Study Plan for
Study 8.3.1.17.3.3

Ground Motion from Regional Earthquakes and Underground Nuclear Explosions

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YUCCA MOUNTAIN SITE CHARACTERIZATION PROJECT

Study Plan: Ground Motion from Regional Earthquakes and Underground Nuclear Explosions, 8.3.1.17.3.3

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Abstract

Section 8.3.1.17.3 of the Site Characterization Plan discusses the need to characterize and predict preclosure vibratory ground motion at the Yucca Mountain repository site. Underground nuclear weapons tests conducted at the Nevada Test Site could be a significant contributor to such motion. This study plan summarizes the history of data gathering and analyses of underground nuclear explosion generated ground motions observed at Yucca Mountain related to the Weapons Test Seismic Investigations at Sandia National Laboratories. The plan then describes the additional data analyses necessary to achieve the goal of developing an empirical prediction procedure for nuclear explosion ground motions likely to be observed at Yucca Mountain.

CONTENTS

	Section	Page
	List of Figures	3
I.	Purpose and Objectives	4
II	Scope of Work	5
	II.1 Summary of previous activities	5
	II.1.1 Data collection	5
	II.1.2 Data analyses	6
	II.2 Key parameters to be analyzed	8
	II.3 Technical Methodology	8
	II.3.1 Yucca Flat source area	8
	II.3.2 Downhole motion	10
	II.3.3 Empirical Model	12
III	Application of Results	13
IV	Schedule and Milestones	14
V	References	15
VI	Figures	18

LIST OF FIGURES

Figure 1. Location map showing Nevada Test Site testing areas, Yucca Mountain, monitored UNE locations through 1990, and Weapons Test Seismic Investigation stations used to monitor UNE ground motions since 1977.

Figure 2. Yucca Mountain ground motion stations fielded since 1980.

Figure 3. Location of recent Yucca Mountain ground motion stations with respect to facilities planned for the repository.

Figure 4. Example of the decay of expected vector acceleration with distance for NTS UNEs, from Vortman (1986).

Figure 5. Example of a seismic response spectrum with various levels of damping, from Hudson (1979).

Figure 6. Example surface and downhole vertical acceleration records for a UNE recorded at Yucca Mountain station 28. Note the different vertical scales on the two plots.

Figure 7. Two-dimensional upper crustal velocity models for two NTS profiles, from Walck and Phillips (1990). Top: western Pahute Mesa to Yucca Mountain. Bottom: Yucca Flat to Yucca Mountain.

I. Purpose and Objectives

Study Plan 8.3.1.17.3.3 has two activities: ground motion from regional earthquakes and ground motion from underground nuclear explosions. The U. S. Geological Survey is preparing a plan for the regional earthquake activity. This study plan refers to the second activity, development of empirical models for underground nuclear explosion ground motions.

The purpose of the work described here is to complete and integrate analyses of previously collected ground motion data from underground nuclear explosions (UNEs) that are relevant to the design of the Yucca Mountain nuclear waste repository. Analyses of these data will be performed specifically to 1) provide complete predictive capabilities for spectra and vibratory motion from UNEs recorded at Yucca Mountain, and 2) construct a geologically consistent model for the behavior with depth of UNE ground motions at the site. The end product of this study will be an empirical model useful for predicting ground motion at or below the surface at the proposed Yucca Mountain waste repository site.

Assessment of likely UNE ground motions is one element of understanding the total seismic hazard present at Yucca Mountain, particularly hazard from ground shaking (section 8.3.1.17.3 of the Site Characterization Plan (SCP)). The significant technical issues with respect to UNEs are the amplitude of motion expected, duration, and spectral content, both at surface and at depth. The proposed analyses support SCP Activity 8.3.1.17.3.3.2: Select or develop empirical models for UNE ground motions. This information obtained from this activity will feed into SCP elements 8.3.1.17.3.3 (Ground motion from regional earthquakes and UNEs), 8.3.1.17.3.6.2 (Evaluate ground-motion probabilities) and SCP element 8.3.1.17.3.5 (Ground motion at the site from controlling seismic events). One proposed analysis (Task 2 of Section II.3) is also related to SCP Activity 8.3.1.17.3.4.2, Model site effects using the wave properties of the local geology. This task would use downhole UNE data and contribute to the empirical ground motion model, but would also yield information on predictive capability at depth within the repository block as related to the local geology.

The proposed analyses, described in Section II.3, will constitute the final analyses necessary to integrate many years of UNE ground motion studies (see Section II.1 for a summary) into an overall regional empirical UNE ground motion model . This model will have input parameters of source strength (generally explosive yield, although seismic magnitude is also appropriate) and distance. Output parameters, for both surface and downhole motions, include peak amplitude estimates for acceleration, velocity, and displacement, and pseudo relative velocity (PSRV) spectra. Error and uncertainty estimates are included in the model evaluation.

Section II summarizes the scope of work for the proposed study, including a synopsis of the history of UNE ground motion measurements in the Yucca Mountain area, key parameters to be analyzed, and the technical methodology for the proposed tasks. Section III describes the applications of the study results to the Site Characterization activity, and Section IV details the schedule and milestones for the study.

II. Scope of Work

II.1 Summary of Previous Activities

Sandia National Laboratories has monitored UNE ground motions at various stations on the Nevada Test Site for many years. In addition to both on-site (local) and off-site (regional) seismometer networks, a network of three-component accelerometers was deployed to measure ground motions from 1977 to 1990. The acceleration monitoring, called the Weapons Test Seismic Investigations (WTSI) project, was supported jointly by the weapons program and the YMP. In addition to the data collection activities (II.1.1), several analyses documenting ground motion characteristics have been conducted, and are described in section II.1.2.

II.1.1 Data collection

The WTSI project deployed a total of 29 seismic stations to record UNE ground motions around the NTS (Figure 1). While all WTSI stations had surface triaxial accelerometers, several have also had identical companion instrumentation installed in boreholes, generally at depths greater than 100m. After Yucca Mountain became the focus of the project in 1980, the first WTSI seismic station at Yucca Mountain was installed, and stations at other locations were removed. Since that time, the WTSI project has fielded a total of 11 stations in the Yucca Mountain area (Figure 2). The most recent configuration included 5 stations, 4 of which had both surface and downhole instrumentation (Figure 3). Three of the recent stations were located in a north-south line through the center of Yucca Mountain (W28, W25, and W30 on Figure 2 or 3). These were located in boreholes USW G-2, USW G-1, and USW G-3, respectively. Downhole instrumentation at stations W30 and W25 were located in the TSw2 stratigraphic unit (Ortiz et al., 1985), the potential repository horizon. W29's downhole instrumentation package was located just above the repository horizon in the TSw1 unit. The other two stations, W26 and W29, were sited in the surface facilities area (Figure 3). Station W29, installed in 1985, had a downhole instrument at the alluvium/tuff interface (80m depth) and station W26 (installed in 1984) was surface only. None of these stations are currently active. Downhole instrumentation failed in W25 and in W30 in 1988. Logistical and project constraints prevented removal of the instrumentation for repair. Finally, all instrumentation was removed in 1990 for calibration and has not been reinstalled to date.

The WTSI monitored selected nuclear tests; generally the larger events (80 - 150kt) were of interest due to the larger expected ground motions at Yucca Mountain. The 150kt maximum value is mandated by the Threshold Test Ban Treaty of 1976. The UNEs in this yield range were conducted in either the Yucca Flat or Pahute Mesa testing areas of NTS, with distances to Yucca Mountain varying from 35 to 60 km. Event-to-station azimuths to Pahute Mesa range from 175 to 200 degrees, and for Yucca Flat are from 230 to 245 degrees. Prior to the 1992 nuclear testing moratorium, there were approximately 5 UNEs annually of interest to the Yucca Mountain Project.

The WTSI UNE data base now contains ground motion data for a total of 85 UNEs, 47 of which were recorded at the Yucca Mountain stations. The data base includes information about each event: name, location (NV grid coordinates), station locations, gages used, and calibration dates. Also included are ground motion parameters such as maximum amplitudes of particle acceleration, velocity and displacements; three-component time histories of acceleration, velocity and

displacement, and pseudo relative velocity spectra (PSRVs). There are several hundred recordings that are relevant for UNE ground motion prediction at Yucca Mountain.

The WTSI also assembled a supplemental data base that includes ground motion data from earlier nuclear tests with larger yields and closer distances than are currently available by monitoring at Yucca Mountain. Because UNE-generated ground motion has been of interest since the beginning of weapons testing, many older measurements are available. These include yields up to 1400kt, at both close-in locations (within a few burial depths of the explosion) and at seismic distances (at least ten times the burial depth from the explosion). Many of these earlier data have been used to develop prediction models for the amplitude of ground motion (e.g., Environmental Research Corporation, 1974) and to study the small-scale velocity structure at the NTS (e.g., Hamilton and Healy, 1969; Helmberger and Hadley, 1981). Prediction equations derived from these data can provide checks on prediction equations developed for the YMP with a much more restricted range of yields and distances.

II.1.2 Data Analyses

Seismic hazard considerations have long motivated the development of equations to predict maximum amplitudes of surface ground motions from seismic events as a function of distance and event size (e.g., Schnabel and Seed, 1973; Murphy and O'Brien, 1977). Because UNE ground motion observed at a point is a complex function of the explosive yield of the source, the energy coupling into the ground at the source point, the transmission characteristics along the seismic travel path, and the material properties at the recording site, predictive models for UNE ground motion have historically been empirically derived (e.g., Environmental Research Corporation, 1974; Vortman, 1980, 1986). In this approach, explosive yield and distance are treated as independent parameters, and ground motion parameters such as acceleration, velocity, or displacement are treated as dependent variables. The parameters are analyzed through standard multiple linear regression techniques to develop the equation of a power curve describing the mean value of the data. A typical prediction equation would be of the form

$$P = KY^aD^b$$

where P is the ground motion parameter to be predicted, K is a fitting constant, Y is the yield in kilotons, D is the event distance in km, and a and b are empirically derived values. The statistics of the fit describe the uncertainty of the estimated mean value and are used to characterize variability in the data from individual explosions. As many have noted (e.g., Trifunac, 1976), simple peak motion predictions may not provide the best information for seismic hazard estimation, because the frequency content and duration of the shaking are not taken into account. Nevertheless, specification of peak ground motion parameters remains standard practice in engineering design for seismic hazards.

Vortman (1980, 1986) and Long (1992) have successfully used this standard approach to analyze Pahute Mesa UNE ground motion data recorded at various stations fielded on and around the NTS for the waste disposal program. Their analyses have developed equations for peak acceleration, velocity and displacement, both for vector motion and separately for the three components (see Figure 4 for an example). There has been additional recent work, unpublished to date, that has used the entire WTSI data base, including Yucca Flat data, to develop prediction equations for peak vector acceleration only. The Yucca Flat work has not yet included ground motion in component form, peak velocity or displacement data, downhole data, or response spectra.

Easterling and Hall (1988) discuss the statistics of the NTS ground motion data related to prediction equations. In particular, they address the issue of validation of UNE ground motion data collected prior to implementation of the Quality Assurance program using post-QA data statistics.

In order to better describe the complete strong ground motion experienced at a site due to a seismic event, the concept of the seismic response spectrum was developed (see e.g., Hudson, 1979, for a summary of the method). Response spectrum parameters are directly applicable to earthquake engineering calculations for seismic design. The response spectrum represents the maximum amplitude of a set of simple, damped harmonic oscillators to input ground motion records. There are a suite of different response spectra; one of the most widely used is that of pseudo-relative velocity (PSRV). If undamped, the PSRV represents an upper bound to the Fourier spectrum, yielding values of maximum spectral amplitude as a function of frequency. In practice, PSRVs are typically damped at a few percent of critical damping. Figure 5 shows an example of an earthquake response spectrum with various damping levels.

Empirical predictions of PSRV spectra have been accomplished through multiple linear regression methods (e.g., Phillips, 1991b). Ground motion time series are transformed to response spectra; given a sufficient data set, pseudo velocity can be calculated as a function of yield and distance for a set of independent frequencies. Because PSRVs contain information about amplitude as a function of frequency, PSRV prediction equations provide additional useful information for seismic design parameters. Phillips (1991b) derived a model useful for predicting surface PSRVs in the entire NTS region, and also downhole PSRVs at specific Yucca Mountain sites. He did not specifically address site effects, and he did not include Yucca Flat data in the analysis.

There have been a limited number of analyses comparing surface and downhole motions. Early efforts included simple regressions of peak motion as a function of sensor depth for both Pahute Mesa and Yucca Flat UNE data recorded all over the NTS (Vortman and Long, 1982a and 1982b). These reports lumped data together regardless of geologic environment, and noted that the station geology appears to have a larger effect on peak motion values than does the depth to the downhole sensor. Another report (Long et al., 1983) described a signal processing method to predict a downhole waveform given a surface ground motion record. While the filters described in the report are successful as transfer functions, they contain no information to link the mathematical model to geologic information. Phillips (1991a, b) studied the surface and downhole behavior at the Yucca Mountain stations (a data example is shown in Figure 6) and, as mentioned above, developed a method to predict downhole PSRVs at those particular locations given the PSRV at the surface. Only one of these analyses has considered Yucca Flat data, and none has produced a general method to predict downhole ground motions in the Yucca Mountain area.

UNE data have often been used to develop local crustal velocity models for portions of NTS, particularly Pahute Mesa (e.g., Hamilton and Healy, 1969; Helmberger and Hadley, 1981; Stump and Johnson, 1984; Leonard and Johnson, 1987; Barker et al, 1991). While some larger-scale regional crustal models have been developed (e.g., Hoffman and Mooney, 1984), understanding of the upper crustal velocities and their lateral heterogeneity on an NTS-wide scale is limited. Walck and Phillips (1990) studied the propagation of UNE energy from the Pahute Mesa and Yucca Flat testing areas specifically to Yucca Mountain. They found, using travel time and 2-D ray tracing synthetic seismogram techniques, large lateral variations in crustal velocity structure to depths of at least 5 km (Figure 7). Walck and Phillips (1990) also documented stable first-arrival relative amplitude patterns at Yucca Mountain stations that are significantly different for the two testing

areas, implying that propagational differences along the travel paths may have important effects on the observed ground motions.

II.2 Key parameters to be analyzed

The current status of the development of the empirical UNE ground motion prediction model is:

- A data base of UNE ground motions at the NTS exists.
- Prediction equations (peak ground motion given event distance and yield) have been developed for Pahute Mesa UNEs recorded at various NTS stations.
- Some aspects of downhole motion characteristics have been documented. The ratio of surface to downhole motion in terms of peak motion and PSRV has been quantified for a limited number of specific sites for Pahute Mesa events only.
- Prediction equations for PSRVs have been developed for Pahute Mesa UNEs. An algorithm exists to estimate downhole PSRVs at specific sites at Yucca Mountain.
- First order two-dimensional crustal velocity models have been constructed for paths from Yucca Flat and Pahute Mesa to Yucca Mountain. These models help separate path and site effects.

For a complete UNE ground motion prediction model, more information is required in the following areas:

- Ground motion predictions for Yucca Flat tests recorded at Yucca Mountain, including component ground motion and PSRV data.
- Documentation of absolute ground motion levels at the repository horizon at Yucca Mountain using the available downhole ground motion records from Yucca Mountain stations, particularly W25, W28, and W30.
- Geologic and stratigraphic relationship of surface and downhole motions at Yucca Mountain.

The key parameters to be measured and analyzed are therefore 1) UNE ground motions, particularly those recorded in boreholes and/or from Yucca Flat sources 2) PSRV spectra from UNEs, particularly those from Yucca Flat sources, and 3) downhole/uphole pairs of UNE time series recorded at Yucca Mountain.

II.3 Technical Methodology

Three tasks comprise the study plan: completion of surface ground motion model to include Yucca Flat data, development of empirical, geology-related models for downhole motion at Yucca Mountain using UNE data, and compilation of these and previous results into a comprehensive empirical model for UNE ground motion data.

II.3.1 Yucca Flat source area (Task 1)

Objectives: To develop predictive capability for all types of surface ground motions in the vicinity of Yucca Mountain resulting from UNEs conducted at Yucca Flat. To generate predictive capability for engineering response spectra (PSRVs) of Yucca Flat UNEs recorded at Yucca Mountain.

Quality Assurance: Quality Assurance will be implemented according to Sandia National Laboratories QAIP 2-10, "Determination of Applicable QA Controls".

The limited Yucca Flat data analysis to date has identified significant differences in peak ground motion amplitudes at Yucca Mountain stations for events at similar distances and yields as the Pahute Mesa data. Walck and Phillips (1990) document that observed relative amplitude patterns at Yucca Mountain for Yucca Flat tests differ substantially from Pahute Mesa tests. These results indicate that prediction equations based on Pahute Mesa data alone are probably not appropriate for Yucca Flat UNEs.

This task will use a stepped approach to determining an appropriate model for ground motion from Yucca Flat UNEs recorded at the NTS. First, the Yucca Flat peak acceleration, velocity, and displacement data will be compared to the appropriate prediction equations already in existence (e.g., Vortman, 1986; Long, 1992). If possible, simple corrections will be developed to describe the attenuation relationships for Yucca Flat data. If the data require a more rigorous approach, complete multiple linear regressions will be performed for the Yucca Flat data. PSRV prediction for Yucca Flat data will also begin with a comparison of the Yucca Flat data to existing models (Phillips, 1991b). If appropriate, a single model describing both Pahute Mesa and Yucca Flat ground motions will be developed, but differences between the source areas may require separate models. Models will include NTS-wide data in order to provide a more complete distance and yield range. The deviation between Yucca Mountain stations and the NTS-wide average will be documented in order to provide more site-specific information.

This task requires use of UNE yields as input data. The yields are determined from a variety of measurements and are not included in the YMP QA program. Official nuclear test yields have an uncertainty of about 10% (H. D. Garbin, personal communication, 1994). The uncertainty estimate for explosion yields will be included in the overall uncertainty estimates for the parameters in the empirical model.

Subtasks:

1a: Compare Yucca Flat ground motion (acceleration, velocity and displacement for vertical, radial and tangential components) to previously published NTS prediction equations based on only Pahute Mesa data (e.g., Long, 1992). Determine whether the Yucca Flat data are compatible with the existing equations. If they are not compatible, determine if simple correction factors can be developed, or whether full data regression is required.

- Assemble Yucca Flat data base including maximum amplitudes, seismograms, and PSRVs.
- Access yields of UNEs in the data base; not to be included in the unclassified data base.
- Compare Yucca Flat component ground motion to that predicted by Long (1992).
- If needed and appropriate, develop correction factors for Yucca Flat data.
- If needed, perform standard linear regression analyses of the form: $P = K W^a R^b$, where P is the ground motion (acceleration, velocity, displacement), K is a constant fitting coefficient, W is the event yield, R is the source-to-station distance, and a and b are fitting parameters. The analyses includes uncertainty estimates on the parameters (see, e.g., Vortman, 1986).
- Evaluate success of equations using events not included in the regression analysis.

1b: Develop predictive capability for PSRVs from Yucca Flat tests for Yucca Mountain stations. Begin by comparing Yucca Flat PSRV values to Phillips' (1991b) models derived from Pahute Mesa data. Determine the necessity of developing correction factors to Phillips' model. If necessary, develop a new, separate PSRV model for Yucca Flat data. Steps include:

- use computer code documented by Phillips (1991b), based standard analyses documented by Newmark and Rosenbluth (1971), to calculate pseudo velocity at 48 different frequencies between 0.3 and 30 Hz for each station/event combination (Yucca Flat events only).
- Compare PSRVs to those predicted by models in Phillips (1991b). Determine, from misfit, the necessity of correction factors.
- If correction factors are not sufficient, perform multiple linear regression using 48 different equations of the power law form above to predict PSRVs, with uncertainty bounds such as 95% confidence limits.
- Develop PSRV predictions for downhole ground motions as well as for surface stations using the same procedure as outlined above.

1c: Compare the Yucca Mountain peak ground motion and PSRV data to those predicted from the NTS-wide prediction equations, and document deviation statistics.

1d: Document study in form of Sandia Report including full assessment of study limitations and uncertainties. Output will be either correction factors to existing prediction equations or new prediction equations for Yucca Flat data, for both peak ground motion and PSRVs. The multiple linear regression fitting procedure provides uncertainty estimates on all derived parameters. Results applicability is limited to the yield and distance range covered by the data included in the regression, and to the NTS geological environment.

II.3.2 Downhole motion (Task 2)

Objective: To develop a generalized empirical model or algorithm for behavior of UNE motions at depth in the Yucca Mountain repository block based on both seismologic and geologic information.

Quality Assurance: Quality Assurance will be implemented according to Sandia National Laboratories QAIP 2-10, "Determination of Applicable QA Controls".

Past analyses of downhole data recorded on the NTS have not been very useful for predicting ground motion at depth. Furthermore, there have been only a few studies directed specifically at Yucca Mountain downhole data (Phillips, 1991a, b). Good estimates of expected repository-horizon ground motion levels from seismic events of known size would clearly be valuable information for the repository design. While downhole data at Yucca Mountain is limited to UNEs, enough exists to conduct potentially useful studies to relate local geological parameters to ground motion attenuation with depth and to compare actual ground motion levels at the repository horizon to those observed on the surface.

Detailed geologic and well-log information are available for the boreholes in which the WTSI instruments resided (e.g., Maldonado and Koether, 1983; Ortiz et al, 1985). Separate one-dimensional layered models for each borehole based on the geologic and lithologic information can be developed through forward modeling using the well-established propagator matrix method (Haskell, 1953; Johnson and Silva, 1981; Shearer and Orcutt, 1987). The recorded downhole signal is used as input, propagated up to the surface, and compared to the surface data. The model is adjusted and tested repeatedly until an acceptable fit between the actual surface data and the

propagated downhole data is achieved. As a check and means to identify sources of uncertainty, surface recordings can also be propagated downward to the repository depth and compared to the downhole recordings. The three one-dimensional models can then be generalized into a two-dimensional model representing a north-south cross-section through Yucca Mountain. Because the propagator matrix method is one-dimensional, a different computational scheme will be necessary to check the two-dimensional model against the data. One available method is that of finite differences. Finite difference versions of the one-dimensional models can be used to validate the selected two-dimensional elastic finite difference code (e.g., Vidale and Clayton, 1986; Vidale and Helmberger, 1987). Another two-dimensional method suitable for site-response calculations is the modified Aki-Larner method of Bard and Gariel (1986). Finally, the success of the 2-D model in fitting the waveforms will be assessed, and the possible need for a three-dimensional model determined.

The model will provide, through a general seismic velocity model representing transfer functions from the surface to repository depth, first-order predictive capability for body wave ground motions at depth in the repository block. The model will be applicable for UNEs and earthquakes at comparable distances, although its earthquake applicability may have some limits due to the relative paucity of shear energy in the UNE waveforms. There is no alternative, however, to using UNE data for this task as no downhole earthquake data have been recorded at Yucca Mountain.

An alternative method for study of uphole/downhole data pairs is the spectral ratio technique (e.g., Archuleta et al., 1992). This frequency domain method compares spectra of the surface record with the downhole record; the ratio identifies frequencies at which surface amplification occurs. It has the advantage that any portion of the record, including surface waves, can be included in the calculated spectra, while the propagator matrix method described above models only body waves. Spectral ratios can also be used to predict event spectra at depth using surface recordings. In fact, Phillips (1991b) has developed PSRV predictions for Pahute Mesa events recorded downhole at Yucca Mountain. The spectral ratio method is empirical in that it identifies frequency ranges of increased relative amplitude (amplification) but does not link them directly to a geological model. The time-domain method described in this task has the advantage of relating the site geology directly to arrivals in the observed seismograms. Uncertainties in the geological structure can be addressed by incorporating variations into the models and assessing their effects on the waveforms.

Subtasks:

2a: Characterize downhole motions for all available data.

- Develop subset of overall database that includes only true surface/downhole pairs (deleting some data, e.g., used in Vortman and Long, 1982a and 1982b).
- Determine feasibility of developing prediction equations for only downhole motions using available data, including 1) all data and 2) Yucca Mountain data only. If feasible, use multiple linear regression to obtain prediction equations for the downhole data alone.

2b: Relate downhole motions to those observed on the surface of Yucca Mountain using available geologic and stratigraphic information.

- Review existing information on detailed stratigraphy at Yucca Mountain and well logs for the boreholes containing the WTSI instrumentation (see, e.g., Maldonado and Koether, 1983).
- Determine detail of lithologic and velocity information needed using frequency content of observed signals as a guide.

- Develop initial 1-D models for propagating observed downhole signal to the surface for comparison with uphole recordings.
- Use propagator matrix formulation (e.g., Johnson and Silva, 1981; Shearer and Orcutt, 1987) in a forward modeling, trial-and-error fashion to derive best-fitting 1-D models for each of the three stations with instrumentation at the repository horizon (W25, W28, W30). Use downhole-recorded waveform as input to algorithm; surface waveform is output. Model representative recorded events at each station. Check model by using surface waveform as input and downhole waveform as output. Assess model uncertainty using variations of model velocities.

2c: Develop 2-D model for the entire repository block.
- Compare the three 1-D models and attempt to integrate them into a 2-D model running north-south through Yucca Mountain that is consistent with known geologic structure.
- Construct finite difference (or other selected method such as that of Bard and Gariel (1986)) version of 2-D model . Calculate synthetic seismograms for both 1-D (as a check) and 2-D models and compare to data.
- Assess adequacy of 2-D model for repository block. If model is not adequate, perform scoping calculations to assess possible 3-D effects such as topography

2d: Document results in the form of a Sandia report. Include detailed description of model, assumptions, algorithm, and uncertainties of results. Output is three 1-D models and a 2-D model related to site geology that predicts to first order surface waveforms given downhole waveforms, or vice versa. Model uncertainty will be documented by varying model parameters and assessing degradation of data fit. Model uncertainty will be higher in areas between boreholes, where no data exist.

II.3.3 Empirical Model

Objective: To synthesize work conducted over a 13-year period into a cohesive model for predicting both surface and downhole motions at Yucca Mountain from UNE sources. This model will include estimates of peak acceleration, velocity, and displacement, and source spectra as represented by PSRVs. The output of this task would represent the end product of the WTSI project for the YMP.

Quality Assurance: Quality Assurance will be implemented according to Sandia National Laboratories QAIP 2-10, "Determination of Applicable QA Controls".

This task directly addresses Activity 8.3.1.17.3.3.2 of the Site Characterization Plan, and is the end product of the study plan.

Subtasks:

3a: Reexamine previous work to ensure that all prediction equation cases covered in older studies are either rejected or superseded by those in the generalized model.

3b: Compile all relevant parameters to be contained in the final model: estimates of peak vector and component acceleration, velocity, and displacement, PSRVs (both surface and downhole when available, and a 2-D seismological model of Yucca Mountain that provides a) downhole-to-surface transfer functions for stations W25, W28, and W30, and

b) the best possible estimate of transfer functions for volumes intermediate to those stations.

3c: Compute and document estimates of surface and downhole (repository horizon) motion for a range of possible design basis UNEs.

3d: Prepare Sandia Report containing the model parameters, description, relevant algorithms, model assumptions, and model limitations.

III. Application of Results

The results of analyses conducted under this study plan will contribute to several activities within the preclosure tectonics program (Program 8.3.1.17 of the SCP). Specifically, the results will provide information needed for Activity 8.3.1.17.3.3.2, Select or develop empirical models for ground motion from underground nuclear explosions. This in turn contributes to Study 8.3.1.17.3.3, Ground motion from regional earthquakes and underground nuclear explosions. Information obtained from Task 2 will also contribute to Study 8.3.1.17.3.4, Effects of local site geology on surface and subsurface motions, specifically Activity 8.3.1.17.3.4.2, Model site effects using the wave properties of the local geology. The UNE empirical model may also provide input to Study 8.3.1.17.3.5, Ground motion at the site from controlling seismic events; specifically the model can be used to determine whether or not a UNE could be a controlling seismic event (Activity 8.3.1.17.3.5.1). Finally, the UNE ground motion model will also provide input to Activity 8.3.1.17.3.6.2, Evaluate ground motion probabilities.

IV. Schedule and Milestones

a. Schedule

The three tasks will be completed approximately as shown below. Current staffing levels require approximately 18 months of effort to complete these tasks.

```
Task      0 mo.  2 mo.  4 mo.  6 mo.  8 mo.  10 mo.  12 mo. 14 mo.  16 mo.  18 mo.
1         +++++++++++++++++++

2                        ++++++++++++++++++++++++++++++++++

3                                                        +++++++++++++++
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b: Milestones

M1:	Complete Yucca Flat ground motion data analysis	4 months
M2:	Complete Draft Sandia Report on Yucca Flat data	6 months
M3:	Complete 1-D surface/downhole transfer functions	11 months
M4:	Complete 2-D surface/downhole model	13 months
M5:	Complete draft Sandia Report on surface/downhole model	15 months
M6:	Complete draft Sandia Report on integrated model	18 months

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Figure 1. Location map of the Nevada Test Site, including representative UNEs recorded by the WTSI project (dots) and stations (squares). Open squares denote stations inactive as of 1988, while solid squares indicate stations active from 1988-1990. Dotted lines indicate approximate boundaries of NTS testing areas.

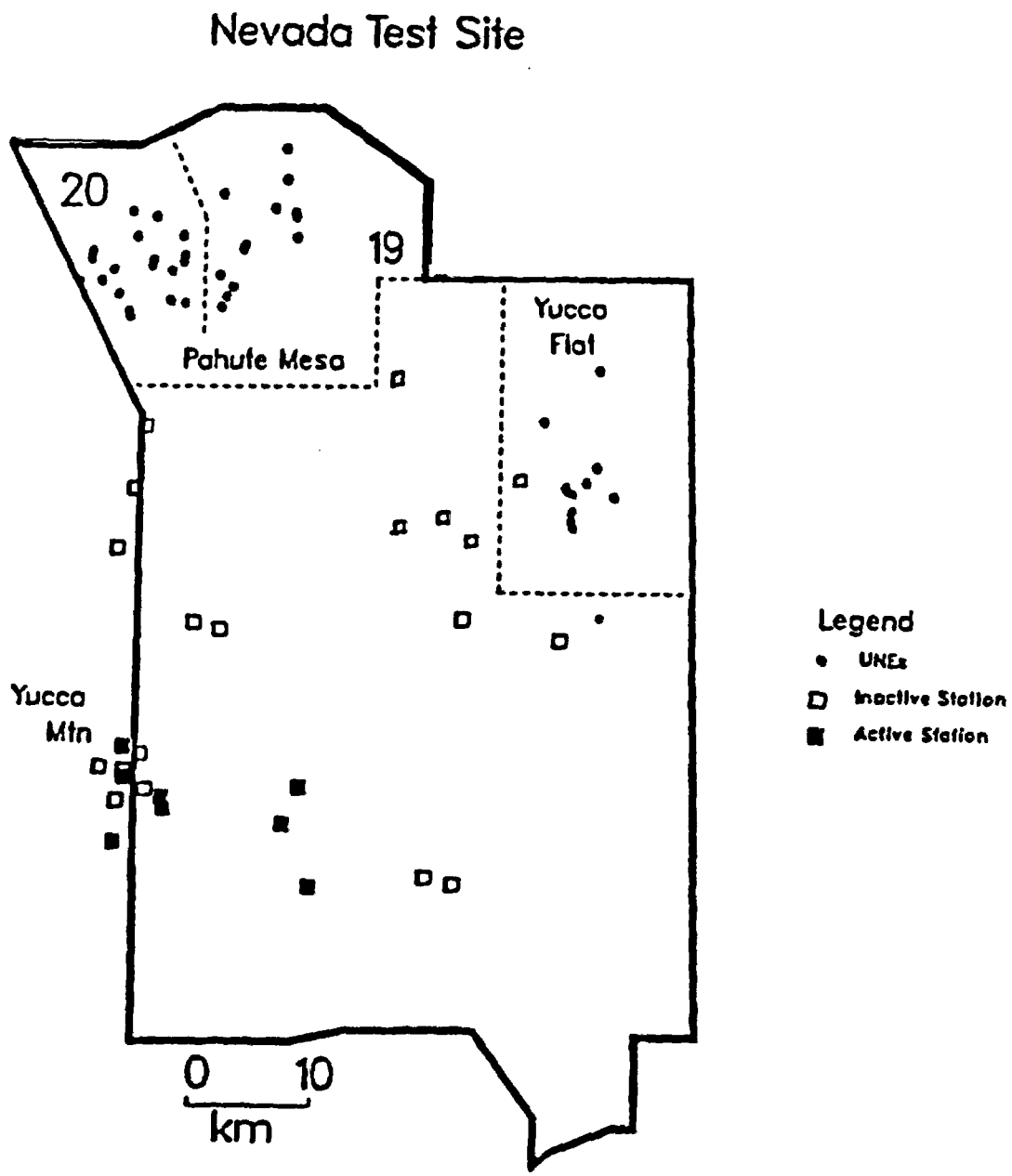
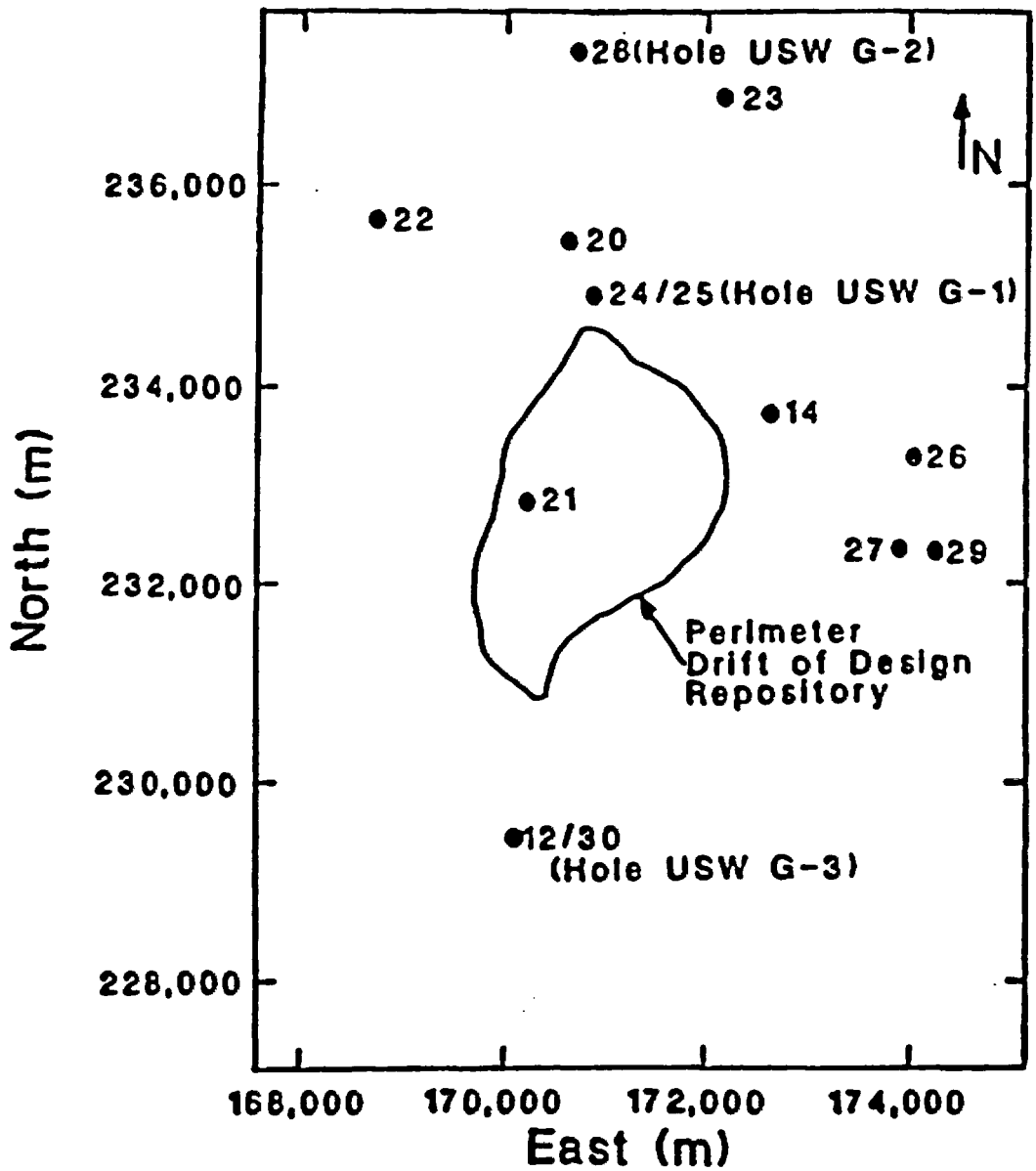


Figure 2. Yucca Mountain ground motion stations fielded since 1980.



NOTE: GRID SHOWN IS BASED ON NEVADA COORDINATE SYSTEM, CENTRAL ZONE

Figure 3. Location of the active Yucca Mountain ground motion stations with respect to facilities planned for the repository (base map from YMP RIB, February 1989).

SITE CHARACTERISTICS	YUCCA MOUNTAIN PROJECT REFERENCE INFORMATION BASE			
GEOHYDROLOGY				
MAXIMUM FLOOD CONDITIONS	CHAPTER 1	SECTION 4	ITEM 1	PAGE 6 of 6
	VERSION 4	REVISION 0	RELEASE DATE 2/1/89	DR1

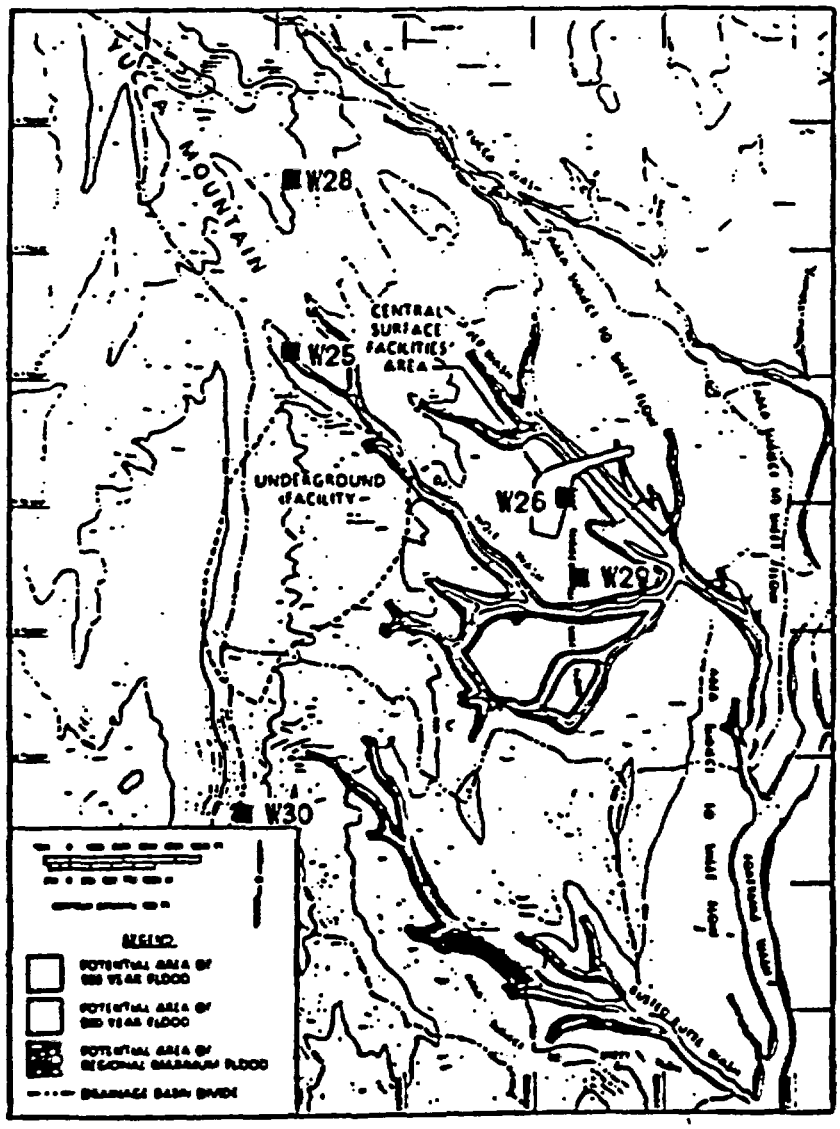


FIGURE 1. REGIONAL MAXIMUM FLOOD BOUNDARIES

NOTE: GRID SHOWN IS BASED ON NEVADA COORDINATE SYSTEM, CENTRAL ZONE

Figure 4. Example of empirical prediction equation for NTS ground motions. Shown is a plot of Vortman's (1986) equation for vector acceleration as a function of range for a yield of 100kt.

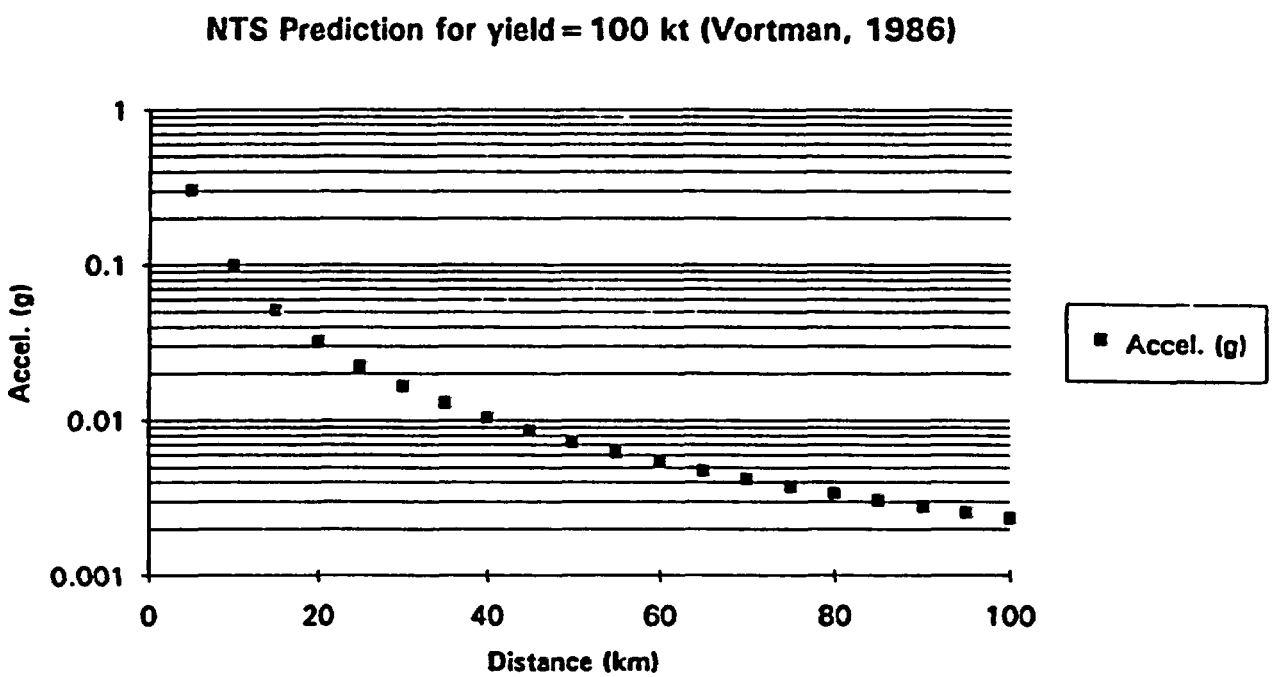


Figure 5: Example of a seismic response spectrum with 0, 2, 5, 10, and 20% damping, for the 1940 Imperial Valley earthquake (from Hudson, 1979).

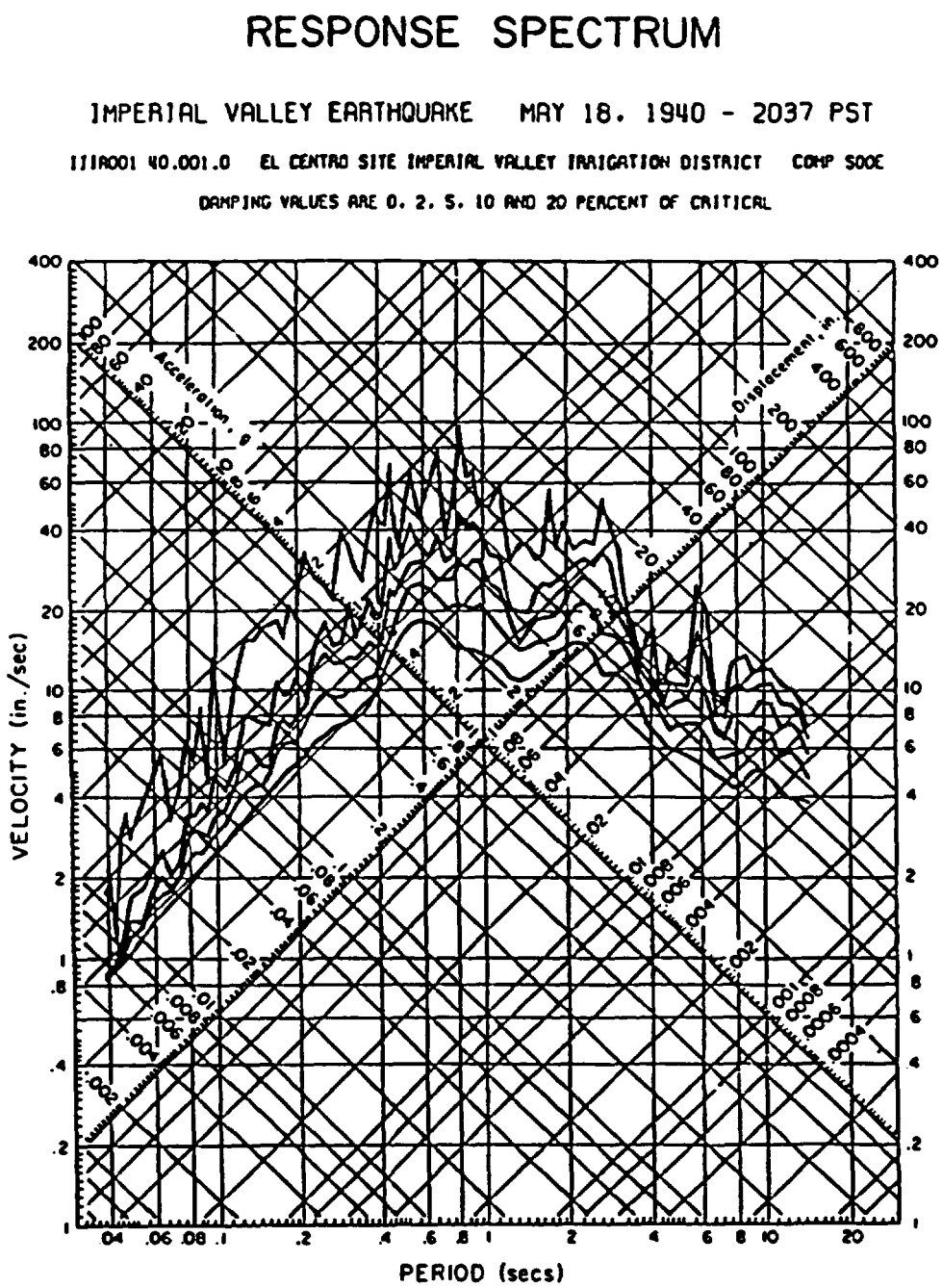


Figure 6: Vertical Surface and Downhole Accelerations Recorded at Station W28

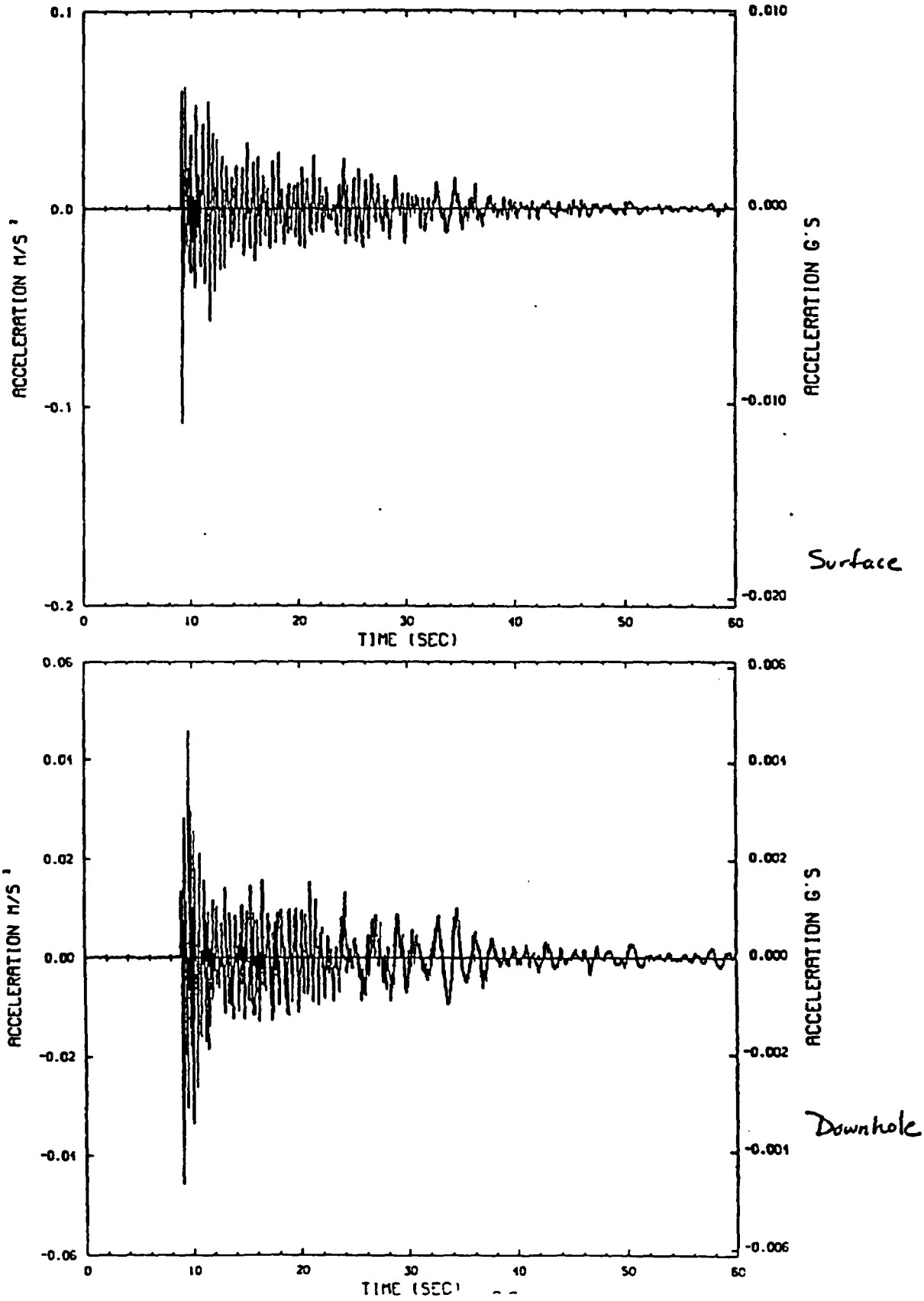
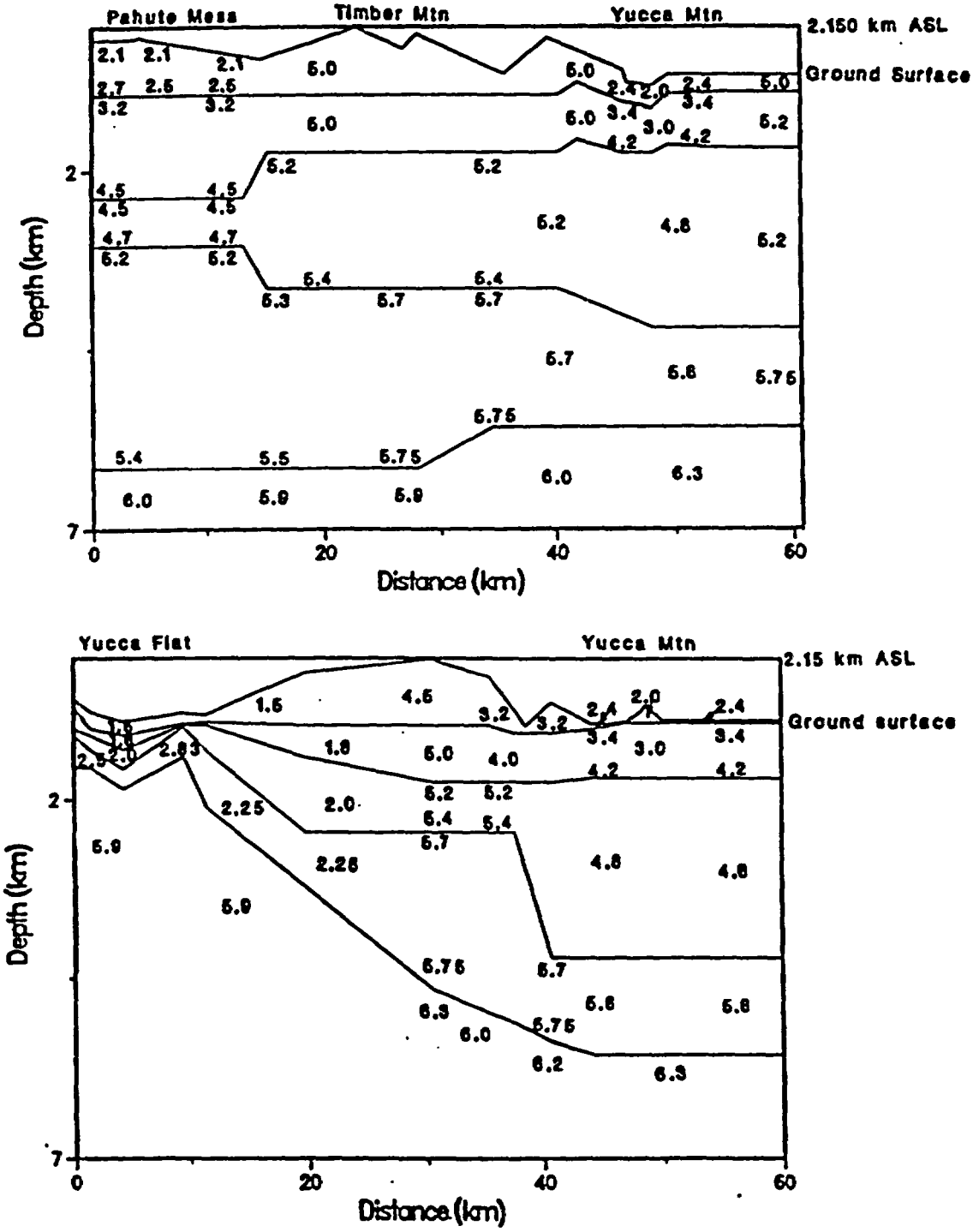


Figure 7: Two-dimensional upper crustal velocity models determined by Walck and Phillips (1990) based on UNE data recorded at Yucca Mountain; these models demonstrate signficant lateral velocity variations in the NTS crust. The top model represents the path from western Pahute Mesa to Yucca Mountain. The bottom model approximates velocities between Yucca Flat and Yucca Mountain. Velocities are indicated in km/s. ASL=above sea level.



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SCA OPEN ITEMS ANALYSIS

DOE's response to SCA question 16 included a commitment to provide more information related to the question in Study Plan 8.3.1.17.3.3. Further information about the use of linear regression techniques can be found in section II.3.1. Further information about 1-D and 2-D modeling techniques can be found in section II.3.2. Discussion of predictions for a design basis UNE can be found in section II.3.3.

Enclosure 2