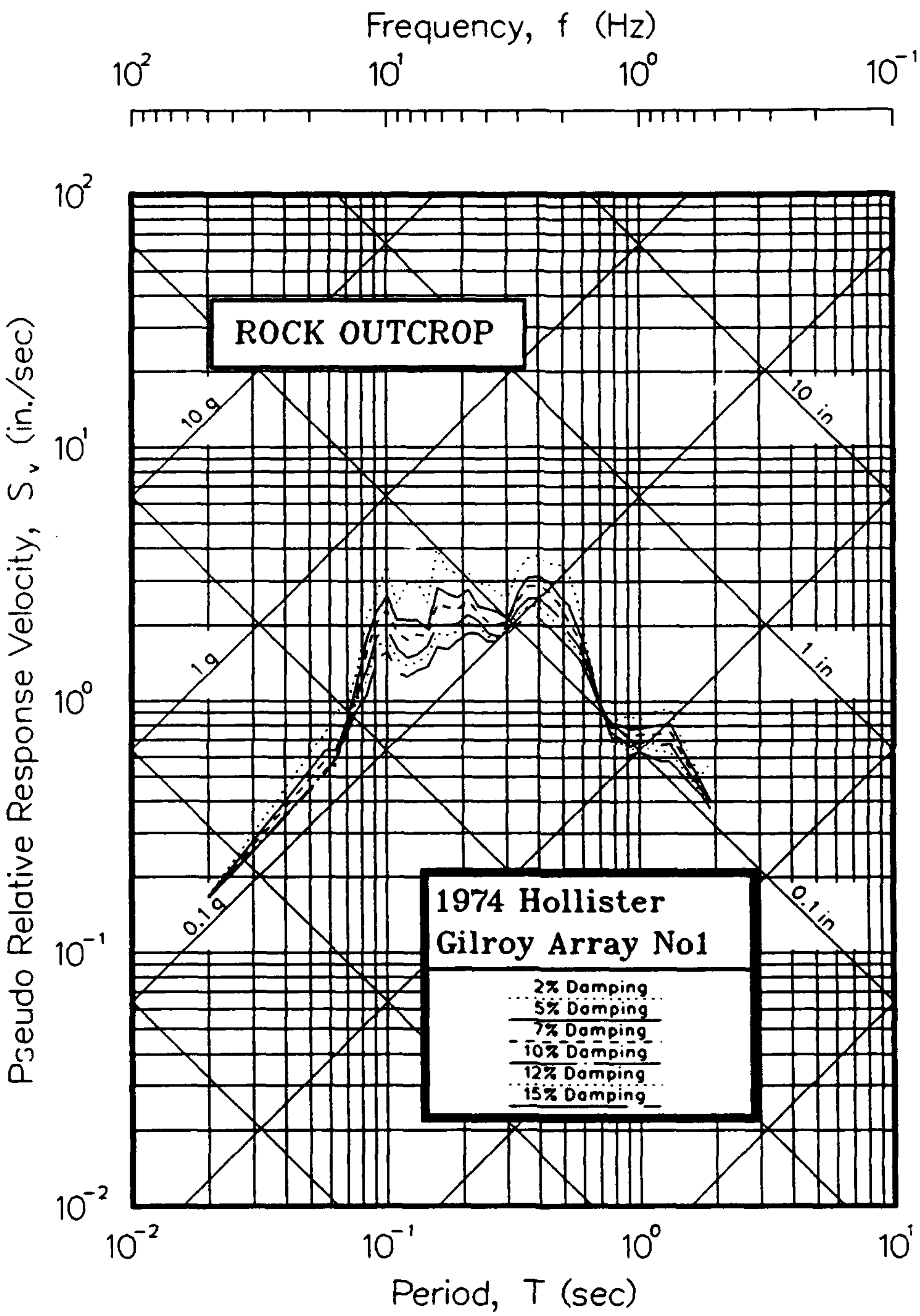

Figure C12. Tripartite presentation of pseudo-velocity spectra for Gilroy No. 1 record of 1974 Hollister, California, earthquake

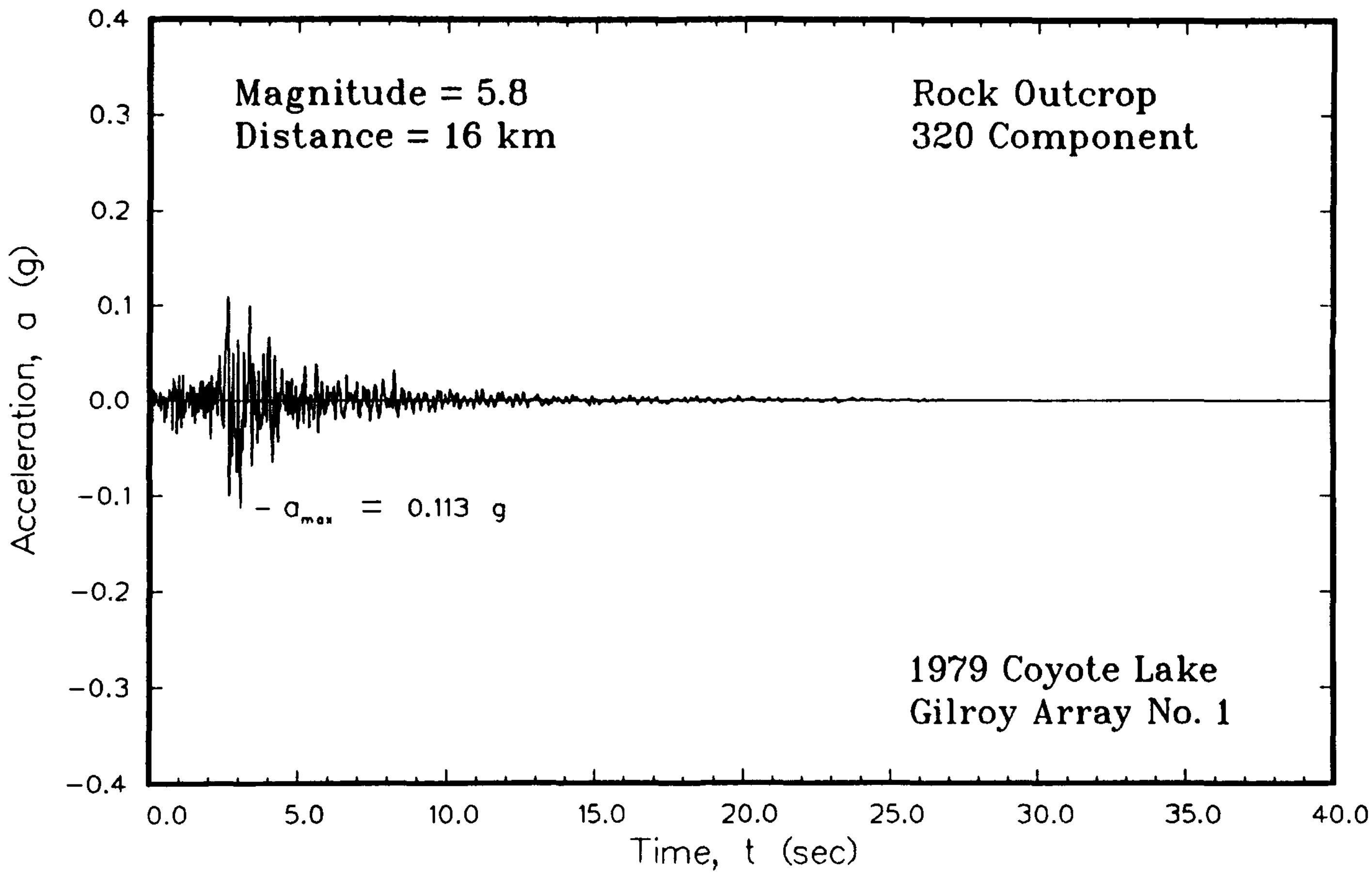

Figure C13. Gilroy No. 1 record of 1979 Coyote Lake, California, earthquake

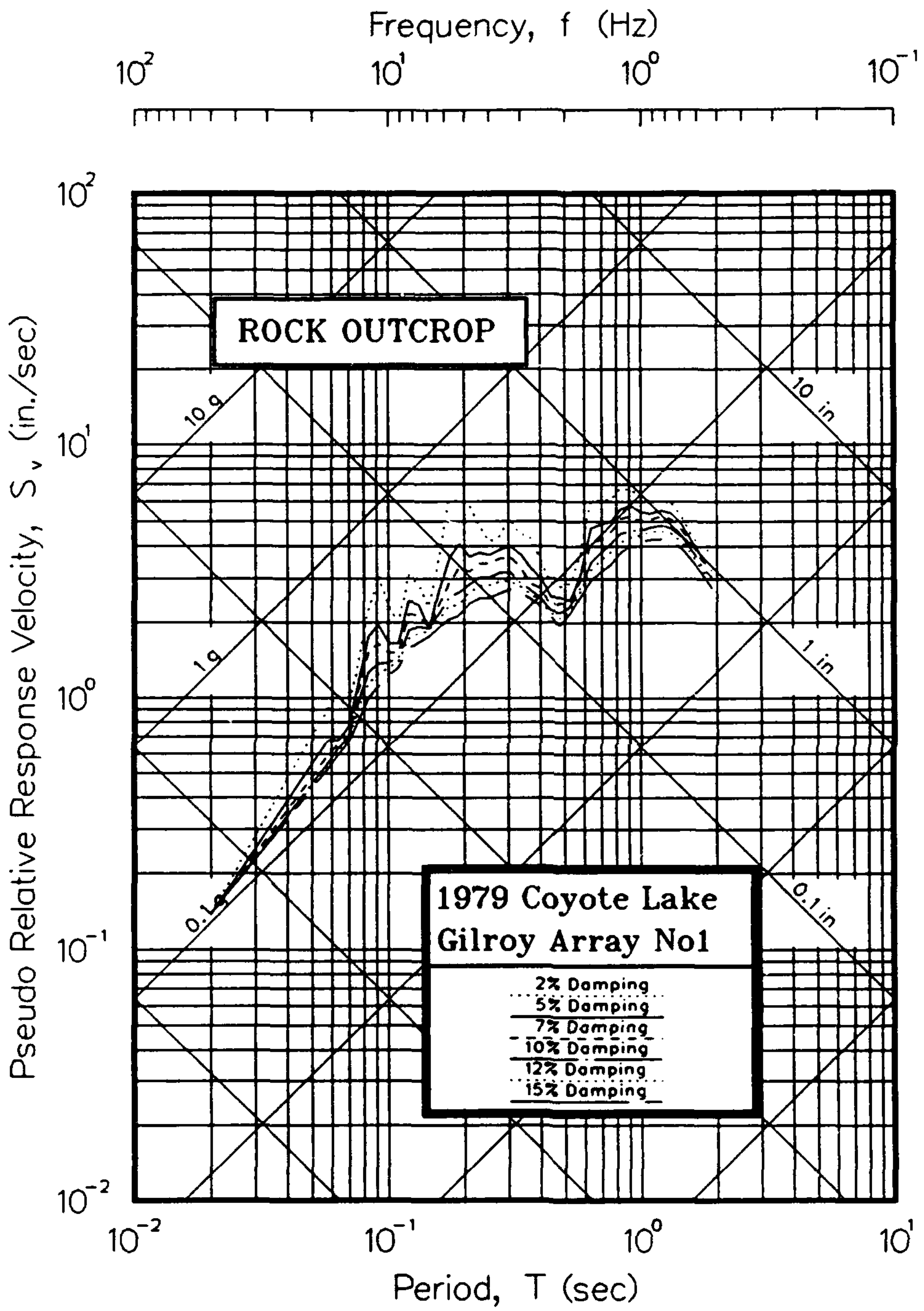

Figure C14. Tripartite presentation of pseudo-velocity spectra for Gilroy No. 1 record of 1979 Coyote Lake, California, earthquake

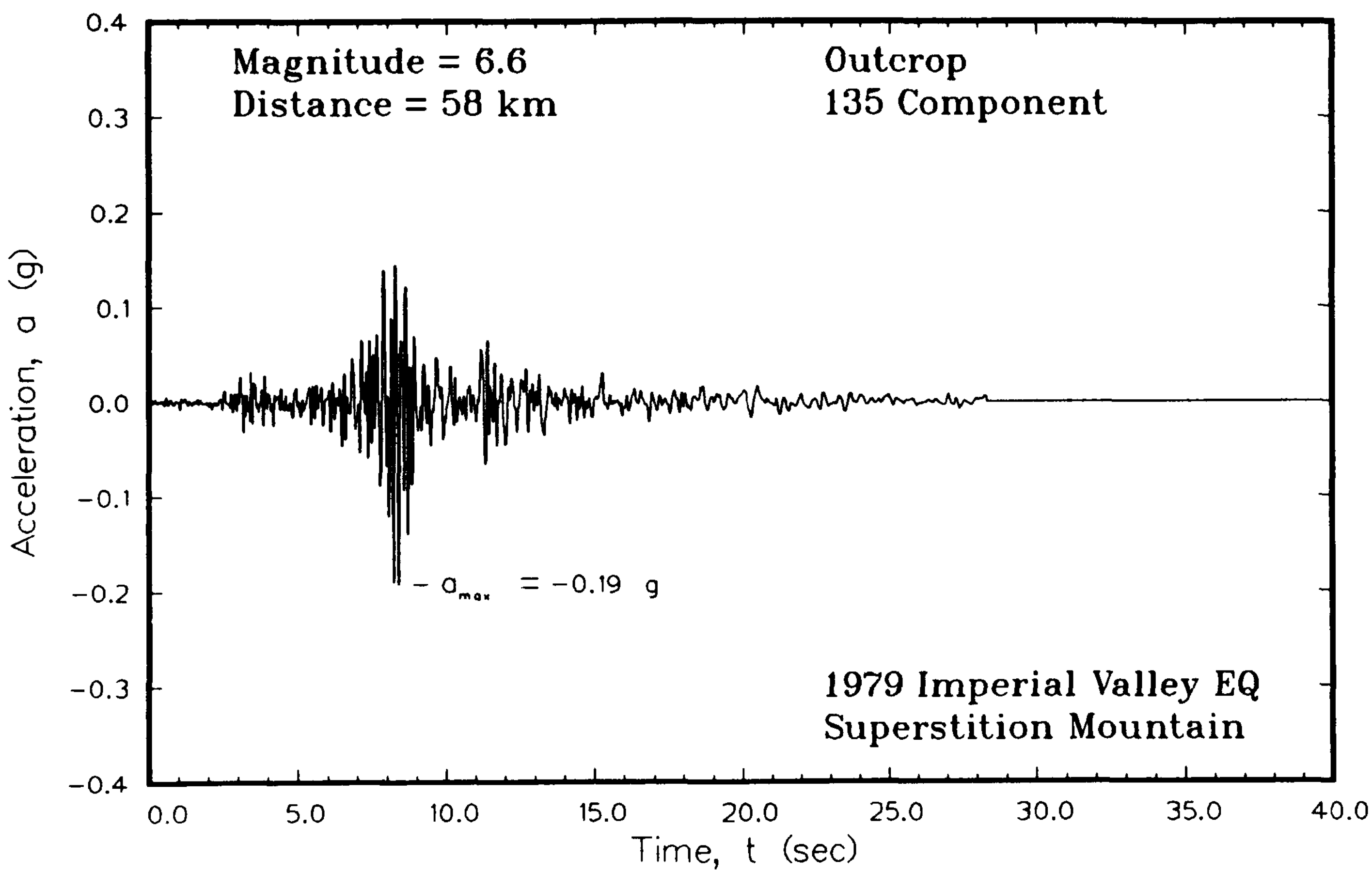

Figure C15. Superstition Mountain record of 1979 Imperial Valley, California, earthquake

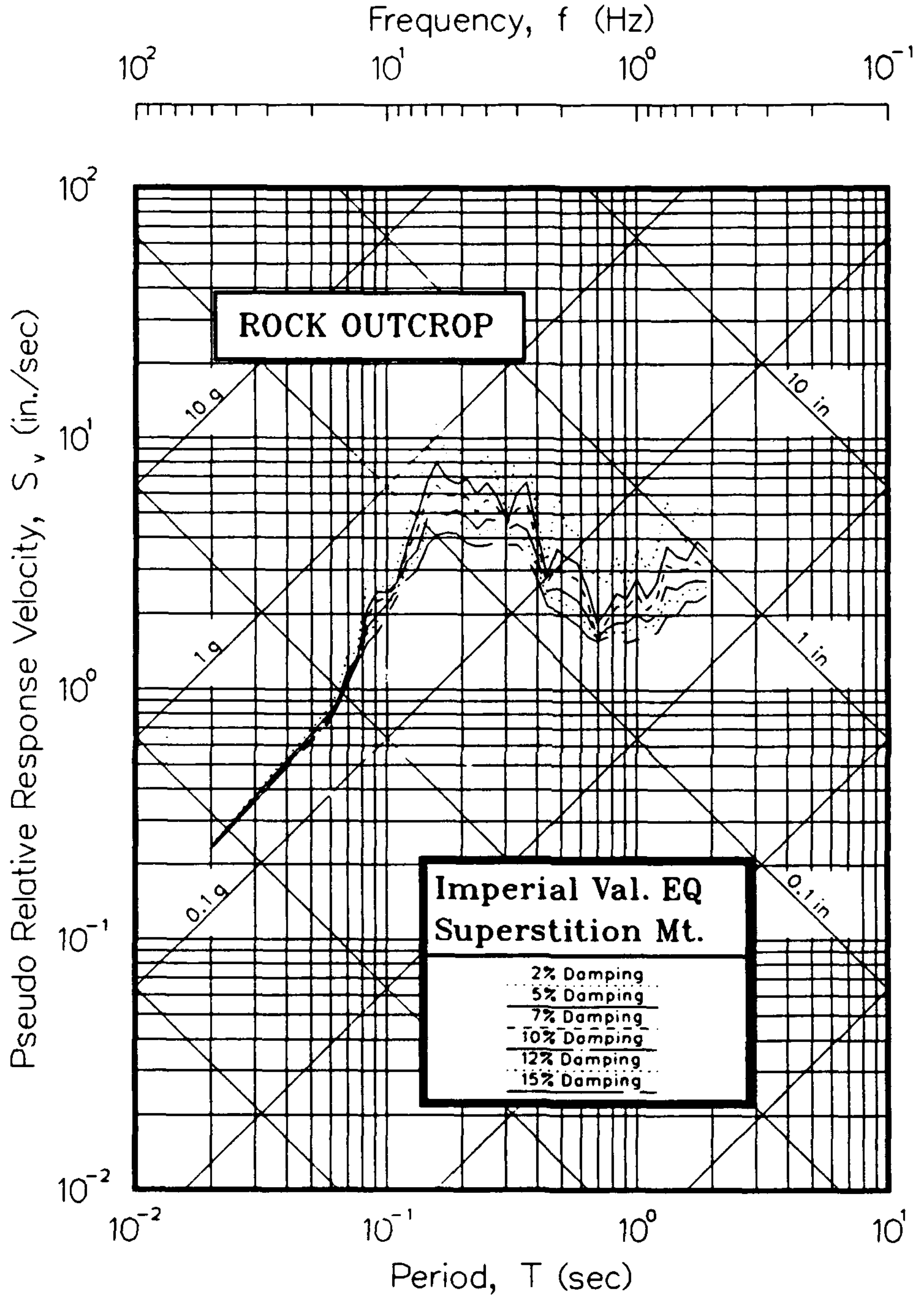

Figure C16. Tripartite presentation of pseudo-velocity spectra for Superstition Mountain record of 1979 Imperial Valley, California, earthquake

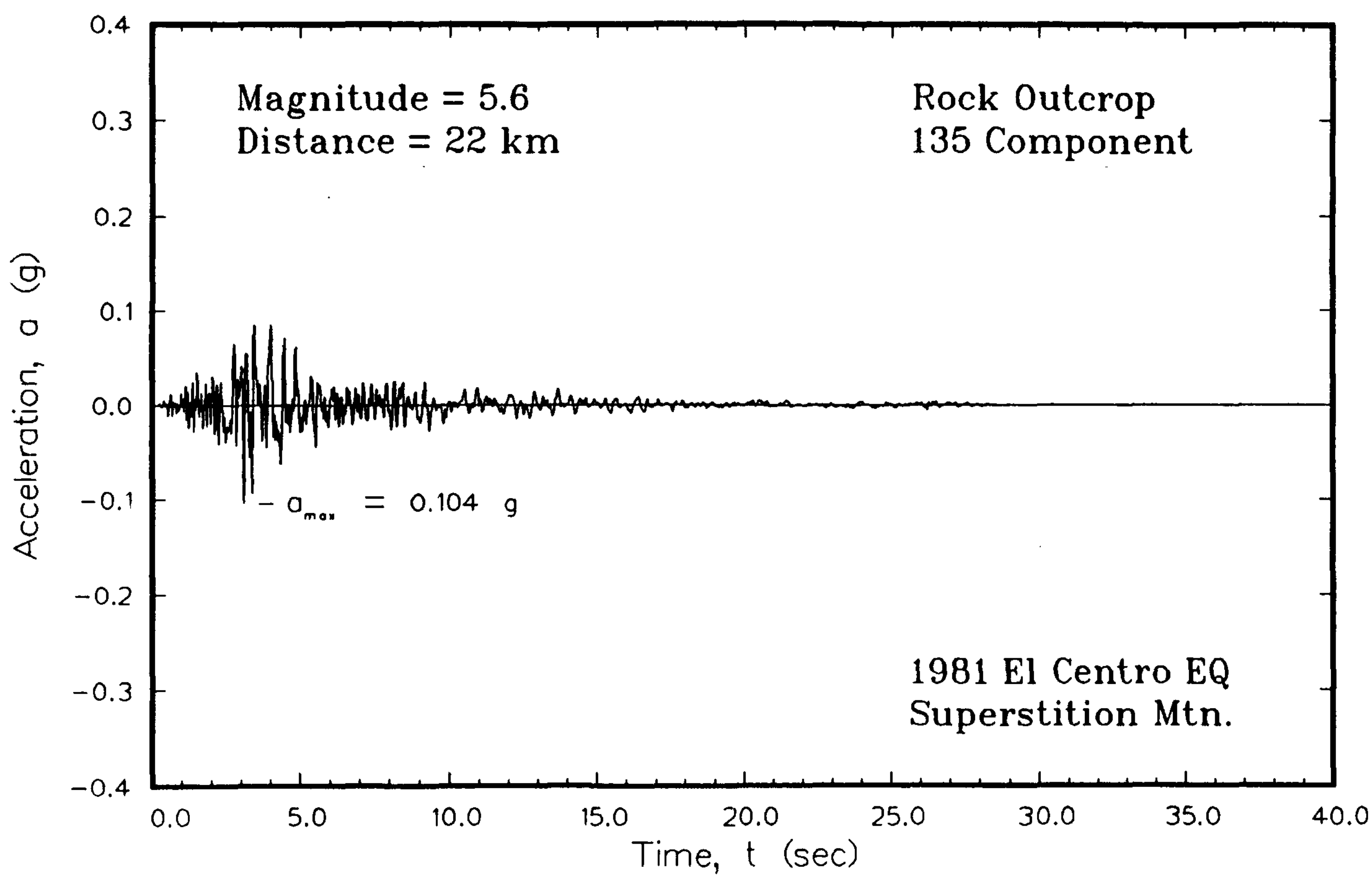

Figure C17. Superstition Mountain record of 1981 El Centro, California, earthquake

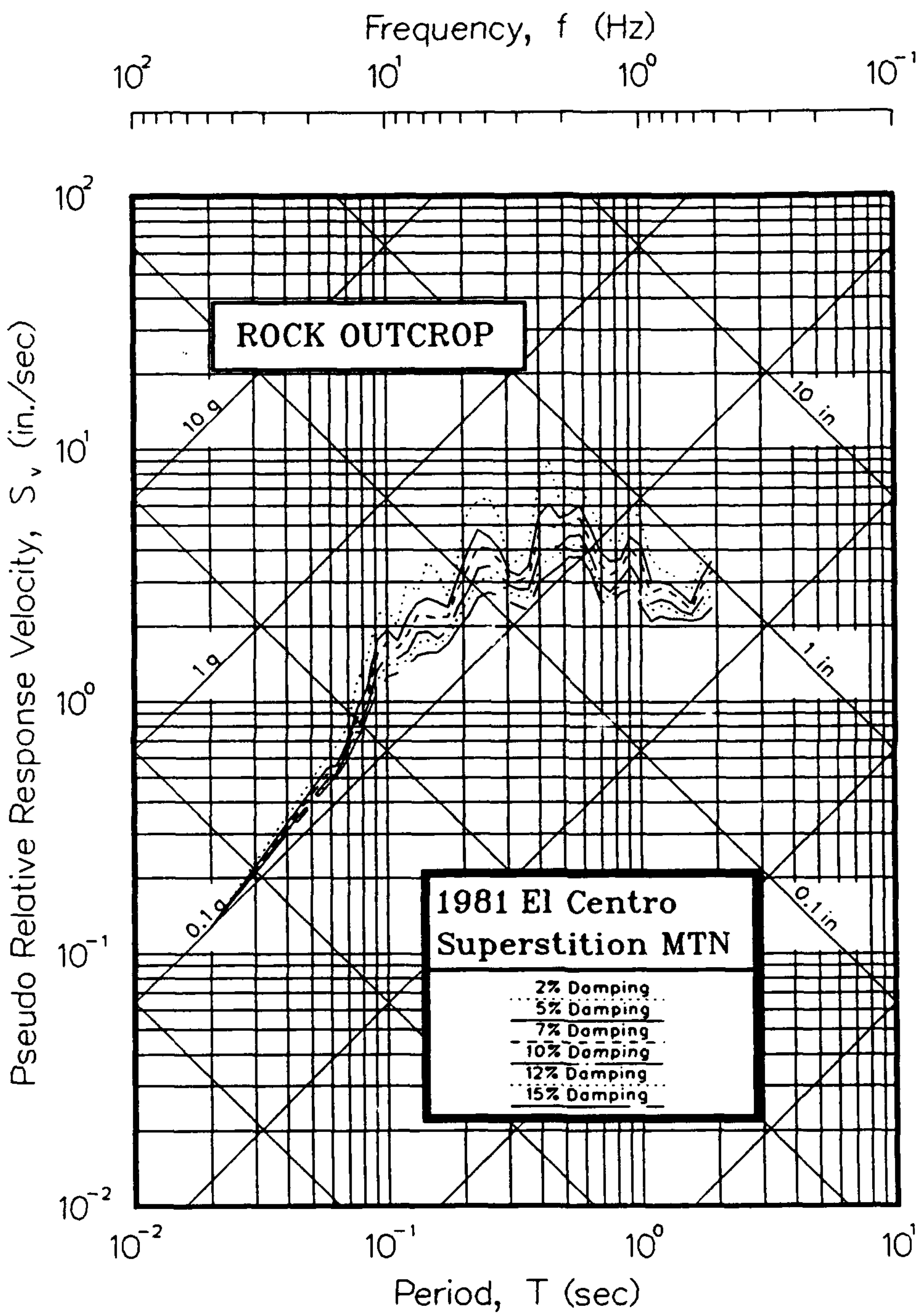

Figure C18. Tripartite presentation of pseudo-velocity spectra for Superstition Mountain record of 1981 El Centro, California, earthquake

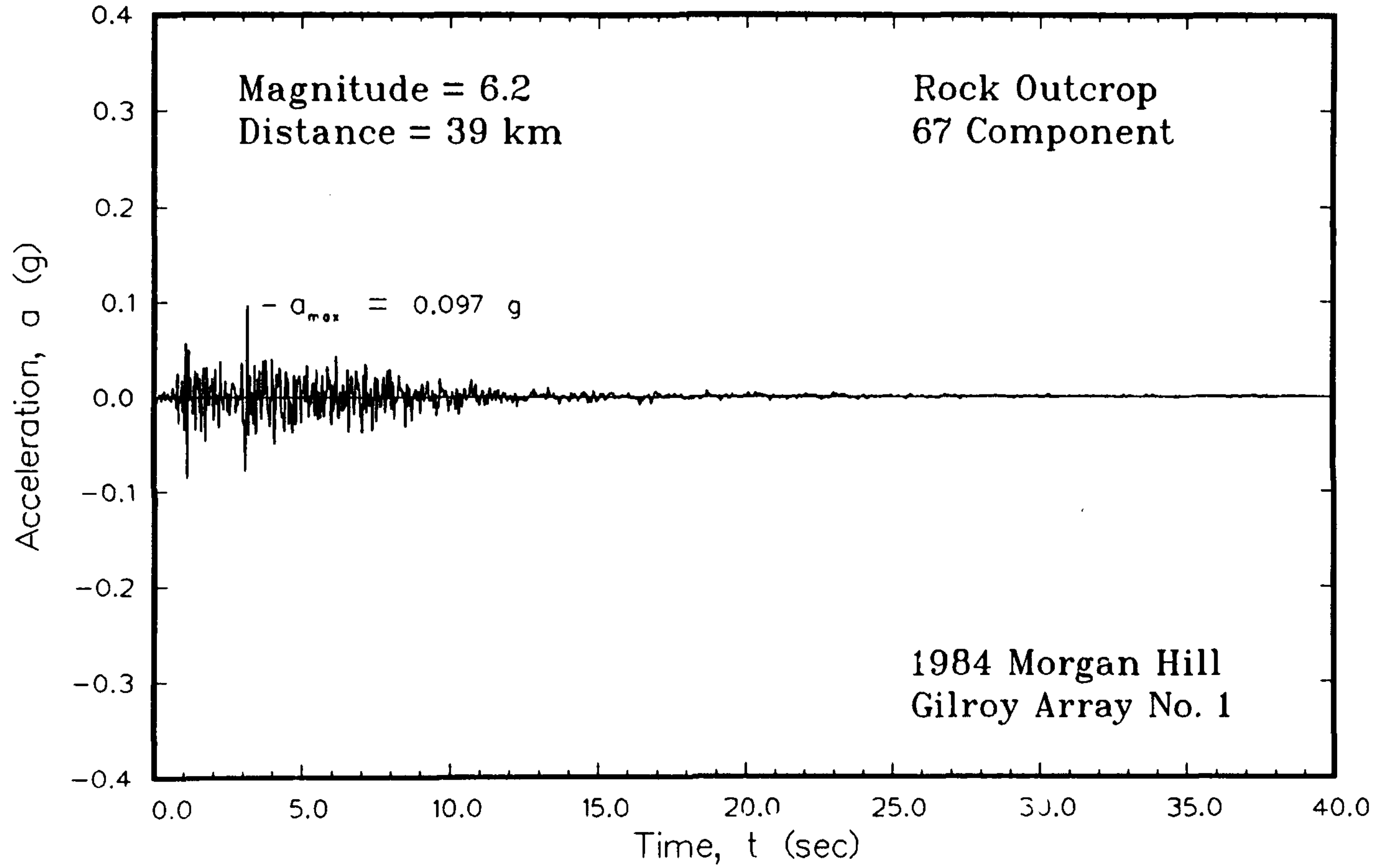

Figure C19. Gilroy No. 1 record of 1984 Morgan Hill, California, earthquake

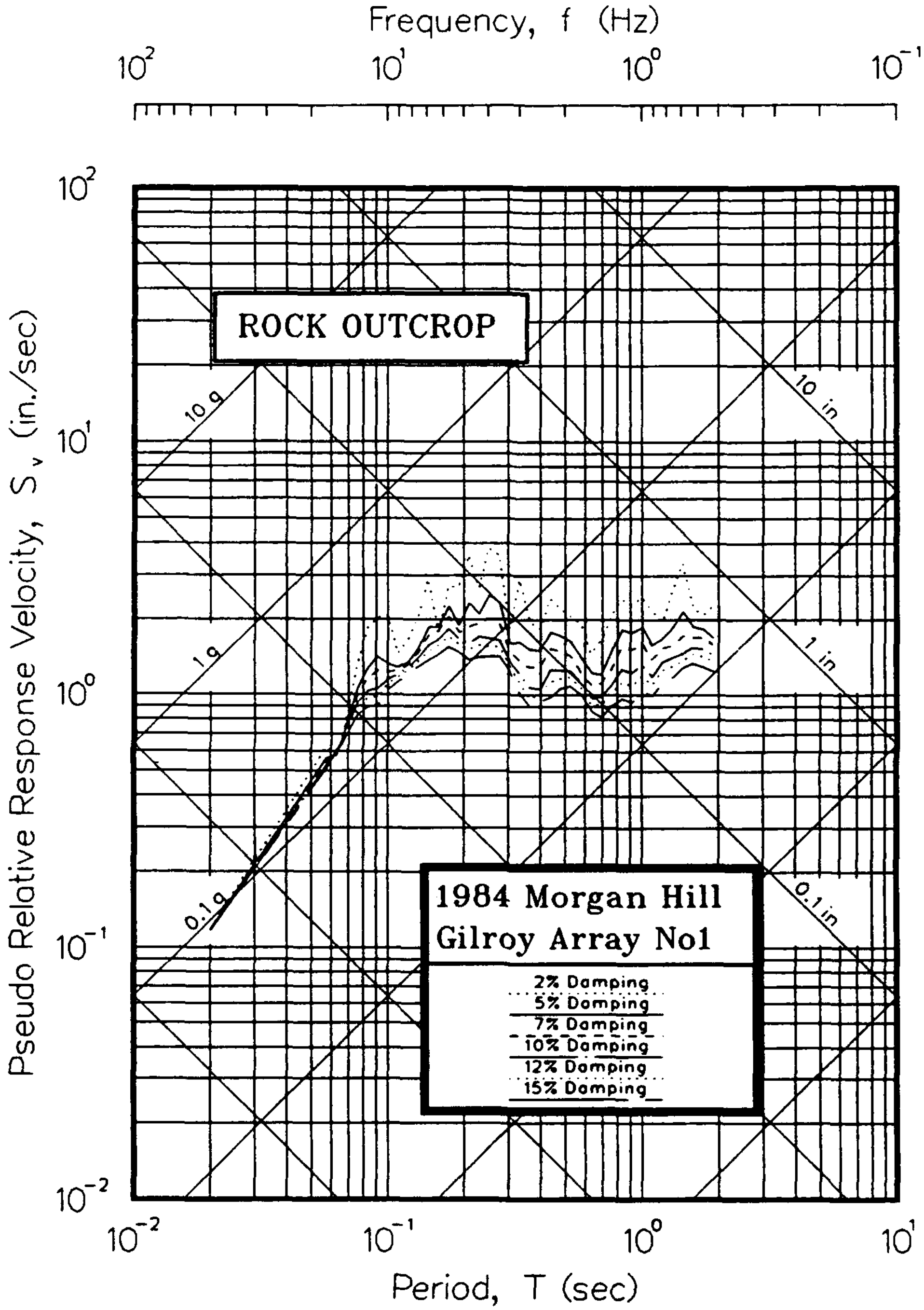

Figure C20. Tripartite presentation of pseudo-velocity spectra for Gilroy No. 1 record of 1984 Morgan Hill, California, earthquake

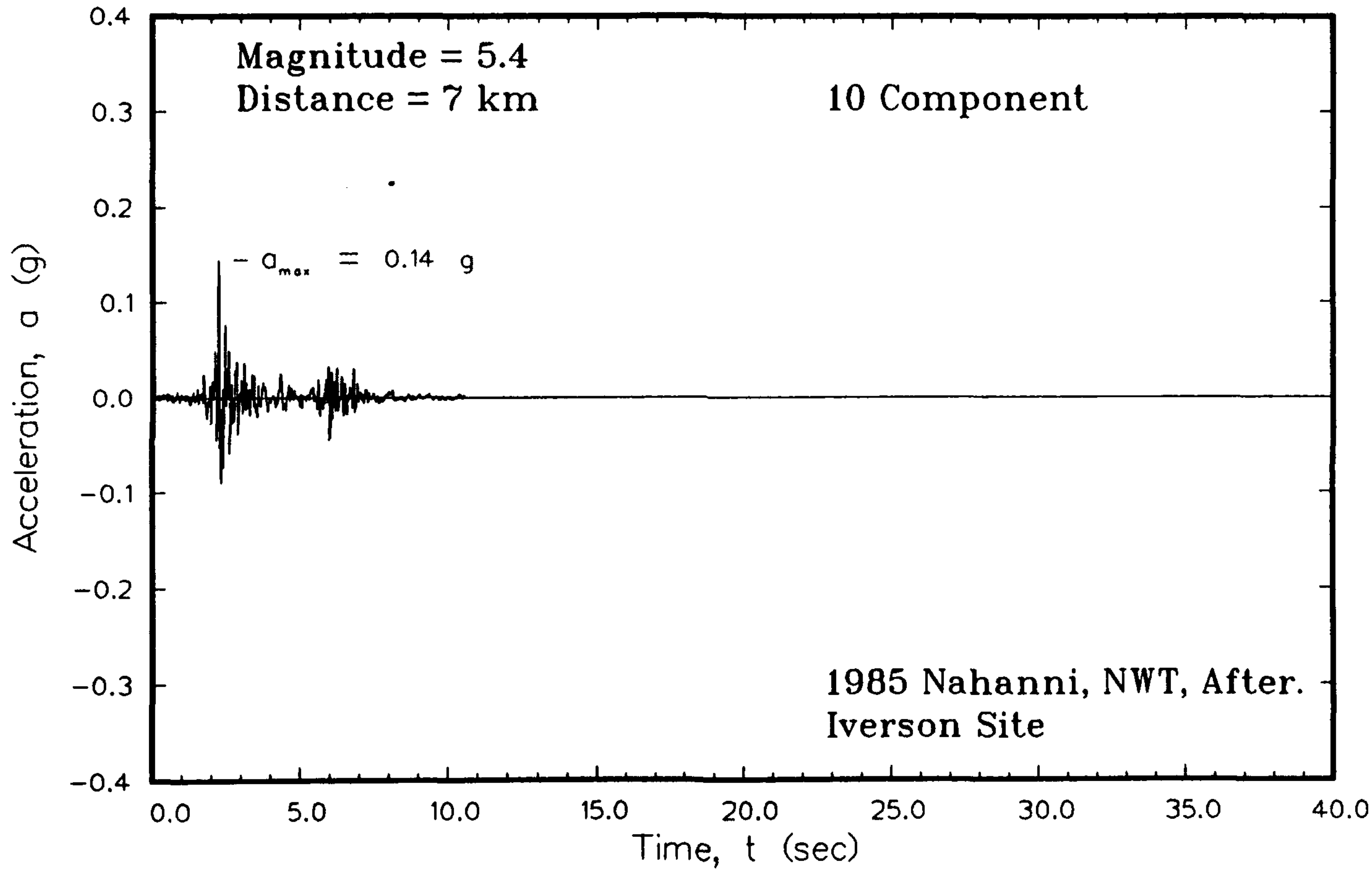

Figure C21. Iverson site record of 1985 Nahanni, Northwest Territories, aftershock

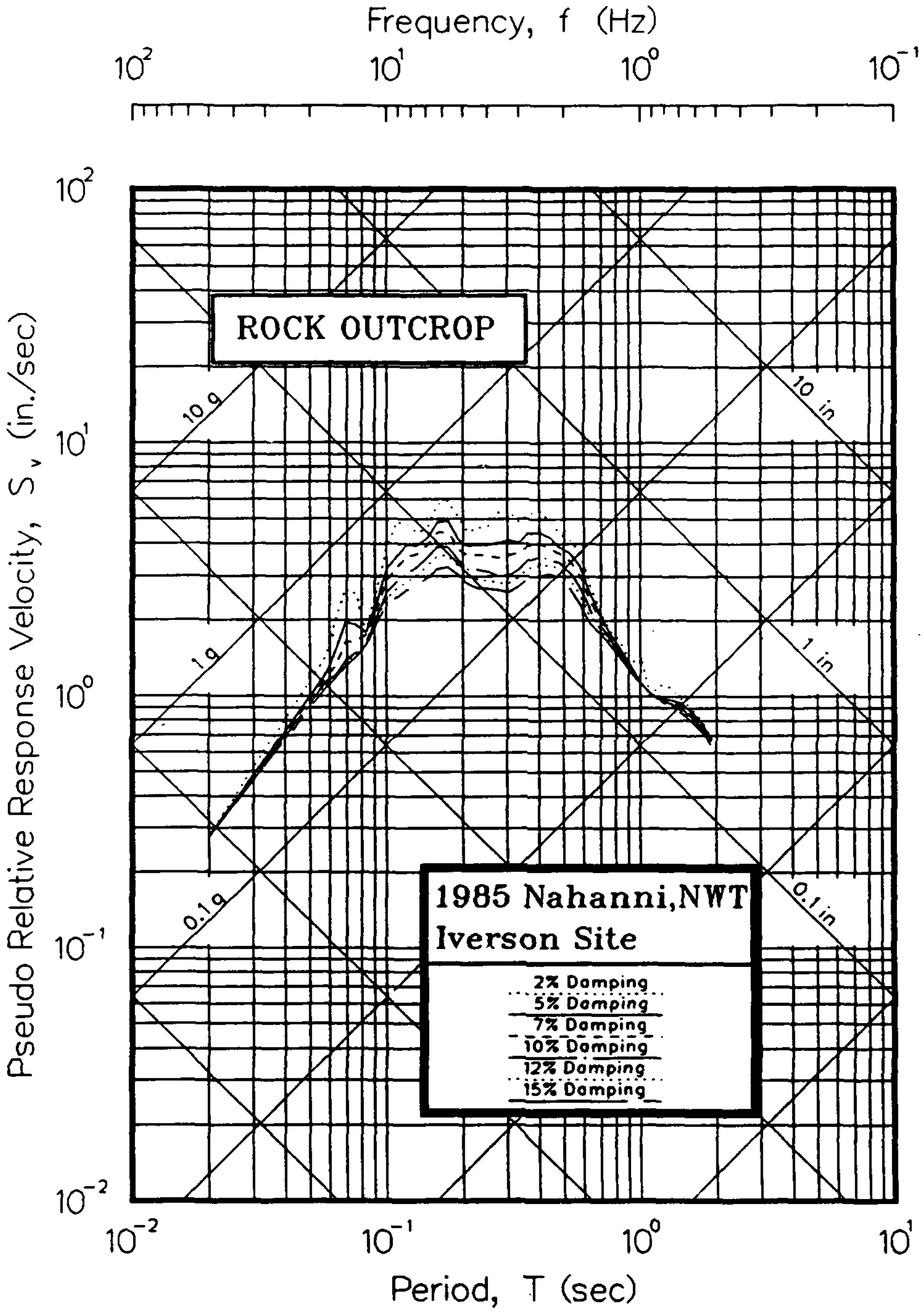

Figure C22. Tripartite presentation of pseudo-velocity spectra for Iverson site record of 1985 Nahanni, Northwest Territories, aftershock

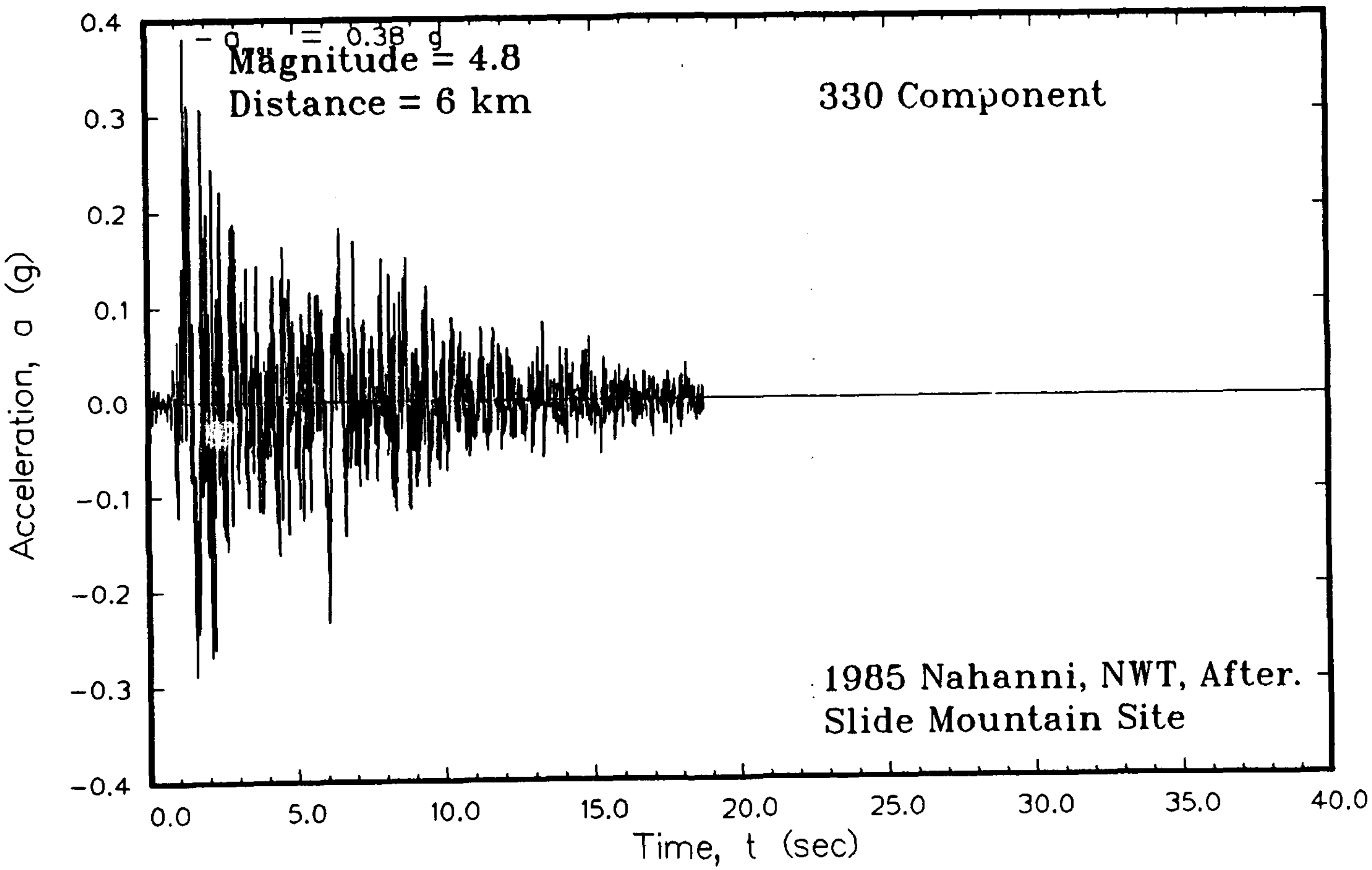

Figure C23. Slide Mountain record of 1985 Nahanni, Northwest Territories, aftershock

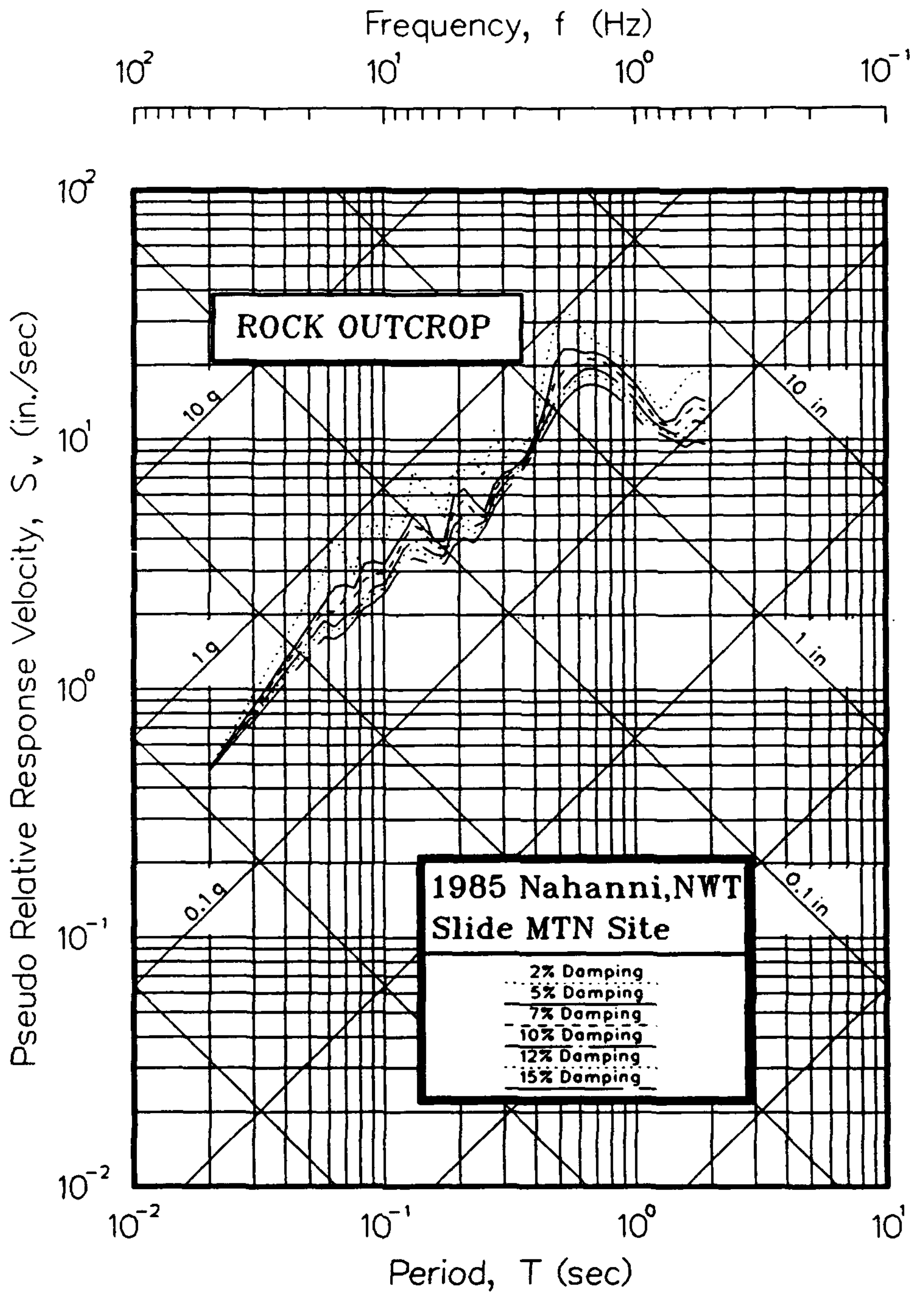

Figure C24. Tripartite presentation of pseudo-velocity spectra for Slide Mountain record of 1985 Nahanni, Northwest Territories, aftershock

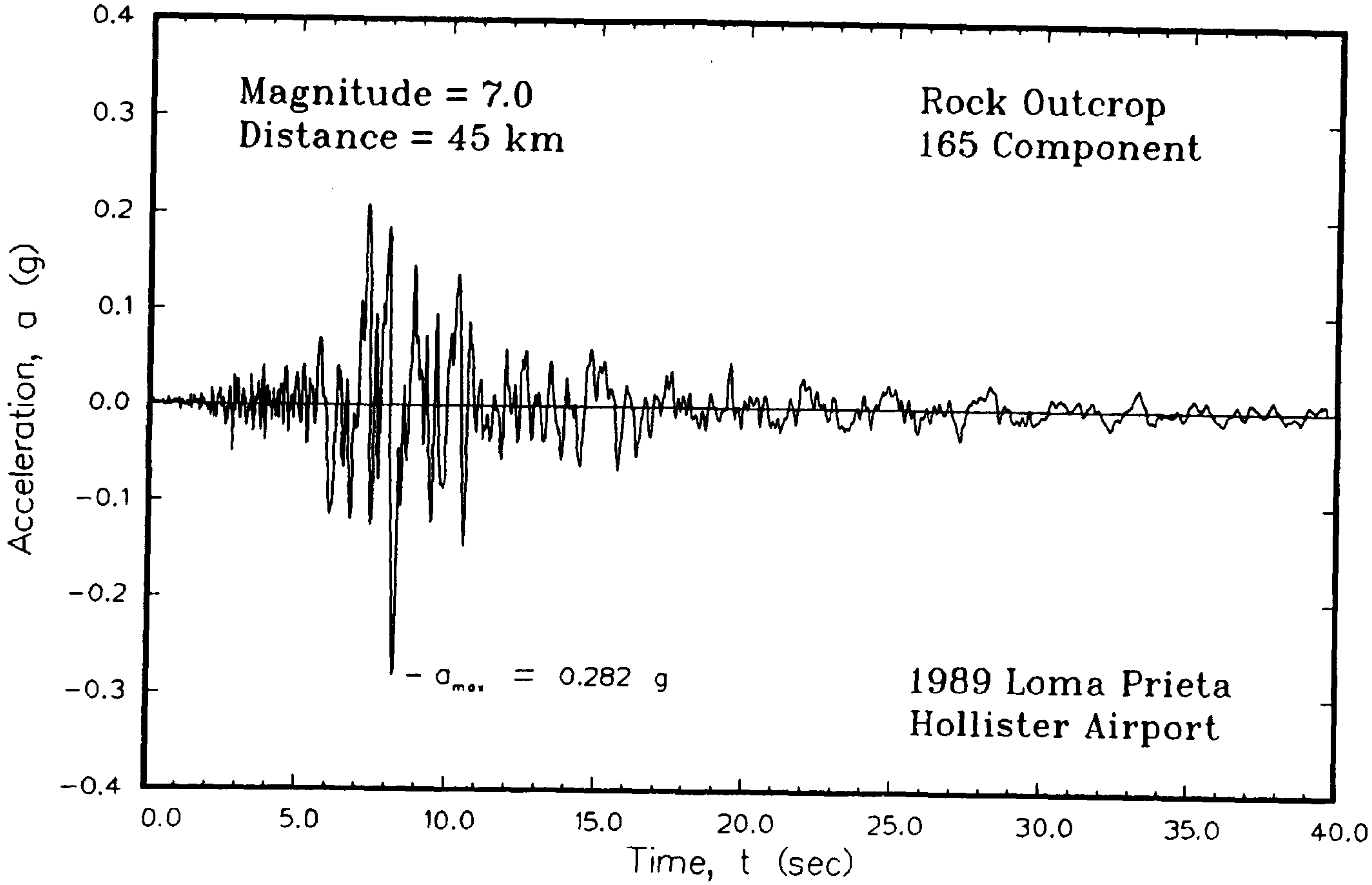

Figure C25. Hollister Airport record of 1989 Loma Prieta, California, earthquake

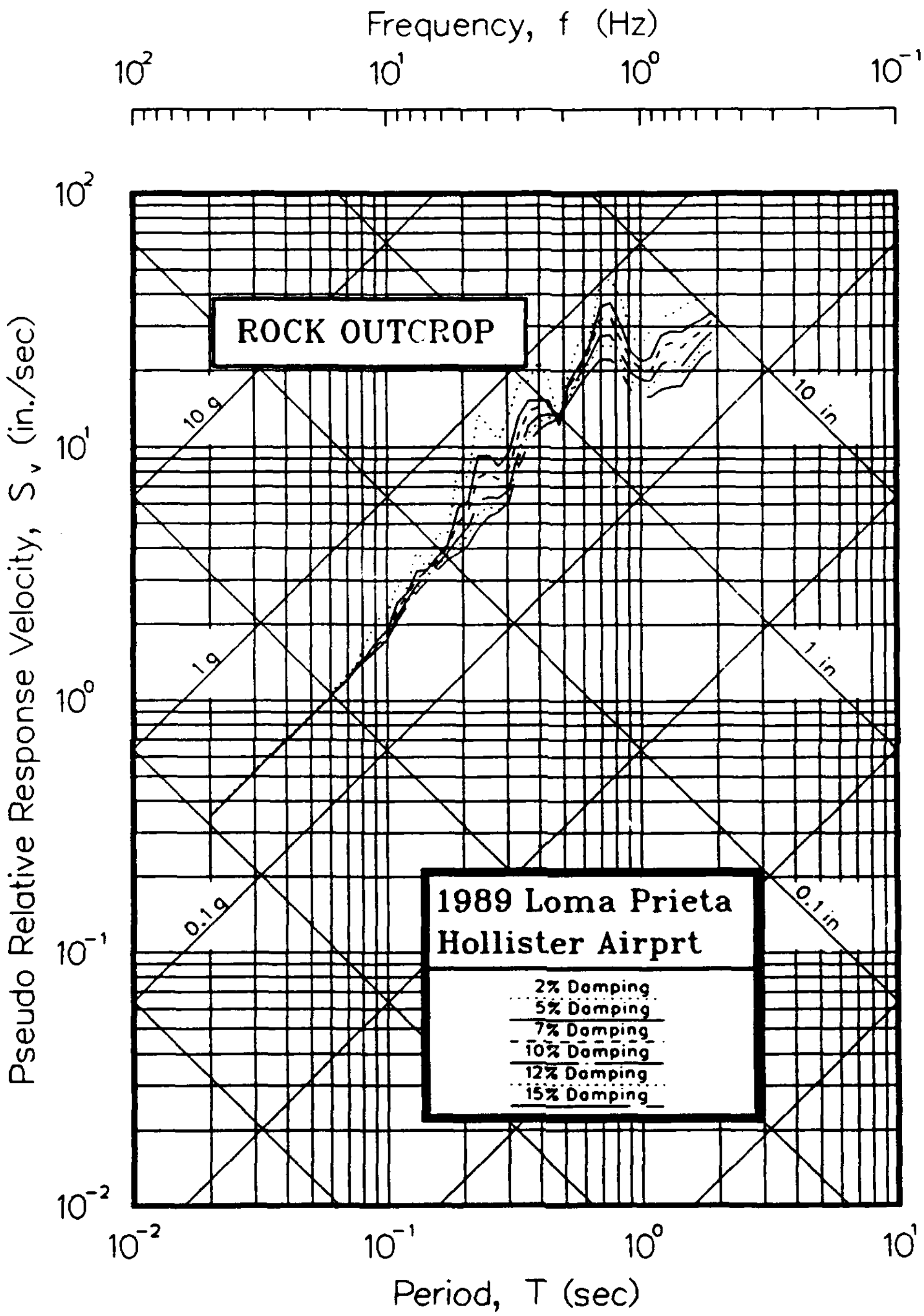

Figure C26. Tripartite presentation of pseudo-velocity spectra for Hollister Airport record of 1989 Loma Prieta, California, earthquake

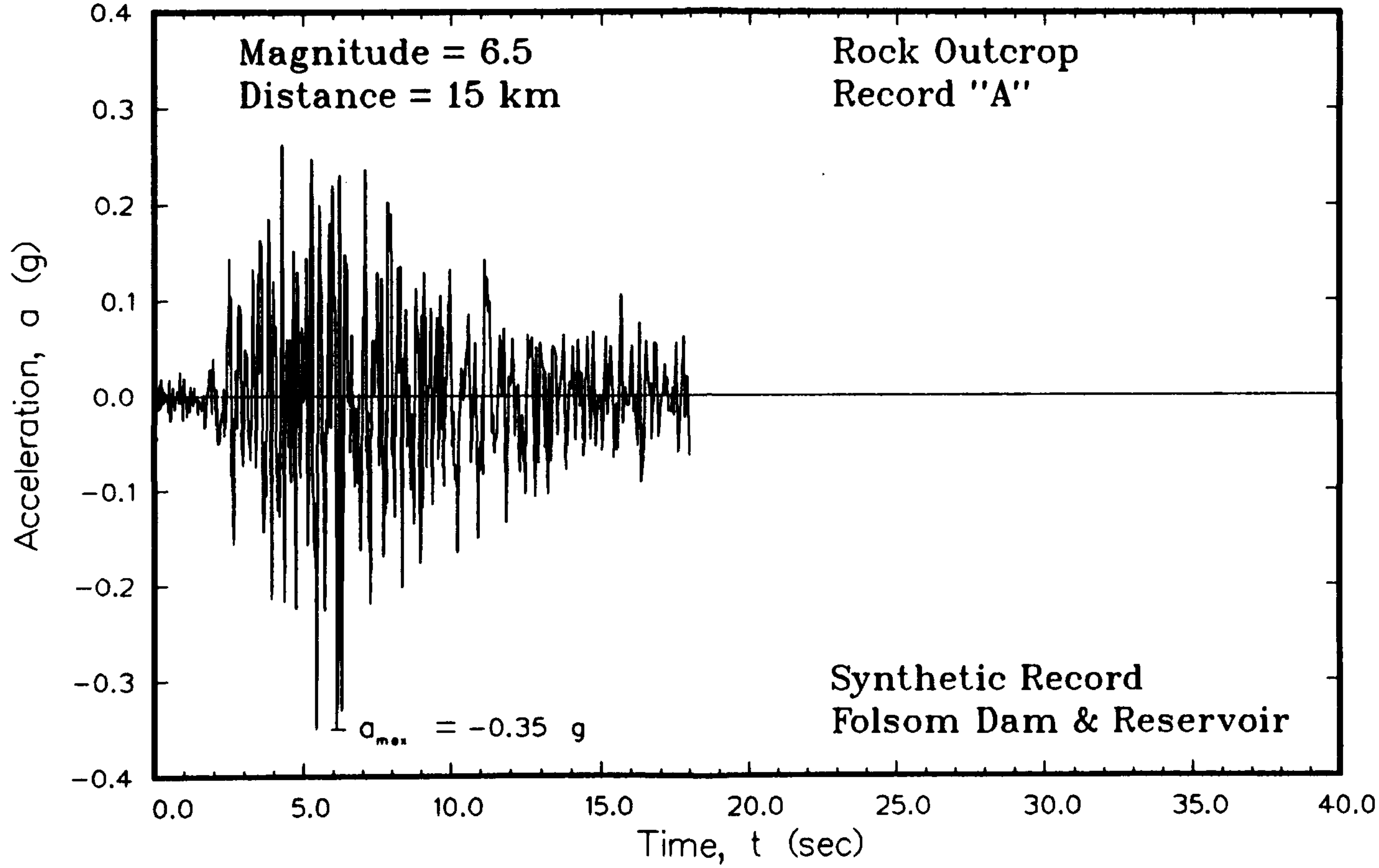

Figure C27. Synthetic MCE "Record A" used for Folsom Dam seismic stability study (Bolt and Seed 1983)

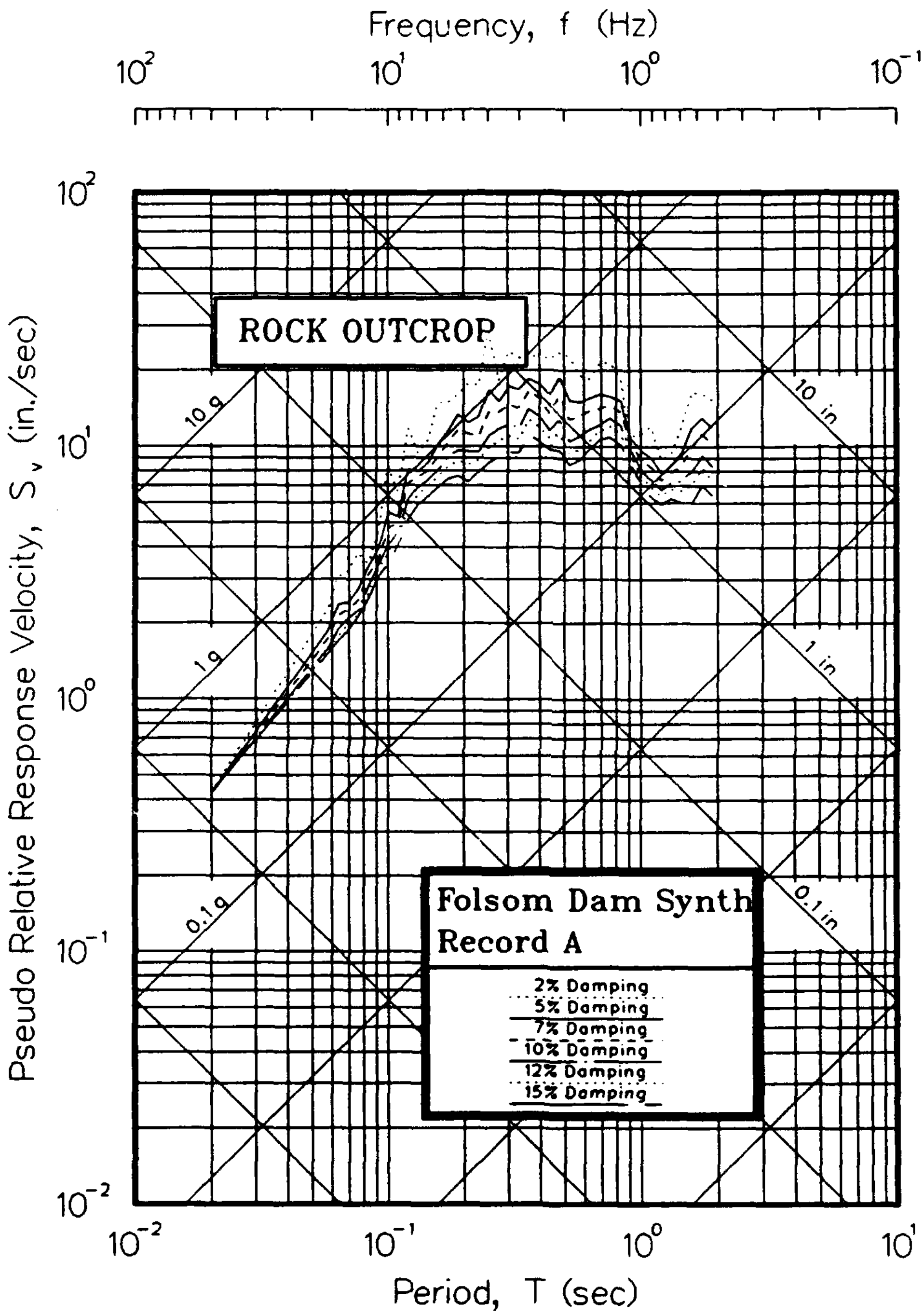

Figure C28. Tripartite presentation of pseudo-velocity spectra for synthetic MCE "Record A" used for Folsom Dam seismic stability study (Bolt and Seed 1983)

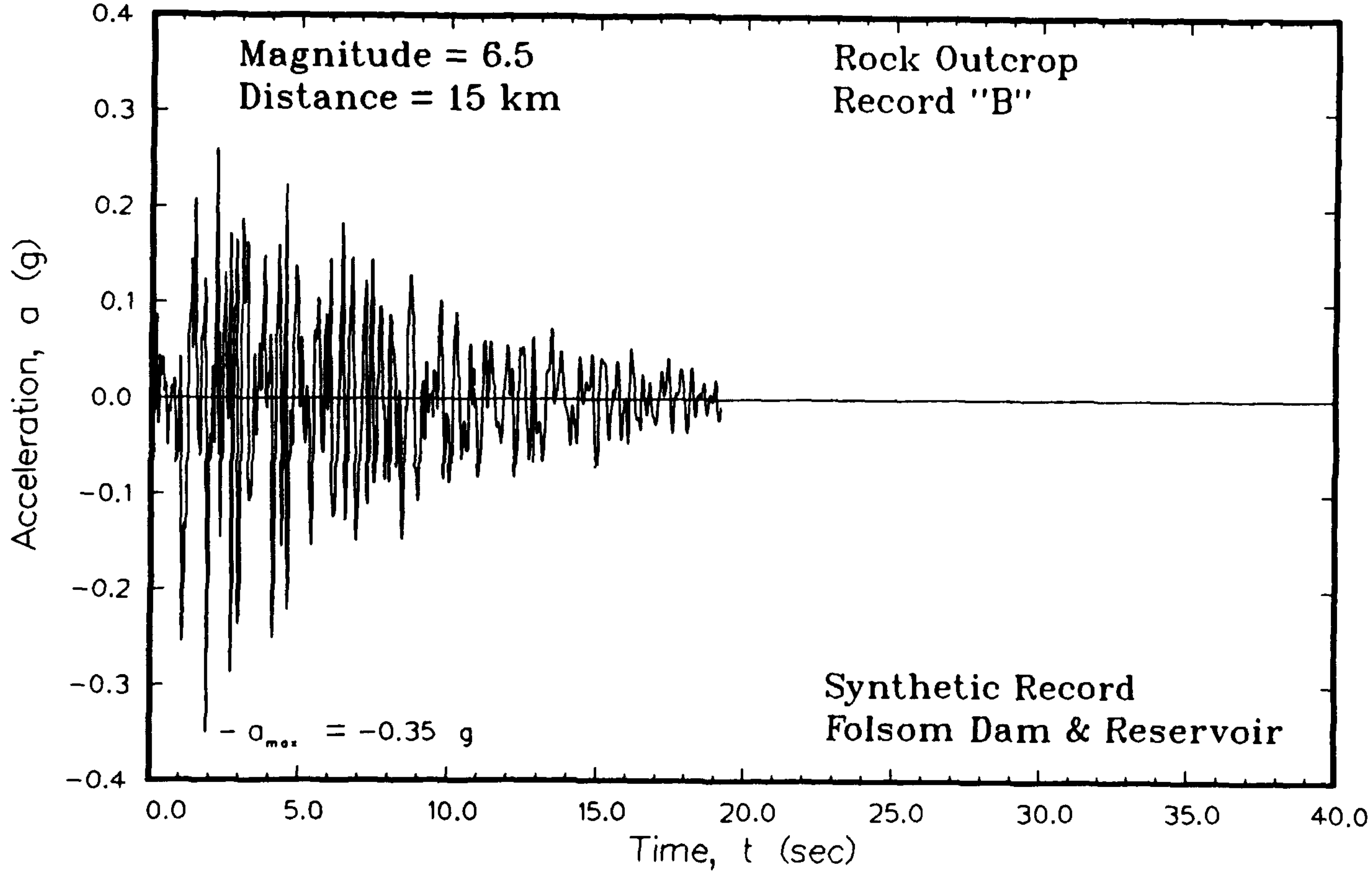

Figure C29. Synthetic MCE "Record B" used for Folsom Dam seismic stability study (Bolt and Seed 1983)

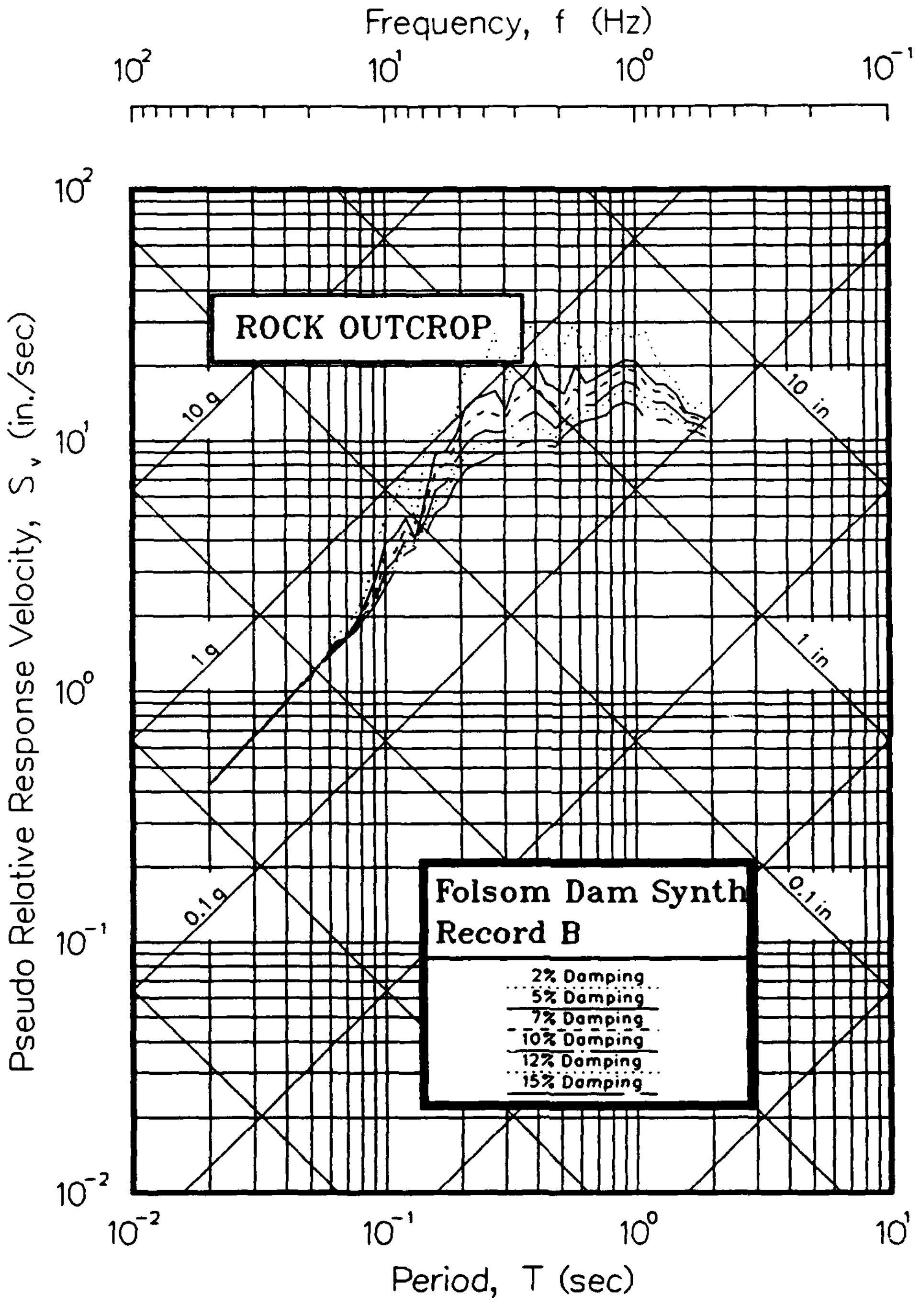

Figure C30. Tripartite presentation of pseudo-velocity spectra for synthetic MCE "Record B" used for Folsom Dam seismic stability study (Bolt and Seed 1983)

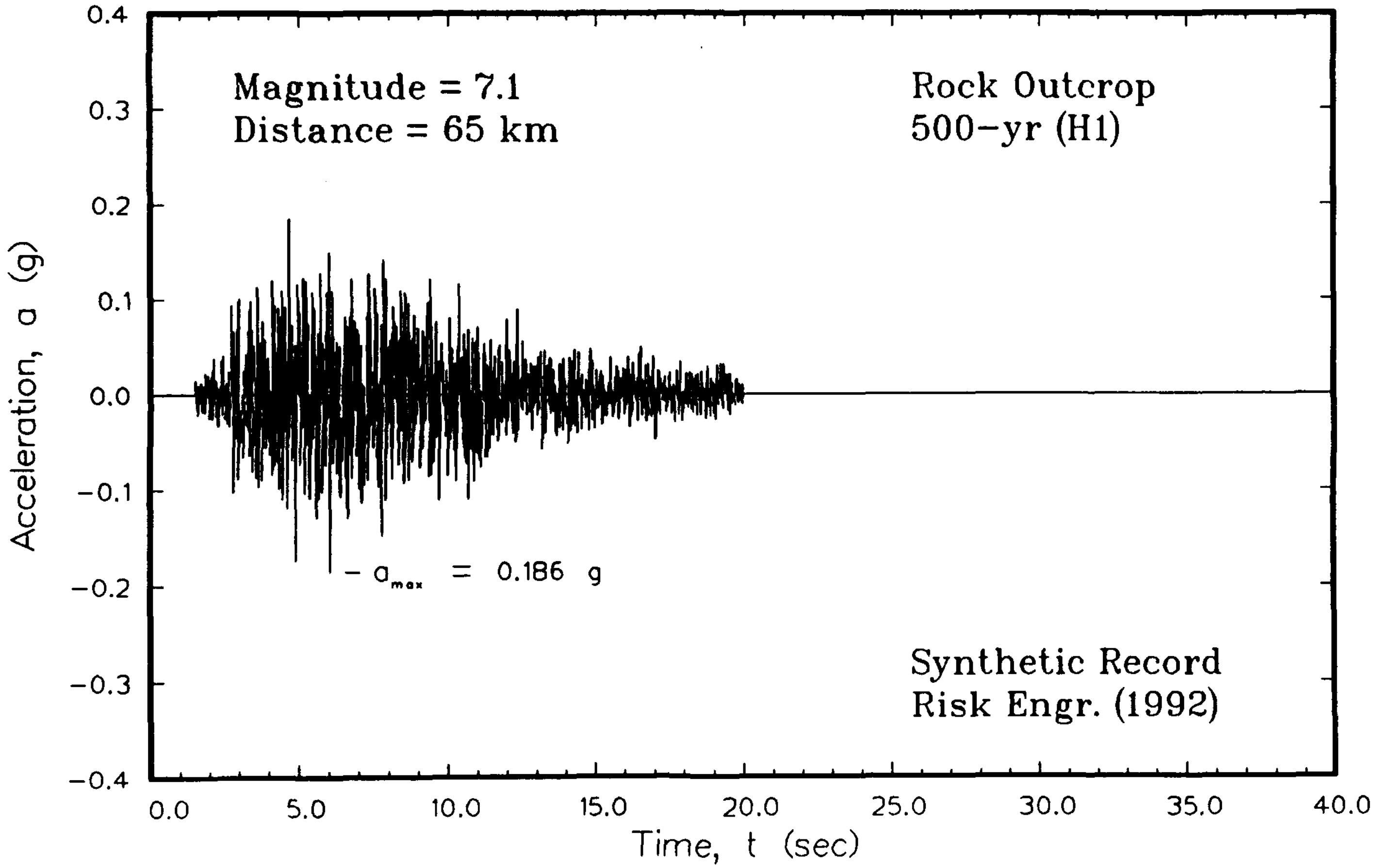

Figure C31. Synthetic 500-year event record, horizontal 1 component, for New Madrid, Missouri, earthquake (Risk Engineering, Inc. 1992)

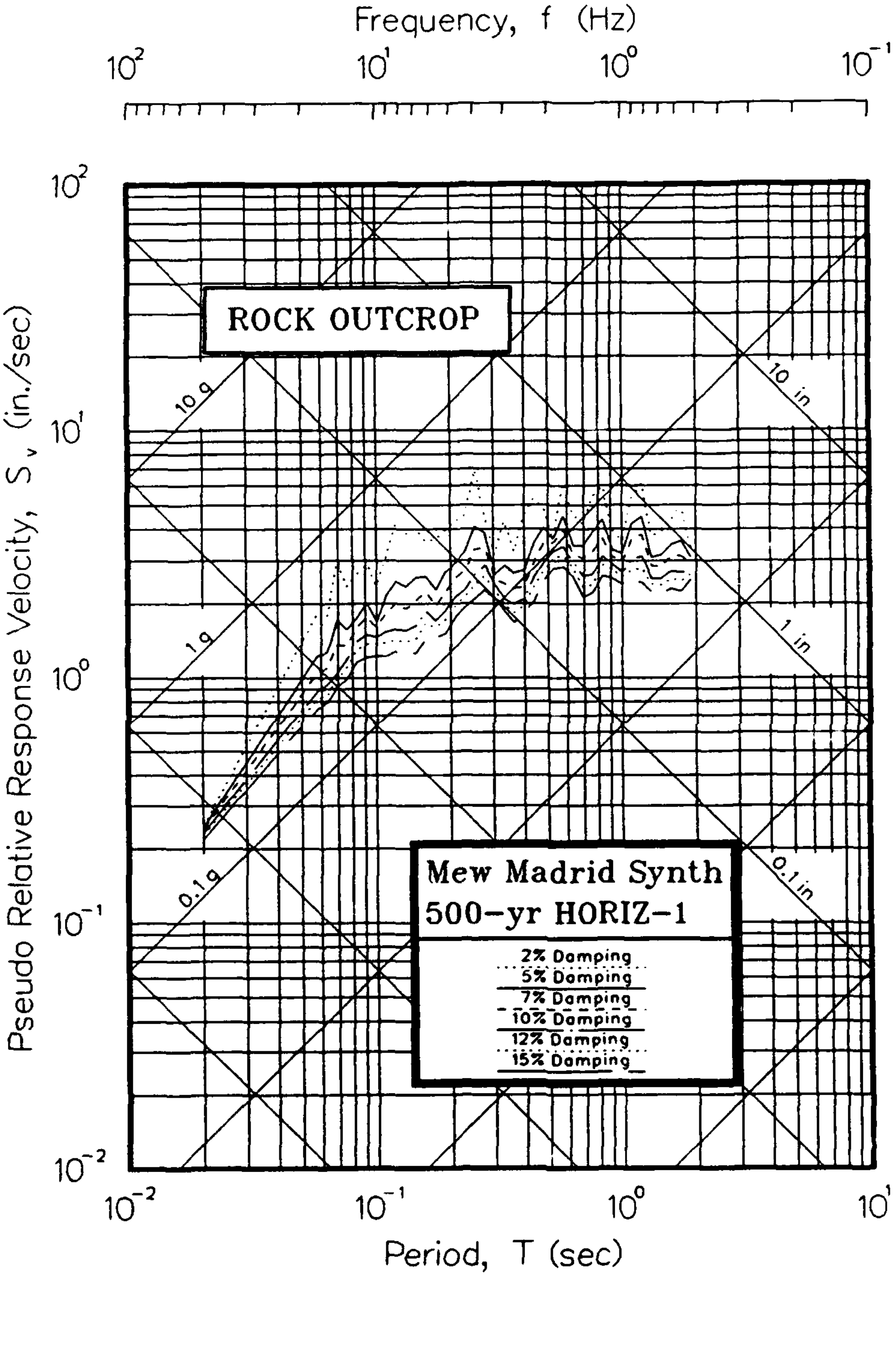

Figure C32. Tripartite presentation of pseudo-velocity spectra for synthetic 500-year event record, horizontal 1 component, for New Madrid, Missouri, earthquake (Risk Engineering, Inc. 1992)

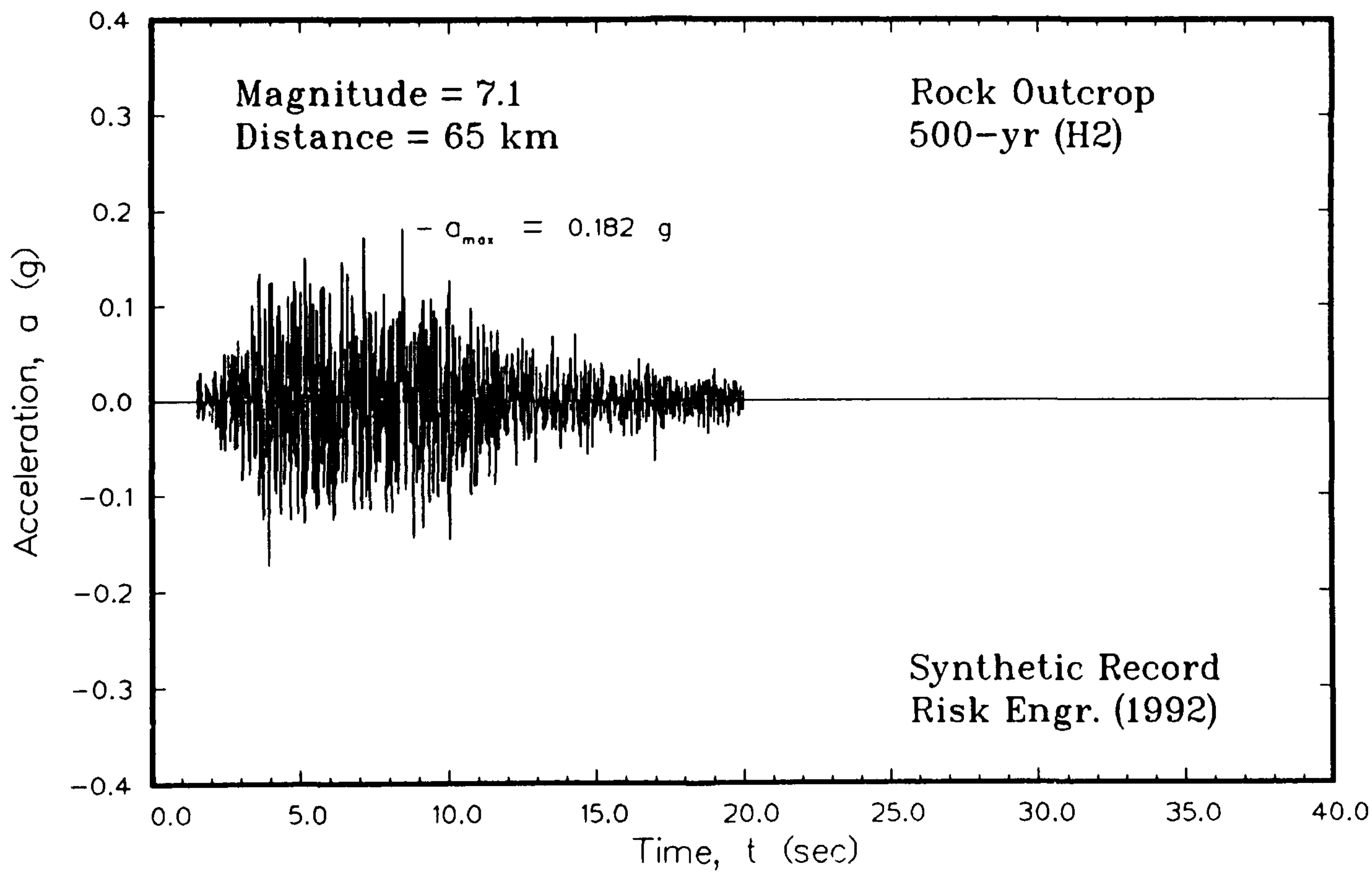

Figure C33. Synthetic 500-year event record, horizontal 2 component, for New Madrid, Missouri, earthquake (Risk Engineering, Inc. 1992)

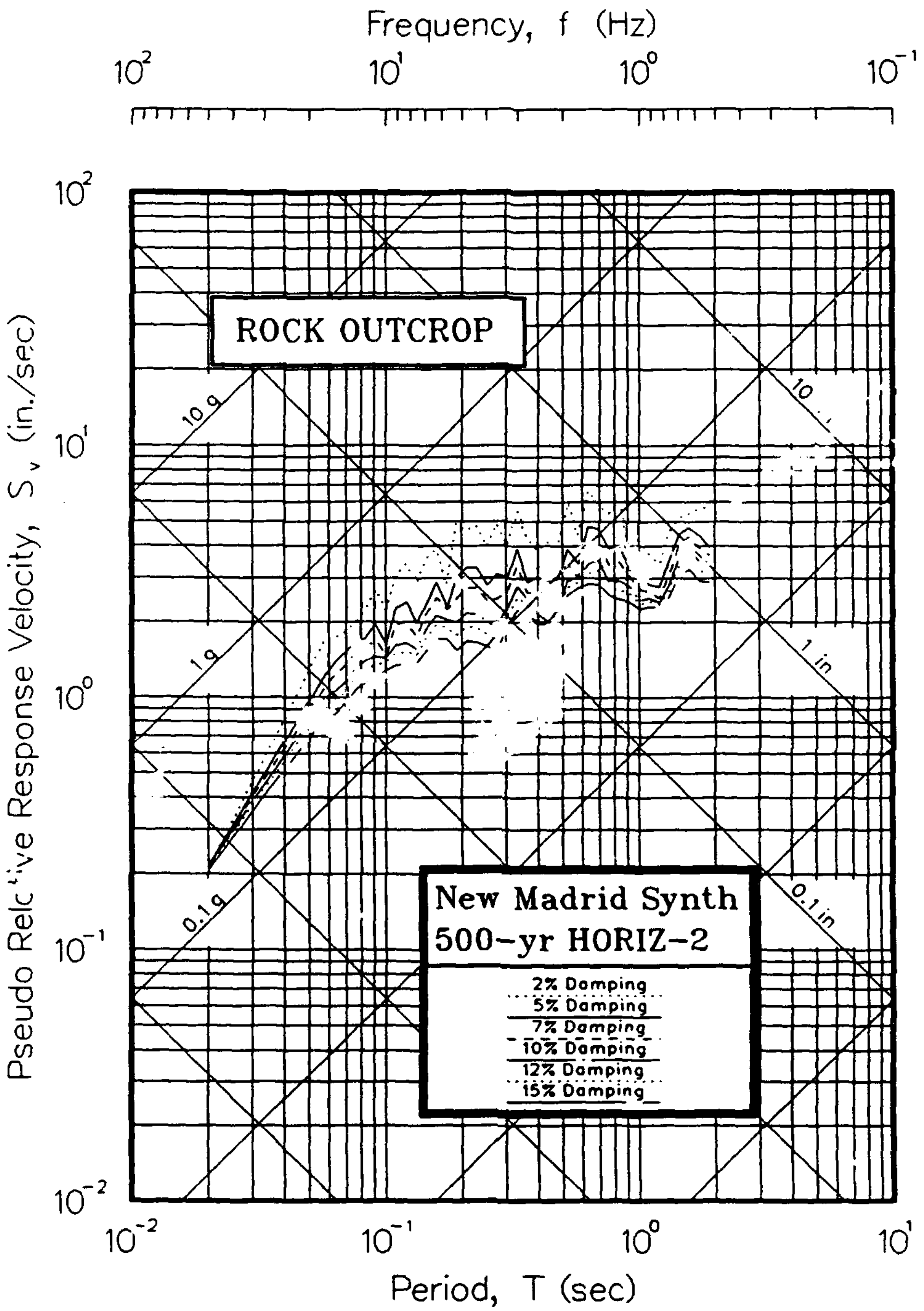

Figure C34. Tripartite presentation of pseudo-velocity spectra for synthetic 500-year event record, horizontal 2 component, for New Madrid, Missouri, earthquake (Risk Engineering, Inc. 1992)

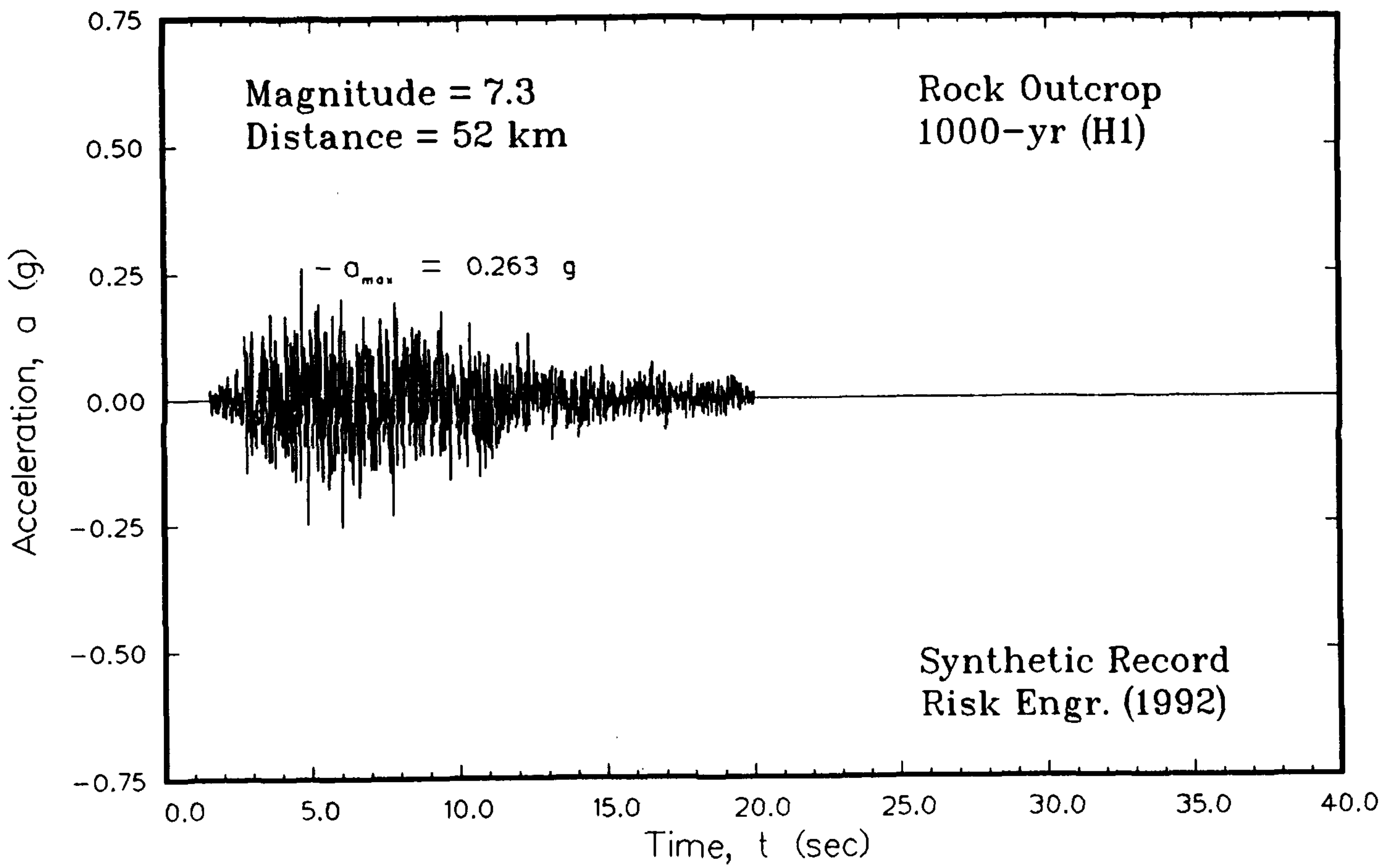

Figure C35. Synthetic 1000-year event record, horizontal 2 component, for New Madrid, Missouri, earthquake (Risk Engineering, Inc. 1992)

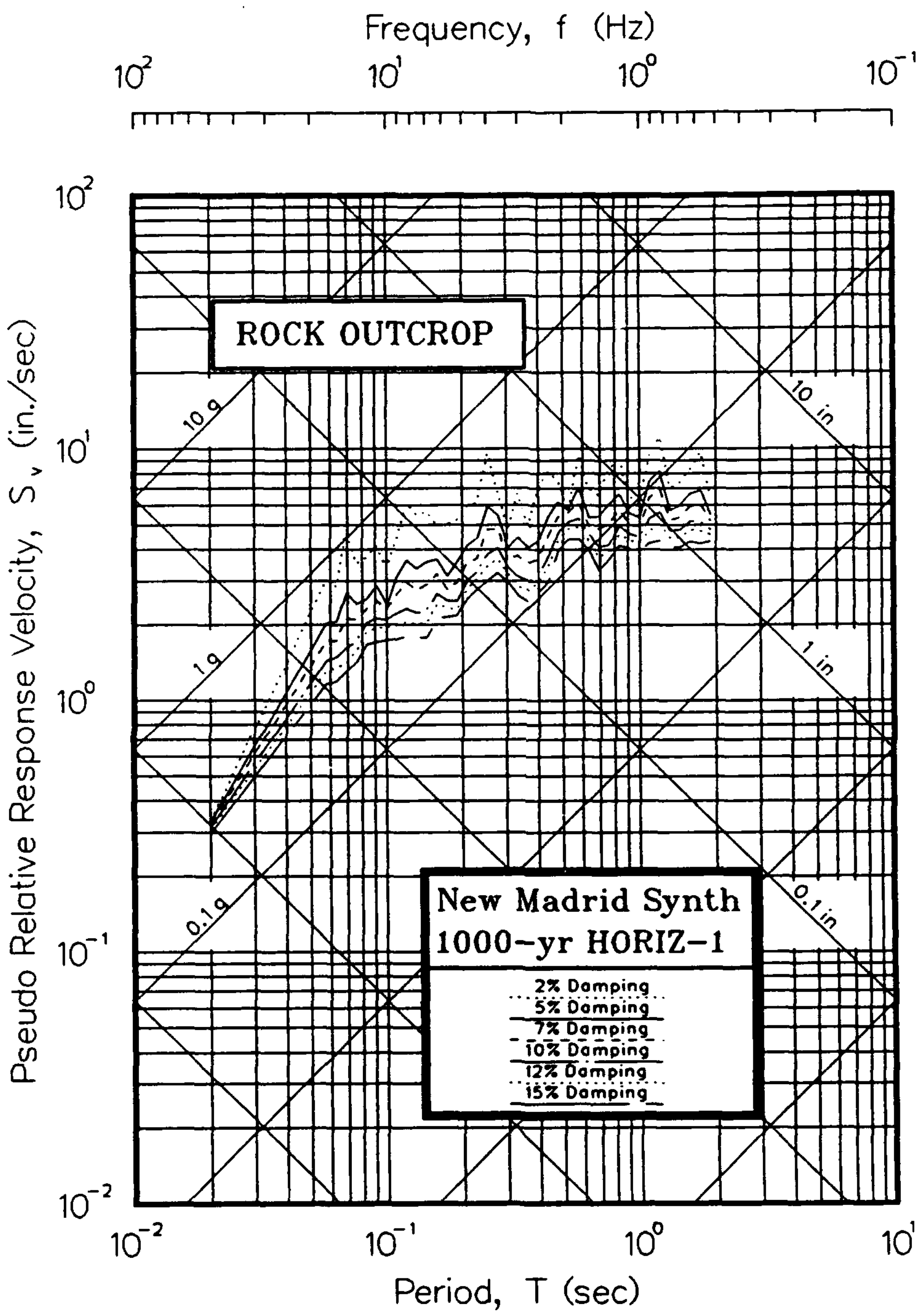

Figure C36. Tripartite presentation of pseudo-velocity spectra for synthetic 1000-year event record, horizontal 1 component, for New Madrid, Missouri, earthquake (Risk Engineering, Inc. 1992)

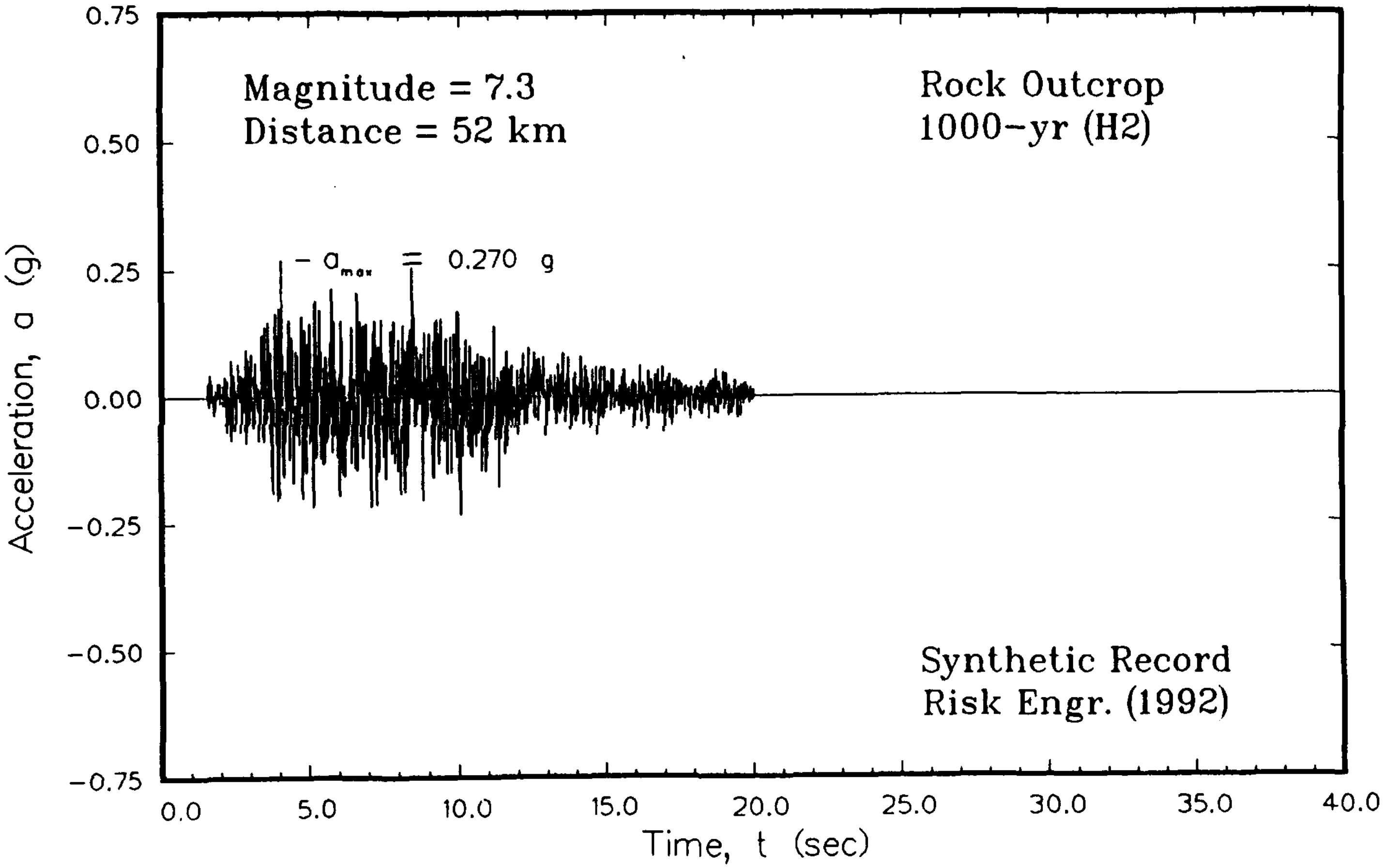

Figure C37. Synthetic 1000-year event record, horizontal 2 component, for New Madrid, Missouri, earthquake (Risk Engineering, Inc. 1992)

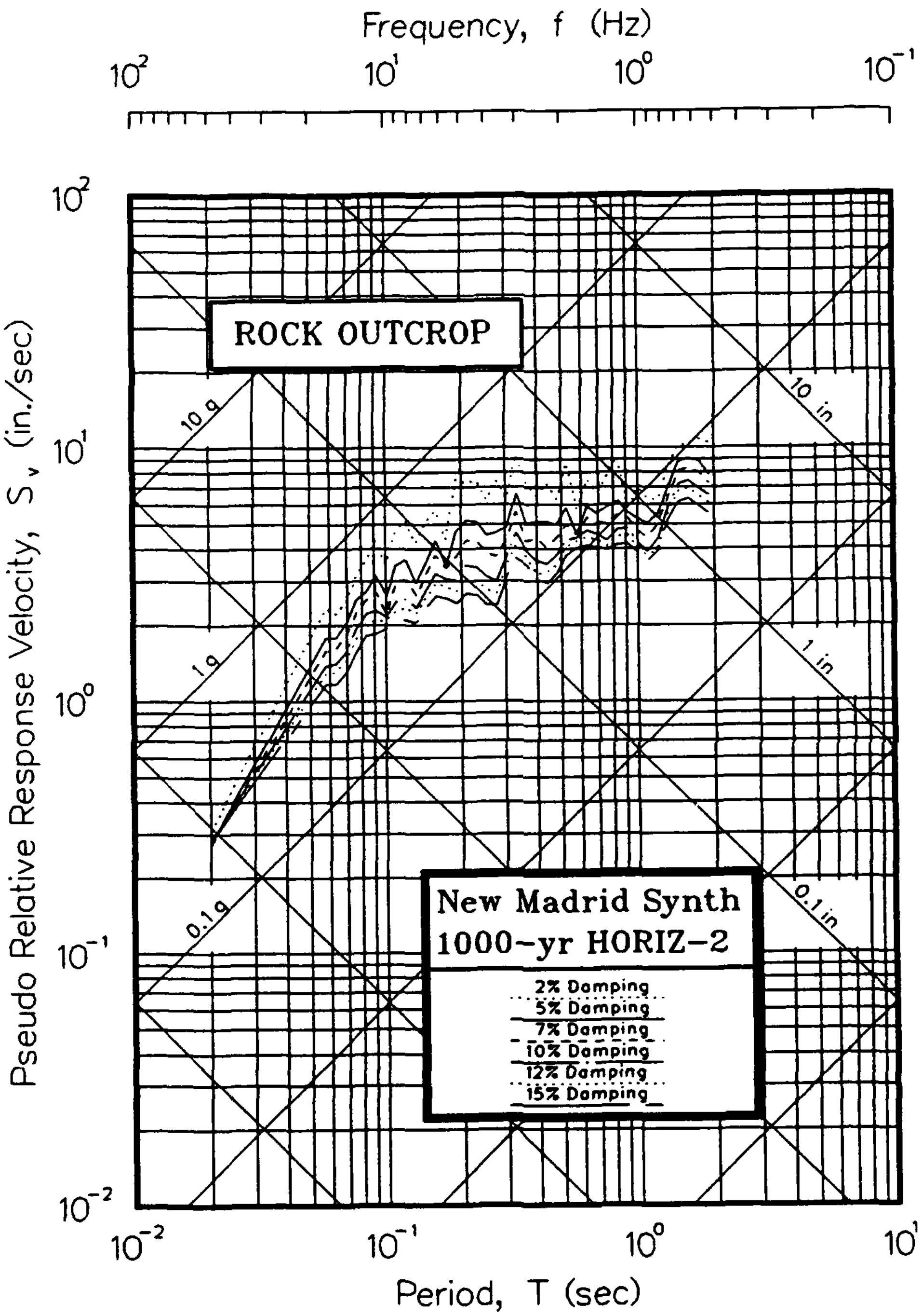

Figure C38. Tripartite presentation of pseudo-velocity spectra for synthetic 1000-year event record, horizontal 2 component, for New Madrid, Missouri, earthquake (Risk Engineering, Inc. 1992)

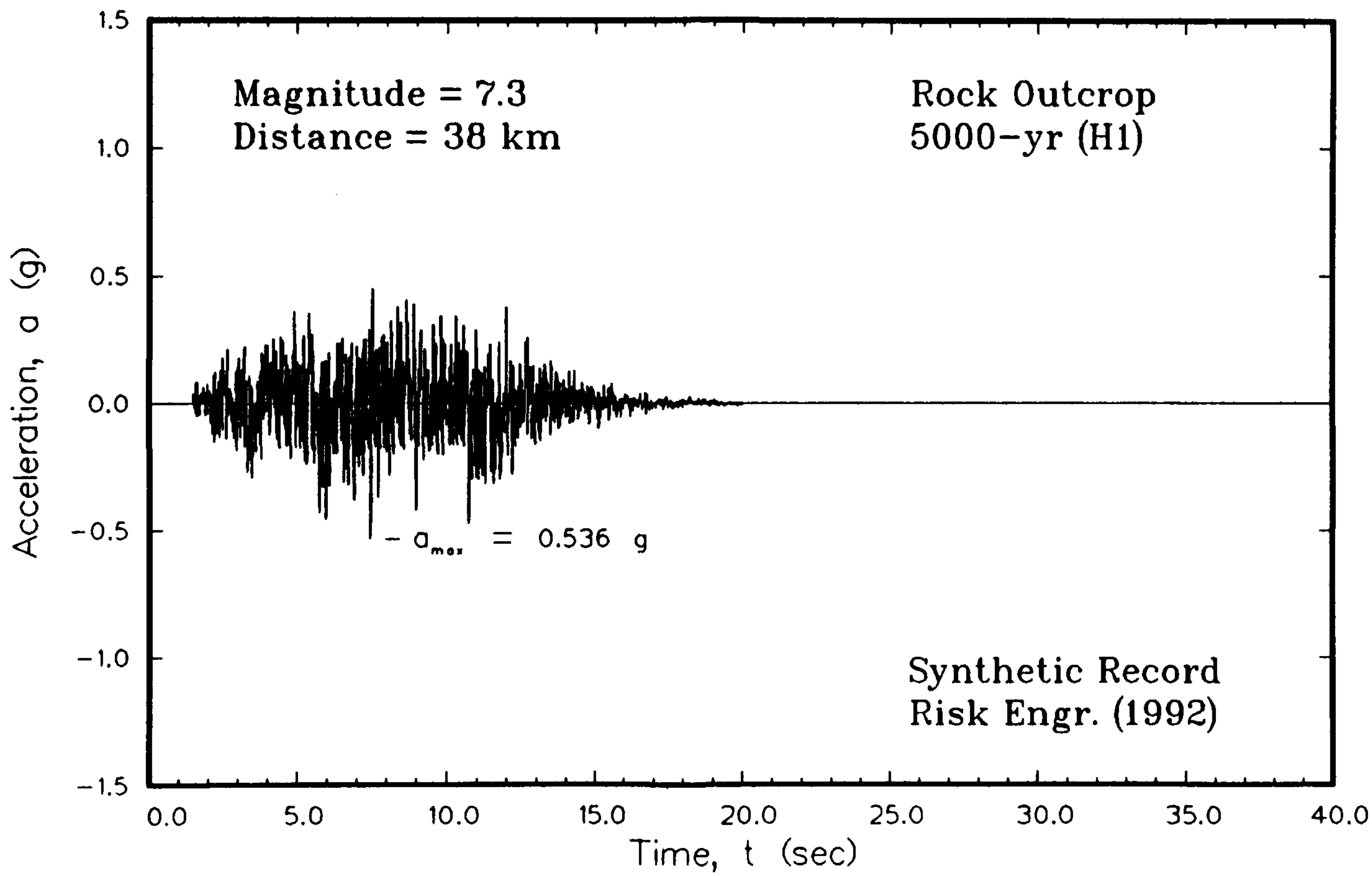

Figure C39. Synthetic 5000-year event record, horizontal 1 component, for New Madrid, Missouri, earthquake (Risk Engineering, Inc. 1992)

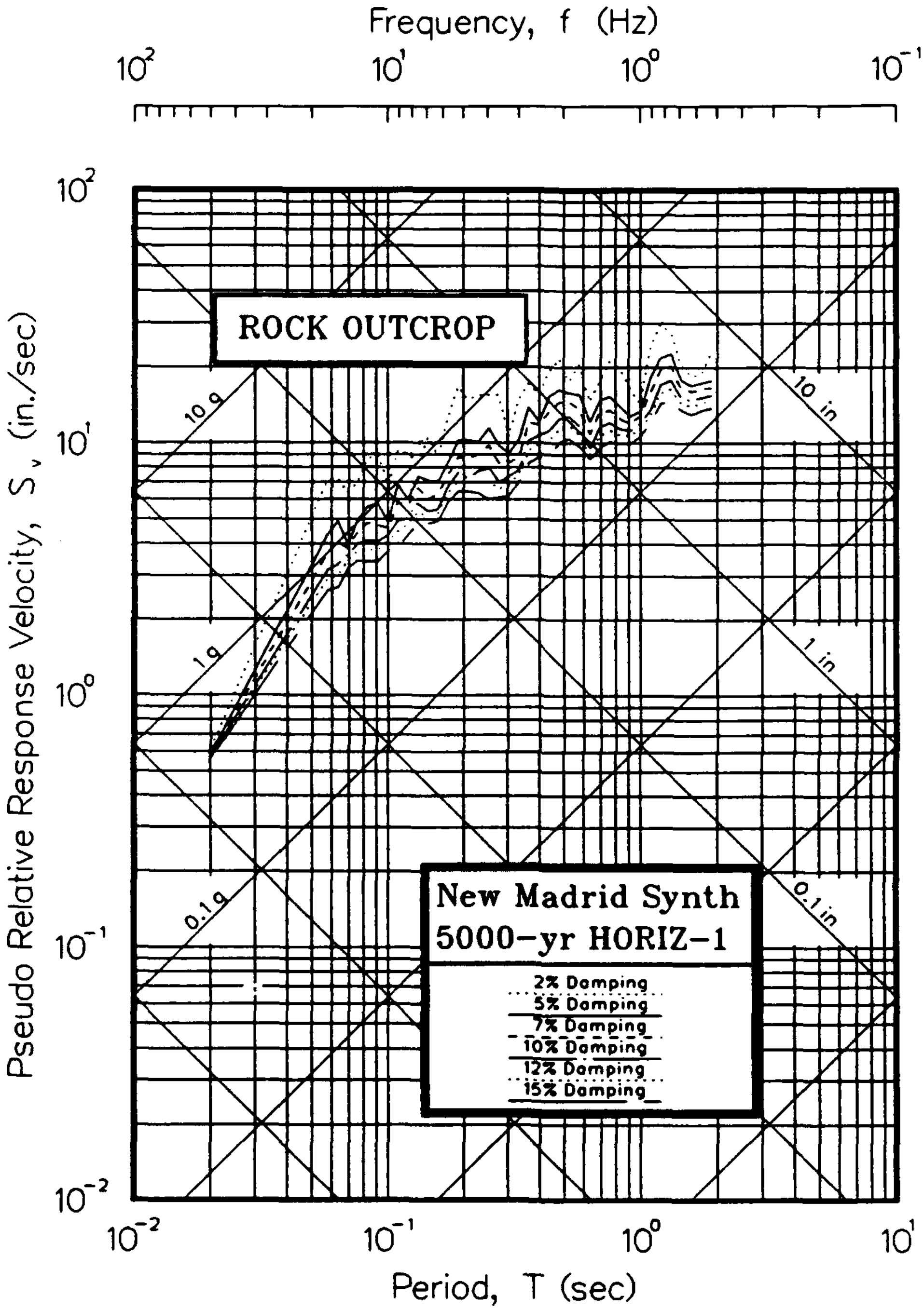

Figure C40. Tripartite presentation of pseudo-velocity spectra for synthetic 5000-year event record, horizontal 1 component, for New Madrid, Missouri, earthquake (Risk Engineering, Inc. 1992)

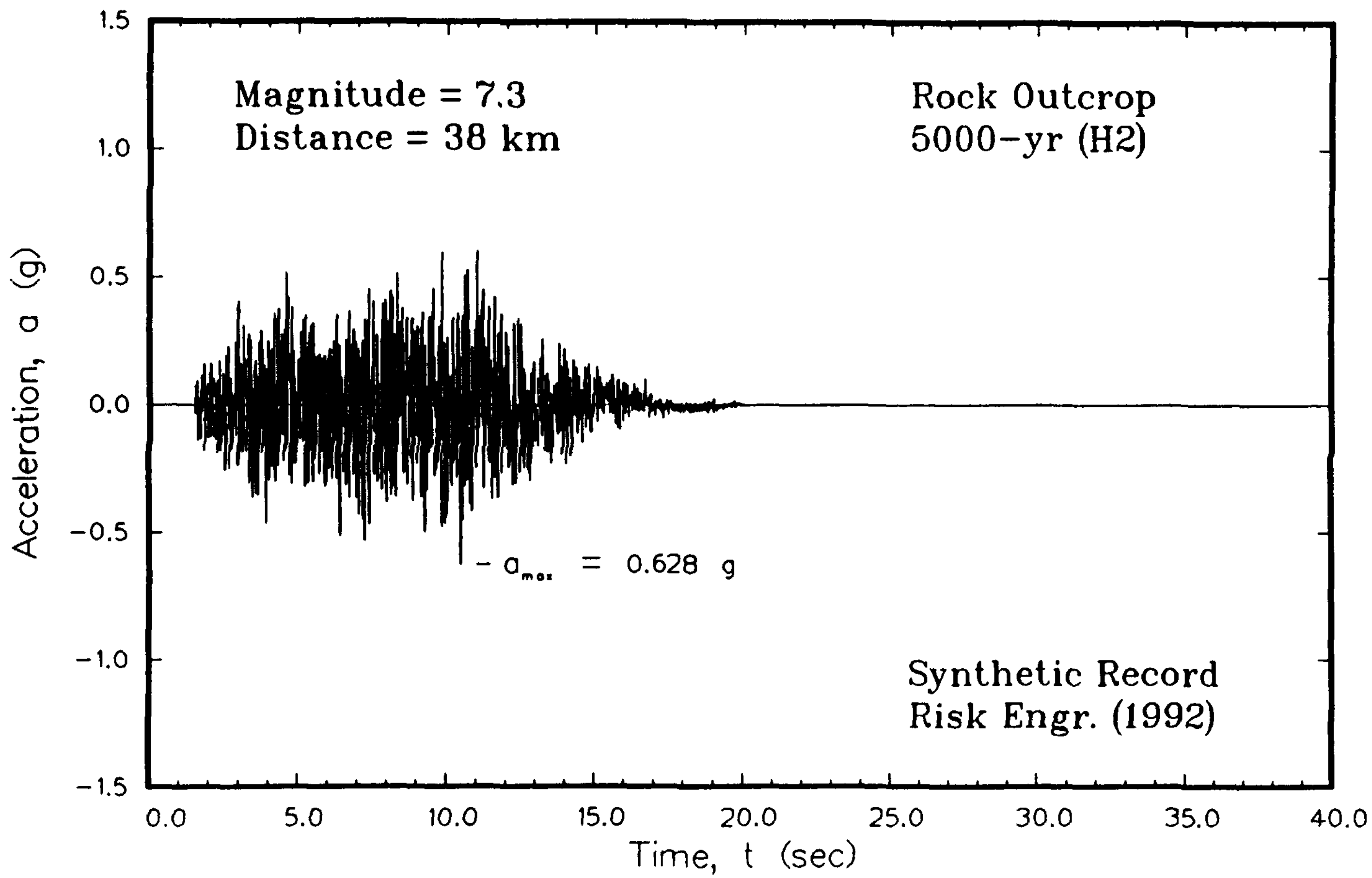

Figure C41. Synthetic 5000-year event record, horizontal 2 component, for New Madrid, Missouri, earthquake (Risk Engineering, Inc. 1992)

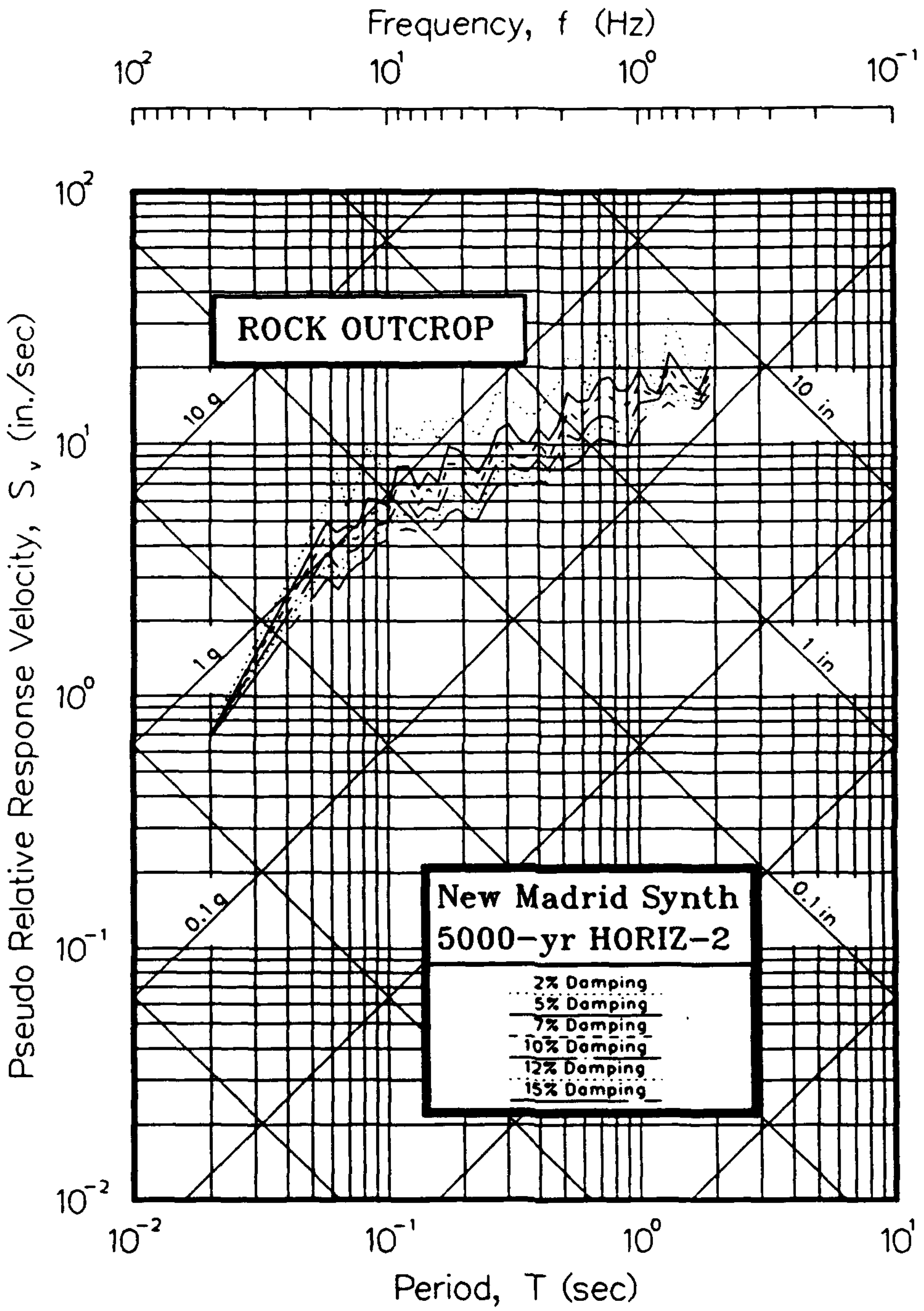

Figure C42. Tripartite presentation of pseudo-velocity spectra for synthetic 5000-year event record, horizontal 2 component, for New Madrid, Missouri, earthquake (Risk Engineering, Inc. 1992)

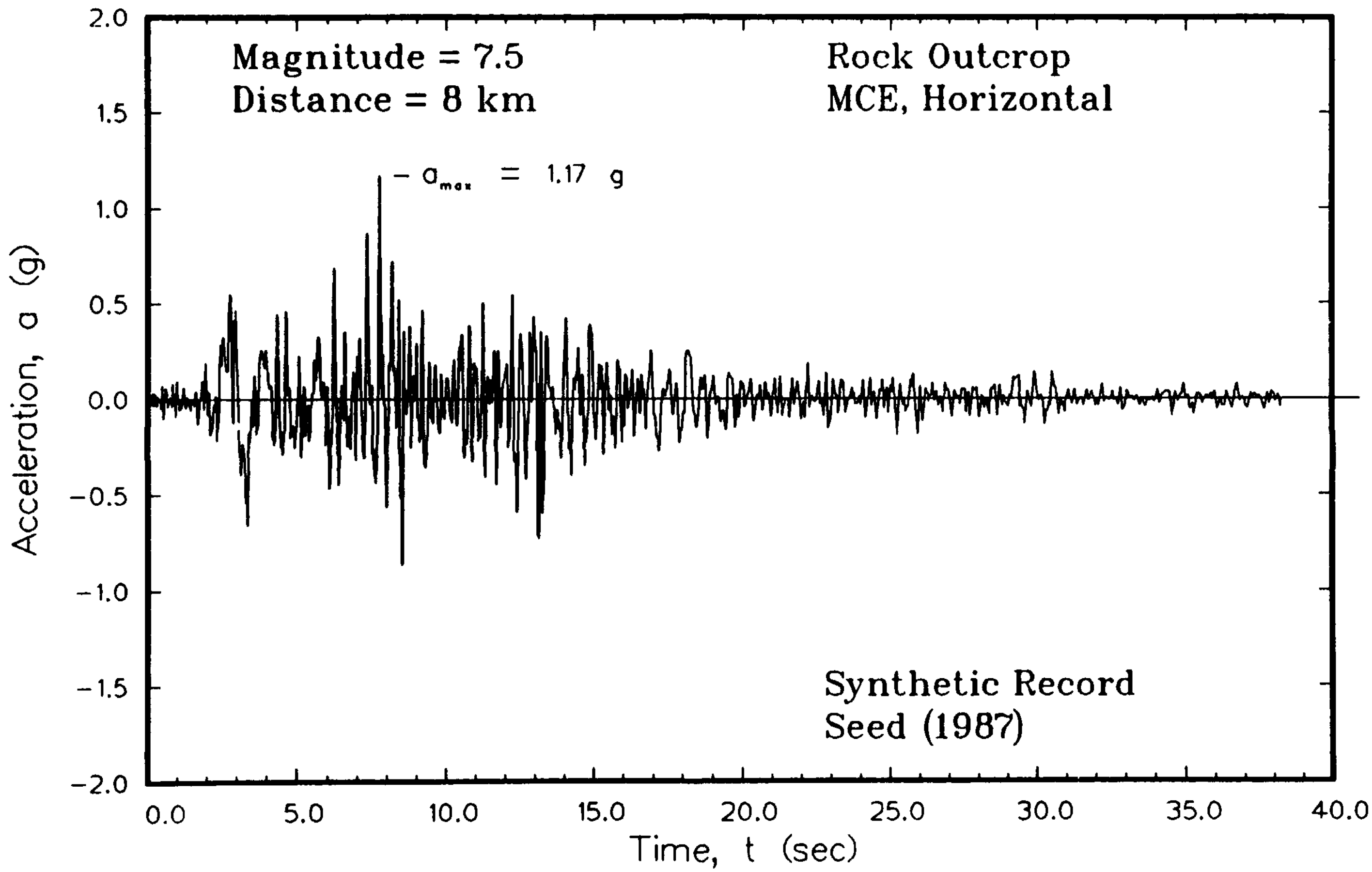

Figure C43. Synthetic MCE record used for Ririe Dam Stability Study (Seed 1987)

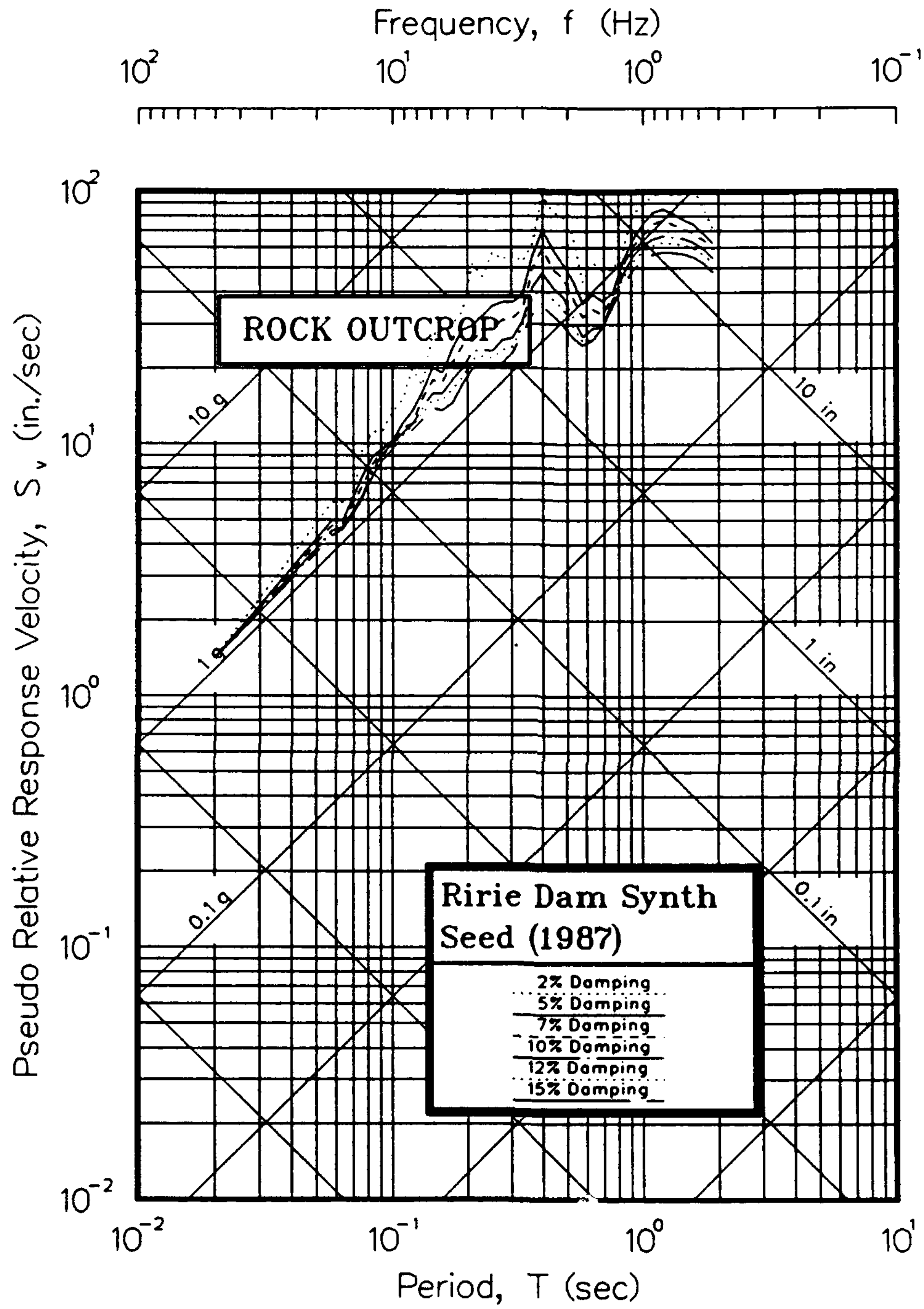

Figure C44. Tripartite presentation of pseudo-velocity spectra for synthetic MCE record used for Ririe Dam Stability Study (Seed 1987)

APPENDIX D:

MOTION: ACCELEROGRAM PLOTTING PROGRAM

D1. The computer plotting program called *MOTION* can be used to visualize earthquake motions that are used in *WESHAKE* program. Currently, earthquake motions must be stored in the earthquake data base called "EARTHQ". If the user has access to better plotting software, *WESHAKE* still prints the earthquake motion to an output file called "EQIN" which can be used as in input to their software package (some modifications to the input file might have to be generated by the user for the various software packages). As the earthquake data base is updated each year, these updates will be automatically incorporated into the *MOTION* software package.

D2. *MOTION* involves two basic stages: identification and plotting. The identification stage involves the selection from a menu sample earthquake motions (identical with the selection of motions in *WESHAKE*). *MOTION* allows the user to pick as many many of the sample earthquake in the data base that will be required for the analaysis. *MOTION* will allow the user to continually pick each earthquake motion. *MOTION* will also generate a print out of the graph. This option is limited to an Epson printer or an emulation of an Epson printer.

D3. In order to execute *MOTION*, the user types **MOTION** at the C:\ prompt. The first screen following the execution of *MOTION* is (next page):

```
                    ********************
                       W E S H A K E
                    ********************
                    EARTHQUAKE PLOT MENU
                    ********************
                         WRITTEN BY:

                    DR. DAVID C. WALLACE
             APPLIED COMPUTER SCIENCE DEPARTMENT
                 ILLINOIS STATE UNIVERSITY
                   NORMAL, ILLINOIS 61761

************************************************************
THE COMPUTER WILL GENERATE A PLOT OF YOUR EARTHQUAKE MOTION
************************************************************
          WHEN YOU ARE FINISHED VIEWING THE DISPLAY,
          CAN HIT THE ENTER KEY TO EXIT THE PROGRAM.
************************************************************


HIT ANY KEY TO CONTINUE
```

The next screen will be the selection screen. The selection screen lists the various earthquake motions which can be plotted on the screen.

```
                    EARTHQUAKE DATA BASE
**********************************************************
* NO.  MEASURED RECORD       NO.   SYNTHETIC RECORD      *
* ---  ----------------      ---   ----------------      *
*  1   GOLDEN GATE 1957       14   FOLSOM RECORD "A"     *
*  2   PARKFIELD 1966         15   FOLSOM RECORD "B"     *
*  3   CASTAIC RIDGE 1971     16   NEW MADRID 500-YR H1  *
*  4   LAKE HUGHES # 4 1971   17   NEW MADRID 500-YR H2  *
*  5   SITKA 1972             18   NEW MADRID 1000-YR H1 *
*  6   GILROY #1 1974         19   NEW MADRID 1000-YR H2 *
*  7   GILROY #1 1979         20   NEW MADRID 5000-YR H1 *
*  8   SUPERSTITION 1979      21   NEW MADRID 5000-YR H2 *
*  9   SUPERSTITION 1981      22   RIRIE DAM             *
* 10   GILROY #1 1984                                    *
* 11   IVERSON 1985                                      *
* 12   SLIDE MT 1985                                     *
* 13   HOLLISTER AIRPORT 1989                            *
**********************************************************
ENTER EARTHQUAKE MOTION NUMBER:
1
```

Once the earthquake motion is selected, the user can choose to generate a print out of the graph on the screen. The following screen prompts the user for print out of the plotted graph.

```
**********************************************************
** DO YOU WANT A PRINT OUT OF THE EARTHQUAKE MOTION ? **
** YOU NEED AN EPSON PRINTER OR AN EMULATION OF AN     **
** EPSON PRINTER FOR BEST RESULTS.                      **
**********************************************************
      ENTER  0  FOR NO
      ENTER  1  FOR YES
0
```

Once the user responds to the last screen, the program will generate the graph of the earthquake motion on the screen. If the user enters 1 for a print out of the motion, the screen graph of the earthquake motion will be basically two colors which are easily generated for the EPSON print. If the user enters 0 for no print outs, the graph should be a muti-color graph. Figure D1 shows the type of graph generated by *MOTION*. The message in the lower right hand corner of the graph tells the user to hit the enter key to continue.

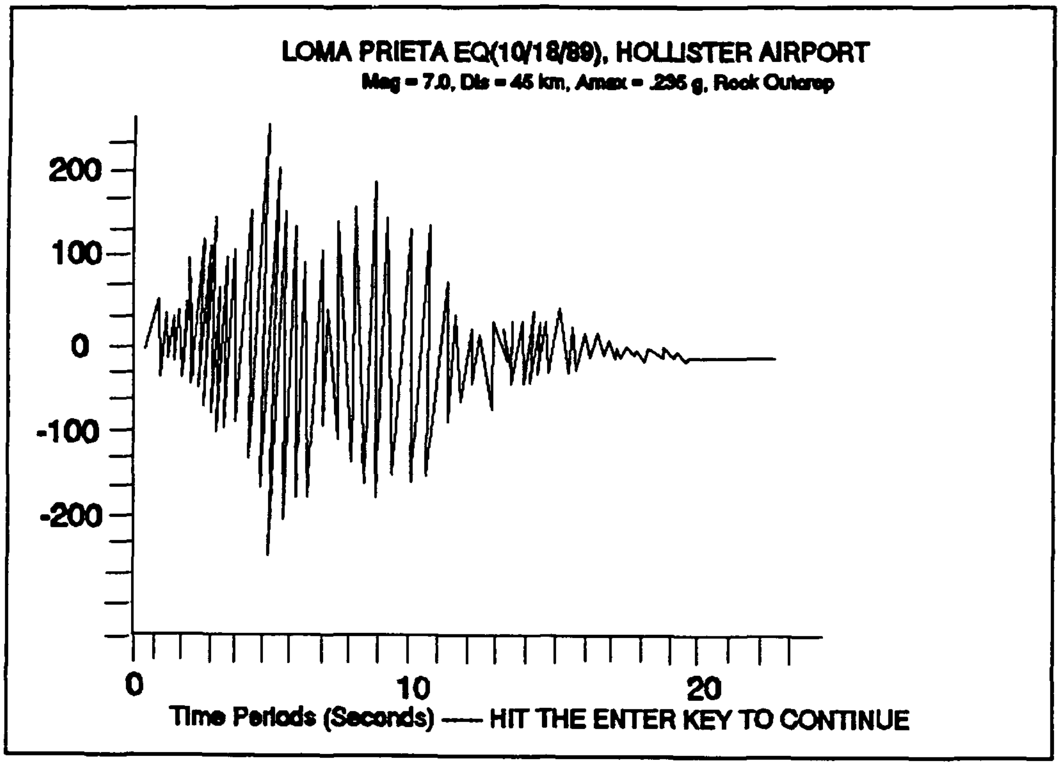

Figure D1. Example plot from *MOTION*

The computer will then prompt:

```
  DO YOU WANT TO PLOT MORE EARTHQUAKE MOTIONS?
    ENTER  0  FOR NO
    ENTER  1  FOR YES
1
```

If the user responds yes to the prompt, the program will start over again by generating the menu for earthquake motions again.

APPENDIX E:

SPECIFICATION FILE FORMAT

Columns	Format	Parameter(s)
I. PROJECT TILE		
FIRST LINE		
1 - 5	I5	MAXIMUM NUMBER OF TERMS FOR FOURIER TRANSFORM [MAMAX]
6 - 65	A60	PROJECT TITLE [PTITLE][1]
II. MANDATORY ACTIONS		
A. READ SOIL COLUMN (OPTION 2 IN SHAKE)		
FIRST LINE		
1 - 5	I5	OPTION NUMBER [KK] = 2
SECOND LINE		
1 - 5	I5	SOIL COLUMN NUMBER [MSOIL]
6 - 10	I5	NUMBER OF SOIL LAYERS [ML]
11 - 15	I5	NUMBER OF SOIL LAYER ABOVE WHICH IS THE WATER TABLE [MWL]
16 - 25	F10.0	UNIT WEIGHT OF PORE LIQUID (kcf) [WW]
26 - 61	6A6	IDENTIFICATION FOR THE SOIL PROFILE [IDNT]
THIRD LINE(S)[1]		
1 - 5	I5	LAYER NUMBER [K]
6 - 10	I5	TYPE OF SOIL LAYER [TP] - Corresponds layer with TP'th set of material properties defined in the next option (*SHAKE* OPTION 8)
11 - 15	I5	NUMBER OF SUBLAYERS IN LAYER K [NLN]
16 - 25	F10.0	THICKNESS OF LAYER (ft) [H]
26 - 35	F10.0	COEFFICIENT OF LATERAL EARTH PRESSURE [SKO][1]
36 - 45	F10.0	DAMPING RATIO (percent) [BL]
46 - 55	F10.0	MOIST UNIT WEIGHT FOR LAYER (kcf) [W]
56 - 65	F10.0	INITIAL SHEAR WAVE VELOCITY OR K_2 [RV1][1]
66 - 75	F10.0	MAXIMUM SHEAR WAVE VELOCITY OR $(K_2)_{max}$ [RV2]
76 - 80	F5.0	DAMPING MODIFICATION FACTOR [BF]
81	I1	CODE INDICATING INPUT TYPE [INKEY][1]: - 0 = SHEAR WAVE. - 1 = $(K_2)_{max}$

The third line is repeated for each soil layer, including rock. For rock, the parameters: H, SKO, and INKEY are not applicable.

[1] Deviation from SHAKE

B. READ MATERIAL PROPERTIES (OPTION 8 IN SHAKE)

FIRST LINE

1 - 5	I5	OPTION NUMBER [KK] = 8

SECOND LINE

1 - 5	I5	NUMBER OF SOIL TYPES FOR PLOTTING [NST]: - Maximum of 4
6 - 10	I5	PLOT OPTION [NPL]: - 0: No plot - 1: Plot in OUTPUT
11 - 15	I5	NUMBER OF STRAIN UNITS IN EACH LOG CYCLE [NPL]
16 - 25	F10.0	MAXIMUM VALUE OF ORDIANTE [SC]: - 0: Maximum value of data

THIRD LINE

1 - 5	I5	NUMBER OF VALUES PLOTTED ON RVE [NV] - Maximum of 20 points per curve
6 - 10	F5.0	MULTIPLICATION FACTOR IN PLOTTING [FPL]
12 - 77	11A6	DESCRIPTION OF SOIL PROFILE [ID]

FOURTH LINE(S)

1 - 80	8F10.3	NV VALUES OF SHEAR STRAIN (percent) IN INCREASING ORDER [S] - Eight per line

The fourth line repeats until all values of shear strain have been specified

FIFTH LINE(S)

1 - 80	8F10.3	NV VALUES OF NORMALIZED SHEAR MODULUS (percent) OR DAMPING RATIO (percent), IN INCREASING ORDER, CORRRESPONDING TO VALUES OF SHEAR STRAIN IN SECOND LINE(S) [Y] - Eight per line

The fifth line repeats until all values of modulus or damping have been specified.

The fourth and fifth lines form a set and a set is created for each material type (i.e., these lines are repeated) in the respective data bases (unique to NUM).

C. SELECT EARTHQUAKE RECORD (OPTION 1 IN SHAKE)

FIRST LINE

1 - 5	I5	OPTION NUMBER [KK] = 1

SECOND LINE

1 - 5	I5	NUMBER OF VALUES IN EARTHQUAKE MOTION [NV]
6 - 10	I5	NUMBER OF TERMS IN FFT [MA]: - Must be a power of 2 and ≤ MAMAX - Should be ≥ 2 * NV
11 - 20	F10.3	TIME STEP FOR MEASUREMENT [DT]
22 - 50	5A6	EARTHQUAKE TITLE [EQTITLE]

THIRD LINE[1]

1 - 10	F10.0	MULTIPLICATION FACTOR FOR ACCELERATION [XF]
11 - 20	F10.0	MAXIMUM ACCELERATION VALUE TO BE USED [XMAX]
21 - 30	F10.0	MAXIMUM (CUTOFF) FREQUENCY [FMAX]
31 - 35	I5	ECHO CODE [OUTKEY]:[1] - 0: Do not echo accelerations in OUTPUT - 1: Echo accelerations in OUTPUT

FOURTH AND SUBSEQUENT LINES

1 - 72	8(1X,F8.6)	NV VALUES OF ACCELERATION (g's) [XR]: - Eight per line
73 - 79	I7	LINE NUMBER [K]

D. ASSIGN OBJECT MOTION (OPTION 3 IN SHAKE)

FIRST LINE

1 - 5	I5	OPTION NUMBER [KK] = 3

SECOND LINE

1 - 5	I5	NUMBER OF (SUB)LAYER WHERE OBJECT MOTION IS ASSIGNED [IN]
6 - 10	I5	TYPE OF (SUB)LAYER [INT]: - 0: Outcropping - 1: (Sub)layer within profile

E. OBTAIN STRAIN COMPATIBLE PROPERTIES (OPTION 4 IN SHAKE)

FIRST LINE

1 - 5	I5	OPTION NUMBER [KK] = 4

SECOND LINE

1 - 5	I5	PUNCH OPTION [KS]: - 0: Do not write to PUNCH file - 1: Write to PUNCH file
6 - 10	I5	MAXIMUM NUMBER OF ITERATIONS [ITMAX]
11 - 20	F10.0	MAXIMUM ACCEPTABLE DIFFERENCE BETWEEN THE LAST-USED MODULUS AND DAMPING VALUES AND THE STRAIN COMPATIBLE VALUES (percent) [ERR]
21 - 30	F10.0	RATIO BETWEEN EFFECTIVE STRAIN AND MAXIMUM STRAIN [PRMUL]: - 0.65 recommended

III. OPTIONAL ACTIONS

A. COMPUTE MOTION IN SPECIFIED LAYERS

FIRST LINE

1 - 5	I5	OPTION NUMBER [KK] = 5

SECOND LINE

1 - 80	15I5	(SUB)LAYERS FOR COMPUTATION OF MOTION [LL5]: - Maximum 15

THIRD LINE

1 - 80	15I5	TYPE OF MOTION CORRESPONDING TO LL5 [LT5]: - Maximum 15 - 0: Outcropping - 1: (Sub)layer within soil profile

FOURTH LINE

1 - 80	15I5	OUPUT OPTION CORRESPONDING TO LL5 and LT5 [LP5]: - 0: Maximum accelerations only to OUTPUT and ACCEL - 1: Acceleration time history to PUNCH

B. PRINT OR PUNCH OBJECT MOTION

FIRST LINE

1 - 5	I5	OPTION NUMBER [KK] = 6

SECOND LINE

1 - 5	I5	SELECT MODE OF OUTPUT [K2]: - 0: Maximum acceleration only - 1: Write to PUNCH file - 2: Write to PUNCH and OUTPUT files

C. CHANGE OBJECT MOTION

FIRST LINE

1 - 5	I5	OPTION NUMBER [KK] = 7

SECOND LINE

1 - 5	I5	NUMBER OF SUBLAYER [LL1]: - 0: OBJECT MOTION ORIGINALLY ASSIGNED IS RETAINED
6 - 10	I5	TYPE OF (SUB)LAYER [LT1]: - 0: Outcropping - 1: (Sub)layer within soil profile
11 - 20	F10.0	MULTIPLICATION FACTOR FOR ACCELERATION VALUES [XF]: - 1.0: No change
21- 30	F10.0	NEW TIME STEP [DTNEW]

D. COMPUTE RESPONSE SPECTRA

FIRST LINE

1 - 5	I5	OPTION NUMBER [KK] = 9

SECOND LINE

1 - 5	I5	SUBLAYER NUMBER [LL1]: - 0: Object Motion
6 - 10	I5	TYPE OF SUBLAYER [LT1]: - 0: Outcropping - 1: (Sub)layer within soil profile

THIRD LINE

1 - 5	I5	UMBER OF DAMPING VALUES TO BE USED [ND]: - Maximum of 6
6 - 10	I5	PUNCH OPTION [KP]: - 0: No write to PUNCH file - 1: Write to PUNCH file
11 - 15	I5	PARAMETER OPTION [KAV]: - 0: Spectral velocity - 1: Spectral acceleration - 2: Spectral velocity and acceleration
16 - 20	I5	PLOT OPTION [KPL]: - 0: Store plot for later (combined) plotting - 1: Plots of all spectra calculated to this point
21 - 25	I5	SITE PERIODS FOR COMPUTATIONS [KPER]: - KPER = 0 9 LINEAR STEPS from 0.1 to 1.0 sec 5 steps from 1.0 to 2.0 sec 4 steps from 2.0 to 4.0 sec - KPER = 1 18 steps from 0.1 to 1.0 sec 10 steps from 1.0 to 2.0 sec 8 steps from 2.0 to 4.0 sec - KPER = 2 38 steps from 0.05 to 1.0 sec 20 steps from 1.0 to 2.0 sec 30 steps from 2.0 to 5.0 sec - KPER = 3 LOG INCREMENTS with 10 steps per log unit from 0.05 TO 5.0 - KPER = 4 LOG INCREMENTS with 10 steps per log unit from 0.05 TO 10.0

FOURTH LINE

1 - 60	6F10.0	ND VALUES OF CRITICAL DAMPING RATIOS (decimal) [ZLD]

E. INCREASE TIME INTERVAL

FIRST LINE

1 - 5	I5	OPTION NUMBER [KK] = 10

SECOND LINE

1 - 5	I5	FACTOR FOR INCREASING TIME INTERVAL [IFR]: - Must be a power of 2

F. DECREASE TIME INTERVAL

FIRST LINE

1 - 5	I5	OPTION NUMBER [KK] = 11

SECOND LINE

1 - 5	I5	FACTOR FOR DECREASING TIME INTERVAL [IFR]: - Must be a power of 2

G. CALCULATE FOURIER SPECTRUM OF OBJECT MOTION

FIRST LINE

1 - 5	I5	OPTION NUMBER [KK] = 12

SECOND LINE

1 - 5	I5	PLOTTING OPTION [K1]: - 0: Store for later (combined) plot - 1: Plot all stored spectra
6 - 10	I5	NUMBER OF TIMES THE SPECTRUM IS TO BE SMOOTHED [NSW]
11 - 15	I5	NUMBER OF VALUES TO BE PLOTTED [N]: - Maximum of 2049

H. CALCULATE FOURIER SPECTRUM OF COMPUTED MOTION

FIRST LINE

1 - 5	I5	OPTION NUMBER [KK] = 13

SECOND LINE

1 - 5	I5	(SUB)LAYER NUMBER [LL]
6 - 10	I5	TYPE OF (SUB)LAYER [LT] - 0: Outcropping - 1: (Sub)layer within soil profile
11 - 15	I5	PLOT OPTION [LP]: - 0: Store for later (combined) plot - 1: Plot all stored spectra
16 - 20	I5	NUMBER OF TIMES THE SPECTRUM IS TO BE SMOOTHED [LNSW]
21 - 25	I5	NUMBER OF VALUES TO BE PLOTTED [LLL]: - Maximum of 2049

I. PLOT TIME HISTORY OF OBJECT MOTION

FIRST LINE

1 - 5	I5	OPTION NUMBER [KK] = 14

SECOND LINE

1 - 5	I5	NUMBER OF VALUES SKIPPED IN PLOTTING [NSKIP]: - Every NSKIP values skipped
6 - 10	I5	NUMBER OF VALUES TO BE PLOTTED [NN]: - Maximum of 2049

J. COMPUTE AMPLIFICATION SPECTRUM

FIRST LINE

1 - 5	I5	OPTION NUMBER [KK] = 15

SECOND LINE

1 - 5	I5	NUMBER OF FIRST LAYER [LIN]
6 - 10	I5	FIRST LAYER TYPE [LINT]: - 0: Outcropping - 1: (Sub)layer within soil profile
11 - 15	I5	NUMBER OF SECOND LAYER [LOUT]:
16 - 20	I5	SECOND LAYER TYPE [LOTP]: - 0: Outcropping - 1: (Sub)layer within soil profile
21 - 25	I5	PLOTTING OPTION [KP]: - 0: Store for later plotting - 1: Plot all stored data
26 - 30	F5.0	NUMBER OF FREQUENCY STEPS [DFA]: - Amplification factor is computed for first 200 frequencies at interval DFA (Hz) beginning at 0.
32 - 78	8A6	DESCRIPTION [IDAMP]

K. COMPUTE STRESS OR STRAIN HISTORY IN MIDDLE SUBLAYERS

FIRST LINE

1 - 5	I5	OPTION NUMBER [KK] = 16

SECOND LINE

1 - 5	I5	FIRST (SUB)LAYER NUMBER [LLL]
6 - 10	I5	SELECT TYPE OF RESPONSE [LLGS]: - 0: STRAIN - 1: STRESS
11 - 15	I5	PUNCH OPTION [LLPCH]: - 0: No write to PUNCH file - 1: Write to PUNCH file
16 - 20	I5	PLOT OPTION [LLPL]: - 0: No plot in OUTPUT - 1: Plot in OUTPUT
21 - 25	I5	NUMBER OF VALUES TO BE PLOTTED [LNV]: - Maximum of 2049
26 - 35	F10.0	SCALE FOR PLOTTING [SK]: - (i.e., maximum value of ordinate) - 0: maximum of data
37 - 65	5A6	DESCRIPTION [ID]

THIRD LINE

1 - 5	I5	SECOND (SUB)LAYER NUMBER [LLL]
6 - 10	I5	SELECT TYPE OF RESPONSE [LLGS]: - 0: STRAIN - 1: STRESS
11 - 15	I5	PUNCH OPTION [LLPCH]: - 0: No write to PUNCH file - 1: Write to PUNCH file
16 - 20	I5	PLOT OPTION [LLPL]: - 0: No plot in OUTPUT - 1: Plot in OUTPUT
21 - 25	I5	NUMBER OF VALUES TO BE PLOTTED [LNV]: - Maximum of 2049
26 - 35	F10.0	SCALE FOR PLOTTING [SK]: - (i.e., maximum value of ordinate) - 0: maximum of data
37 - 65	5A6	DESCRIPTION [ID]

NOTE: LEAVE THIRD LINE BLANK IF ONLY ONE RESPONSE IS TO BE COMPUTED

IV. END OF INPUT FILE

1 - 5	I5	OPTION NUMBER [KK] = 0

APPENDIX F:
VALIDATION OF *WESHAKE*

Specification File

```
1024  VALIDATION PROBLEM:  Example problem from Schnabel, Lysmer, Seed (1972)
  2    OPTION 2:  READ SOIL COLUMN DATA
  0    9    9    .06240  Example
  1    2    1       7.0       .45      .050      .120      61.3       43.1.0001
  2    1    1      13.0       .45      .100      .100      254.      430.1.0000
  3    1    1      10.0       .45      .050      .100      567.      745.1.0000
  4    1    1      12.0       .45      .050      .100      567.      920.1.0000
  5    2    1      20.0       .45      .050      .125      33.6       76.1.0001
  6    1    1      18.0       .45      .050      .125      507.      910.1.0000
  7    1    1      20.0       .45      .050      .125      717.     1090.1.0000
  8    1    1      20.0       .45      .050      .125      802.     1155.1.0000
  9    3    1                          .050      .150     8000.     8000.1.0000
  8    OPTION 8: READ MATERIAL PROPERTIES
  3    0    2   100.     STRAIN COMPATIBLE PROPERTIES
  9100.0 CLAY (Schnabel, Lysmer, & Seed 1972)  Shear Modulus
   .0001   .000316     .0010    .00316     .0100     .0316     .1000     .3160
  1.0000
  1.0000     .9130     .7610     .5650     .4000     .2610     .1520     .0760
   .0370
  8  5.0 CLAY (Schnabel, Lysmer, & Seed 1972)  Damping
   .0001     .0010    .00316     .0100     .0316     .1000     .3160    1.0000
  2.0000    2.5000    3.5000    4.7500    6.5000    9.2500   13.7500   20.0000
  9100.0 SAND (Schnabel, Lysmer, & Seed 1972)  Shear Modulus
   .0001   .000316     .0010    .00316     .0100     .3316     .1000     .3160
  1.0000
  1.0000     .9840     .9340     .8260     .6560     .4430     .2460     .1150
   .0490
  8  5.0 SAND (Schnabel, Lysmer & Seed 1972)   Damping
   .0001     .0010     .0030     .0100     .0300     .1000     .3000    1.0000
   .8000    1.6000    3.1200    5.8000    9.5000   15.4000   20.9000   25.0000
  8100.0 ROCK (Schnabel, Lysmer, & Seed 1972)  Shear Modulus
   .0001     .0003     .0010     .0030     .0100     .0300     .1000    1.0000
  1.0000    1.0000     .9880     .9530     .9000     .8100     .7250     .5500
  5  5.0 ROCK (Schnabel, Lysmer, & Seed 1972)  Damping
   .0001     .0010     .0100     .1000    1.0000
   .4000     .8000    1.5000    3.0000    4.6000
  1    OPTION 1:  READ EARTHQUAKE RECORD
 800 1024      .020     PASADENA 1952
   1.000      0.02      25.    1
-.002493 -.003313 -.002623 -.002526 -.001317 -.000128  .001274  .002382      1
 .002625  .002518  .002590  .002513  .002569  .002502  .002551  .002491      2
 .002533  .002478  .002516  .002465  .002500  .002451  .002486  .002408      3
 .001994  .001425  .000925  .000445  .000425  .000420  .000066 -.000829      4
-.001525 -.002386 -.002381 -.001979 -.001647 -.001658 -.001639 -.001645      5
-.001099 -.000510  .000131 -.000088 -.000763 -.001374 -.002079 -.002893      6
-.003579 -.003281 -.002718 -.002255 -.001509  .000499  .002231  .002675      7
 .003059  .003649  .004454  .005218  .005970  .006832  .006573  .004815      8
 .003340  .000761 -.001550 -.001932 -.001298 -.000592  .000267  .000936      9
 .001844  .001562  .000454 -.000521 -.001442 -.002425 -.003165 -.003689     10
-.004324 -.005168 -.005828 -.005715 -.005336 -.005068 -.003841 -.002305     11
-.001126 -.000120  .001399  .002900  .004500  .004992  .004919  .004081     12
 .002851  .001865  .001481  .001031  .001121  .001382  .001816  .001063     13
-.001154 -.003149 -.005312 -.006564 -.007083 -.007836 -.007772 -.006705     14
```

-.005669	-.004535	-.003444	-.002324	-.001229	-.000185	.000867	.002097	15
.003343	.004508	.004360	.003868	.004611	.005548	.006484	.007403	16
.008347	.009253	.010469	.012118	.012267	.011130	.010349	.008871	17
.006792	.005192	.004711	.003808	.005427	.011079	.011994	.012237	18
.012588	.013730	.015396	.016909	.018496	.020026	.021497	.021543	19
.021695	.019953	.015352	.013395	.013656	.013217	.009669	.005633	20
.004387	.003030	.002845	.003635	.004411	.004443	.004606	.003431	21
.000276	-.001939	-.001932	-.006423	-.009774	-.011147	-.012292	-.012660	22
-.013513	-.014858	-.017037	-.018811	-.020927	-.022735	-.024635	-.025974	23
-.027901	-.026475	-.019656	-.014708	-.007272	.002294	.003546	.006332	24
.004549	.003636	.002636	.002806	.001202	-.000432	-.002572	-.001484	25
-.000616	.000291	-.000486	-.006645	-.014722	-.012778	-.033575	-.042831	26
-.043009	-.045807	-.043294	-.041669	-.037745	-.025278	-.019201	.001040	27
.013648	.012866	.015824	.016378	.018696	.019668	.021342	.020955	28
.021309	.022849	.026435	.029246	.031983	.033228	.[illegible]739	.031762	29
.027738	.024080	.020339	.017203	.011562	.007591	-.015690	-.028448	30
-.029791	-.038844	-.042214	-.043695	-.040997	-.038664	-.033649	-.030902	31
-.020213	-.001768	.002023	.007762	.006125	.004710	.007523	.009468	32
.010966	.011913	.012652	.020084	.028702	.032657	.038837	.040949	33
.041798	.038336	.032960	.031175	.029425	.026144	.025072	.022677	34
.021590	.016643	.017778	.015500	.019219	-.005005	-.018653	-.035037	35
-.047254	-.042567	-.045124	-.039513	-.034399	-.020552	-.004749	-.002274	36
-.000997	-.001284	-.000624	-.000064	.000558	.000123	-.001028	-.000921	37
-.000648	.000488	.003457	.006631	.007229	.005943	.005730	.005723	38
.005276	.003131	.003588	.004385	.001724	-.000949	.000235	.003089	39
.004174	.002623	.003442	.003680	.004803	.005154	.005346	.007711	40
.010554	.009195	.008490	.005691	.005005	.000425	-.003943	-.006070	41
-.007428	-.009936	-.010439	-.012590	-.011388	-.019622	-.039587	-.041574	42
-.046392	-.048356	-.052906	-.052793	-.049356	-.045835	-.043181	-.027839	43
-.014535	-.013859	.025816	.043108	.043491	.047994	.047682	.051035	44
.051602	.054637	.054828	.057238	.055020	.049601	.043950	.040517	45
.037062	.034520	.031703	.024568	.014474	.011676	.004249	-.007235	46
-.026973	-.041443	-.042865	-.045273	-.045146	-.044333	-.040249	-.033307	47
-.017015	-.004583	-.004544	-.003638	-.004924	-.004706	-.005664	-.005841	48
-.007728	-.008074	-.010774	-.012404	-.014434	-.009161	-.007826	.003369	49
.024767	.025711	.029998	.032436	.034883	.034808	.035693	.035950	50
.031252	.022314	.016231	.008574	-.003059	-.007785	-.009396	-.009446	51
-.008794	-.008981	-.009000	-.009324	-.009375	-.009651	-.009853	-.011662	52
-.013760	-.015836	-.017792	-.018124	-.018907	-.016268	-.010307	-.003454	53
.002631	.004109	.004371	.001234	-.001186	-.005053	-.008826	-.012269	54
-.013740	-.015331	-.017610	-.022831	-.024390	-.026574	-.024601	-.022072	55
-.018882	-.015641	-.011956	-.012234	-.014489	-.016093	-.017898	-.021668	56
-.027007	-.027043	-.017194	-.007552	.001476	.017401	.023309	.023177	57
.027040	.028719	.032583	.031626	.030859	.028315	.027878	.023949	58
.023372	.013997	-.008389	-.017724	-.021337	-.033693	-.037941	-.036294	59
-.036374	-.035359	-.034194	-.030404	-.027147	-.023444	-.020092	-.016374	60
-.012404	-.008319	-.004306	-.000756	.002788	.006267	.010007	.013599	61
.017748	.020897	.018017	.012843	.010150	.006306	.00431[illegible]	-.002774	62
-.011569	-.013108	-.012718	-.009093	-.004293	.000[illegible]96	.001663	.003167	63
.003833	.005218	.005565	.005307	.004555	.004324	.002268	-.002006	64
-.005485	-.008136	-.010942	-.013972	-.017321	-.020956	-.023507	-.019832	65
-.016115	-.014444	-.012891	-.011308	-.009298	-.007287	-.006066	-.004843	66
-.004426	-.005197	-.005685	-.006885	-.009521	-.010996	-.009946	-.009179	67
-.007934	-.005983	-.004401	-.005072	-.005589	-.006038	-.002838	.000617	68

```
 .003857  .006366  .007463  .005531  .004975  .002051 -.001933 -.008681    69
-.011511 -.011291 -.011264 -.011423 -.011180 -.012156 -.013166 -.014751    70
-.015533 -.016972 -.018909 -.024914 -.024367 -.021703 -.017011 -.016185    71
 .007941  .017308  .015199  .017725  .017247  .018997  .018977  .019598    72
 .018284  .018230  .017224  .017375  .016698  .015711  .010446  .008182    73
 .009113  .010604  .011417  .011690  .011490  .011663  .011506  .011620    74
 .011817  .012871  .013767  .013843  .009655  .005485  .001648 -.001211    75
-.005169 -.009233 -.013879 -.018128 -.015787 -.010113 -.006007 -.002833    76
-.000194  .002856  .005626  .008930  .011888  .014931  .016787  .018965    77
 .020808  .022943  .025558  .026834  .023618  .021884  .018231  .015899    78
 .006415 -.003205 -.005577 -.014988 -.018955 -.021957 -.024742 -.027639    79
-.030063 -.028838 -.026851 -.025145 -.026489 -.029640 -.032318 -.035157    80
-.035179 -.034898 -.033905 -.032181 -.030237 -.028657 -.025223 -.019982    81
-.014925 -.009185 -.003261  .001808  .005464  .009307  .012679  .014940    82
 .017126  .019247  .020912  .022423  .024020  .025809  .029569  .031829    83
 .030313  .028309  .026858  .022232  .013520  .010163  .006899  .003967    84
 .000597 -.000495  .000120  .000476  .000989  .001265  .000967  .000524    85
 .000241 -.000063 -.000264 -.000584  .000541  .002474  .004356  .005954    86
 .007249  .008512  .009877  .010134  .009723  .009107  .007355  .005186    87
 .004931  .006719  .008156  .009798  .012428  .016216  .018755  .016836    88
 .014459  .011738  .008580  .005413  .002914  .001680  .000421 -.000937    89
-.002750 -.004659 -.006680 -.012302 -.015390 -.015706 -.016604 -.017175    90
-.017957 -.018356 -.014196 -.010422 -.009050 -.006920 -.005341 -.002633    91
-.000002  .003054  .004365  .004209  .004327  .003693  .001851  .000085    92
-.001814 -.003043 -.003466 -.004068 -.004504 -.003832 -.001625 -.000235    93
 .002278  .005874  .014722  .025498  .026123  .028565  .029956  .031018    94
 .029316  .028463  .026981  .026664  .025729  .025371  .024097  .023324    95
 .021865  .021047  .018546  .014894  .012006  .010343  .008053  .005314    96
 .001757 -.002601 -.007363 -.010712 -.015489 -.021659 -.021587 -.019652    97
-.018365 -.016570 -.015225 -.013493 -.011212 -.007042 -.006514 -.007858    98
-.009230 -.010467 -.012825 -.015684 -.016584 -.010786 -.005233  .000579    99
 .005328  .009647  .012139  .015901  .018338  .021552  .019896  .021718   100
    3     OPTION 3:  ASSIGN OBJECT MOTION
    9     0
    4     OPTION 4:  OBTAIN STRAIN-COMPATIBLE PROPERTIES
    0    10       5.00       .65
    5     OPTION 5:  ACCELERATION RECORDS
    1     2     3     4     5     6     7     8     9     9
    1     1     1     1     1     1     1     1     1     0
    0     0     0     0     0     0     0     0     0     0
    9     OPTION 9:  RESPONSE SPECTRUM
    1     0
    1     0     2     1     1
  0.05
    0     OPTION 0: END OF INPUT
```

OUTPUT File

VALIDATION PROBLEM: Example problem from Schnabel, Lysmer

```
MAX. NUMBER OF TERMS IN FOURIER TRANSFORM =     1024
NECESSARY LENGTH OF BLANK COMMON X        =     6419

1******  OPTION  2  ***  READ SOIL PROFILE

MSOIL =     0
ML =     9
MWL =     9
WW =   .0624
IDNT = Example
NEW SOIL PROFILE NO.  0      IDENTIFICATION -   Example

SHEAR/K2 FACTOR WAVE VELOCITY INPUT BY LAYER

NUMBER OF LAYERS                    9          DEPTH TO BEDROCK        120.00
NUMBER OF FIRST SUBMERGED LAYER     9          DEPTH TO WATER LEVEL    120.00

UNIT WEIGHT OF WATER =     .0624 kcf
```

Layer	Lib. Key	Soil Classification	Thickness (ft)	--Depth (ft)--- Top	Bottom
1	2	M: SHEAR MODULUS SAND SQ.ROOT REL. D: DAMPING SAND	7.0	.0	7.0
2	1	M: SHEAR MODULUS CLAY D: DAMPING CLAY	13.0	7.0	20.0
3	1	M: SHEAR MODULUS CLAY D: DAMPING CLAY	10.0	20.0	30.0
4	1	M: SHEAR MODULUS CLAY D: DAMPING CLAY	12.0	30.0	42.0
5	2	M: SHEAR MODULUS SAND SQ.ROOT REL. D: DAMPING SAND	20.0	42.0	62.0
6	1	M: SHEAR MODULUS CLAY D: DAMPING CLAY	18.0	62.0	80.0
7	1	M: SHEAR MODULUS CLAY D: DAMPING CLAY	20.0	80.0	100.0
8	1	M: SHEAR MODULUS CLAY D: DAMPING CLAY	20.0	100.0	120.0
9	3	M: ATTENUATION OF ROCK, AVERAGE D: DAMPING IN ROCK, AVERAGE		120.0	

Layer	Mid-depth (ft)	Coeff. Earth Press.	Unit Weight (kcf)	Mean Effective Stress (ksf)
1	3.5	.45	.120	.27
2	13.5	.45	.100	.94
3	25.0	.45	.100	1.67
4	36.0	.45	.100	2.37
5	52.0	.45	.125	3.54
6	71.0	.45	.125	5.04
7	90.0	.45	.125	6.55
8	110.0	.45	.125	8.13
9			.150	

	Damping	Small Strain			Initial Est.		
	Est.	Vs	K2max	Gmax	Vs	G	G/Gmax
Layer	(-)	(fps)	(-)	(ksf)	(fps)	(ksf)	(-)
1	.050	434.	43.	701.	518.	1000.	1.43
2	.100	430.	19.	575.	254.	201.	.35
3	.050	745.	42.	1725.	567.	999.	.58
4	.050	920.	54.	2631.	567.	999.	.38
5	.050	1079.	76.	4522.	718.	1999.	.44
6	.050	910.	45.	3218.	507.	999.	.31
7	.050	1090.	57.	4616.	717.	1998.	.43
8	.050	1155.	57.	5183.	802.	2499.	.48
9	.050	8000.		298415.	8004.	298415.	1.00

PERIOD = .79 FROM AVERAGE SHEAR VELOCITY = 610. FT/SEC

MAXIMUM AMPLIFICATION = 14.06
FOR FREQUENCY = 1.41 C/SEC.
PERIOD = .71 SEC.

1****** 8 *** READ RELATION BETWEEN SOIL PROPERTIES AND STRAIN

1****** 1 *** READ INPUT MOTION

EARTHQUAKE - PASADENA 1952

800 ACCELERATION VALUES AT TIME INTERVAL .0200

THE VALUES ARE LISTED ROW BY ROW AS READ FROM CARDS
TRAILING ZEROS ARE ADDED TO GIVE A TOTAL OF 1024 VALUES

-.00249	-.00331	-.00262	-.00253	-.00132	-.00013	.00127	.00238	1
.00262	.00252	.00259	.00251	.00257	.00250	.00255	.00249	2
.00253	.00248	.00252	.00246	.00250	.00245	.00249	.00241	3
.00199	.00143	.00093	.00045	.00043	.00042	.00007	-.00083	4
-.00152	-.00239	-.00238	-.00198	-.00165	-.00166	-.00164	-.00164	5
-.00110	-.00051	.00013	-.00009	-.00076	-.00137	-.00208	-.00289	6
-.00358	-.00328	-.00272	-.00225	-.00151	.00050	.00223	.00268	7
.00306	.00365	.00445	.00522	.00597	.00683	.00657	.00482	8
.00334	.00076	-.00155	-.00193	-.00130	-.00059	.00027	.00094	9
.00184	.00156	.00045	-.00052	-.00144	-.00243	-.00316	-.00369	10
-.00432	-.00517	-.00583	-.00571	-.00534	-.00507	-.00384	-.00231	11
-.00113	-.00012	.00140	.00290	.00450	.00499	.00492	.00408	12
.00285	.00186	.00148	.00103	.00112	.00138	.00182	.00106	13
-.00115	-.00315	-.00531	-.00656	-.00708	-.00784	-.00777	-.00671	14
-.00567	-.00453	-.00344	-.00232	-.00123	-.00018	.00087	.00210	15
.00334	.00451	.00436	.00387	.00461	.00555	.00648	.00740	16
.00835	.00925	.01047	.01212	.01227	.01113	.01035	.00887	17
.00679	.00519	.00471	.00381	.00543	.01108	.01199	.01224	18
.01259	.01378	.01540	.01691	.01850	.02003	.02150	.02154	19
.02169	.01995	.01535	.01340	.01366	.01322	.00967	.00563	20
.00439	.00303	.00285	.00363	.00441	.00444	.00461	.00343	21
.00028	-.00194	-.00193	-.00642	-.00977	-.01115	-.01229	-.01266	22
-.01351	-.01486	-.01704	-.01881	-.02093	-.02273	-.02464	-.02597	23
-.02790	-.02647	-.01966	-.01471	-.00727	.00229	.00355	.00633	24
.00455	.00364	.00264	.00281	.00120	-.00043	-.00257	-.00148	25
-.00062	.00029	-.00049	-.00665	-.01472	-.01278	-.03357	-.04283	26
-.04301	-.04581	-.04329	-.04167	-.03774	-.02528	-.01920	.00104	27
.01365	.01287	.01582	.01638	.01870	.01967	.02134	.02096	28
.02131	.02285	.02644	.02925	.03198	.03323	.03474	.03176	29
.02774	.02408	.02034	.01720	.01156	.00759	-.01569	-.02845	30
-.02979	-.03884	-.04221	-.04369	-.04100	-.03866	-.03365	-.03090	31
-.02021	-.00177	.00202	.00776	.00612	.00471	.00752	.00947	32
.01097	.01191	.01265	.02008	.02870	.03266	.03884	.04095	33
.04180	.03834	.03296	.03118	.02943	.02614	.02507	.02268	34
.02159	.01664	.01778	.01550	.01922	-.00501	-.01865	-.03504	35
-.04725	-.04257	-.04512	-.03951	-.03440	-.02055	-.00475	-.00227	36
-.00100	-.00128	-.00062	-.00006	.00056	.00012	-.00103	-.00092	37
-.00065	.00049	.00346	.00663	.00723	.00594	.00573	.00572	38
.00528	.00313	.00359	.00439	.00172	-.00095	.00023	.00309	39
.00417	.00262	.00344	.00368	.00480	.00515	.00535	.00771	40
.01055	.00919	.00849	.00569	.00501	.00043	-.00394	-.00607	41
-.00743	-.00994	-.01044	-.01259	-.01139	-.01962	-.03959	-.04157	42
-.04639	-.04836	-.05291	-.05279	-.04936	-.04583	-.04318	-.02784	43
-.01453	-.01386	.02582	.04311	.04349	.04799	.04768	.05103	44
.05160	.05464	.05483	.05724	.05502	.04960	.04395	.04052	45
.03706	.03452	.03170	.02457	.01447	.01168	.00425	-.00723	46
-.02697	-.04144	-.04287	-.04527	-.04515	-.04433	-.04025	-.03331	47
-.01702	-.00458	-.00454	-.00364	-.00492	-.00471	-.00566	-.00584	48
-.00773	-.00807	-.01077	-.01240	-.01443	-.00916	-.00783	.00337	49
.02477	.02571	.03000	.03244	.03488	.03481	.03569	.03595	50
.03125	.02231	.01623	.00857	-.00306	-.00778	-.00940	-.00945	51
-.00879	-.00898	-.00900	-.00932	-.00938	-.00965	-.00985	-.01166	52
-.01376	-.01584	-.01779	-.01812	-.01891	-.01627	-.01031	-.00345	53
.00263	.00411	.00437	.00123	-.00119	-.00505	-.00883	-.01227	54
-.01374	-.01533	-.01761	-.02283	-.02439	-.02657	-.02460	-.02207	55
-.01888	-.01564	-.01196	-.01223	-.01449	-.01609	-.01790	-.02167	56
-.02701	-.02704	-.01719	-.00755	.00148	.01740	.02331	.02318	57

.02704	.02872	.03258	.03163	.03086	.02832	.02788	.02395	58
.02337	.01400	-.00839	-.01772	-.02134	-.03369	-.03794	-.03629	59
-.03637	-.03536	-.03419	-.03040	-.02715	-.02344	-.02009	-.01637	60
-.01240	-.00832	-.00431	-.00076	.00279	.00627	.01001	.01360	61
.01775	.02090	.01802	.01284	.01015	.00631	.00431	-.00277	62
-.01157	-.01311	-.01272	-.00909	-.00429	.00070	.00166	.00317	63
.00383	.00522	.00557	.00531	.00455	.00432	.00227	-.00201	64
-.00549	-.00814	-.01094	-.01397	-.01732	-.02096	-.02351	-.01983	65
-.01612	-.01444	-.01289	-.01131	-.00930	-.00729	-.00607	-.00484	66
-.00443	-.00520	-.00569	-.00689	-.00952	-.01100	-.00995	-.00918	67
-.00793	-.00598	-.00440	-.00507	-.00559	-.00604	-.00284	.00062	68
.00386	.00637	.00746	.00553	.00497	.00205	-.00193	-.00868	69
-.01151	-.01129	-.01126	-.01142	-.01118	-.01216	-.01317	-.01475	70
-.01553	-.01697	-.01891	-.02491	-.02437	-.02170	-.01701	-.01619	71
.00794	.01731	.01520	.01773	.01725	.01900	.01898	.01960	72
.01828	.01823	.01722	.01737	.01670	.01571	.01045	.00818	73
.00911	.01060	.01142	.01169	.01149	.01166	.01151	.01162	74
.01182	.01287	.01377	.01384	.00965	.00549	.00165	-.00121	75
-.00517	-.00923	-.01388	-.01813	-.01579	-.01011	-.00601	-.00283	76
-.00019	.00286	.00563	.00893	.01189	.01493	.01679	.01897	77
.02081	.02294	.02566	.02683	.02362	.02188	.01823	.01590	78
.00642	-.00320	-.00558	-.01499	-.01895	-.02196	-.02474	-.02764	79
-.03006	-.02884	-.02685	-.02514	-.02649	-.02964	-.03232	-.03516	80
-.03518	-.03490	-.03390	-.03218	-.03024	-.02866	-.02522	-.01998	81
-.01493	-.00919	-.00326	.00181	.00546	.00931	.01268	.01494	82
.01713	.01925	.02091	.02242	.02402	.02581	.02957	.03183	83
.03031	.02831	.02686	.02223	.01352	.01016	.00690	.00397	84
.00060	-.00049	.00012	.00048	.00099	.00126	.00097	.00052	85
.00024	-.00006	-.00026	-.00058	.00054	.00247	.00436	.00595	86
.00725	.00851	.00988	.01013	.00972	.00911	.00735	.00519	87
.00493	.00672	.00816	.00980	.01243	.01622	.01876	.01684	88
.01446	.01174	.00858	.00541	.00291	.00168	.00042	-.00094	89
-.00275	-.00466	-.00668	-.01230	-.01539	-.01571	-.01660	-.01718	90
-.01796	-.01836	-.01420	-.01042	-.00905	-.00692	-.00534	-.00263	91
.00000	.00305	.00436	.00421	.00433	.00369	.00185	.00008	92
-.00181	-.00304	-.00347	-.00407	-.00450	-.00383	-.00163	-.00023	93
.00228	.00587	.01472	.02550	.02612	.02857	.02996	.03102	94
.02932	.02846	.02698	.02666	.02573	.02537	.02410	.02332	95
.02186	.02105	.01855	.01489	.01201	.01034	.00805	.00531	96
.00176	-.00260	-.00736	-.01071	-.01549	-.02166	-.02159	-.01965	97
-.01836	-.01657	-.01522	-.01349	-.01121	-.00704	-.00651	-.00786	98
-.00923	-.01047	-.01283	-.01568	-.01658	-.01079	-.00523	.00058	99
.00533	.00965	.01214	.01590	.01834	.02155	.01990	.02172	100

MAXIMUM ACCELERATION = .05724
AT TIME = 7.10 SEC

THE VALUES WILL BE MULTIPLIED BY A FACTOR = .349
TO GIVE NEW MAXIMUM ACCELERATION = .02000

MEAN SQUARE FREQUENCY = 1.58 C/SEC.

MAX ACCELERATION = .02000 FOR FREQUENCIES REMOVED ABOVE 25.00 C/SEC.

```
1******     3  ***  READ WHERE OBJECT MOTION IS GIVEN

  OBJECT MOTION IN LAYER NUMBER  9  OUTCROPPING


1******     4  ***  OBTAIN STRAIN COMPATIBLE SOIL PROPERTIES


  MAXIMUM NUMBER OF ITERATIONS                -    10
  MAXIMUM ERROR IN PERCENT                    -  5.00
  FACTOR FOR EFFECTIVE STRAIN IN TIME DOMAIN  -   .65


     EARTHQUAKE    -     PASADENA 1952
     SOIL PROFILE -   Example
```

ITERATION NUMBER 1

THE CALCULATION HAS BEEN CARRIED OUT IN THE TIME DOMAIN WITH EFF. STRAIN - .65* MAX. STRAIN

LAYER	TYPE	DEPTH FT	EFF. STRAIN PRCNT	NEW DAMP.	DAMP USED	ERROR PRCNT	NEW G KSF	G USED KSF	ERROR PRCNT
1	2	3.5	.00226	.027	.050	-83.3	601.352	999.773	-66.3
2	1	13.5	.03885	.070	.100	-43.0	138.774	200.547	-44.5
3	1	25.0	.01215	.050	.050	.9	649.473	999.344	-53.9
4	1	36.0	.01586	.055	.050	8.3	905.860	999.344	-10.3
5	2	52.0	.01073	.060	.050	17.2	2947.063	1999.223	32.2
6	1	71.0	.02702	.063	.050	20.2	900.622	998.792	-10.9
7	1	90.0	.01544	.054	.050	7.6	1604.370	1997.548	-24.5
8	1	110.0	.01351	.052	.050	4.0	1885.121	2499.239	-32.6

VALUES IN TIME DOMAIN

LAYER	TYPE	THICKNESS FT	DEPTH FT	MAX STRAIN PRCNT	MAX STRESS PSF	TIME SEC
1	2	7.0	3.5	.00348	20.91	5.84
2	1	13.0	13.5	.05977	82.95	5.84
3	1	10.0	25.0	.01870	121.43	5.82
4	1	12.0	36.0	.02440	221.00	5.82
5	2	20.0	52.0	.01651	486.53	5.80
6	1	18.0	71.0	.04158	374.44	5.80
7	1	20.0	90.0	.02375	381.08	5.44
8	1	20.0	110.0	.02078	391.74	5.44

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EARTHQUAKE - PASADENA 1952
SOIL PROFILE - Example

ITERATION NUMBER 2

THE CALCULATION HAS BEEN CARRIED OUT IN THE TIME DOMAIN WITH EFF. STRAIN = .65* MAX. STRAIN

LAYER	TYPE	DEPTH FT	EFF. STRAIN PRCNT	NEW DAMP.	DAMP USED	ERROR PRCNT	NEW G KSF	G USED KSF	ERROR PRCNT
1	2	3.5	.00424	.039	.027	29.9	548.783	601.352	-9.6
2	1	13.5	.06144	.081	.070	13.5	113.853	138.774	-21.9
3	1	25.0	.01890	.057	.050	11.7	557.480	649.473	-16.5
4	1	36.0	.01630	.055	.055	.8	897.070	905.860	-1.0
5	2	52.0	.00647	.048	.060	-25.0	3256.895	2947.063	9.5
6	1	71.0	.02757	.063	.063	.5	892.878	900.622	-.9
7	1	90.0	.01805	.056	.054	4.2	1517.289	1604.370	-5.7
8	1	110.0	.01669	.055	.052	5.8	1752.656	1885.121	-7.6

VALUES IN TIME DOMAIN

LAYER	TYPE	THICKNESS FT	DEPTH FT	MAX STRAIN PRCNT	MAX STRESS PSF	TIME SEC
1	2	7.0	3.5	.00653	35.82	5.88
2	1	13.0	13.5	.09452	107.62	5.88
3	1	10.0	25.0	.02907	162.06	5.88
4	1	12.0	36.0	.02508	224.99	5.88
5	2	20.0	52.0	.00996	324.25	7.64
6	1	18.0	71.0	.04241	378.69	8.08
7	1	20.0	90.0	.02777	421.30	8.08
8	1	20.0	110.0	.02568	450.01	8.06

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EARTHQUAKE - PASADENA 1952
SOIL PROFILE - Example

ITERATION NUMBER 3

THE CALCULATION HAS BEEN CARRIED OUT IN THE TIME DOMAIN WITH EFF. STRAIN = .65* MAX. STRAIN

LAYER	TYPE	DEPTH FT	EFF. STRAIN PRCNT	NEW DAMP.	DAMP USED	ERROR PRCNT	NEW G KSF	G USED KSF	ERROR PRCNT
1	2	3.5	.00434	.039	.039	1.2	546.509	548.783	-.4
2	1	13.5	.06945	.084	.081	3.5	107.191	113.853	-6.2
3	1	25.0	.02172	.059	.057	3.6	528.475	557.480	-5.5
4	1	36.0	.01724	.056	.055	1.5	879.311	897.070	-2.0
5	2	52.0	.00624	.048	.048	-1.7	3280.750	3256.895	.7
6	1	71.0	.02965	.064	.063	1.7	864.612	892.878	-3.3
7	1	90.0	.02019	.058	.056	2.9	1454.839	1517.289	-4.3
8	1	110.0	.01883	.057	.055	3.2	1677.157	1752.656	-4.5

VALUES IN TIME DOMAIN

LAYER	TYPE	THICKNESS FT	DEPTH FT	MAX STRAIN PRCNT	MAX STRESS PSF	TIME SEC
1	2	7.0	3.5	.00667	36.47	5.90
2	1	13.0	13.5	.10684	114.52	5.92
3	1	10.0	25.0	.03341	176.57	7.68
4	1	12.0	36.0	.02652	233.21	7.66
5	2	20.0	52.0	.00961	315.15	7.64
6	1	18.0	71.0	.04561	394.36	8.10
7	1	20.0	90.0	.03106	451.82	8.08
8	1	20.0	110.0	.02897	485.81	8.08

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EARTHQUAKE - PASADENA 1952
SOIL PROFILE - Example

ITERATION NUMBER 4

THE CALCULATION HAS BEEN CARRIED OUT IN THE TIME DOMAIN WITH EFF. STRAIN = .65* MAX. STRAIN

LAYER	TYPE	DEPTH FT	EFF. STRAIN PRCNT	NEW DAMP.	DAMP USED	ERROR PRCNT	NEW G KSF	G USED KSF	ERROR PRCNT
1	2	3.5	.00452	.040	.039	2.3	542.189	546.509	-.8
2	1	13.5	.07859	.087	.084	3.4	100.465	107.191	-6.7
3	1	25.0	.02423	.061	.059	2.7	505.648	528.475	-4.5
4	1	36.0	.01824	.057	.056	1.5	861.383	879.311	-2.1
5	2	52.0	.00635	.048	.048	.8	3269.553	3280.750	-.3
6	1	71.0	.03179	.065	.064	1.7	838.028	864.612	-3.2
7	1	90.0	.02186	.059	.058	2.0	1410.502	1454.839	-3.1
8	1	110.0	.02014	.058	.057	1.8	1634.988	1677.157	-2.6

VALUES IN TIME DOMAIN

LAYER	TYPE	THICKNESS FT	DEPTH FT	MAX STRAIN PRCNT	MAX STRESS PSF	TIME SEC
1	2	7.0	3.5	.00696	37.72	7.68
2	1	13.0	13.5	.12091	121.47	7.70
3	1	10.0	25.0	.03728	188.49	7.68
4	1	12.0	36.0	.02806	241.71	7.66
5	2	20.0	52.0	.00977	319.39	7.66
6	1	18.0	71.0	.04890	409.81	8.10
7	1	20.0	90.0	.03363	474.29	8.10
8	1	20.0	110.0	.03098	506.58	8.10

1

EARTHQUAKE - PASADENA 1952
SOIL PROFILE - Example

ITERATION NUMBER 5

THE CALCULATION HAS BEEN CARRIED OUT IN THE TIME DOMAIN WITH EFF. STRAIN = .65* MAX. STRAIN

LAYER	TYPE	DEPTH FT	EFF. STRAIN PRCNT	NEW DAMP.	DAMP USED	ERROR PRCNT	NEW G KSF	G USED KSF	ERROR PRCNT
1	2	3.5	.00478	.042	.040	3.0	536.384	542.189	-1.1
2	1	13.5	.08765	.089	.087	2.9	94.534	100.465	-6.3
3	1	25.0	.02615	.062	.061	1.9	489.763	505.648	-3.2
4	1	36.0	.01915	.057	.057	1.3	845.958	861.383	-1.8
5	2	52.0	.00647	.048	.048	.9	3257.186	3269.553	-.4
6	1	71.0	.03344	.066	.065	1.8	822.601	838.028	-1.9
7	1	90.0	.02281	.060	.059	1.1	1386.817	1410.502	-1.7
8	1	110.0	.02080	.059	.058	.8	1614.798	1634.988	-1.3

VALUES IN TIME DOMAIN

LAYER	TYPE	THICKNESS FT	DEPTH FT	MAX STRAIN PRCNT	MAX STRESS PSF	TIME SEC
1	2	7.0	3.5	.00736	39.47	7.70
2	1	13.0	13.5	.13484	127.47	7.70
3	1	10.0	25.0	.04023	197.03	7.32
4	1	12.0	36.0	.02946	249.18	7.30
5	2	20.0	52.0	.00995	324.13	8.12
6	1	18.0	71.0	.05144	423.17	8.12
7	1	20.0	90.0	.03508	486.56	8.12
8	1	20.0	110.0	.03200	516.72	8.10

1

EARTHQUAKE - PASADENA 1952
SOIL PROFILE - Example

ITERATION NUMBER 6

THE CALCULATION HAS BEEN CARRIED OUT IN THE TIME DOMAIN WITH EFF. STRAIN = .65* MAX. STRAIN

LAYER	TYPE	DEPTH FT	EFF. STRAIN PRCNT	NEW DAMP.	DAMP USED	ERROR PRCNT	NEW G KSF	G USED KSF	ERROR PRCNT
1	2	3.5	.00500	.043	.042	2.3	531.874	536.384	-.8
2	1	13.5	.09533	.091	.089	2.2	89.962	94.534	-5.1
3	1	25.0	.02756	.063	.062	1.3	478.803	489.763	-2.3
4	1	36.0	.01984	.058	.057	.9	834.598	845.958	-1.4
5	2	52.0	.00653	.049	.048	.4	3250.656	3257.186	-.2
6	1	71.0	.03403	.067	.066	.6	817.242	822.601	-.7
7	1	90.0	.02316	.060	.060	.4	1378.202	1386.817	-.6
8	1	110.0	.02085	.059	.059	.1	1613.271	1614.798	-.1

VALUES IN TIME DOMAIN

LAYER	TYPE	THICKNESS FT	DEPTH FT	MAX STRAIN PRCNT	MAX STRESS PSF	TIME SEC
1	2	7.0	3.5	.00769	40.88	7.70
2	1	13.0	13.5	.14667	131.94	7.72
3	1	10.0	25.0	.04240	203.02	7.32
4	1	12.0	36.0	.03053	254.78	7.32
5	2	20.0	52.0	.01005	326.67	7.30
6	1	18.0	71.0	.05236	427.88	8.14
7	1	20.0	90.0	.03563	491.07	8.12
8	1	20.0	110.0	.03208	517.49	8.12

1

EARTHQUAKE - PASADENA 1952
SOIL PROFILE - Example

ITERATION NUMBER 7

THE CALCULATION HAS BEEN CARRIED OUT IN THE TIME DOMAIN WITH EFF. STRAIN = .65* MAX. STRAIN

LAYER	TYPE	DEPTH FT	EFF. STRAIN PRCNT	NEW DAMP.	DAMP USED	ERROR PRCNT	NEW G KSF	G USED KSF	ERROR PRCNT
1	2	3.5	.00514	.043	.043	1.5	528.942	531.874	-.6
2	1	13.5	.10208	.093	.091	2.1	86.583	89.962	-3.9
3	1	25.0	.02841	.063	.063	.7	472.492	478.803	-1.3
4	1	36.0	.02023	.058	.058	.5	828.459	834.598	-.7
5	2	52.0	.00655	.049	.049	.1	3248.661	3250.656	-.1
6	1	71.0	.03420	.067	.067	.2	815.705	817.242	-.2
7	1	90.0	.02310	.060	.060	-.1	1379.632	1378.202	.1
8	1	110.0	.02068	.059	.059	-.2	1618.468	1613.271	.3

VALUES IN TIME DOMAIN

LAYER	TYPE	THICKNESS FT	DEPTH FT	MAX STRAIN PRCNT	MAX STRESS PSF	TIME SEC
1	2	7.0	3.5	.00791	41.82	7.70
2	1	13.0	13.5	.15704	135.97	7.72
3	1	10.0	25.0	.04371	206.50	7.32
4	1	12.0	36.0	.03112	257.84	7.32
5	2	20.0	52.0	.01008	327.44	7.30
6	1	18.0	71.0	.05262	429.24	8.14
7	1	20.0	90.0	.03554	490.32	8.12
8	1	20.0	110.0	.03181	514.87	8.12

PERIOD = .87 FROM AVERAGE SHEAR VELOCITY = 552. FT/SEC

MAXIMUM AMPLIFICATION = 12.74
FOR FREQUENCY = 1.18 C/SEC.
PERIOD = .84 SEC.

1****** 5 *** COMPUTE MOTION IN NEW SUBLAYERS

EARTHQUAKE - PASADENA 1952
SOIL DEPOSIT - Example

LAYER	DEPTH FT	MAX. ACC. (g) WESHAKE	SHAKE*	TIME SEC	MEAN SQ. FR. C/SEC	ACC. RATIO QUIET ZONE	PUNCHED CARDS ACC. RECORD
WITHIN	.0	.102	.099	7.70	1.28	.306	0
WITHIN	7.0	.101	.098	7.70	1.27	.305	0
WITHIN	20.0	.059	.059	8.12	1.22	.245	0
WITHIN	30.0	.055	.055	8.12	1.22	.218	0
WITHIN	42.0	.050	.050	8.12	1.21	.205	0
WITHIN	52.0	.045	.047	8.10	1.20	.207	0
WITHIN	80.0	.031	.031	7.20	1.30	.177	0
WITHIN	100.0	.024	.024	6.80	1.48	.122	0
WITHIN	120.0	.017	.018	6.78	1.61	.055	0
OUTCR.	120.0	.020	.020	7.10	1.58	.000	0

* The values derived from SHAKE include the revision to the constitutive model documented by Udaka and Lysmer (1973).

```
1******     9  ***  COMPUTE RESPONSE SPECTRUM

  COMPUTE RESPONSE SPECTRUM IN LAYER  1

  RESPONSE SPECTRUM ANALYSIS FOR LAYER NUMBER   1
  CALCULATED FOR DAMPING        .050

  TIMES AT WHICH MAX. SPECTRAL VALUES OCCUR
     TD - TIME FOR MAX. RELATIVE DISP.
     TV - TIME FOR MAX. RELATIVE VEL.
     TA - TIME FOR MAX. ABSOLUTE ACC.
```

DAMPING RATIO = .05

PERIOD	TIMES FOR MAXIMA (SEC) TD	TV	TA WESHAKE	TA SHAKE*
.00	7.6800	7.1800	7.68	7.66
.10	7.6600	8.3400	7.66	7.66
.15	7.6800	7.4400	7.66	7.64
.20	7.7200	7.8000	7.70	7.70
.25	7.3000	6.0200	7.30	7.28
.30	7.3200	8.3400	7.32	7.30
.35	8.5200	8.4000	8.52	8.50
.40	7.6600	7.5200	7.66	7.62
.45	13.0000	12.8800	13.00	12.94
.50	7.7000	7.5400	7.68	7.66
.55	7.7400	7.9000	7.74	7.72
.60	7.7800	7.9400	7.76	8.08
.65	8.5600	8.0200	8.56	8.54
.70	6.4200	6.2400	6.40	6.38
.75	6.4800	6.3000	6.46	6.44
.80	8.6800	8.8800	8.66	8.62
.85	8.7600	8.9600	8.74	8.70
.90	8.8200	8.6200	8.82	8.78
.95	8.8800	8.6600	8.86	8.40
1.00	8.4800	8.7000	8.48	8.44
1.10	8.1000	8.3200	8.08	8.04
1.20	8.1000	8.3200	8.08	8.06
1.30	8.1000	8.3200	8.08	8.06
1.40	7.6600	7.8800	7.64	7.60
1.50	7.6800	7.4600	7.66	7.64
1.60	15.5600	7.4800	15.54	15.50
1.70	15.6000	7.4800	15.58	15.54
1.80	15.6600	7.8800	15.64	15.62
1.90	7.6600	7.8800	7.62	7.60
2.00	7.6600	7.9000	7.64	7.62
2.25	13.4200	7.4800	13.40	13.38
2.50	7.2400	7.4800	7.20	7.18
2.75	7.2800	7.5000	7.24	7.22
3.00	7.3000	8.3400	7.24	7.22
3.25	5.9600	8.3400	5.90	5.88
3.50	8.1400	7.8800	8.08	6.68
3.75	6.7800	7.8800	6.74	6.70
4.00	15.6600	7.8800	15.60	7.60

* Results using SHAKE do not include correction to constitutitive model by Udaka and Lysmer (1973).

1 SPECTRAL VALUES--
PASADENA 1952 Example DAMPING RATIO = .05

NO.	PERIOD SEC.	REL. DISP. FT.	REL. VEL. FT./SEC.	PSUEDO-RELATIVE VELOCITY (FT/SEC) WESHAKE	SHAKE*	ABS. ACC. G.	PSU.ABS.ACC. G.	FREQ. C/SEC.
1	.00	.00000	.00000	.001	.000	.10247	.10247	1000.00
2	.10	.00087	.00770	.055	.051	.10680	.10650	10.00
3	.15	.00200	.02191	.084	.077	.10940	.10916	6.67
4	.20	.00376	.03581	.118	.108	.11563	.11547	5.00
5	.25	.00616	.06629	.155	.152	.12052	.12092	4.00
6	.30	.01004	.10163	.210	.207	.13645	.13683	3.33
7	.35	.01525	.15976	.274	.283	.15280	.15275	2.86
8	.40	.02232	.24771	.351	.377	.17121	.17120	2.50
9	.45	.03265	.36833	.456	.438	.19744	.19787	2.22
10	.50	.04609	.42924	.579	.551	.22691	.22626	2.00
11	.55	.06554	.62265	.749	.698	.26662	.26586	1.82
12	.60	.09383	.89776	.983	.933	.31979	.31984	1.67
13	.65	.11676	.98412	1.13	1.12	.34156	.33915	1.54
14	.70	.13725	1.16946	1.23	1.28	.34532	.34374	1.43
15	.75	.15324	1.23211	1.28	1.31	.33503	.33432	1.33
16	.80	.26103	1.99914	2.05	1.97	.50385	.50052	1.25
17	.85	.32329	2.36614	2.39	2.27	.55291	.54912	1.18
18	.90	.31132	2.23485	2.17	2.03	.47325	.47166	1.11
19	.95	.26914	1.93889	1.78	1.65	.36745	.36596	1.05
20	1.00	.22972	1.58655	1.44	1.33	.28335	.28190	1.00
21	1.10	.15417	1.09813	.881	.810	.15760	.15636	.91
22	1.20	.11341	.82974	.594	.551	.09747	.09665	.83
23	1.30	.11795	.80361	.570	.535	.08642	.08565	.77
24	1.40	.11731	.77046	.526	.499	.07427	.07345	.71
25	1.50	.11401	.69673	.478	.444	.06296	.06218	.67
26	1.60	.10285	.63247	.404	.379	.04970	.04931	.62
27	1.70	.11163	.53053	.413	.381	.04778	.04740	.59
28	1.80	.10530	.55289	.368	.332	.04022	.03988	.56
29	1.90	.09869	.60664	.326	.313	.03415	.03355	.53
30	2.00	.12260	.61788	.385	.370	.03829	.03761	.50
31	2.25	.14414	.68103	.403	.395	.03538	.03494	.44
32	2.50	.12039	.66624	.303	.296	.02412	.02364	.40
33	2.75	.12708	.55997	.290	.278	.02115	.02062	.36
34	3.00	.10768	.50172	.226	.211	.01520	.01468	.33
35	3.25	.08621	.46203	.167	.162	.01044	.01002	.31
36	3.50	.08014	.41287	.144	.144	.00843	.00803	.29
37	3.75	.08117	.42587	.136	.135	.00730	.00708	.27
38	4.00	.08583	.41985	.135	.123	.00679	.00658	.25

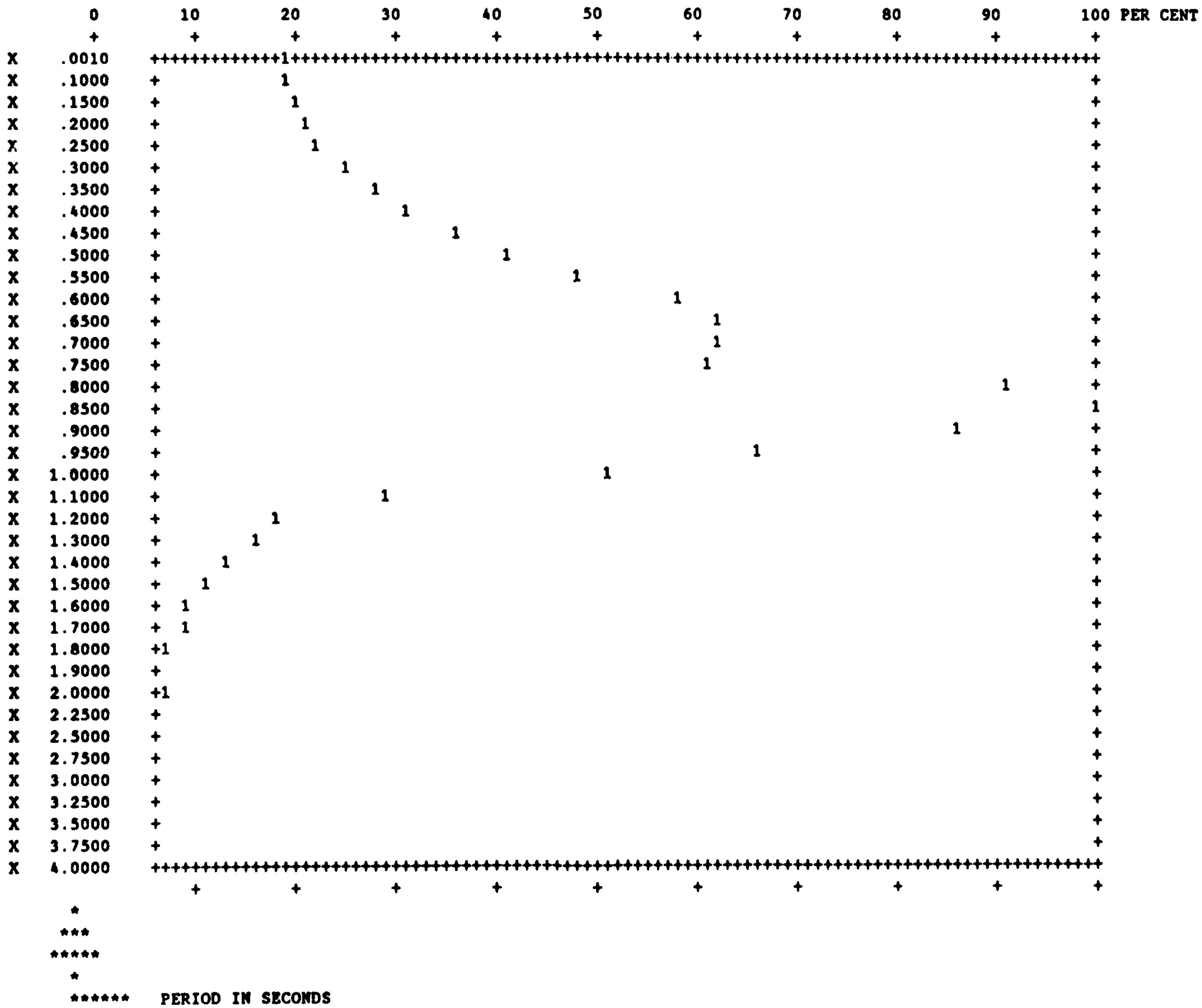
* The results using SHAKE do not reflect update to constitutive model by Udaka and Lysmer (1973).

VALUES IN PERIOD RANGE .1 TO 2.5 SEC.

AREA OF ACC. RESPONSE SPECTRUM	=	.344
AREA OF VEL. RESPONSE SPECTRUM	=	1.877
MAX. ACCELERATION RESPONSE VALUE	=	.553
MAX. VELOCITY RESPONSE VALUE	=	2.366

1 PLOT OF ACCELERATION SPECTRA

100 PER CENT CORRESPONDS TO .5529

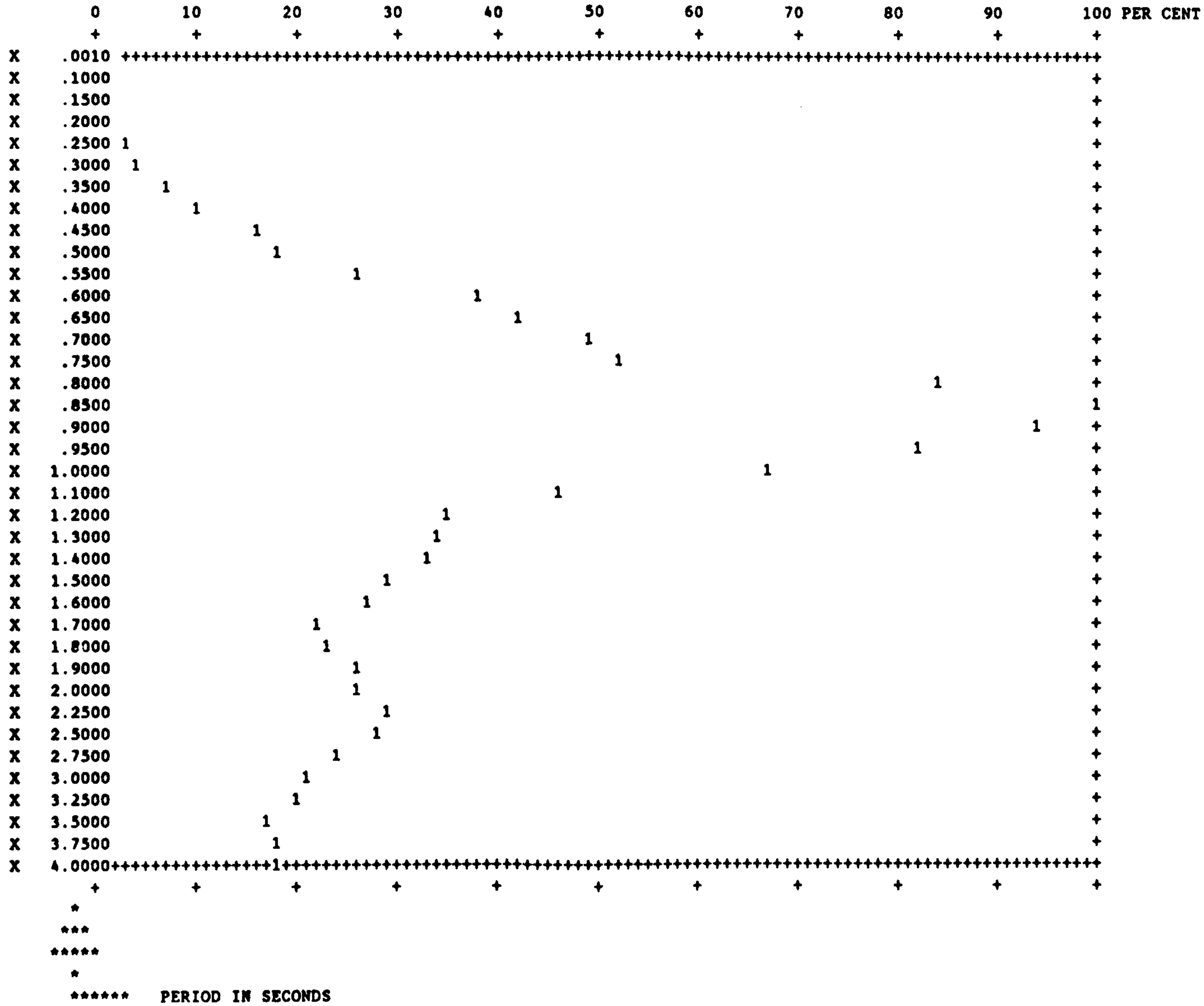


CURVE 1 5.00 % DAMPING

1 ABSISSA	CURVE 1
.001	.102
.100	.107
.150	.109
.200	.116
.250	.121
.300	.136
.350	.153
.400	.171
.450	.197
.500	.227
.550	.267
.600	.320
.650	.342
.700	.345
.750	.335
.800	.504
.850	.553
.900	.473
.950	.367
1.000	.283
1.100	.158
1.200	.097
1.300	.086
1.400	.074
1.500	.063
1.600	.050
1.700	.048
1.800	.040
1.900	.034
2.000	.038
2.250	.035
2.500	.024
2.750	.021
3.000	.015
3.250	.010
3.500	.008
3.750	.007
4.000	.007

1 PLOT OF VELOCITY SPECTRA

100 PER CENT CORRESPONDS TO 2.3661

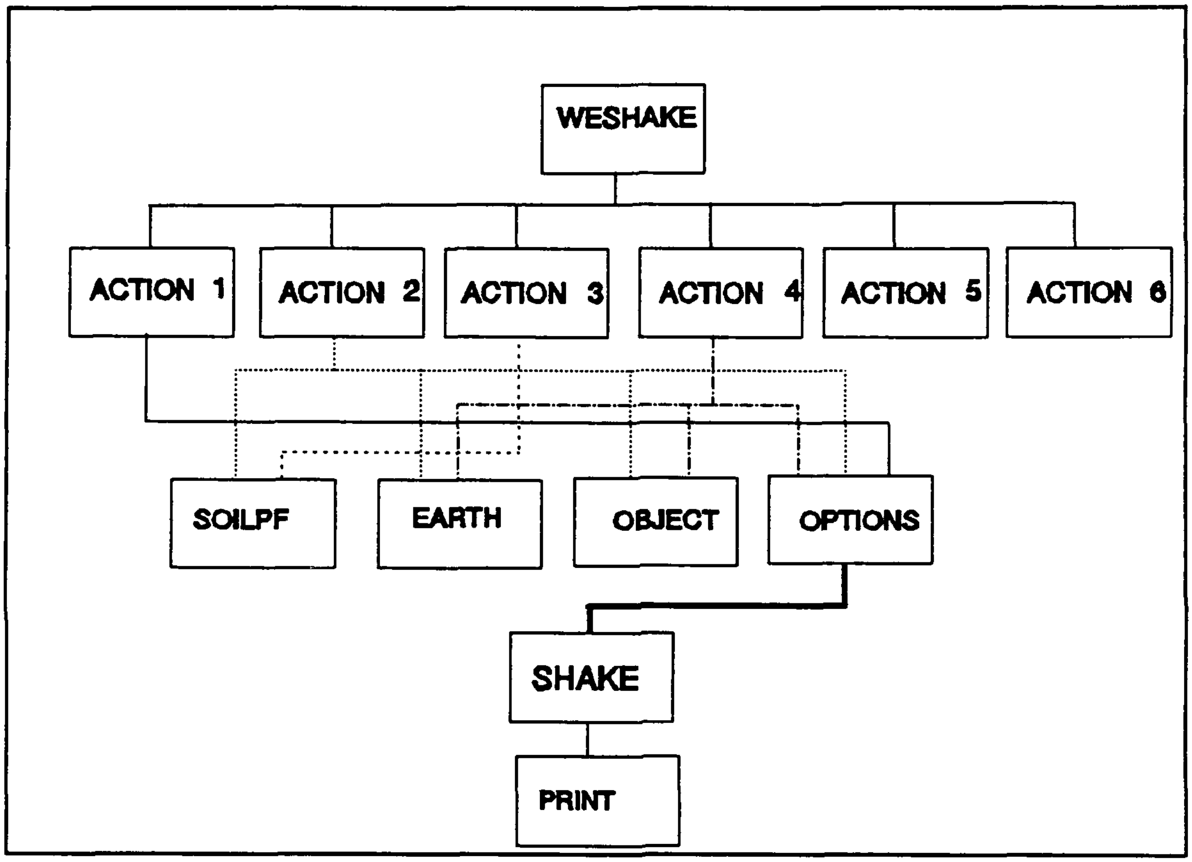


CURVE 1 5.00 % DAMPING

1 ABSISSA	CURVE 1
.001	.000
.100	.008
.150	.022
.200	.036
.250	.066
.300	.102
.350	.160
.400	.248
.450	.368
.500	.429
.550	.623
.600	.898
.650	.984
.700	1.169
.750	1.232
.800	1.999
.850	2.366
.900	2.235
.950	1.939
1.000	1.587
1.100	1.098
1.200	.830
1.300	.804
1.400	.770
1.500	.697
1.600	.632
1.700	.531
1.800	.553
1.900	.607
2.000	.618
2.250	.681
2.500	.666
2.750	.560
3.000	.502
3.250	.462
3.500	.413
3.750	.426
4.000	.420

Total execution time - 120.91 secs

APPENDIX G:
FLOWCHART OF *WESHAKE*


WESHAKE
ACTION 1
ACTION 2
ACTION 3
ACTION 4
ACTION 5
ACTION 6
SOILPF
EARTH
OBJECT
OPTIONS
SHAKE
PRINT

APPENDIX H:

EXAMPLE SPECIFICATION FILE

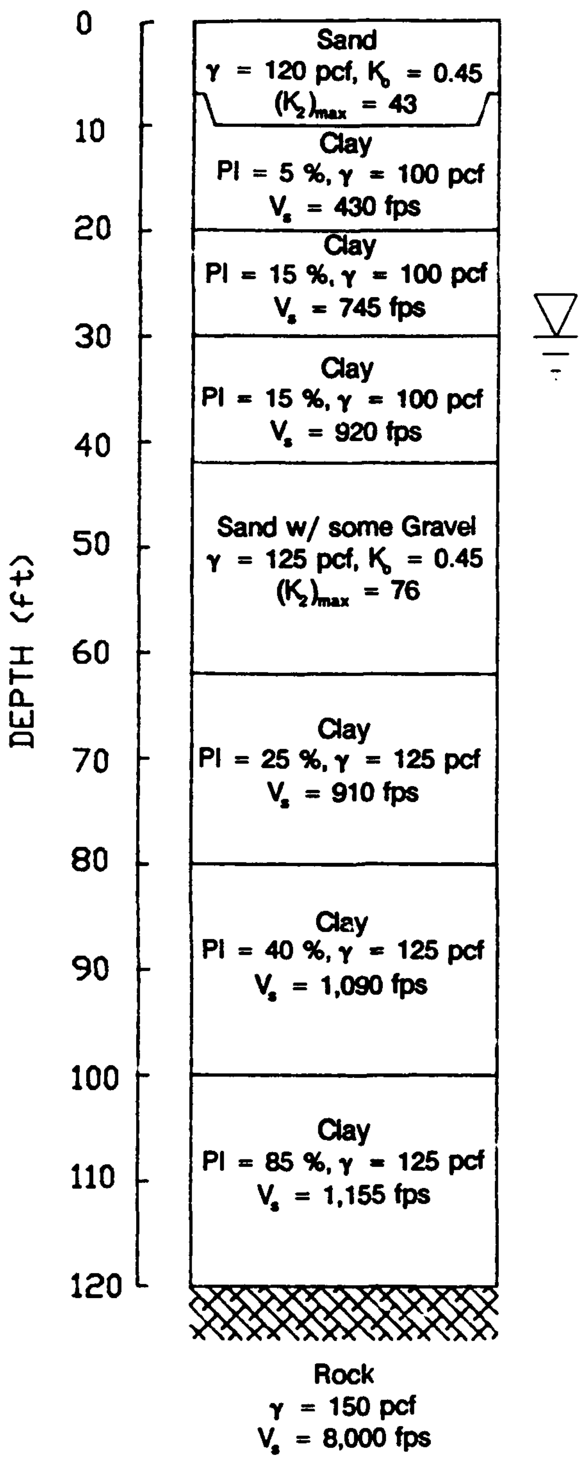


Figure H1. Soil profile used for example problem in Appendices H and I

```
4096   EXAMPLE PROBLEM FOR WESHAKE USER'S MANUAL
  2             OPTION 2:  READ SOIL COLUMN DATA
  0     9     4     .06240  EIGHT LAYERS OVERLYING ROCK
  1   3   1       8.0       .45       .050      .120       43.       43.1.0001
  2   4   1      12.0       .00       .050      .100      430.      430.1.0000
  3   5   1      10.0       .00       .050      .100      745.      745.1.0000
  4   5   1      11.0       .00       .050      .100      920.      920.1.0000
  5   2   1      20.0       .45       .050      .125       76.       76.1.0001
  6   6   1      19.0       .00       .050      .125      910.      910.1.0000
  7   7   1      20.0       .00       .050      .125     1090.     1090.1.0000
  8   8   1      20.0       .00       .050      .125     1155.     1155.1.0000
  9   1   1                           .020      .150     8000.     8000.1.0000
  8       OPTION 8: READ MATERIAL PROPERTIES
  8     0     2    100.                 STRAIN COMPATIBLE PROPERTIES
 8100.0 ROCK (Schnabel 1973)
  .0001    .0003    .0010    .0030    .0100    .0300    .1000   1.0000
 1.0000   1.0000    .9900    .9500    .9000    .8100    .7250    .5500
 5  5.0 ROCK (Schnabel 1973)
  .0001    .0010    .0100    .1000   1.0000
  .4000    .8000   1.5000   3.0000   4.6000
 9100.0 SAND, Lower Bound (Seed & Idriss 1970)
  .0001    .0003    .0010    .0030    .0100    .0300    .1000    .3000
 1.0000
 1.0000    .9850    .9300    .8300    .6350    .4250    .2250    .1100
  .0400
 9  5.0 SAND, Lower Bound (Seed & Idriss 1970)
  .0001    .0003    .0010    .0030    .0100    .0300    .1000    .3000
 1.0000
  .3000    .4000    .7000   1.4000   2.7000   5.0000   9.8000  15.0000
20.7000
 9100.0 SAND, Average (Seed & Idriss 1970)
  .0001    .0003    .0010    .0030    .0100    .0300    .1000    .3000
 1.0000
 1.0000    .9800    .9500    .8900    .7300    .5200    .2900    .1400
  .0600
 9  5.0 SAND, Average (Seed & Idriss 1970)
  .0001    .0003    .0010    .0030    .0100    .0300    .1000    .3000
 1.0000
  .8000   1.0000   1.9000   3.0000   5.4000   9.6000  15.4000  20.8000
24.6000
 9100.0 CLAY/SILT (PI=5-10, Sun et al. 1988)
  .0001    .0003    .0010    .0030    .0100    .0300    .1000    .3000
 1.0000
 1.0000   1.0000    .9750    .9100    .7800    .5650    .3050    .1400
  .0400
 9  5.0 CLAY, Lower Bound (Seed & Idriss 1970)
  .0001    .0003    .0010    .0030    .0100    .0300    .1000    .3000
 1.0000
 1.3000   1.3000   1.3000   1.5000   1.7000   2.5000   4.0000   6.5000
12.3000
```

```
  9100.0 CLAY/SILT (PI=10-20, Sun et al. 1988)
   .0001     .0003     .0010     .0030     .0100     .0300     .1000     .3000
  1.0000
  1.0000    1.0000    1.0000     .9600     .8700     .7000     .4100     .2000
   .0800
  9  5.0 CLAY, Average  (Seed & Idriss 1970)
   .0001     .0003     .0010     .0030     .0100     .0300     .1000     .3000
  1.0000
  2.5000    2.5000    2.5000    3.2000    4.5000    6.5000    9.0000   13.5000
 20.5000
  9100.0 CLAY/SILT (PI=20-40, Sun et al. 1988)
   .0001     .0003     .0010     .0030     .0100     .0300     .1000     .3000
  1.0000
  1.0000    1.0000    1.0000     .9700     .9000     .7700     .5200     .3000
   .1400
  9  5.0 CLAY, Average  (Seed & Idriss 1970)
   .0001     .0003     .0010     .0030     .0100     .0300     .1000     .3000
  1.0000
  2.5000    2.5000    2.5000    3.2000    4.5000    6.5000    9.0000   13.5000
 20.5000
  9100.0 CLAY/SILT (PI=40-80, Sun et al. 1988)
   .0001     .0003     .0010     .0030     .0100     .0300     .1000     .3000
  1.0000
  1.0000    1.0000    1.0000     .9850     .9200     .8150     .6200     .4100
   .2000
  9  5.0 CLAY, Average  (Seed & Idriss 1970)
   .0001     .0003     .0010     .0030     .0100     .0300     .1000     .3000
  1.0000
  2.5000    2.5000    2.5000    3.2000    4.5000    6.5000    9.0000   13.5000
 20.5000
  9100.0 CLAY/SILT (PI>80, Sun et al. 1988)
   .0001     .0003     .0010     .0030     .0100     .0300     .1000     .3000
  1.0000
  1.0000    1.0000    1.0000     .9850     .9400     .8600     .7100     .5300
   .3300
  9  5.0 CLAY Upper Bound (Seed & Idriss 1970)
   .0001     .0003     .0010     .0030     .0100     .0300     .1000     .3000
  1.0000
  4.0000    4.0000    4.0000    5.0000    7.5000   11.0000   16.0000   21.8000
 27.0000
   1      OPTION 1:  READ ACCELERATION VALUES FROM "EARTHQ"
2048 4096     0.02    Alaska EQ  (7/30/72)  Sitka Record
      1.0        0.        25.0      0
 0.00000 -0.00434  0.00860  0.00540 -0.00565 -0.00944 -0.00369 -0.00669    1
-0.00336 -0.00111  0.00358  0.00303 -0.00323 -0.00907 -0.01522 -0.01029    2
-0.00706 -0.00194  0.00135  0.00191  0.00743  0.00043 -0.00657  0.00527    3
-0.01948 -0.00854 -0.01807 -0.01060 -0.00396  0.00315  0.01088  0.01252    4
 0.00859  0.00066 -0.00698 -0.01661 -0.01454 -0.00959 -0.00047  0.01193    5
 0.02522  0.02534  0.02107 -0.00808 -0.01286 -0.00702 -0.01510 -0.00409    6
 0.00969  0.00253 -0.00687 -0.01304 -0.00716  0.00005  0.00802  0.00310    7
-0.00076  0.00385 -0.00101  0.00063 -0.00544 -0.00056  0.00393  0.00958    8
 0.01092  0.00872  0.00348 -0.00373 -0.00907 -0.00171  0.00996  0.01039    9
 0.00378  0.00255  0.00594  0.00241  0.01074  0.00452 -0.00165 -0.01075   10
-0.01783 -0.00081  0.01251  0.01050  0.00821  0.01259  0.01636  0.01832   11
```

0.00521	0.00569	0.00351	-0.01063	-0.03369	-0.04154	-0.04725	-0.05131	12
-0.02420	0.02808	0.04292	0.05900	0.05520	0.04862	0.03961	0.02367	13
0.00012	-0.00870	-0.01417	-0.02311	0.00280	0.03229	0.04878	0.05455	14
0.05449	0.01070	-0.02089	-0.04311	-0.04944	-0.01474	0.01639	0.03284	15
-0.00108	-0.03383	-0.04305	-0.00785	0.01159	0.02328	0.04201	0.01461	16
-0.02062	-0.03449	-0.05223	-0.06713	-0.03791	0.01826	0.01450	0.00062	17
-0.00322	-0.02040	-0.03647	-0.00725	0.02286	0.02432	0.02051	0.01305	18
0.00005	-0.01511	-0.01056	-0.02773	-0.04252	-0.02969	0.00359	0.03776	19
0.03332	-0.00455	-0.01688	-0.00372	0.02375	0.04392	0.01144	-0.02161	20
-0.03177	-0.01033	0.02196	0.02633	-0.00478	-0.03830	-0.05378	-0.06298	21
-0.04843	0.00853	0.02995	0.04202	0.05444	0.04226	-0.01146	-0.01436	22
-0.00422	-0.00614	0.00187	0.00510	0.00357	-0.00764	-0.01967	-0.01591	23
-0.01152	0.01078	0.00464	-0.00813	-0.00155	0.01288	0.00717	0.02209	24
0.02745	0.00331	-0.01182	-0.00357	0.00114	0.00461	0.02062	0.03680	25
0.02713	0.01034	-0.00558	0.00056	-0.01203	-0.02606	-0.02043	-0.00679	26
-0.01686	-0.01296	0.01295	0.04609	0.01396	0.00772	0.02510	0.01280	27
0.00439	0.00485	-0.00509	-0.03677	-0.04885	-0.02148	0.00154	0.00619	28
0.00957	0.01188	0.01098	0.00701	-0.00082	-0.01205	-0.02089	-0.00942	29
-0.01372	-0.02214	-0.02724	-0.01255	0.00013	-0.00418	-0.00666	0.00568	30
-0.00094	-0.00631	0.00213	0.02019	0.04131	0.01411	-0.00789	-0.00313	31
0.00241	0.01099	0.01575	0.00035	-0.01550	-0.00539	0.01984	0.01635	32
-0.00499	-0.02736	-0.00499	0.01117	-0.01109	-0.01614	-0.00198	0.00614	33
-0.00590	0.00388	0.01022	0.00928	0.00519	0.01408	0.00196	-0.00296	34
0.00979	-0.00824	-0.01684	0.00068	0.01020	0.00442	0.00309	-0.01187	35
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0.00811	0.01547	0.00337	-0.00634	-0.00365	0.01147	0.00627	-0.01083	42
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0.03136	0.02286	0.01396	[illegible]	0.00588	-0.00117	-0.00988	-0.01560	44
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0.01610	0.02566	0.01704	0.01297	0.01980	0.01014	0.00440	0.00664	56
0.00489	0.00926	0.00140	-0.00020	0.01116	0.01507	0.00220	-0.01522	57
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0.01212	-0.00123	0.00050	-0.00230	-0.00115	0.00499	0.01707	0.00707	109
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0.00917	0.00175	-0.00861	0.00103	0.00946	-0.00435	-0.01179	-0.01044	125
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-0.01749	-0.01077	-0.00422	-0.00469	-0.01339	-0.01759	-0.00293	0.00949	127
0.00762	0.00525	-0.00012	-0.00810	-0.00598	0.00035	0.01293	0.01819	128
0.00800	-0.00402	-0.00995	-0.00809	0.00630	-0.00034	-0.00866	-0.00029	129
0.01437	0.00786	0.01259	0.02087	0.01806	0.01357	0.01173	0.00841	130
0.00167	0.00807	0.01183	0.00321	-0.00817	-0.00706	0.00138	-0.00155	131
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0.00295	-0.00657	-0.01397	-0.01907	-0.02469	-0.01445	0.00439	0.01419	135
0.01525	0.00351	-0.01094	-0.01070	-0.01037	-0.01861	-0.01630	-0.00346	136
0.00570	0.01115	0.01472	0.00047	-0.00584	0.00059	0.00703	0.00023	137
0.00148	0.00649	-0.00782	-0.00223	0.01217	0.00815	-0.00778	-0.00269	138
0.01192	0.00161	-0.00220	0.00712	0.00298	-0.00314	0.00569	0.00965	139
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-0.00071	-0.00745	-0.00817	-0.00267	0.00723	0.00277	-0.00153	0.00364	147
0.00140	-0.00566	-0.00300	0.00377	0.00697	0.00417	0.00776	0.00667	148
0.00347	-0.00393	-0.00604	-0.00667	-0.00916	-0.01441	-0.01089	-0.00789	149
-0.00531	-0.00096	0.00533	0.01282	0.02221	0.01700	0.00353	-0.00643	150
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-0.00248	0.00020	0.00301	0.00566	0.00292	-0.00116	-0.00074	0.00369	154
0.00509	0.00084	0.00433	0.00283	-0.00149	0.00130	0.00629	0.00654	155
0.00134	0.00009	0.00788	-0.00943	-0.00186	0.00674	0.01803	0.01094	156
0.00796	0.00370	-0.00353	-0.01033	-0.01017	-0.01023	-0.00701	-0.00323	157
0.00117	0.00667	-0.00035	-0.01017	-0.01683	-0.01599	-0.00368	0.00526	158
0.01373	0.01238	0.00499	0.00882	0.01371	0.00870	0.00469	-0.00052	159
0.00046	0.00561	0.00819	0.00272	-0.00303	-0.00032	0.00057	-0.00456	160
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-0.00842	-0.00086	0.00957	0.00599	-0.00191	-0.00465	-0.00024	0.00593	169
0.01396	0.00757	-0.00518	-0.00572	-0.00576	-0.00872	-0.01399	-0.00976	170
0.00127	-0.00064	0.00412	0.01191	0.00472	-0.00737	-0.00015	0.00802	171
-0.00227	-0.00340	-0.00040	-0.00234	-0.00234	0.00959	0.01954	0.01481	172
0.01338	0.01174	0.00714	0.00451	0.00713	0.00041	-0.00738	-0.00125	173

0.00526	0.00051	-0.01404	-0.01610	-0.00978	-0.00691	-0.01593	-0.01908	174
-0.01067	-0.00362	0.00773	0.00369	0.00843	0.01329	0.00978	0.00003	175
-0.00444	0.00691	0.01310	0.00232	0.01163	0.00343	-0.00324	0.00427	176
0.01460	0.00533	-0.00439	0.00164	-0.00869	-0.01688	-0.01292	-0.00925	177
-0.01491	-0.00750	0.01235	0.00462	-0.00211	0.00310	0.00652	0.00391	178
-0.00674	-0.00587	0.00429	0.00288	-0.00264	0.00252	0.00834	0.00018	179
-0.00659	0.00110	-0.00003	-0.00652	0.00328	-0.00140	-0.01767	-0.01005	180
0.00255	0.00410	0.00229	0.01794	0.01057	-0.01580	-0.02630	-0.00572	181
0.01804	0.01007	-0.00375	-0.00191	0.00433	-0.00454	-0.01267	-0.02232	182
-0.00865	0.00292	0.00633	0.01642	0.00621	-0.00904	-0.01407	0.00341	183
0.01094	0.00423	-0.01288	-0.01305	-0.01069	-0.00231	-0.00348	-0.00155	184
0.00349	0.00367	0.00618	0.00650	0.00551	0.00083	-0.00506	0.00128	185
0.01664	0.00907	-0.00772	-0.01304	-0.00309	0.00273	-0.00175	-0.00238	186
0.00014	0.00405	0.00676	0.00696	-0.00069	-0.00173	0.00307	0.00024	187
0.00461	-0.00160	-0.00588	-0.00888	-0.00027	0.00441	0.00029	-0.00213	188
-0.00195	0.00085	0.00575	0.01111	0.00865	0.00504	0.00359	0.00265	189
0.00865	-0.00472	-0.01937	-0.01073	0.00773	0.01535	0.00532	-0.00272	190
-0.00626	0.00019	0.00218	0.00178	0.00861	0.01788	0.02463	0.01591	191
0.00537	0.00333	0.01023	0.01439	0.00877	0.00134	0.00161	-0.00218	192
-0.00871	-0.01528	-0.00942	0.00272	0.00657	-0.00581	-0.02075	-0.01980	193
-0.01109	-0.00358	0.00258	-0.00117	-0.00444	0.00247	-0.00274	-0.00953	194
-0.00832	-0.00303	0.00896	0.01694	0.01604	0.00847	-0.00449	-0.01003	195
-0.01478	-0.00969	-0.00734	-0.00592	0.00215	0.00973	0.00837	0.00574	196
0.01087	0.00418	-0.00381	-0.00441	-0.01057	-0.01705	-0.01061	-0.00392	197
-0.00857	-0.01133	-0.00758	-0.00265	0.00192	-0.00095	-0.00734	-0.00193	198
0.00078	0.00111	0.00130	0.00223	0.00368	0.01050	0.01233	0.00451	199
-0.00419	-0.00129	0.00963	0.00933	0.00408	0.00656	0.00824	0.00264	200
-0.00814	-0.01375	-0.01036	-0.00782	-0.00014	0.00614	0.00113	-0.00744	201
-0.00987	-0.00432	0.00332	-0.00196	-0.00883	-0.00171	0.00008	-0.00105	202
-0.00458	0.00326	0.00657	0.00175	0.01363	0.01516	0.00405	0.00112	203
-0.00042	-0.00296	-0.00334	0.00346	0.00734	0.00117	0.00074	0.00736	204
0.01305	0.00937	0.00492	0.00476	0.00452	-0.00131	-0.00478	-0.00833	205
-0.00594	-0.00493	-0.00572	-0.00769	-0.00519	-0.00077	0.00435	0.00944	206
0.00797	0.00689	0.00597	-0.00162	-0.00001	-0.00187	-0.00538	-0.00212	207
0.00196	-0.00355	-0.00234	-0.00053	0.00061	-0.00275	-0.00431	0.00156	208
0.00099	-0.00087	-0.00554	-0.00042	0.00440	0.00125	-0.00179	-0.00029	209
0.00420	0.00873	0.00232	0.00236	0.00402	0.00218	0.00652	0.00714	210
0.00041	-0.00780	-0.00370	0.00135	0.00254	0.00296	0.00201	0.00315	211
0.00806	0.00585	0.00240	0.00201	0.00141	-0.00149	-0.00462	-0.00621	212
-0.00528	-0.00608	-0.00850	-0.00667	-0.00066	-0.00524	-0.00071	-0.00217	213
-0.00459	-0.00280	-0.00246	-0.00295	0.00012	0.00214	-0.00317	-0.00417	214
-0.00561	-0.00801	-0.00409	-0.00225	-0.00371	0.00263	-0.00303	-0.00208	215
0.00017	-0.00240	-0.00030	-0.00081	-0.00396	-0.00724	0.00198	0.00630	216
0.00556	0.00399	0.00596	0.00366	0.00045	-0.00190	0.00343	0.00061	217
-0.00385	-0.00298	0.00076	-0.00179	-0.00166	-0.00192	0.00027	0.00409	218
0.00450	0.00087	-0.00585	-0.00549	-0.00501	-0.00232	0.00212	0.00004	219
-0.00178	0.00006	0.00018	-0.00189	-0.00588	-0.01025	-0.00791	0.00046	220
-0.00421	-0.00756	-0.00048	0.00860	0.00606	0.00799	0.00519	-0.00399	221
-0.00573	-0.00082	0.00731	0.00202	0.00415	0.00491	0.00502	0.00119	222
-0.00350	-0.00503	-0.00221	-0.00285	-0.00586	-0.00953	-0.01040	-0.00525	223
-0.00008	0.00085	0.00940	0.01439	0.00796	0.00377	-0.00201	0.00464	224
0.01212	0.01037	0.00155	-0.00968	-0.00531	-0.00181	0.00343	0.00781	225
0.00150	-0.00103	0.00140	-0.00006	-0.00545	-0.00038	0.00170	0.00386	226
0.00453	0.00381	0.00080	-0.00276	0.00166	0.00204	0.00140	0.00343	227

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 0.00560  0.00546  0.00180 -0.00141 -0.00027 -0.00087 -0.00379 -0.01018     228
-0.00799 -0.00204 -0.00492  0.00122 -0.00428 -0.00634 -0.00138  0.00291     229
 0.00336 -0.00305 -0.01595 -0.00003  0.00940  0.00570  0.00315  0.00755     230
-0.00227 -0.00019  0.00464  0.00433 -0.00018 -0.00015  0.00351  0.00793     231
 0.00340 -0.00091 -0.00134 -0.00063  0.00099  0.00257  0.00320  0.00227     232
-0.00150 -0.00044  0.00353  0.00802  0.00292 -0.00261 -0.00374 -0.00288     233
-0.00360  0.00369  0.00984  0.00620  0.00638  0.00612  0.00371 -0.00288     234
-0.00680 -0.00078  0.00961 -0.00069  0.00312  0.00151  0.00078 -0.00128     235
-0.00528 -0.01092 -0.00871  0.00074 -0.00467 -0.00113  0.00680 -0.00210     236
-0.00959 -0.00009  0.00430  0.00009  0.00923  0.01201  0.00479 -0.00273     237
-0.00122 -0.00366 -0.00120  0.01083 -0.00002 -0.00782 -0.00656 -0.00167     238
 0.00085 -0.00290 -0.00291 -0.00542 -0.00715 -0.00277  0.00182  0.00738     239
 0.00267 -0.00792 -0.00918 -0.00088  0.00111 -0.00308 -0.01068 -0.00549     240
 0.00238  0.00541  0.00617  0.00160 -0.00530 -0.01071 -0.00747 -0.00244     241
 0.00112 -0.00105 -0.00316 -0.00082 -0.00390 -0.00567  0.00074  0.00271     242
-0.00343 -0.00642 -0.00055 -0.00409 -0.01229 -0.00478  0.00025  0.00281     243
 0.00196  0.00996  0.00687 -0.00482  0.00244  0.00702 -0.00025 -0.00578     244
 0.00554  0.01694  0.00300 -0.00745 -0.00379 -0.00143 -0.00443 -0.00423     245
 0.00206  0.00680 -0.00042  0.00647  0.00482 -0.00147 -0.00288 -0 00179     246
 0.00209  0.01019  0.00571  0.00180  0.00593  0.01130  0.00726  0.00596     247
 0.00827  0.00250 -0.00167  0.00186 -0.00006 -0.00163 -0.00471 -0.00738     248
-0.00999 -0.00573 -0.00147  0.00298  0.01015  0.00287 -0.00733 -0.00010     249
 0.00366  0.00740  0.00463 -0.00107 -0.00869 -0.00025  0.00574  0.00011     250
 0.00095  0.00234  0.00194 -0.00064 -0.00351 -0.00212  0.00033  0.00165     251
 0.00600  0.00984  0.00584 -0.00597  0.00197  0.00268 -0.00498 -0.00370     252
 0.00307  0.00438 -0.00118 -0.00108  0.00030 -0.00243 -0.00631 -0.00363     253
-0.00317 -0.00467 -0.00851 -0.00520  0.00064  0.00181 -0.00349 -0.00195     254
-0.00074 -0.00335 -0.00189 -0.00637 -0.00593 -0.00091  0.00204 -0.00005     255
-0.00517 -0.00781 -0.00562 -0.00368 -0.00413 -0.00607 -0.00206  0.00118     256
    3      OPTION 3:  ASSIGN OBJECT MOTION
    9    0
    4      OPTION 4:  OBTAIN STRAIN-COMPATIBLE PROPERTIES
    0   20        .05        .65
    5      OPTION 5: COMPUTE MOTION IN SPECIFIC LAYERS
    1    2    3    4    5    6    7    8
    1    1    1    1    1    1    1    1
    0    0    0    0    0    0    0    0
    9      OPTION 9:  COMPUTE RESPONSE SPECTRA
    1    1
    5    0    1    1    1
      .020      .050      .070      .100      .120
   16      OPTION 16: COMPUTE STRESS/STRAIN HISTORY
    5    1    1    1  512      .000Sand and gravel layer

    0      END OF INPUT
```

APPENDIX I:
EXAMPLE OUTPUT FILES

"GMOD"

NORMALIZED SHEAR MODULUS CURVES FOR 8 MATERIALS:

IN PAIRS OF: EFF. SHEAR STRAIN (%), NORMALIZED MODULUS

1	2	3	4	5	6	7	8
.100E-03,1.000,	.100E-03,1.000,	.100E-03,1.000,	.100E-03,1.000,	.100E-03,1.000,	.100E-03,1.000,	.100E-03,1.000,	.100E-03,1.000,
.300E-03,1.000,	.300E-03, .985,	.300E-03, .980,	.300E-03,1.000,	.300E-03,1.000,	.300E-03,1.000,	.300E-03,1.000,	.300E-03,1.000,
.100E-02, .990,	.100E-02, .930,	.100E-02, .950,	.100E-02, .975,	.100E-02,1.000,	.100E-02,1.000,	.100E-02,1.000,	.100E-02,1.000,
.300E-02, .950,	.300E-02, .830,	.300E-02, .890,	.300E-02, .910,	.300E-02, .960,	.300E-02, .970,	.300E-02, .985,	.300E-02, .985,
.100E-01, .900,	.100E-01, .635,	.100E-01, .730,	.100E-01, .780,	.100E-01, .870,	.100E-01, .900,	.100E-01, .920,	.100E-01, .940,
.300E-01, .810,	.300E-01, .425,	.300E-01, .520,	.300E-01, .565,	.300E-01, .700,	.300E-01, .770,	.300E-01, .815,	.300E-01, .860,
.100E+00, .725,	.100E+00, .225,	.100E+00, .290,	.100E+00, .305,	.100E+00, .410,	.100E+00, .520,	.100E+00, .620,	.100E+00, .710,
.100E+01, .550,	.300E+00, .110,	.300E+00, .140,	.300E+00, .140,	.300E+00, .200,	.300E+00, .300,	.300E+00, .410,	.300E+00, .530,
.000E+00, .000,	.100E+01, .040,	.100E+01, .060,	.100E+01, .040,	.100E+01, .080,	.100E+01, .140,	.100E+01, .200,	.100E+01, .330,

"DAMP"

CRITICAL DAMPING RATIO CURVES FOR 8 MATERIALS:

IN PAIRS OF: EFF. SHEAR STRAIN (%), DAMPING RATIO

1	2	3	4	5	6	7	8
.100E-03, .4,	.100E-03, .3,	.100E-03, .8,	.100E-03, 1.3,	.100E-03, 2.5,	.100E-03, 2.5,	.100E-03, 2.5,	.100E-03, 4.0,
.100E-02, .8,	.300E-03, .4,	.300E-03, 1.0,	.300E-03, 1.3,	.300E-03, 2.5,	.300E-03, 2.5,	.300E-03, 2.5,	.300E-03, 4.0,
.100E-01, 1.5,	.100E-02, .7,	.100E-02, 1.9,	.100E-02, 1.3,	.100E-02, 2.5,	.100E-02, 2.5,	.100E-02, 2.5,	.100E-02, 4.0,
.100E+00, 3.0,	.300E-02, 1.4,	.300E-02, 3.0,	.300E-02, 1.5,	.300E-02, 3.5,	.300E-02, 3.5,	.300E-02, 3.5,	.300E-02, 5.0,
.100E+01, 4.6,	.100E-01, 2.7,	.100E-01, 5.4,	.100E-01, 1.7,	.100E-01, 4.5,	.100E-01, 4.5,	.100E-01, 4.5,	.100E-01, 7.5,
.000E+00, .0,	.300E-01, 5.0,	.300E-01, 9.6,	.300E-01, 3.5,	.300E-01, 6.5,	.300E-01, 6.5,	.300E-01, 6.5,	.300E-01, 11.0,
.000E+00, .0,	.100E+00, 9.8,	.100E+00, 15.4,	.100E+00, 4.0,	.100E+00, 9.0,	.100E+00, 9.0,	.100E+00, 9.0,	.100E+00, 16.0,
.000E+00, .0,	.300E+00, 15.0,	.300E+00, 20.8,	.300E+00, 6.5,	.300E+00, 13.5,	.300E+00, 13.5,	.300E+00, 13.5,	.300E+00, 21.8,
.000E+00, .0,	.100E+01, 20.7,	.100E+01, 24.6,	.100E+01, 12.3,	.100E+01, 20.5,	.100E+01, 20.5,	.100E+01, 20.5,	.100E+01, 27.0,

"EQIN"

INPUT EARTHQUAKE MOTION:

TIME(sec)	ACCELERATION (g)
.000	.00000
.020	-.00434
.040	.00860
.060	.00540
.080	-.00565
.100	-.00944
.120	-.00369
.140	-.00669
.160	-.00336
.180	-.00111
.200	.00358
.220	.00303
.240	-.00323
.260	-.00907
.280	-.01522
.300	-.01029
.320	-.00706
.340	-.00194
.360	.00135
.380	.00191
.400	.00743

(intermediate lines not shown)

40.480	-.00317
40.500	-.00467
40.520	-.00851
40.540	-.00520
40.560	.00064
40.580	.00181
40.600	-.00349
40.620	-.00195
40.640	-.00074
40.660	-.00335
40.680	-.00189
40.700	-.00637
40.720	-.00593
40.740	-.00091
40.760	.00204
40.780	-.00005
40.800	-.00517
40.820	-.00781
40.840	-.00562
40.860	-.00368
40.880	-.00413
40.900	-.00607
40.920	-.00206
40.940	.00118

"AMAX"

(TOP OF LAYER) DEPTH (ft)	MAXIMUM ACCELERATION (g)
.0,	.257
8.0,	.222
20.0,	.146
30.0,	.143
41.0,	.115
61.0,	.115
80.0,	.094
100.0,	.082

"STRESS"

LAYER	MID-DEPTH (ft)	EFF. SHEAR STRESS (psf)	EFF. SHEAR STRAIN (%)
1,	4.0,	79.,	.17E-01
2,	14.0,	196.,	.13E+00
3,	25.0,	216.,	.16E-01
4,	35.5,	259.,	.12E-01
5,	51.0,	339.,	.16E-01
6,	70.5,	422.,	.15E-01
7,	90.0,	447.,	.11E-01
8,	110.0,	441.,	.90E-02

"ACCSPEC"

ABSOLUTE ACCELERATION SPECTRA (g):

PERIOD (sec)	DAMPING RATIOS .02	.05	.07	.10	.12
.001,	.257,	.257,	.257,	.257,	.257,
.100,	.477,	.415,	.403,	.389,	.382,
.150,	.803,	.526,	.431,	.408,	.401,
.200,	.562,	.493,	.460,	.422,	.401,
.250,	.687,	.543,	.531,	.504,	.482,
.300,	1.337,	.947,	.798,	.676,	.612,
.350,	.797,	.566,	.540,	.506,	.476,
.400,	.763,	.576,	.515,	.450,	.423,
.450,	.928,	.575,	.499,	.434,	.406,
.500,	.895,	.534,	.455,	.388,	.354,
.550,	.797,	.433,	.347,	.283,	.261,
.600,	.510,	.324,	.281,	.240,	.221,
.650,	.412,	.280,	.237,	.197,	.183,
.700,	.276,	.218,	.206,	.192,	.184,
.750,	.328,	.232,	.200,	.176,	.165,
.800,	.182,	.140,	.136,	.132,	.130,
.850,	.167,	.116,	.106,	.101,	.102,
.900,	.127,	.091,	.087,	.087,	.089,
.950,	.150,	.105,	.090,	.079,	.078,
1.000,	.149,	.103,	.089,	.078,	.074,
1.100,	.087,	.069,	.067,	.062,	.059,
1.200,	.087,	.071,	.065,	.060,	.058,
1.300,	.060,	.062,	.060,	.057,	.055,
1.400,	.076,	.063,	.057,	.052,	.049,
1.500,	.066,	.047,	.043,	.040,	.039,
1.600,	.054,	.037,	.033,	.031,	.033,
1.700,	.043,	.032,	.030,	.030,	.032,
1.800,	.036,	.032,	.029,	.030,	.031,
1.900,	.033,	.031,	.030,	.030,	.031,
2.000,	.050,	.037,	.033,	.030,	.029,
2.250,	.039,	.034,	.032,	.030,	.029,
2.500,	.037,	.033,	.032,	.030,	.029,
2.750,	.041,	.033,	.029,	.027,	.026,
3.000,	.022,	.022,	.022,	.021,	.020,
3.250,	.026,	.023,	.021,	.019,	.018,
3.500,	.029,	.023,	.020,	.017,	.016,
3.750,	.024,	.019,	.017,	.015,	.015,
4.000,	.016,	.015,	.015,	.014,	.013,

"OUTPUT"

```
EXAMPLE PROBLEM FOR WESHAKE USER'S MANUAL


MAX. NUMBER OF TERMS IN FOURIER TRANSFORM -     4096
NECESSARY LENGTH OF BLANK COMMON X        -    25619


*******   OPTION  2  ***  READ SOIL PROFILE


MSOIL -      0
ML -     9
MWL -     4
WW -   .0624
IDNT - EIGHT LAYERS OVERLYING ROCK
NEW SOIL PROFILE NO.  0      IDENTIFICATION -   EIGHT LAYERS OVERLYING ROCK


SHEAR/K2 FACTOR WAVE VELOCITY INPUT BY LAYER

NUMBER OF LAYERS                    9         DEPTH TO BEDROCK        120.00
NUMBER OF FIRST SUBMERGED LAYER     4         DEPTH TO WATER LEVEL     30.00

UNIT WEIGHT OF WATER -      .0624 kcf
```

Layer	Lib. Key	Soil Classification	Thickness (ft)	--Depth (ft)--- Top	Bottom
1	3	M: SAND, Average (Seed & Idriss 1970)	8.0	.0	8.0
		D: SAND, Average (Seed & Idriss 1970)			
2	4	M: CLAY/SILT (PI=5-10, Sun et al. 1988	12.0	8.0	20.0
		D: CLAY, Lower Bound (Seed & Idriss 19			
3	5	M: CLAY/SILT (PI=10-20, Sun et al. 198	10.0	20.0	30.0
		D: CLAY, Avergae (Seed & Idriss 1970)			
4	5	M: CLAY/SILT (PI=10-20, Sun et al. 198	11.0	30.0	41.0
		D: CLAY, Avergae (Seed & Idriss 1970)			
5	2	M: SAND, Lower Bound (Seed & Idriss 19	20.0	41.0	61.0
		D: SAND, Lower Bound (Seed & Idriss 19			
6	6	M: CLAY/SILT (PI=20-40, Sun et al. 198	19.0	61.0	80.0
		D: CLAY, Avergae (Seed & Idriss 1970)			
7	7	M: CLAY/SILT (PI=40-80, Sun et al. 198	20.0	80.0	100.0
		D: CLAY, Avergae (Seed & Idriss 1970)			
8	8	M: CLAY/SILT (PI>80, Sun et al. 1988)	20.0	100.0	120.0
		D: CLAY Upper Bound (Seed & Idriss 197			
9	1	M: ROCK (Schnabel 1973)		120.0	
		D: ROCK (Schnabel 1973)			

Layer	Mid-depth (ft)	Coeff. Earth Press.	Unit Weight (kcf)	Mean Effective Stress (ksf)
1	4.0	.45	.120	.30
2	14.00		.100	.52
3	25.00		.100	.89
4	35.50		.100	1.12
5	51.0	.45	.125	2.66
6	70.50		.125	1.81
7	90.00		.125	2.21
8	110.00		.125	2.63
9			.150	

Layer	Damping Est. (-)	Small Strain Vs (fps)	Small Strain K2max (-)	Small Strain Gmax (ksf)	Initial Est. Vs (fps)	Initial Est. G (ksf)	Initial Est. G/Gmax (-)
1	.050	448.	43.	750.	449.	750.	1.00
2	.050	430.	25.	575.	430.	575.	1.00
3	.050	745.	58.	1725.	745.	1725.	1.00
4	.050	920.	79.	2631.	920	2631.	1.00
5	.050	1004.	76.	3920.	1005.	3920.	1.00
6	.050	910.	76.	3218.	910.	3218.	1.00
7	.050	1090.	98.	4616.	1091.	4616.	1.00
8	.050	1155.	101.	5183.	1156.	5183.	1.00
9	.020	8000.		298415.	8004.	298415.	1.00

PERIOD = .53 FROM AVERAGE SHEAR VELOCITY = 905. FT/SEC

MAXIMUM AMPLIFICATION = 15.39
FOR FREQUENCY = 2.19 C/SEC.
PERIOD = .46 SEC.

******* OPTION 8 *** READ RELATION BETWEEN SOIL PROPERTIES AND STRAIN

******* OPTION 1 *** READ INPUT MOTION

EARTHQUAKE - Alaska EQ (7/30/72) Sitka Record

2048 ACCELERATION VALUES AT TIME INTERVAL .0200

THE VALUES ARE LISTED ROW BY ROW AS READ FROM CARDS
TRAILING ZEROS ARE ADDED TO GIVE A TOTAL OF 4096 VALUES

MAXIMUM ACCELERATION = .09012
AT TIME = 10.16 SEC

THE VALUES WILL BE MULTIPLIED BY A FACTOR = 1.000
TO GIVE NEW MAXIMUM ACCELERATION = .09012

MEAN SQUARE FREQUENCY = 5.65 C/SEC.

MAX ACCELERATION = .09015 FOR FREQUENCIES REMOVED ABOVE 25.00 C/SEC.

******* OPTION 3 *** READ WHERE OBJECT MOTION IS GIVEN

OBJECT MOTION IN LAYER NUMBER 9 OUTCROPPING

******* OPTION 4 *** OBTAIN STRAIN COMPATIBLE SOIL PROPERTIES

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MAXIMUM NUMBER OF ITERATIONS                 -   20
MAXIMUM ERROR IN PERCENT                     -  .05
FACTOR FOR EFFECTIVE STRAIN IN TIME DOMAIN   -  .65
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EARTHQUAKE - Alaska EQ (7/30/72) Sitka Record
SOIL PROFILE - EIGHT LAYERS OVERLYING ROCK

ITERATION NUMBER 1

THE CALCULATION HAS BEEN CARRIED OUT IN THE TIME DOMAIN WITH EFF. STRAIN = .65* MAX. STRAIN

LAYER	TYPE	DEPTH FT	EFF. STRAIN PRCNT	NEW DAMP.	DAMP USED	ERROR PRCNT	NEW G KSF	G USED KSF	ERROR PRCNT
1	3	4.0	.01123	.058	.050	14.4	530.646	749.731	-41.3
2	4	14.0	.04131	.036	.050	-37.6	285.019	574.759	-101.7
3	5	25.0	.01751	.055	.050	9.4	1351.398	1725.288	-27.7
4	5	35.5	.01318	.050	.050	.1	2176.589	2631.023	-20.9
5	2	51.0	.01138	.030	.050	-68.3	2392.088	3919.527	-63.9
6	6	70.5	.01759	.055	.050	9.6	2680.878	3217.672	-20.0
7	7	90.0	.01381	.051	.050	1.7	4104.804	4616.491	-12.5
8	8	110.0	.01333	.084	.050	40.6	4764.06?	5183.498	-8.8

VALUES IN TIME DOMAIN

LAYER	TYPE	THICKNESS FT	DEPTH FT	MAX STRAIN PRCNT	MAX STRESS PSF	TIME SEC
1	3	8.0	4.0	.01728	91.70	10.30
2	4	12.0	14.0	.06356	181.16	13.34
3	5	10.0	25.0	.02694	364.11	13.34
4	5	11.0	35.5	.02028	441.33	13.22
5	2	20.0	51.0	.01751	418.78	13.20
6	6	19.0	70.5	.02706	725.49	13.18
7	7	20.0	90.0	.02124	871.99	13.16
8	8	20.0	110.0	.02050	976.77	13.16

1

EARTHQUAKE - Alaska EQ (7/30/72) Sitka Record
SOIL PROFILE - EIGHT LAYERS OVERLYING ROCK

ITERATION NUMBER 2

THE CALCULATION HAS BEEN CARRIED OUT IN THE TIME DOMAIN WITH EFF. STRAIN = .65* MAX. STRAIN

LAYER	TYPE	DEPTH FT	EFF. STRAIN PRCNT	NEW DAMP.	DAMP USED	ERROR PRCNT	NEW G KSF	G USED KSF	ERROR PRCNT
1	3	4.0	.01277	.063	.058	7.7	512.252	530.646	-3.6
2	4	14.0	.06984	.039	.036	5.7	219.853	285.019	-29.6
3	5	25.0	.02001	.058	.055	4.2	1315.870	1351.398	-2.7
4	5	35.5	.01441	.052	.050	3.2	2140.135	2176.589	-1.7
5	2	51.0	.01612	.037	.030	19.7	2131.393	2392.088	-12.2
6	6	70.5	.01725	.055	.055	-.6	2688.335	2680.878	.3
7	7	90.0	.01226	.049	.051	-4.4	4157.318	4104.804	1.3
8	8	110.0	.01048	.076	.084	-10.0	4854.795	4764.083	1.9

VALUES IN TIME DOMAIN

LAYER	TYPE	THICKNESS FT	DEPTH FT	MAX STRAIN PRCNT	MAX STRESS PSF	TIME SEC
1	3	8.0	4.0	.01965	100.64	10.34
2	4	12.0	14.0	.10745	236.23	13.38
3	5	10.0	25.0	.03078	405.00	13.24
4	5	11.0	35.5	.02218	474.59	13.22
5	2	20.0	51.0	.02479	528.43	13.22
6	6	19.0	70.5	.02654	713.39	13.20
7	7	20.0	90.0	.01886	784.05	13.18
8	8	20.0	110.0	.01612	782.73	13.16

1

EARTHQUAKE - Alaska EQ (7/30/72) Sitka Record
SOIL PROFILE - EIGHT LAYERS OVERLYING ROCK

NOTE: ITERATIONS 3 THROUGH 8 NOT SHOWN!!

ITERATION NUMBER 9

THE CALCULATION HAS BEEN CARRIED OUT IN THE TIME DOMAIN WITH EFF. STRAIN = .65* MAX. STRAIN

LAYER	TYPE	DEPTH FT	EFF. STRAIN PRCNT	NEW DAMP.	DAMP USED	ERROR PRCNT	NEW G KSF	G USED KSF	ERROR PRCNT
1	3	4.0	.01663	.073	.073	.0	474.420	474.342	.0
2	4	14.0	.12606	.045	.045	.1	155.308	155.420	-.1
3	5	25.0	.01562	.053	.053	.0	1381.974	1381.671	.0
4	5	35.5	.01163	.048	.048	.0	2227.632	2227.329	.0
5	2	51.0	.01579	.037	.037	-.1	2146.617	2144.765	.1
6	6	70.5	.01547	.053	.053	.0	2729.782	2729.614	.0
7	7	90.0	.01058	.046	.046	.0	4222.131	4221.976	.0
8	8	110.0	.00901	.073	.073	.0	4892.729	4892.504	.0

VALUES IN TIME DOMAIN

LAYER	TYPE	THICKNESS FT	DEPTH FT	MAX STRAIN PRCNT	MAX STRESS PSF	TIME SEC
1	3	8.0	4.0	.02558	121.37	10.36
2	4	12.0	14.0	.19394	301.21	10.36
3	5	10.0	25.0	.02403	332.06	13.24
4	5	11.0	35.5	.01789	398.46	13.22
5	2	20.0	51.0	.02429	521.49	13.20
6	6	19.0	70.5	.02380	649.68	13.18
7	7	20.0	90.0	.01628	687.49	13.18
8	8	20.0	110.0	.01386	678.06	2.50

1

EARTHQUAKE - Alaska EQ (7/30/72) Sitka Record
SOIL PROFILE - EIGHT LAYERS OVERLYING ROCK

ITERATION NUMBER 10

THE CALCULATION HAS BEEN CARRIED OUT IN THE TIME DOMAIN WITH EFF. STRAIN = .65* MAX. STRAIN

LAYER	TYPE	DEPTH FT	EFF. STRAIN PRCNT	NEW DAMP.	DAMP USED	ERROR PRCNT	NEW G KSF	G USED KSF	ERROR PRCNT
1	3	4.0	.01662	.073	.073	.0	474.455	474.420	.0
2	4	14.0	.12611	.045	.045	.0	155.274	155.308	.0
3	5	25.0	.01561	.053	.053	.0	1382.050	1381.974	.0
4	5	35.5	.01162	.048	.048	.0	2227.714	2227.632	.0
5	2	51.0	.01578	.037	.037	-.1	2147.355	2146.617	.0
6	6	70.5	.01547	.053	.053	.0	2729.811	2729.782	.0
7	7	90.0	.01058	.046	.046	.0	4222.:27	4222.131	.0
8	8	110.0	.00900	.073	.073	.0	4892.799	4892.729	.0

VALUES IN TIME DOMAIN

LAYER	TYPE	THICKNESS FT	DEPTH FT	MAX STRAIN PRCNT	MAX STRESS PSF	TIME SEC
1	3	8.0	4.0	.02558	121.35	10.36
2	4	12.0	14.0	.19402	301.26	10.36
3	5	10.0	25.0	.02402	331.98	13.24
4	5	11.0	35.5	.01788	398.39	13.22
5	2	20.0	51.0	.02427	521.16	13.20
6	6	19.0	70.5	.02380	649.64	13.18
7	7	20.0	90.0	.01628	687.49	13.18
8	8	20.0	110.0	.01385	677.82	2.50

1

EARTHQUAKE - Alaska EQ (7/30/72) Sitka Record
SOIL PROFILE - EIGHT LAYERS OVERLYING ROCK

ITERATION NUMBER 11

THE CALCULATION HAS BEEN CARRIED OUT IN THE TIME DOMAIN WITH EFF. STRAIN = .65* MAX. STRAIN

LAYER	TYPE	DEPTH FT	EFF. STRAIN PRCNT	NEW DAMP.	DAMP USED	ERROR PRCNT	NEW G KSF	G USED KSF	ERROR PRCNT
1	3	4.0	.01662	.073	.073	.0	474.468	474.455	.0
2	4	14.0	.12613	.045	.045	.0	155.264	155.274	.0
3	5	25.0	.01561	.053	.053	.0	1382.067	1382.050	.0
4	5	35.5	.01162	.048	.048	.0	2227.734	2227.714	.0
5	2	51.0	.01577	.037	.037	.0	2147.641	2147.355	.0
6	6	70.5	.01547	.053	.053	.0	2729.813	2729.811	.0
7	7	90.0	.01058	.046	.046	.0	4222.111	4222.127	.0
8	8	110.0	.00900	.073	.073	.0	4892.821	4892.799	.0

VALUES IN TIME DOMAIN

LAYER	TYPE	THICKNESS FT	DEPTH FT	MAX STRAIN PRCNT	MAX STRESS PSF	TIME SEC
1	3	8.0	4.0	.02557	121.34	10.36
2	4	12.0	14.0	.19404	301.28	10.36
3	5	10.0	25.0	.02402	331.96	13.24
4	5	11.0	35.5	.01788	398.38	13.22
5	2	20.0	51.0	.02426	521.03	13.20
6	6	19.0	70.5	.02380	649.63	13.18
7	7	20.0	90.0	.01628	687.52	13.18
8	8	20.0	110.0	.01385	677.74	2.50

PERIOD = .60 FROM AVERAGE SHEAR VELOCITY = 797. FT/SEC

MAXIMUM AMPLIFICATION = 18.03
FOR FREQUENCY = 1.83 C/SEC.
PERIOD = .55 SEC.

******* OPTION 5 *** COMPUTE MOTION IN NEW SUBLAYERS

EARTHQUAKE - Alaska EQ (7/30/72) Sitka Record
SOIL DEPOSIT - EIGHT LAYERS OVERLYING ROCK

LAYER	DEPTH	MAX. ACC.	TIME	MEAN SQ. FR.	ACC. RATIO	PUNCHED CARDS
	FT	G	SEC	C/SEC	QUIET ZONE	ACC. RECORD
WITHIN	.0	.257	10.36	3.20	.000	0
WITHIN	8.0	.222	10.36	2.75	.000	0
WITHIN	20.0	.146	10.36	5.02	.001	0
WITHIN	30.0	.143	10.36	4.30	.001	0
WITHIN	41.0	.115	10.36	3.87	.000	0
WITHIN	61.0	.115	10.22	4.62	.001	0
WITHIN	80.0	.094	2.48	5.46	.001	0
WITHIN	100.0	.082	2.64	5.53	.001	0

******* OPTION 9 *** COMPUTE RESPONSE SPECTRUM

COMPUTE RESPONSE SPECTRUM IN LAYER 1

RESPONSE SPECTRUM ANALYSIS FOR LAYER NUMBER 1
CALCULATED FOR DAMPING .020 .050 .070 .100 .120

TIMES AT WHICH MAX. SPECTRAL VALUES OCCUR
TD - TIME FOR MAX. RELATIVE DISP.
TV - TIME FOR MAX. RELATIVE VEL.
TA - TIME FOR MAX. ABSOLUTE ACC.

DAMPING RATIO - .02

PERIOD	TIMES FOR MAXIMA		
	TD	TV	TA
.00	10.3400	10.3000	10.3400
.10	10.3400	10.9600	10.3400
.15	3.6400	3.9000	3.6400
.20	13.4200	13.4600	13.4200
.25	13.4400	2.8200	13.4400
.30	11.1600	11.2400	11.1600
.35	4.0800	4.0000	4.0800
.40	16.0600	15.9600	16.0600
.45	15.8600	15.9800	15.8600
.50	20.2600	20.1400	20.2600
.55	19.1400	19.2600	19.1400
.60	16.5200	16.3800	16.5200
.65	15.5200	15.6600	15.5200
.70	10.3000	10.4200	10.3000
.75	13.4000	13.5400	13.4000
.80	13.2000	13.3200	13.2000
.85	11.3800	10.2800	11.3800
.90	7.4400	15.6600	7.4200
.95	13.4200	10.2800	13.4200
1.00	9.2800	10.9800	9.2800
1.10	22.8600	23.0400	22.8600
1.20	9.0000	9.1800	9.0000
1.30	9.0200	28.0200	9.0200
1.40	9.0400	13.5400	9.0400
1.50	10.8000	13.3200	10.7800
1.60	22.7000	10.5800	22.7000
1.70	22.0600	13.3200	22.0400
1.80	5.0400	13.3200	5.0400
1.90	5.0600	10.5800	5.0600
2.00	13.4400	13.3200	13.4400
2.25	14.0800	15.6600	14.0600
2.50	14.0200	13.3200	14.0000
2.75	15.5800	13.3200	15.5600
3.00	15.9800	15.4400	15.9600
3.25	16.0800	15.4400	16.0600
3.50	16.5200	15.4600	16.4800
3.75	18.9000	15.4600	18.8800
4.00	23.3800	2.2800	23.3600

1 SPECTRAL VALUES--
Alaska EQ (7/30/72) Sitka Record EIGHT LAYERS OVERLYING ROCK DAMPING RATIO = .02

NO.	PERIOD SEC.	REL. DISP. FT.	REL. VEL. FT./SEC.	PSU.REL.VEL. FT./SEC.	ABS. ACC. G.	PSU.ABS.ACC. G.	FREQ. C/SEC.
1	.00	.00000	.00001	.00131	.25675	.25674	1000.00
2	.10	.00389	.13158	.24468	.47663	.47788	10.00
3	.15	.01483	.57880	.62119	.80335	.80884	6.67
4	.20	.01840	.44994	.57809	.56171	.56454	5.00
5	.25	.03500	.81772	.87970	.68656	.68726	4.00
6	.30	.09791	2.04021	2.05060	1.33691	1.33502	3.33
7	.35	.07941	1.43917	1.42554	.79749	.79550	2.86
8	.40	.09921	1.59478	1.55845	.76315	.76096	2.50
9	.45	.15255	2.18977	2.13002	.92821	.92449	2.22
10	.50	.18228	2.29721	2.29058	.89472	.89476	2.00
11	.55	.19692	2.38514	2.24962	.79652	.79887	1.82
12	.60	.14910	1.72560	1.56133	.50987	.50824	1.67
13	.65	.14144	1.59077	1.36718	.41176	.41081	1.54
14	.70	.10961	1.23730	.98389	.27581	.27452	1.43
15	.75	.15010	1.36754	1.25744	.32765	.32746	1.33
16	.80	.09473	1.06679	.74399	.18206	.18164	1.25
17	.85	.09844	.89944	.72765	.16696	.16720	1.18
18	.90	.08389	.78057	.58565	.12703	.12709	1.11
19	.95	.11044	.95235	.73045	.15027	.15017	1.05
20	1.00	.12082	.96318	.75915	.14860	.14827	1.00
21	1.10	.08572	.67696	.48964	.08695	.08694	.91
22	1.20	.10166	.75638	.53229	.08664	.08664	.83
23	1.30	.08256	.54750	.39905	.06027	.05995	.77
24	1.40	.12110	.65860	.54350	.07586	.07582	.71
25	1.50	.12043	.89956	.50447	.06568	.06569	.67
26	1.60	.11300	.61795	.44375	.05428	.05417	.62
27	1.70	.10213	.53336	.37748	.04338	.04337	.59
28	1.80	.09378	.59612	.32735	.03567	.03552	.56
29	1.90	.09811	.54652	.32446	.03344	.03335	.53
30	2.00	.16351	.70248	.51368	.05025	.05016	.50
31	2.25	.15855	.73321	.44275	.03855	.03843	.44
32	2.50	.18835	.83048	.47337	.03707	.03698	.40
33	2.75	.25206	.78608	.57590	.04106	.04090	.36
34	3.00	.16047	.61214	.33609	.02191	.02188	.33

35	3.25	.22638	.72142	.43766	.02633	.02630	.31
36	3.50	.28584	.78789	.51314	.02871	.02864	.29
37	3.75	.27531	.57176	.46128	.02409	.02403	.27
38	4.00	.20935	.48072	.32885	.01608	.01606	.25

VALUES IN PERIOD RANGE .1 TO 2.5 SEC.

AREA OF ACC. RESPONSE SPECTRUM	=	.586
AREA OF VEL. RESPONSE SPECTRUM	=	2.240
MAX. ACCELERATION RESPONSE VALUE	=	1.337
MAX. VELOCITY RESPONSE VALUE	=	2.385

TIMES AT WHICH MAX SPECTRAL VALUES OCCUR
TD - TIME FOR MAX. RELATIVE DISP.
TV - TIME FOR MAX. RELATIVE VEL.
TA - TIME FOR MAX. ABSOLUTE ACC.

DAMPING RATIO - .05

PERIOD	TIMES FOR MAXIMA TD	TV	TA
.00	10.3400	13.3200	10.3400
.10	10.3400	3.4600	10.3400
.15	3.6400	3.6000	3.6400
.20	13.4200	10.4400	13.4200
.25	10.5200	2.8200	13.4400
.30	11.1600	11.0800	11.1600
.35	3.9200	10.7000	3.9000
.40	15.8600	15.9600	15.8600
.45	13.7800	13.6600	13.7600
.50	13.8200	13.7000	13.8200
.55	19.1200	19.2400	19.1000
.60	15.9600	15.8400	15.9600
.65	13.9400	15.6400	13.9400
.70	14.0000	13.5200	13.9800
.75	13.4000	13.3000	13.4000
.80	2.7600	13.3200	2.7400
.85	11.3600	10.2800	11.3600
.90	11.4000	15.6600	11.4000
.95	11.0800	13.3200	11.0600
1.00	9.2800	13.3200	9.2800
1.10	9.3200	9.1600	9.3200
1.20	9.0000	9.1600	8.9800
1.30	9.0200	9.1800	9.0000
1.40	9.0400	10.2800	9.0200
1.50	9.0800	13.3200	9.0600
1.60	10.1600	13.3200	10.1400
1.70	5.0400	13.3200	5.0000
1.80	5.0400	13.3200	5.0200
1.90	13.4400	13.3200	13.4000
2.00	13.4600	13.3200	13.4200
2.25	14.0400	13.3200	14.0000
2.50	14.0400	13.3200	14.0000
2.75	15.5600	13.3200	15.5200
3.00	14.4600	13.3200	14.3800
3.25	14.4800	15.4400	14.4400
3.50	16.5000	15.4600	16.4600
3.75	18.8800	15.4600	18.8400
4.00	18.9400	15.4600	18.8800

1 SPECTRAL VALUES--

Alaska EQ (7/30/72) Sitka Record EIGHT LAYERS OVERLYING ROCK DAMPING RATIO = .05

NO.	PERIOD SEC.	REL. DISP. FT.	REL. VEL. FT./SEC.	PSU.REL.VEL. FT./SEC.	ABS. ACC. G.	PSU.ABS.ACC. G.	FREQ. C/SEC.
1	.00	.00000	.00001	.00131	.25675	.25673	1000.00
2	.10	.00339	.11088	.21315	.41535	.41630	10.00
3	.15	.00980	.32738	.41052	.52644	.53453	6.67
4	.20	.01617	.37042	.50807	.49290	.49616	5.00
5	.25	.02770	.60420	.69616	.54293	.54387	4.00
6	.30	.06963	1.39582	1.45840	.94749	.94948	3.33
7	.35	.05588	1.04259	1.00323	.56569	.55984	2.86
8	.40	.07556	1.21864	1.18696	.57639	.57957	2.50
9	.45	.09403	1.33019	1.31294	.57502	.56985	2.22
10	.50	.10863	1.38429	1.36513	.53369	.53325	2.00
11	.55	.10597	1.37065	1.21062	.43281	.42990	1.82
12	.60	.09448	1.14412	.98935	.32433	.32205	1.67
13	.65	.09611	1.05828	.92907	.27961	.27917	1.54
14	.70	.08670	.96304	.77822	.21806	.21714	1.43
15	.75	.10510	.99010	.88047	.23195	.22929	1.33
16	.80	.07258	.95777	.57004	.14015	.13917	1.25
17	.85	.06785	.72917	.50157	.11626	.11525	1.18
18	.90	.05980	.70392	.41746	.09119	.09059	1.11
19	.95	.07592	.76680	.50213	.10471	.10323	1.05
20	1.00	.08333	.76911	.52356	.10314	.10226	1.00
21	1.10	.06722	.60977	.38398	.06897	.06818	.91
22	1.20	.08211	.64537	.42995	.07076	.06998	.83
23	1.30	.08376	.54421	.40484	.06167	.06082	.77
24	1.40	.09856	.56375	.44234	.06259	.06171	.71
25	1.50	.08564	.71135	.35872	.04744	.04671	.67
26	1.60	.07443	.56820	.29229	.03664	.03568	.62
27	1.70	.07399	.55148	.27347	.03194	.03142	.59
28	1.80	.08171	.57761	.28521	.03163	.03095	.56
29	1.90	.08699	.57034	.28769	.03055	.02957	.53
30	2.00	.11863	.68659	.37269	.03725	.03640	.50
31	2.25	.13937	.73744	.38919	.03426	.03378	.44
32	2.50	.16686	.77487	.41937	.03324	.03276	.40
33	2.75	.19610	.75119	.44805	.03265	.03182	.36
34	3.00	.16349	.62418	.34241	.02246	.02229	.33

35	3.25	.19439	.66298	.37582	.02277	.02259	.31
36	3.50	.21896	.69147	.39308	.02251	.02194	.29
37	3.75	.21116	.57286	.35381	.01880	.01843	.27
38	4.00	.19597	.48696	.30783	.01540	.01503	.25

VALUES IN PERIOD RANGE .1 TO 2.5 SEC.

AREA OF ACC. RESPONSE SPECTRUM = .417
AREA OF VEL. RESPONSE SPECTRUM = 1.814
MAX. ACCELERATION RESPONSE VALUE = .947
MAX. VELOCITY RESPONSE VALUE = 1.396

NOTE: TABLES FOR OTHER THREE DAMPING RATIOS NOT SHOWN

1 PLOT OF ACCELERATION SPECTRA

100 PER CENT CORRESPONDS TO 1.3369

```
                10        20        30        40        50        60        70        80        90       100%
             +  +         +         +         +         +         +         +         +         +          +
X    .0010   ++++++++++++X++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
X    .1000   +                     X32     1                                                               +
X    .1500   +                      543      2                    1                                        +
X    .2000   +                      5 4 3  2    1                                                          +
X    .2500   +                            5 4 32         1                                                 +
X    .3000   +                                      5    4        3          2                             1
X    .3500   +                            5 4 3 2                 1                                        +
X    .4000   +                        5 4    3   2             1                                           +
X    .4500   +                      5 4    3     2                         1                               +
X    .5000   +                   5 4    3     2                          1                                 +
X    .5500   +            54    3     2                           1                                        +
X    .6000   +        5 4  3  2             1                                                              +
X    .6500   +      54  3  2         1                                                                     +
X    .7000   +      X32    1                                                                               +
X    .7500   +    54 3 2       1                                                                           +
X    .8000   +  X   1                                                                                      +
X    .8500   +X2  1                                                                                        +
X    .9000   X  1                                                                                          +
X    .9500   32  1                                                                                         +
X   1.0000   32  1                                                                                         +
X   1.1000   1                                                                                             +
X   1.2000   +                                                                                             +
X   1.3000   +                                                                                             +
X   1.4000   +                                                                                             +
X   1.5000   +                                                                                             +
X   1.6000   +                                                                                             +
X   1.7000   +                                                                                             +
X   1.8000   +                                                                                             +
X   1.9000   +                                                                                             +
X   2.0000   +                                                                                             +
X            +++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
             +  +         +         +         +         +         +         +         +         +          +
             0 10         20        30        40        50        60        70        80        90        100

      *
     ***
    *****
      *
      ******   PERIOD IN SECONDS
```

CURVE 1 2.00 % DAMPING
CURVE 2 5.00 % DAMPING
CURVE 3 7.00 % DAMPING
CURVE 4 10.00 % DAMPING
CURVE 5 12.00 % DAMPING

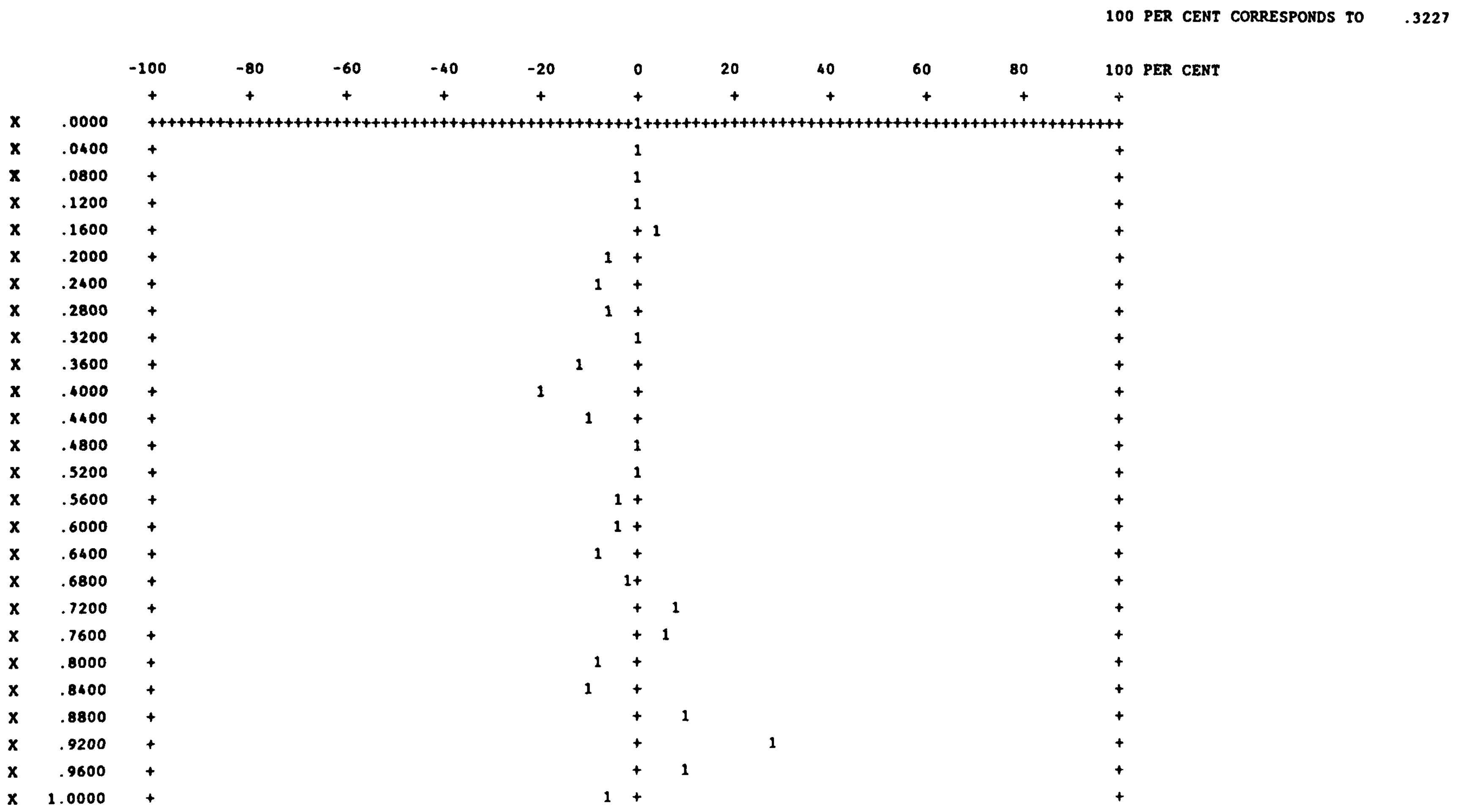
1 ABSISSA	CURVE 1	CURVE 2	CURVE 3	CURVE 4	CURVE 5
.001	.257	.257	.257	.257	.257
.100	.477	.415	.403	.389	.382
.150	.803	.526	.431	.408	.401
.200	.562	.493	.460	.422	.401
.250	.687	.543	.531	.504	.482
.300	1.337	.947	.798	.676	.612
.350	.797	.566	.540	.506	.476
.400	.763	.576	.515	.450	.423
.450	.928	.575	.499	.434	.406
.500	.895	.534	.455	.388	.354
.550	.797	.433	.347	.283	.261
.600	.510	.324	.281	.240	.221
.650	.412	.280	.237	.197	.183
.700	.276	.218	.206	.192	.184
.750	.328	.232	.200	.176	.165
.800	.182	.140	.136	.132	.130
.850	.167	.116	.106	.101	.102
.900	.127	.091	.087	.087	.089
.950	.150	.105	.090	.079	.078
1.000	.149	.103	.089	.078	.074
1.100	.087	.069	.067	.062	.059
1.200	.087	.071	.065	.060	.058
1.300	.060	.062	.060	.057	.055
1.400	.076	.063	.057	.052	.049
1.500	.066	.047	.043	.040	.039
1.600	.054	.037	.033	.031	.033
1.700	.043	.032	.030	.030	.032
1.800	.036	.032	.029	.030	.031
1.900	.033	.031	.030	.030	.031
2.000	.050	.037	.033	.030	.029
2.250	.039	.034	.032	.030	.029
2.500	.037	.033	.032	.030	.029
2.750	.041	.033	.029	.027	.026
3.000	.022	.022	.022	.021	.020
3.250	.026	.023	.021	.019	.018
3.500	.029	.023	.020	.017	.016
3.750	.024	.019	.017	.015	.015
4.000	.016	.015	.015	.014	.013

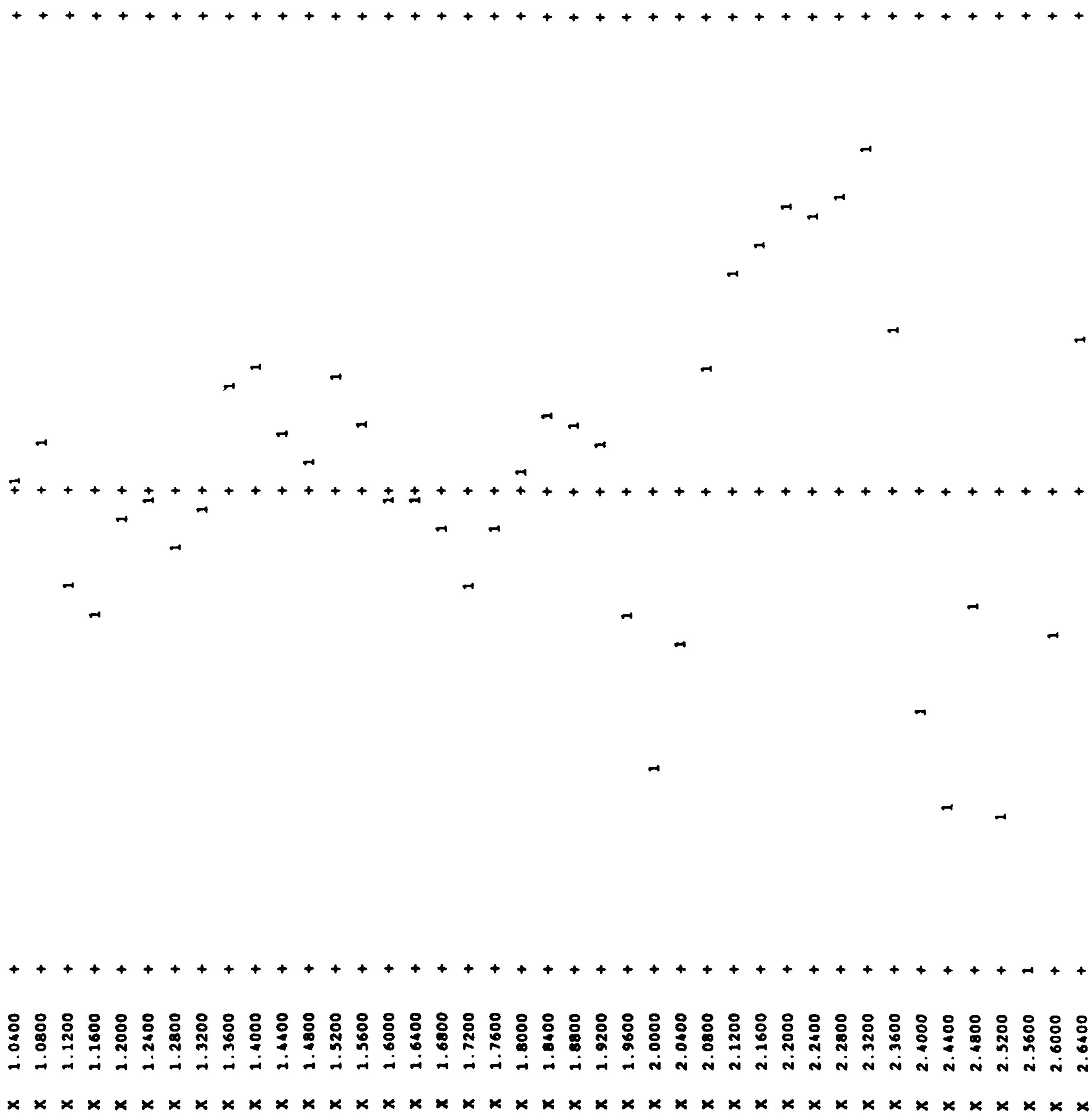
******* OPTION 16 *** COMPUTE STRESS/STRAIN HISTORY

COMPUTE STRESS OR STRAIN TIME HISTORY AT THE TOP OF LAYER 5
SCALE FOR PLOTTING = .0000
IDENTIFICATION - Sand and gravel layer

1 TIME HISTORY OF STRESS IN KIPS

NOTE:(Every other point removed from OUTPUT file for this plot)

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X 1.0800
X 1.1200
X 1.1600
X 1.2000
X 1.2400
X 1.2800
X 1.3200
X 1.3600
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X 1.4400
X 1.4800
X 1.5200
X 1.5600
X 1.6000
X 1.6400
X 1.6800
X 1.7200
X 1.7600
X 1.8000
X 1.8400
X 1.8800
X 1.9200
X 1.9600
X 2.0000
X 2.0400
X 2.0800
X 2.1200
X 2.1600
X 2.2000
X 2.2400
X 2.2800
X 2.3200
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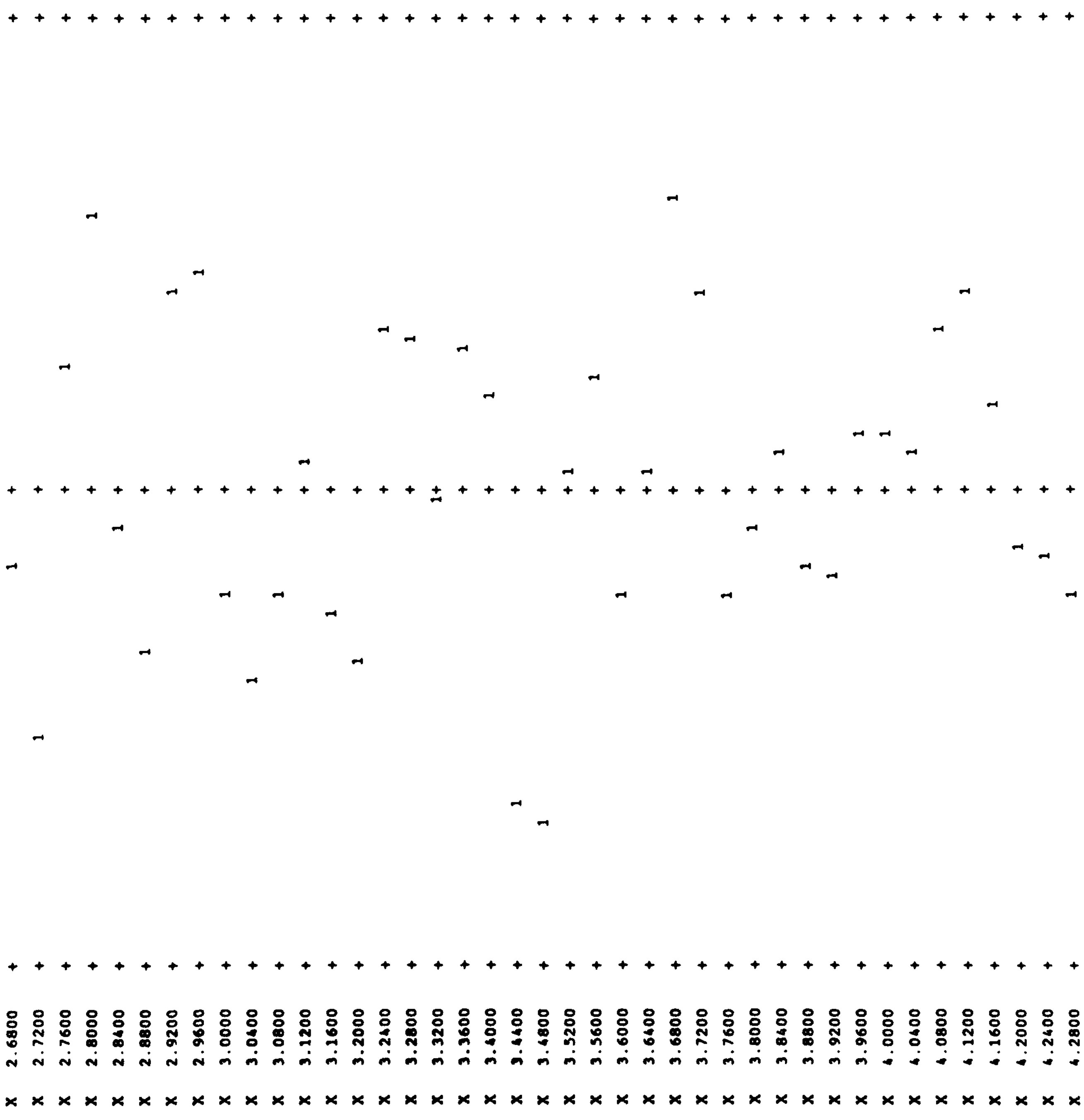
X 2.5200
X 2.5600
X 2.6000
X 2.6400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X 2.7200
X 2.7600
X 2.8000
X 2.8400
X 2.8800
X 2.9200
X 2.9600
X 3.0000
X 3.0400
X 3.0800
X 3.1200
X 3.1600
X 3.2000
X 3.2400
X 3.2800
X 3.3200
X 3.3600
X 3.4000
X 3.4400
X 3.4800
X 3.5200
X 3.5600
X 3.6000
X 3.6400
X 3.6800
X 3.7200
X 3.7600
X 3.8000
X 3.8400
X 3.8800
X 3.9200
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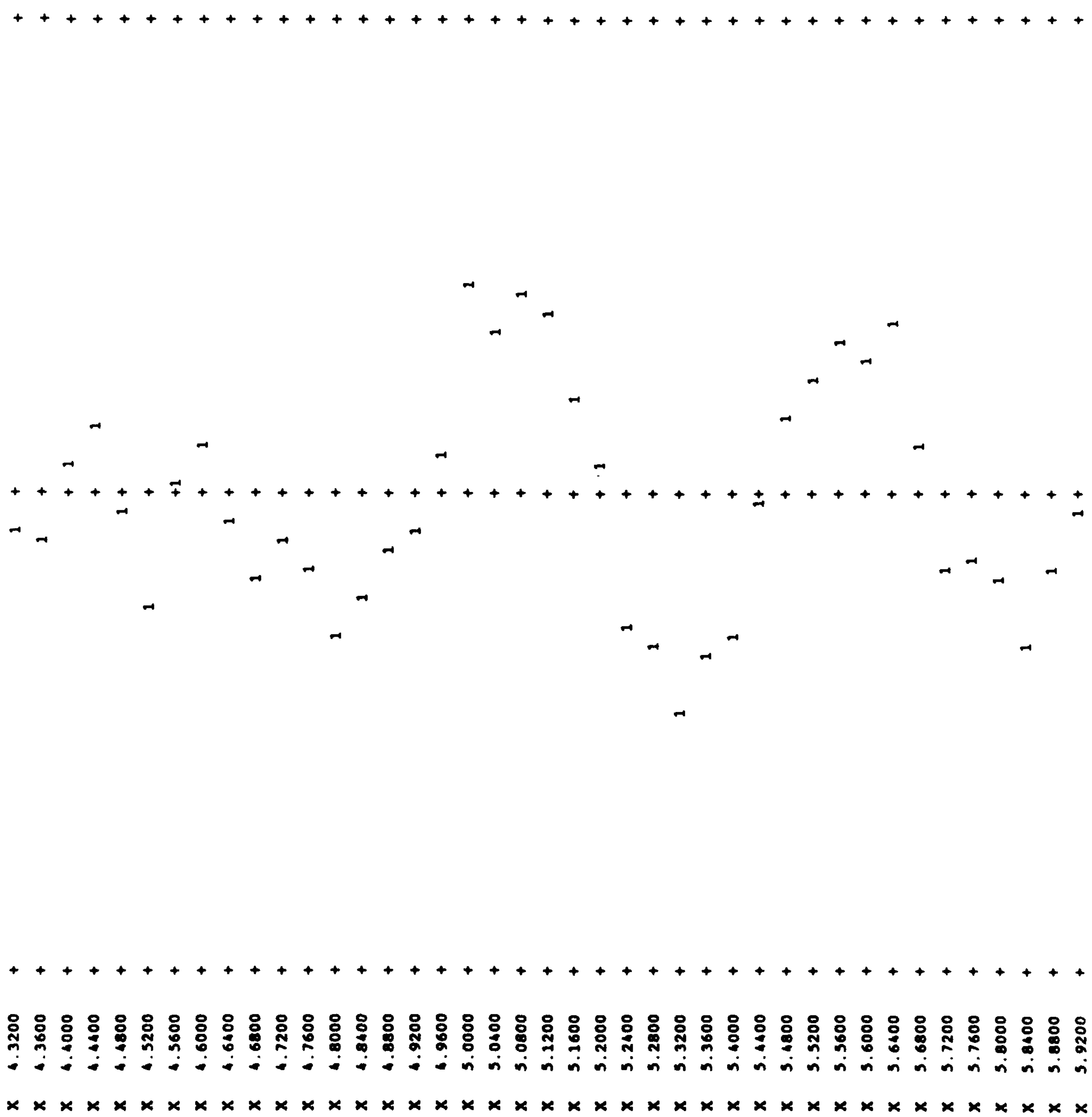
X 4.2800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X 4.3600
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X 4.4400
X 4.4800
X 4.5200
X 4.5600
X 4.6000
X 4.6400
X 4.6800
X 4.7200
X 4.7600
X 4.8000
X 4.8400
X 4.8800
X 4.9200
X 4.9600
X 5.0000
X 5.0400
X 5.0800
X 5.1200
X 5.1600
X 5.2000
X 5.2400
X 5.2800
X 5.3200
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X 5.4000
X 5.4400
X 5.4800
X 5.5200
X 5.5600
X 5.6000
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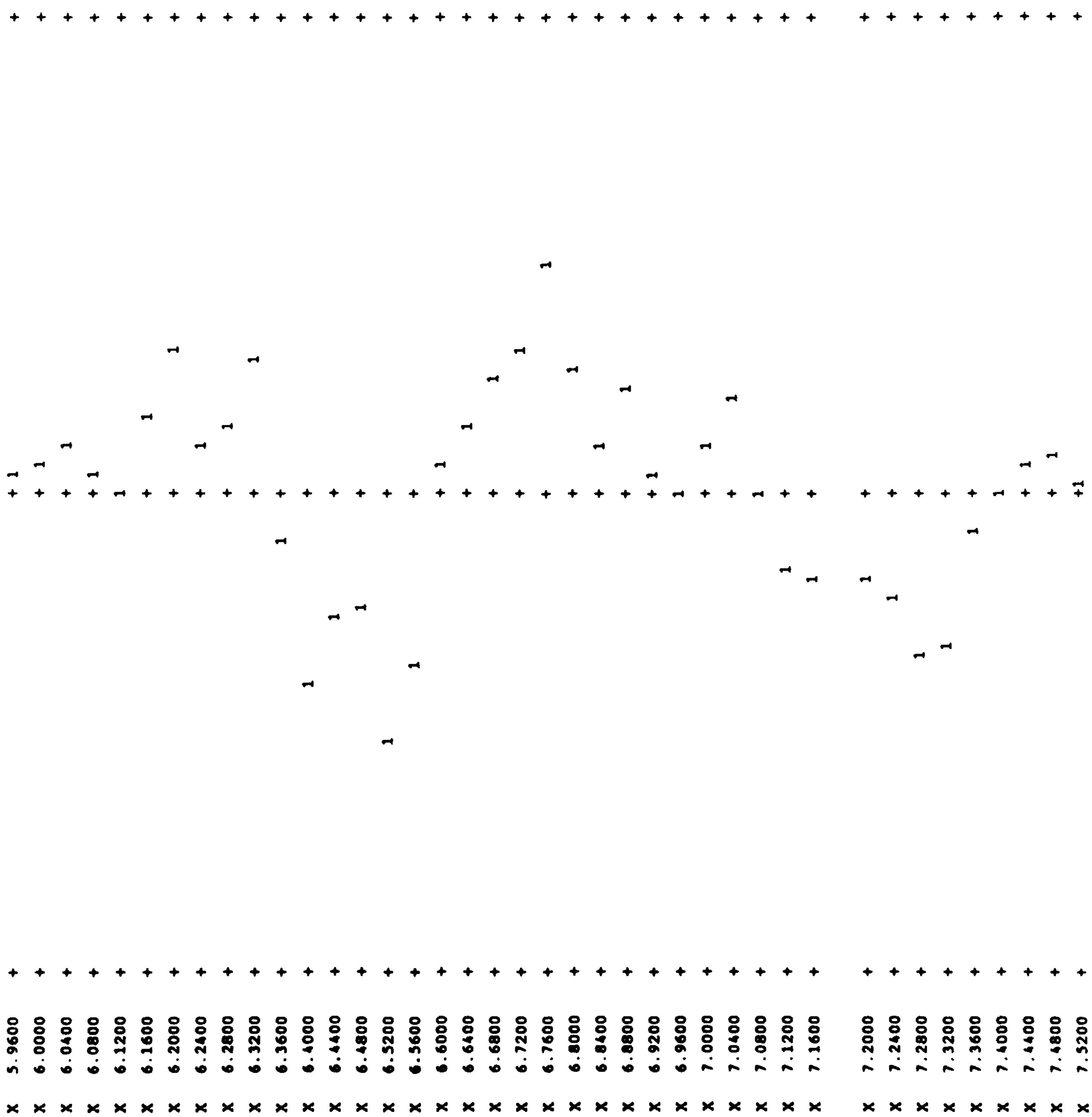
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6.5200
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6.6000
6.6400
6.6800
6.7200
6.7600
6.8000
6.8400
6.8800
6.9200
6.9600
7.0000
7.0400
7.0800
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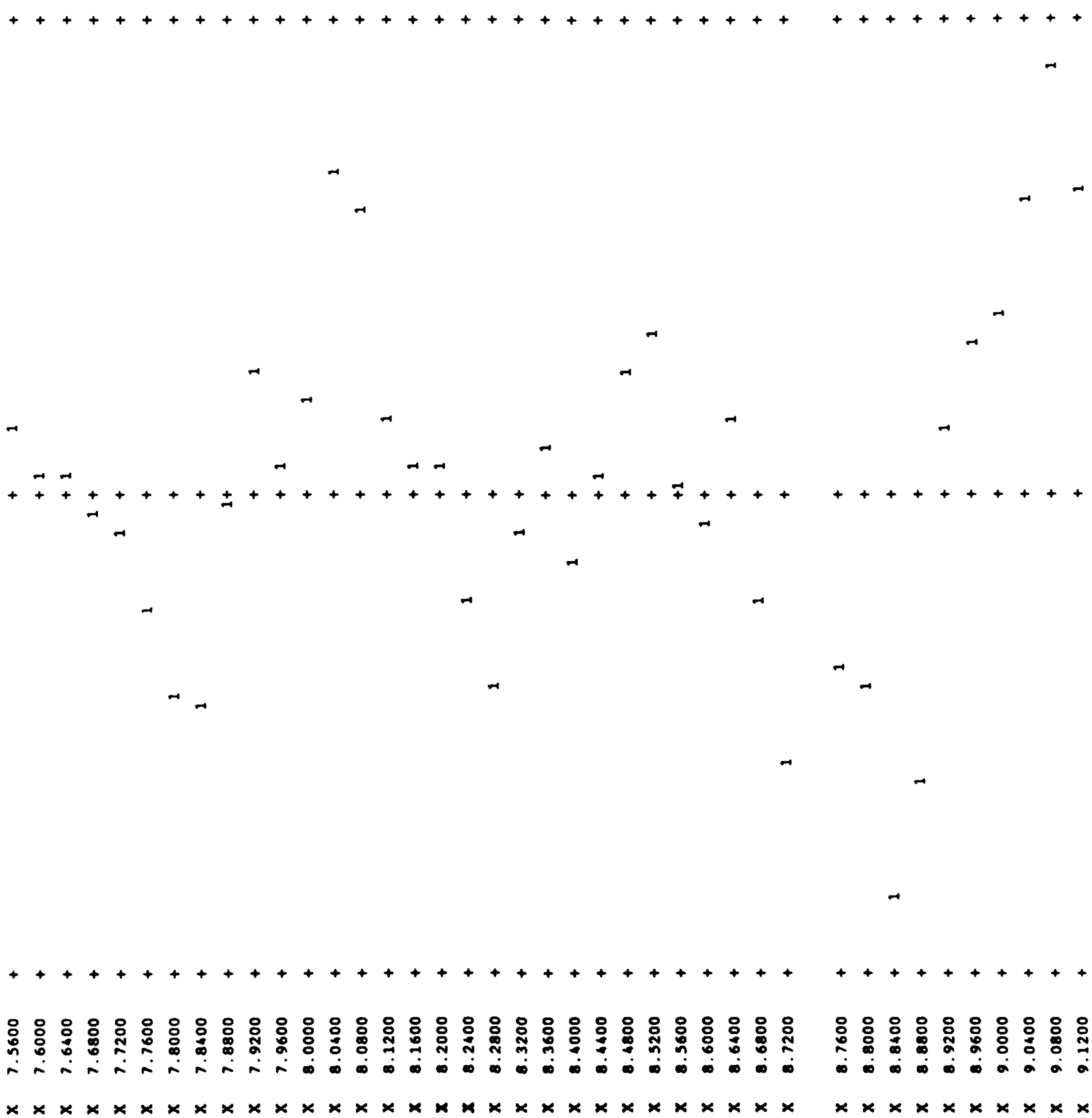
7.5200


X 7.5600
X 7.6000
X 7.6400
X 7.6800
X 7.7200
X 7.7600
X 7.8000
X 7.8400
X 7.8800
X 7.9200
X 7.9600
X 8.0000
X 8.0400
X 8.0800
X 8.1200
X 8.1600
X 8.2000
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X 8.2800
X 8.3200
X 8.3600
X 8.4000
X 8.4400
X 8.4800
X 8.5200
X 8.5600
X 8.6000
X 8.6400
X 8.6800
X 8.7200
X 8.7600
X 8.8000
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X 8.8800
X 8.9200
X 8.9600
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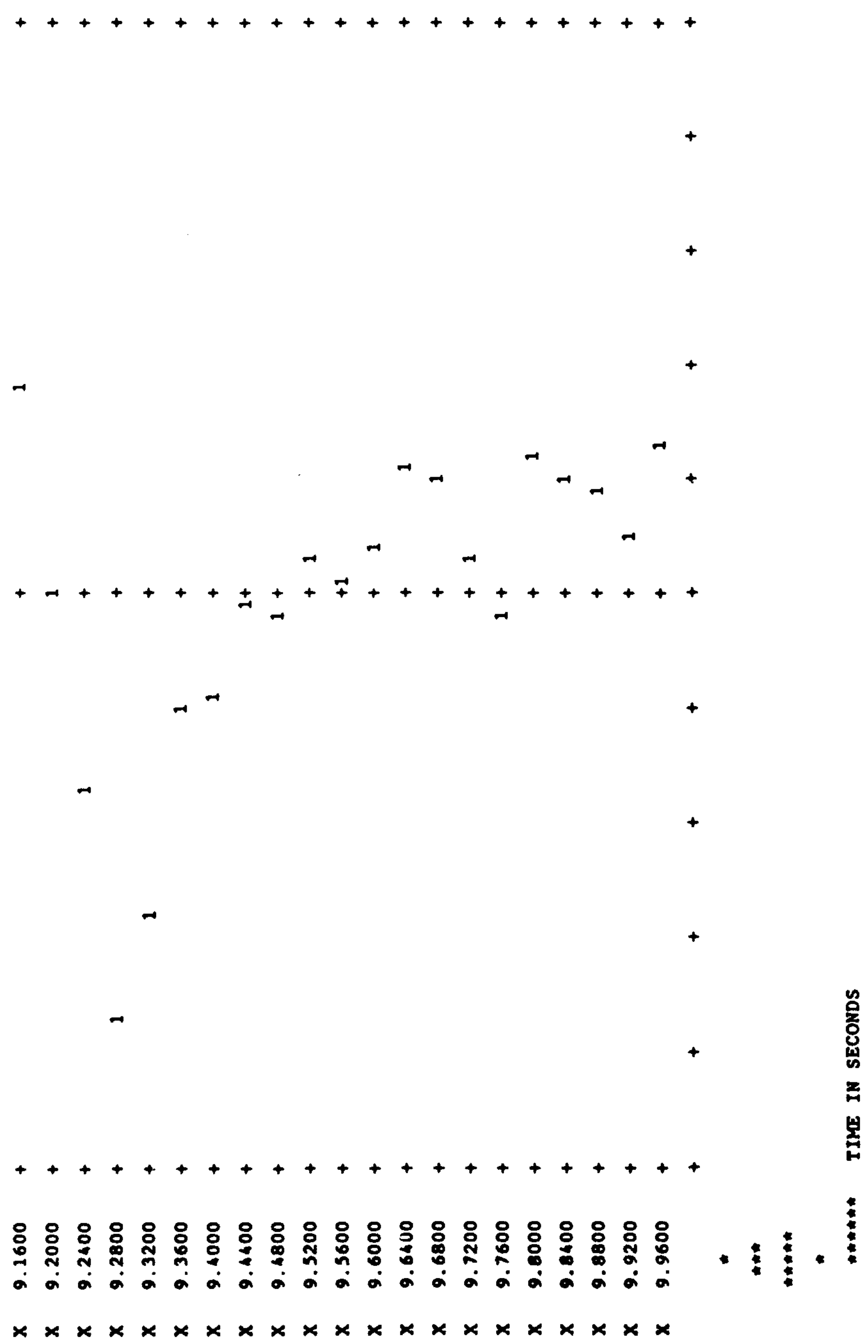
X 9.0800
X 9.1200


X 9.1600
X 9.2000
X 9.2400
X 9.2800
X 9.3200
X 9.3600
X 9.4000
X 9.4400
X 9.4800
X 9.5200
X 9.5600
X 9.6000
X 9.6400
X 9.6800
X 9.7200
X 9.7600
X 9.8000
X 9.8400
X 9.8800
X 9.9200
X 9.9600
TIME IN SECONDS

CURVE 1 2.00 % DAMPING

1 ABSISSA	CURVE 1
.000	.000
.020	.000
.040	.000
.060	.000
.080	.000
.100	-.002
.120	-.003
.140	.010
.160	.014
.180	.002
.200	-.016
.220	-.023
.240	-.027
.260	-.024
.280	-.019
.300	-.006
.320	-.001
.340	-.013
.360	-.040
.380	-.061
.400	-.064

(intermediate lines not shown)

9.700	.056
9.720	.019
9.740	-.017
9.760	-.010
9.780	.045
9.800	.076
9.820	.073
9.840	.062
9.860	.067
9.880	.058
9.900	.033
9.920	.029
9.940	.050
9.960	.085
9.980	.110
10.000	.133
10.020	.138
10.040	.083
10.060	-.031
10.080	-.126
10.100	-.164
10.120	-.144
10.140	-.109
10.160	-.125
10.180	-.197
10.200	-.248
10.220	-.204

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USACE geotechnical earthquake engineering software. Report 1, WESHAKE for personal computers (version 1.0) / by David W. Sykora, Ronald E. Wahl and David C. Wallace ; prepared for Department of the Army, U.S. Army Corps of Engineers.
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1. Earthquake engineering — Computer programs. 2. Engineering geology — Computer programs. 3. WESHAKE (Computer program) 4. Soil mechanics — Computer programs. I. Wahl, Ronald E. II. Wallace, David C. III. United States. Army. Corps of Engineers. IV. U.S. Army Engineer Waterways Experiment Station. V. Title. VI. Series: Instruction report (U.S. Army Engineer Waterways Experiment Station) ; GL-92-4.
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(back cover)

As of this publication date, the software and user's manuals available are:

Report 1 WESHAKE for Personal Computers (Version 1.0)

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