Rev. 6

NNA.880427.0015

Nevada Nuclear Waste Storage Investigations Project

Working Group Report

Exploratory Shaft Seismic Design Basis

April 1988

NH03
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WM-11

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		Insert 1.2.6.2.1 Power Systems, Rev. 6, 3 pgs.	2.1-1, 2.1-2 & 2.1-3

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12/13/88 Rev. 6	89/002	Remove	1.2.6.3.8 Temporary Facilities, Rev. 1, 1 pg.	3.8-1
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12/13/88 Rev. 6	89/012 89/013	Remove	1.2.6.4 First Shaft, Rev. 1, 3 pgs.	4-1, 4-2, 4-3
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WORKING GROUP

REPORT

ES SEISMIC DESIGN BASIS

Prepared By

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Los Alamos National Laboratory	Lawrence Livermore National Laboratory
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Sandia National Laboratories	U.S. Geological Survey

March 1, 1988

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EXECUTIVE SUMMARY

This report prepared by a special working group (WG) authorized by the Exploratory Shaft (ES) Interface Control Working Group (ICWG), provides recommendations for the seismic design parameters for the design of the shafts associated with the Exploratory Shaft Facility (ESF) of the proposed nuclear waste repository at Yucca Mountain, Nevada. Although directly intended for design of ESF shaft liners, much of this design basis is also appropriate for seismic design of other shafts and underground structures which do not affect public safety. The recommendations include parameters for both natural earthquakes that may possibly occur at or near the repository site and for underground nuclear explosions (UNEs) which are regularly detonated at the Nevada Test Site (NTS). An evaluation was conducted very recently to determine the functions which the shafts must perform during the pre-closure period of the repository facilities. Based on this evaluation together with the results of studies conducted to support the conceptual design for the site characterization, it was concluded that the shafts need only be designed adequately to provide for worker safety. A failure of the ES will not affect the public radiological safety.

Specifically, the recommended control motion values which are to be applied at the surface are:

<u>Earthquake</u>:

Maximum Horizontal component of acceleration	- 0.3 g
Maximum Vertical component of acceleration	- 0.3 g
Maximum Horizontal component of velocity	- 30 cm/sec.
Maximum Vertical component of velocity	- 20 cm/sec.

UNE:

Maximum Vertical component of acceleration	- 0.2 g
Maximum Radial component of acceleration	- 0.1 g
Maximum Transverse component of acceleration	- 0.1 g
Maximum Vertical component of velocity	- 9 cm/sec.
Maximum Radial component of velocity	- 12 cm/sec.
Maximum Transverse component of velocity	- 12 cm/sec.

An evaluation of faulting potential at the ES site and its vicinity indicates that the annual probability of faulting in excess of a few centimeters (5 cm) is less than 10^{-4} per year. On the basis of this, the report recommends that faulting effects need not be considered in the design of the ES. Further, the report also provides specific guidance for determining or provides (i) the control motions at depth, (ii) the material properties for the different rock layers relevant to seismic design, (iii) the strain tensor for each of the wave forms and the maximum strain components along the shaft liner, and (iv) the method for combining the different strain components along the shaft liner. Finally, to provide further assurance that the design has adequate conservatism or margin to accommodate any uncertainties such as site effects, the WG recommends that the performance of the exploratory shaft be confirmed using best estimate conditions when subjected to ground motions that are a factor of 1.67 times the proposed design basis motions. This evaluation for the larger motions should provide assurance that the major damage of the ES is not expected at these levels.

The report also lists the assumptions and other conditions used to develop the recommendations. In developing the basis for the recommendations, the WG utilized currently available site-specific seismic and geologic data. In recognition of the uncertainties in these data, the seismic design parameters recommended include a reasonable degree of conservatism and are consistent with the seismic design requirements used for similar types of facilities.

ACKNOWLEDGMENT

In addition to the organizations called out in the front page of this report, there were others who helped in putting together this report. This includes J. Kimball of DOE/HQ, J. S. Phillips of division 7111 of Sandia National Laboratories (SNL), G. N. Owen of URS/John A. Blume, Associates & Engineers, Richard Lee (working as a consultant to URS/Blume), and R. P. Kennedy of Structural Mechanics Consulting (working as a consultant to Holmes & Narver). Their contributions included participation in the working group (WG) meetings, providing technical consultation and input to the WG, providing written input to the preparation of the report, reviewing the report contents, and help resolve review comments on the report. Their contributions are gratefully acknowledged herewith.

1.0 INTRODUCTION

This report was prepared by a special Working Group (WG) authorized by the Exploratory Shaft (ES) Interface Control Working Group (ICWG). It provides recommendations for the seismic design parameters to be used for the design of the shafts associated with the Exploratory Shaft Facility (ESF) of the proposed nuclear waste repository at Yucca Mountain, Nevada. In developing the basis for these recommendations, the WG utilized currently available site specific seismic and geologic data. In recognition of the uncertainties in these data, the seismic design parameters recommended include a reasonable degree of conservatism.

There are two shafts in the ES facilities configuration. These shafts have a two-stage service life. First, they will support site characterization by providing access, ventilation, utility support, and emergency egress from the underground test areas; secondly, pending results of site characterization, the shafts will be converted to support repository operations as intake ventilation shafts, a function they will perform until repository closure. As discussed in the baselined Generic Requirements for a Mined Geologic Disposal System (OGR/B-2), four permanent items have been identified that shall be designed, procured, and constructed to be incorporated into the repository. The permanent items include underground openings, operational seals, ground support, and shaft liners. The seismic design recommendations included in this report relate to the above permanent items as appropriate. Other items and structures in the ESF will be designed using other requirements like those of the Uniform Building Code (UBC) (Reference 24).

During the operations phase, the ESF shafts will supply approximately 60 percent of the total air flow needed to support waste emplacement. The remaining air needed is supplied through the waste ramp. Exhausting fans on the emplacement exhaust shaft maintain pressures in the emplacement area lower than the pressures in the development (mining) area.

Concrete liners will be installed in the exploratory shafts concurrent with their sinking. Their functions are:

- to provide effective structural support to the ground
- to eliminate minor rockfall hazards
- to provide a dimensionally consistent cross-section and stable anchorage for installation and alignment of shaft equipment
- to provide a low-friction surface for efficient ventilation throughout the life of the repository.

Neither of the exploratory shafts will at any time, be used to handle radioactive waste. Additionally, the liners are not intended to serve as barriers to radionuclide migration or to entry of water into the repository either during operations or after closure.

The shafts are located in unsaturated geologic formations and are not expected to penetrate any aquifers at the site. Further, any perched water zones encountered during shaft sinking are expected to drain fairly quickly. Thus, the shaft liners will not be required to prevent or control ground water inflows into the shaft. The construction joints between each concrete pour are not planned to be water tight.

If one or both of the exploratory shafts were to be completely blocked due to a failure of a shaft liner (which is highly unlikely), the emplacement area would still be under negative pressure with respect to the development area, and the ventilation leakage path would be maintained in a direction towards the emplacement area. If a waste canister were to be ruptured simultaneously with the failure of the ES shaft, any potentially contaminated air would still be exhausted via the emplacement exhaust shaft through HEPA filters (Reference 25). At this time, no credible accident scenarios have been identified whereby failure of the shaft liner could result in a release of radiation. Therefore, public safety does not appear to be an issue in shaft liner design.

In addition, a preliminary analysis has been completed to determine which structures, systems, and components are important to public radiological safety. This analysis is described in Reference 26. Results of this analysis indicate that there are no shaft structures, systems, and components identified as important to safety.

These discussions indicate that the ES (especially the liner), is not an "essential" or even a "low hazard" facility (i.e., a facility which does not handle or process plutonium) as defined in Reference 1. Based on these reasons, it is justified to design the exploratory shaft liner as a structure which is only required to provide worker safety, i.e., the permanent items such as the liner associated with the exploratory shafts need not be designed as items important to provide public radiological safety, but need to be designed only for a level of seismic input that is sufficient to ensure worker safety and reasonably uninterrupted functions, a level that is consistent with those used for other similar types of facilities. However, the seismic design basis recommendations in this report for the ES are consistent with those required for a low hazard or essential facility, and hence, judged to be more conservative than what may be required. Other non-permanent items and structures in the ES facilities will be designed using other requirements like those of the Uniform Building Code (UBC) (Reference 24).

The recommendations for the seismic design basis parameters given in Section 2 and 3 of this report are based on the discussions in the preceding paragraphs. The recommendations will include ground motion parameters for both natural earthquakes that may possibly occur at or near the site and for underground nuclear explosions (UNEs) which might occur at the Nevada Test Site (NTS).

Section 2.0 of this report provides the recommendations for characterizing the wave motions along with conditions and assumptions used for the development of control motions for natural earthquakes. Section 3.0 provides the same for UNEs. Section 4.0 describes the rule to be used for combining the maximum strains (responses) due to the different wave components. Section 5.0 describes the strain tensors including bending strains for each of the propagating waves due to earthquakes and UNEs which should be considered in the design of the ES. It also describes the determination of the worst strain combination case for use in the design.

Section 6.0 identifies the recommendations for the rock properties for the stratigraphy at the ES site. Section 7.0 presents the WG recommendations regarding consideration of potential fault offsets at the site for the ES design. Finally, the report contains appendices supporting the WG recommendations.

It is noted here that the seismic design basis control motions being proposed for the ES are consistent with the values of effective peak acceleration in ATC-3 (Reference 30) map from which UBC (Reference 24) Zones 2 and 3 are derived for the design of an essential facility. In addition, the proposed recommendations in this report are also consistent with the requirements for important low hazard facilities as called out in References 1 and 2. In Reference 1, the use of UBC requirements for seismic loads for such facilities is recommended. Further, the seismic design basis motions being proposed for the ES are similar to those for nuclear power plant structures, systems and components that may be required for operation of the facility, but which are not important to public safety. They need not be designed to seismic Category I requirements, as per Reference 3. The Standard Review Plan recommends the use of other industrial codes like those from American Petroleum Institute (API) and American Water Works Association (AWWA) both of which utilize UBC type requirements for these structures.

2.0 GROUND MOTION DUE TO EARTHQUAKES

2.1 Introduction

In Section 1.0 it is concluded that the Exploratory Shaft Facility (ESF) need not be designed as a facility important to public radiological safety. Based on this, the Working Group believes that the ESF design should consider earthquake ground motions (vibratory ground motion and faulting) that are reasonably likely to occur during the operating lifetime (less than 100 yr) of the ESF. Specifically, the Working Group recommends consideration of ground motion conditions that recur at average intervals of about one thousand years, i.e., with about one chance in ten of occurring during the maximum operating life. This would result in more conservative values of vibratory ground motions than those given in Reference 30 upon which the UBC (Reference 24) is based.

In June of 1987, design and evaluation guidelines for DOE facilities subjected to natural phenomena hazards were prepared (Reference 2). These guidelines recommend that for mission dependent facilities (where confinement of contents is not essential) that a hazard exceedence probability of 1E-3 be used (recurrence of 1,000 years). These guidelines have been incorporated into a draft revision of Reference 1 which was published in January of 1988. The ESF seismic design recommendation is also consistent with this draft revision.

Deterministic methods are appropriate for establishing conservative levels of ground motion for consideration in the ESF design. Probabilistic methods are appropriate for confirming that the resulting motions are unlikely to be exceeded during the operating lifetime of the ESF.

2.2 Relevant Earthquake Sources

As discussed in Section 7-2, faults in the immediate area of ESF including the Ghost Dance fault appear to slip at intervals measured in tens of thousands of years or longer and, therefore, are an unlikely source of significant earthquake ground motion during the operating life of the ESF. The average slip rate on local faults during the late Quarternary period appears to be less than about 0.02 mm/yr (Carr, 1984-Reference 5). The average recurrence time for magnitude 5 1/2 (potentially damaging) earthquakes on a fault with a slip rate of 0.02 mm/yr exceeds 10,000 yr according to a relationship developed by Slemmons (1982) in Reference 9. Larger magnitude earthquakes (M greater than 5 1/2) would thus have recurrence intervals of longer than 10,000 years, possibly as long as 100,000 years. Geologic evidence suggests that slip on one of the more significant local faults, the Windy Wash fault, results from earthquakes that produce ten centimeters or more displacement per event at recurrence intervals of several tens of thousands of years (Whitney et al., 1986, Reference 10). Although an earthquake of magnitude 5 or smaller might occur on a local fault during the operating life of the ESF, such events are not known to significantly damage well-engineered structures. In addition, experience with underground facilities inc :ates that earthquakes of magnitude less than about 6.0 are not expected to cause significant damage to underground facilities (Pratt, et al., 1978, Reference 8).

The north-trending Bare Mountain fault, located about 16 km west of the exploratory shaft, appears to be the most likely source of potentially severe ground shaking during the lifetime of the ESF. This fault may have an average Quarternary slip rate of up to 0.15 mm/yr (Reference 12), which indicates that this fault is much more active than faults local to Yucca Mountain. Applying the relationship of (Slemmons, 1982, Reference 9) to a fault with a slip rate of 0.15 mm/yr indicates a minimum recurrence interval of about 6,000 yr for a magnitude 6 1/2 earthquake. Based on this and other considerations including the fact that site ground motions derived from this earthquake are roughly comparable with those from suitably conservative probabilistic hazard analyses (References 11, 13), a magnitude 6 1/2 earthquake on the Bare Mountain fault is used herein as the deterministic basis for establishing ground motion conditions to be considered in the design of the exploratory shaft facilities.

2.3 Control Values for Peak Ground Motions

Among the many parameters that influence earthquake ground motion, earthquake magnitude and source distance appear to be the most important. Many strong-motion recordings have been obtained within 20 km of several earthquakes in the magnitude range 6 to 7. Even though none of these earthquakes are perfect analogs for conditions at Yucca Mountain, the range of observational data is adequate for direct extrapolation.

Regression relationships between peak ground-motion parameters and earthquake magnitude, source distance, local site conditions (e.g., rock or soil), and other parameters have been developed by a number of workers (see the references found in Campbell, 1985, Reference 28). Two recent and representative sets of regression relations for peak horizontal acceleration and peak horizontal velocity are those in Joyner and Fumal (1985) and Campbell (1987), (References 4,6). Results obtained using these relationships are presented in Table 2.1. The results assume reverse and thrust mechanisms for conservatism and that the surface trace of the Bare Mountain fault is 16 km from the ESF location and that the fault is planar and dips eastward at an angle of 70° from the horizontal, the midrange of current estimates (Reference 12). More discussions on this conservative assumption may be found in page 9. For the Campbell (1987) relationships given in Reference 4, the closest distance to the zone of seismic energy release, R, was conservatively taken to be the closest distance to the fault plane, 15.0 km. For the Joyner and Fumal (1985) relationships given in Reference 6, the distance, d, to the surface projection of the rupture zone was estimated at 10.9 km by assuming a maximum rupture depth of 15 km; a shallower rupture depth would increase the distance and reduce the estimated motions.

Based on the results in Table 2.1 and other considerations such as probabilistic hazards, the Working Group recommends that 0.3 g and 30 cm/s be used as control values for peak horizontal acceleration (larger of two randomly oriented horizontal components) and velocity, respectively. The use of the larger of two randomly oriented horizontal components is more conservative than the use of the average of the two components by about 13 percent (Reference 4). Standard practice for defining the design vibratory ground motion for nuclear power plants is to use both of the horizontal components.

Standard engineering practice is to set vertical ground-motion values at two-thirds those of the horizontal values. This approach would probably be adequate for peak accelerations from a magnitude 6 1/2 earthquake at a distance of about 15 km. However, a number of recently obtained close-in recordings of strong motion from large earthquakes have evidenced vertical peak accelerations equal to or even exceeding the peak horizontal accelerations (Shakal, et al., 1986, Huang, et al., 1987-Reference 19, 20). In light of the marginal probability of large vertical accelerations from an earthquake on the Bare Mountain fault and the marginal probability of an earthquake on one of the closer faults (which could be expected to generate vertical accelerations on the order of the horizontal accelerations), the

Working Group deems it prudent to assume equal peak values for horizontal and vertical acceleration, namely 0.3 g.

Empirical observations indicate that ground velocities do not exhibit such near-field increases in the relative amplitude of the vertical components due in part to the relatively lower frequency content associated with ground velocity as compared with ground accelerations. Consequently, the standard practice of setting the vertical component at 2/3 the value of the horizontal component is used to establish a control value of 20 cm/s for the vertical component of ground velocity.

Whereas earthquake ground shaking results from a myriad of seismic waves, the peak motions are expected to be dominated by waves that follow the most direct and efficient route from the earthquake source. As discussed in Appendix A-1, the largest amplitude waves are expected to emerge at a steep angle, within 30° of vertical, at the ES location. These body waves include longitudinal P waves and two types of transverse S waves: horizontally polarized SH waves and orthogonally polarized SV waves with a vertical component of motion. Because the ratio of P-wave to S-wave velocities in the earth's crust is nearly constant (ranging from about 1.6 to 1.7), the three types of body waves (P, SH and SV) are expected to emerge at about the same angle. Futhermore, because of the characteristics of earthquakes waves, the vertical component of peak motion can be associated with P waves or SV waves, and the horizontal components can be associated with SH and SV waves. It should be noted however, that the amplitude of steeply emerging SV waves is constrained by the peak horizontal motions and is therefore limited in its contribution to the vertical motion.

2.4 Checks on Design Basis Motions

Two reconnaissance probabilistic seismic hazard analyses for Yucca Mountain support the adequacy of 0.3 g as a control value for peak horizontal acceleration. Probabilistic seismic hazard analysis integrates the contribution of all known faults and seismic source zones to the probability of exceeding a particular ground motion level and, thus, is a useful means of confirming the adequacy of deterministically derived estimates. A reconnaissance assessment of probabilistic earthquake accelerations at Yucca Mountain by Perkins, et al. (1987) in Reference 12 indicates that a peak horizontal acceleration of 0.3 g has a return period of about 1,500 to 3,000 yrs. A sensitivity study by URS/Blume (1987) in Reference 11 suggests a return period on the order of 1,000 yr for 0.3 g. Both analyses are subject to very large uncertainties but tend to confirm that 0.3 g is a conservative estimate of the peak horizontal ground acceleration that is reasonably likely to occur during the operating lifetime of the ESF.

2.5 Factors That May Influence Ground Motion

In addition to earthquake magnitude and distance, the factors that most influence ground motion include: source type (normal, reverse or strike-slip), rupture dynamics (directivity and variability of stress release on the fault surface), transmission-path effects (wave scattering, attenuation, multi-pathing and dispersion), and site geology (topography and vertical and lateral variations in soil/rock densities seismic velocities and Q values). Considerations of each class of influences are discussed next.

The Bare Mountain fault is a Basin and Range, range-front fault (Carr, 1984, Reference 5), with a normal or oblique-normal sense of slip. McGarr (1984) (Reference 7) has suggested that normal faulting occurs at lower stresses than strike-slip or thrust faulting and that normal-fault events are less energetic at high frequencies than earthquakes with strike-slip or thrust mechanisms. Since the large majority of data that constrain the empirical relationships used in Table 2.1 are from strike-slip and thrust earthquakes, the use of these relationships would result in the direction of added conservatism in the predicted design-basis motions. The Campbell (1987) (Reference 4) peak ground motion regressions used in Table 2-1 take into account fault type (strike-slip or reverse and thrust). In order to provide margin for possible re-evaluation of the tectonic environment by on-going geologic and geophysical studies, the WG has used Campbell's regressions for reverse and thrust earthquake mechanisms. Joyner and

Fumal's regressions do not provide for a distinction in ground motion due to source mechanism.

Effects of rupture dynamics are most influential at distances closer than those being considered here. Close-in strong-motion records sometimes evidence (J. P. Singh, Reference 31) anomalous or at least identifiable motions that can be attributed to irregularities in the rupture process or to focusing (or defocusing) that results from the approaching (or receding) rupture front. J. P. Singh (Reference 31) has written about this and his general conclusions seem to be that the near-field behavior produces great variability in individual parameters, no one of which is sufficient to account for the variability in near-field damage, nor is it possible to estimate near-field spectra by using these parameters to set the levels of spectral shapes based on local site conditions. Individual near-field spectra have to be estimated in a site-specific, rupture specific way. Major effects in the near field are due to "enhancement of the long duration pulse called the 'fling,' which is related to the elastic rebound on the fault, and . . . compression of the duration of the strong shaking in the direction of rupture propagation." The long duration pulse is probably most important for damage to longer period structures. As for the effect of direction of rupture propagation, Singh does not discuss whether the near-field ground motion parameters have greater means or medians than predicted by current attenuation functions if the rupture propagation direction is not known, even though higher ground motions for an approaching rupture and lower ground motions for a receding rupture should be expected. As for the expected effects at the ES site, since large normal-faulting earthquakes typically initiate at depth and propagate upward (Smith and Richins, 1984, Reference 21) away from the site in this case, any bias due to rupture dynamics is expected to reduce ground motions at the site.

Data are not yet available to evaluate the possibility of local biases in the regional seismic-wave transmission characteristics. There are some indications that waves may transmit more efficiently in the southern Great Basin than in California, where most of the relevant strong motion data have been recorded (Rogers, 1987, Reference 22). However, the effects of regional differences in attenuation scale with distance and are probably not significant at source-receiver distances around 15 km. Also, the soil conditions that are generally associated with increased earthquake motions are not present at the rock site.

Perhaps the biggest single source of dispersion in the observations of earthquake motions results from the effects of the local geology. Based on Campbell's (1981) estimates in Reference 23 for dispersion from all sources, a site that amplifies motions more than 84 percent of all sites of the same classification (i.e., a mean-plus-one-standard-deviation site) could result in peak motions about one and one half times as large as the hypothetical average site. Conversely, a site that amplifies motions less than 84 percent of the sites (i.e., a mean-minus-one-standard-deviation site) could attenuate motions by a factor of about two-thirds.

Additional considerations are identified below to accommodate possible uncertainties in the determination of ESF design motions.

2.6 Further Recommendations

Until determinations of local site factors are available, added conservatism is warranted to compensate for this source of uncertainty. Specifically, the Working Group recommends that no credit be taken for attenuation of ground motion with depth below the ground surface nor for the reduction in seismic strains due to the stress-free boundary condition at the ground surface. Available surface and downhole recordings of motions in the area of Yucca Mountain from underground nuclear explosions have been compiled in Appendix A-4 and indicate a reduction in ground motions with depth.

Finally, to provide further assurance that the design has adequate conservatism or margin to accommodate any uncertainties such as site effects, the Working Group recommends that the performance of the exploratory shaft facility be evaluated using best estimate conditions when subjected to ground motions that are a factor of 1.67 larger than the design-basis motions, i.e., for a peak horizontal acceleration of 0.5 g and a peak horizontal velocity of 50 cm/sec. This evaluation for the larger motions should provide assurance that major damage of the ES is not expected at these 'g' levels.

Table 2-1

Predicted Peak Ground Motion Values at the ES Site for an Earthquake on the Bare Mountain Fault and Recommended Peak Ground Motion Values for Consideration in ES Design

	Peak Horizontal Acceleration(1)			Peak Horizontal Velocity(1)		
M	J&F-85(3)	C-87(2)	ESF Design Basis	J&F-85(3)	C-87(2)	ESF Design Basis
6.0	0.21g	0.19g		11.9 cm/s	10.8 cm/s	
6.5	0.27	0.26	0.30g	20.9	16.8	30.0 cm/s
6.75	0.31	0.30		27.8	20.7	

(1) Predicted median (most probable) peak ground motion values (larger of two randomly oriented components) at the ES site from an earthquake on the Bare Mountain Fault.

(2) Campbell (1987), "unconstrained" model; acceleration values have been increased by 13 percent and velocity values by 17 percent to convert from mean of two components to larger of two components. The closest distance to zone of seismogenic rupture, R, is taken as the closest distance to the fault plane, 15.0 km, assuming a 70° eastward dip. For conservatism, higher values corresponding to the assumption of a reverse or thrust mechanism are calculated.

(3) Joyner and Fumal (1985); distance to surface projection of fault rupture, d = 10.9 km, assuming a 70° eastward dip and 15 km maximum rupture depth. Joyner and Fumal do not attempt to obtain distinct regressions for different source mechanisms.

3.0 CONTROL MOTIONS FROM UNDERGROUND NUCLEAR EXPLOSIONS

The control motions from the design basis underground nuclear explosion (UNE) are specified in this section. In addition, background on the design basis UNE and the various assumptions made in the specification of ground motions are also included. Backup material and additional references are provided in Appendices A-2 and A-4.

The nuclear waste repository to be located in the Yucca Mountain is adjacent to the Nevada Test Site (NTS). The repository must not limit the ability of the United States government to test nuclear weapons. The definition of the design basis UNE must reflect this position. Therefore, the event chosen has to produce the maximum ground motions at Yucca Mountain for the maximum credible yield for any given area (regardless of current or future treaties). Figure 3-1 shows the current and proposed testing areas at NTS and their relationship to the Yucca Mountain Area. Vortman (Reference 14) used the results of a 1977 USGS real estate availability study of several areas of NTS and the upper yield limits established for these areas by the Ground Motion and Seismic Evaluation Subcommittee to define the design basis UNE for the repository site. The yield limits were based on offsite damage criteria with special emphasis on damage in Las Vegas. Given the areas selected and the yield limits established, the design basis UNE was chosen as a 700 kt event at a distance of 22.8 km. This event is the largest yield at the closest practical point (from a UNE fielding point of view) in the Buckboard Mesa Area of NTS. This event results in the worst-case situation for ground motions at Yucca Mountain.

The prediction of peak ground motions for this UNE is done with empirical equations developed for the NTS. The major assumptions made in the development of these equations are: (i) source geology is considered to be the same, and (ii) differences in the travel paths are ignored. These equations are based on measured ground motion from many UNEs conducted in the Pahute Mesa Area of NTS. The recording stations used were from several areas of NTS including a few at Yucca Mountain. Equations fitting this data were developed using standard linear regression analysis. An evaluation of the ground motion data recorded at Yucca Mountain indicated that observed ground motions at Yucca Mountain were larger than predicted using the prediction equations; however, the underestimation of the ground motions was within the expected accuracy of the prediction equations (i.e., within the expected accuracy of the mean of all observations at the site). Future work to be completed as part of site characterization will investigate if ground motions in the Yucca Mountain region are larger than other regions in the Nevada Test Site. This work will include an accurate confirmation of accelerograph recording site conditions and an assessment of the representativeness of UNE attenuation equations. In order to provide a conservative estimate of UNE design basis motions, the design basis UNE ground motion parameters specified are given for a nonexceedance probability level of 95 percent (this corresponds to 1.65 times the standard deviation for a normal or lognormal distribution which increases the most probable values by a factor ranging from 2 to 4). The mean values of the predicted ground motions and the recommended design basis values are summarized in Table 3-1. Further discussions of the prediction equations and the various references are given in Appendix A-2.

Assumptions made and conditions used in the development of the design basis UNE are listed below.

- Potential site effects at Yucca Mountain are not included in the specification of the UNE design basis motions because they are not quantified at this time.

- No attenuation of ground motion with depth will be used in the specification of design motions. This assumption is conservative. UNE ground motions are known to attenuate with depth at Yucca Mountain (see Appendix A-4). This assumption along with the use of design basis motions based on the 95 percent nonexceedance probability, makes the recommended values conservative and should compensate for the potential site effects.

- The angle of incidence for ground motions from the UNE to the ES is taken as ranging between 0° (vertical propogation) and 90° (horizontal propagation).

- For nearly horizontal propagation (60° to 90°) peak radial response is primarily from P waves, peak vertical response is primarily from the S_v waves, and peak transverse response is primarily from the S_h waves.

The incidence angle of the ground motions from UNEs are a function of material wave speed through which the waves are travelling. At first, it may appear that each ground motion component (i.e., P, S_v, S_h, and surface waves) could have its own incidence angle. In practice, however, the incidence angles (θ) for all the components are essentially the same. This stems from the way in which the incidence angle is calculated. This calculation uses the change in the arrival times (Δt) of a component of a ground motion from two nearby stations, the distance (Δx) between the two stations and the material wave speed (v); i.e., $\theta = \sin^{-1}(\Delta tV/\Delta x)$ (Reference 15). For the same two stations (i.e., Δx is constant), the wave speed and Δt will change for each ground motion component. These changes will be in opposite directions (as wave speed decreases, Δt will increase). These differences will have a tendency to offset one another, such that the incidence angle calculated will be about the same for all components.

This incidence angle can vary from zero to 90 degrees. A preliminary survey of the UNE ground motion data recorded at Yucca Mountain from Pahute Mesa events indicates that the range of the incidence angle is generally between 10 to 50 degrees. However, because the incidence angle is also a function of distance from the source and because the Yucca Mountain recordings are at distances which are a factor of two more distant from the source than the design-basis UNE, there is a reasonably large amount of uncertainty in the definition of this angle for ES design. To provide adequate conservatism, incidence angles recommended for use in this report are between zero and 90 degrees.

The equations used for the prediction of UNE motions were determined from the absolute peak values recorded on the waveform. No effort was made to determine a fit for each component (P, S_v, S_h, and surface waves). In general, peak accelerations observed in UNE recordings are associated with the P-wave. Peak vertical and transverse velocity may be the result of P-waves or shear waves. All displacements are due to the surface wave components. The design parameter of interest to the ES is the peak particle velocity. It is assumed that the velocity corresponding to the P-waves is the same as the radial component of velocity and the velocities corresponding to the S_v and S_h waves are the same as the vertical and transverse components of velocities, respectively.

Table 3-1

Recommended Motions for the Design Basis UNE

Component	Median Predicted Value	Design Basis UNE Values (95 percent nonexceedance level or 1.65σ)
Vert. Accel. (g)	0.05	0.2
Rad. Accel. (g)	0.03	0.1
Trans. Accel. (g)	0.03	0.1
Vert. Vel. (cm/s)	4	9
Rad. Vel. (cm/s)	4	12
Trans Vel. (cm/s)	3	12
Vert. Disp. (cm)	1	2
Rad. Disp. (cm)	1	3
Trans. Disp. (cm)	1	4

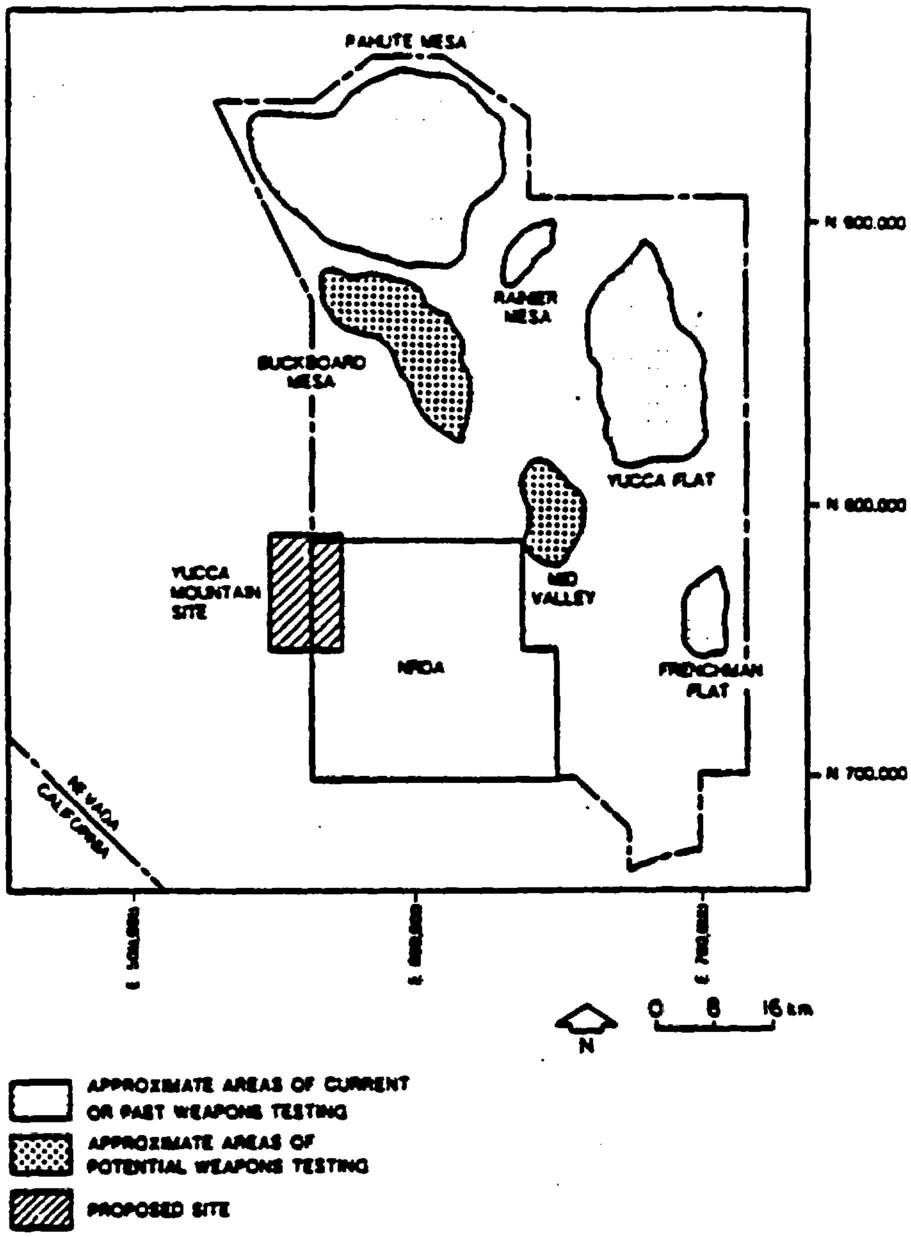


Figure 3-1. Locations of Current and Proposed Testing Areas at NTS and the Yucca Mountain Site

4.0 COMBINATION OF INDIVIDUAL COMPONENT WAVE EFFECTS

Newmark and Hall (Reference 16) have suggested that peak effects from the three orthogonal components of earthquake input motion be considered to be randomly phased relative to each other and thus be combined probabilistically. They then go on to suggest that a conservative and simpler approach to this probabilistic combination can be obtained by absolute vector addition of 100 percent of the largest peak effect from any of the three orthogonal components plus 40 percent of the peak effects from each of the other two components. This approach has come to be known as the 100-40-40 Combination Rule.

This same 100-40-40 Combination Rule can be used for the combination of peak effects from the individual P, S_V, and S_H component waves, so long as these peak component effects can be conservatively or realistically treated as randomly phased relative to each other. Such an assumption is reasonable and slightly conservative for both earthquake and UNE control motions. This point is illustrated by the following examples.

The earthquake control motion peak particle velocities for the three orthogonal components are 30 cm/sec, 30 cm/sec, and 20 cm/sec. Using the 100-40-40 Combination Rule, the absolute addition of these three orthogonal components is given by:

$$V_c = \sqrt{(V_1)^2 + (0.4)^2 \left[(V_2)^2 + (V_3)^2\right]} \qquad (4\text{-}1)$$

where V_c is the combined vector sum, V_1 is the largest orthogonal component effect, and V_2 and V_3 are the other two orthogonal component effects. Using Equation (4-1) together with the three orthogonal component peak particle velocities leads to a vector sum peak particle velocity of 33.3 cm/sec which is 11 percent greater than the largest individual component peak particle velocity. Similarly, peak particle accelerations for the three orthogonal components of the earthquake control motion are each 0.3 g. Using Equation (4-1), the vector sum peak particle acceleration is 0.345 g or 15 percent greater than the largest individual component peak value. A review of actual earthquake records indicates that the peak vector velocities and accelerations tend to be only 4 percent to 12 percent greater than the largest orthogonal component velocities and accelerations (Reference 29), so that the recommended probabilistic combination of the control motions tends to be on the conservative side for earthquakes.

Actually, this conservatism is increased somewhat by the way peak horizontal and vertical control motions are converted into peak P and S_V wave particle motions for inclined waves. For waves that are inclined 30° from the vertical, the P, S_V, and S_H peak particle velocities for the earthquake control motions become 23.1 cm/sec, 34.6 cm/sec, and 30 cm/sec, respectively, which leads to a vector sum peak particle velocity for Equation 4-1 of 37.8 cm/sec or 26 percent greater than the peak control motion particle velocity of 30 cm/sec. Similarly, for the 30° inclined wave case, the vector sum peak particle acceleration becomes 0.392 g which is 31 percent greater than the peak control motion particle acceleration of 0.30 g. Thus, the combined effect of converting control motions to P, S_V and S_H components and then combining these peak component effects by the 100-40-40 rule introduces significant conservatism for 30° inclined waves.

Conservatism also exists when the effects of the three defined orthogonal components of the UNE control motions are combined by the 100-40-40 Combination Rule. For example, the three orthogonal peak particle velocities defined in Table A2-1 of Appendix A-2 are 9 cm/sec, 12 cm/sec, and 12 cm/sec; when combined by Equation 4-1, these values lead to a combined vector sum peak particle velocity of 13.4 cm/sec, which significantly exceeds the peak vector velocity of 10 cm/sec listed in Table A2-1. Similarly, using the three orthogonal peak particle accelerations of 0.2 g, 0.1 g and 0.1 g results in a vector sum peak particle acceleration of 0.21 g using Equation (4-1) versus the vector sum of 0.2 g shown in Table A2-1.

5.0 DEVELOPMENT OF STRAIN TENSORS

5.1 Strain Tensors for Earthquakes

It is concluded in Appendix A-1 that body waves due to earthquakes impinge on the shaft with steep angles of incidence, namely, steeper (less than) than 30°. Further, as discussed in Section 2.3, it can be assumed that the three wave types--P, SV, and SH emerge along the same ray path, that is, with the same angle of incidence and along the same azimuth.

The coordinate system consists of the z axis oriented downward along the axis of the shaft and the x-y plane corresponding to the ground surface. Without loss of generalization, the wave front of each incident wave is normal to the x-z plane, as illustrated in Figure 5-1, so that particle motion is either in the x-z plane (for P- and SV-waves) or normal to the x-z plane (for SH-waves). The following notation is used in the subsequent expressions for strain:

θ = Angle of incidence for P-, SV-, and SH-waves
C_p = Propagation velocity of the P-wave
C_s = Propagation velocity of the SV- and SH-waves
v_p = Peak particle velocity of the P-wave
v_{sv} = Peak particle velocity of the SV-wave
v_{sh} = Peak particle velocity of the SH-wave
a_p = Peak acceleration of the P-wave
a_{sv} = Peak acceleration of the SV-wave
a_{sh} = Peak acceleration of the SH-wave
v_v = Peak particle velocity at the ground in the vertical direction
v_h = Peak particle velocity at the ground in the horizontal direction
a_v = Peak acceleration at the ground in the vertical direction
a_h = Peak acceleration at the ground in the horizontal direction

The symmetric strain tensor, $\bar{\epsilon}$, consists of three axial strain components and three shear strain components defined as follows:

$$\bar{\epsilon} = \begin{bmatrix} \epsilon_{xx} & \epsilon_{xy} & \epsilon_{xz} \\ \epsilon_{xy} & \epsilon_{yy} & \epsilon_{yz} \\ \epsilon_{xz} & \epsilon_{yz} & \epsilon_{zz} \end{bmatrix} = \begin{bmatrix} \epsilon_{xx} & \frac{1}{2}\gamma_{xy} & \frac{1}{2}\gamma_{xz} \\ \frac{1}{2}\gamma_{xy} & \epsilon_{yy} & \frac{1}{2}\gamma_{yz} \\ \frac{1}{2}\gamma_{xz} & \frac{1}{2}\gamma_{yz} & \epsilon_{zz} \end{bmatrix}$$

where

$$\epsilon_{xx} = \frac{\partial u_x}{\partial x}$$

$$\epsilon_{yy} = \frac{\partial u_y}{\partial y}$$

$$\epsilon_{zz} = \frac{\partial u_z}{\partial z}$$

$$\epsilon_{xy} = \frac{1}{2}\left(\frac{\partial u_x}{\partial y} + \frac{\partial u_y}{\partial x}\right)$$

$$\epsilon_{xz} = \frac{1}{2}\left(\frac{\partial u_x}{\partial z} + \frac{\partial u_z}{\partial x}\right)$$

$$\epsilon_{yz} = \frac{1}{2}\left(\frac{\partial u_y}{\partial z} + \frac{\partial u_z}{\partial y}\right)$$

u_x, u_y, u_z, = particle displacement in x-, y-, z-direction, respectively

The "engineering shear strain," denoted by γ, is defined as two times the tensor shear strain, i.e., $\gamma_{xy} = 2\epsilon_{xy}$.

The extreme fiber bending strain, ϵ_b, induced in the liner by the passage of waves is defined by:

$$\epsilon_b = R\,\kappa$$

where R = Radius of the liner

κ = Curvature of the shaft axis

Along the ray paths, a P-wave generates axial strain given by

$$\epsilon = \frac{v_p}{C_p}$$

while a shear wave generates pure shear strain given by

$$\gamma = \frac{v_s}{C_s}$$

Transforming these strains to the xyz-coordinate system yields the expressions for free-field strains shown on Table 5-1.

Curvature along an axis is given by the acceleration normal to the axis divided by the square of the apparent wave speed along that axis. This relationship is used to derive the expressions for bending strain, also shown on Table 5-1.

For the case of earthquakes, the particle motions in the P-, SV- and SH-waves will be controlled by the ground motion control parameters in the z-, x-, and y-directions, respectively. Comparing the components shown in Figure 5-2a with those in Figure 5-2b, the particle velocities are given as follows:

$$v_p = v_v/\cos\theta$$

$$v_{sv} = v_h/\cos\theta$$

$$v_{sh} = v_h$$

The same relations hold for acceleration, where a is substituted for v. The substitution of these relations into the expressions on Table 5-1 yields the expressions on Table 5-2.

5.2 Strain Tensors for UNEs

It is not known at this time how much of the incident wave energy impinging on the shaft from a UNE will be associated with shallow incidence angles versus energy associated steeper angles. However, it is not necessary to know the distribution of the incident wave energy with incidence angle, because the strains due to earthquakes will be an upper bound on the strains due to UNEs, as demonstrated in Section 5-3 below.

The maximum strains generated by earthquake waves emerging with θ between 0° and 30° are compared to the maximum strains due to UNE waves emerging with θ between 0° and 90°. The strains due to steeply emerging waves (i.e., between θ = 0° and 30°), be they generated by earthquakes or UNEs, are computed from the expressions on Table 5-2. New expressions are derived for shallow emerging waves (i.e., between θ = 60° and 90°).

For UNE waves emerging at shallow angles (say, θ = 60° to 90°) P-, SV-, and SH-waves will be controlled by the ground motion control parameters in the x-, z-, and y-directions, respectively. Comparing Figures 6-1a and 6-2c, the particle velocities are given as follows (for shallow emerging waves):

$$v_p = v_h/\sin\theta$$

$$v_{sv} = v_v/\sin\theta$$

$$v_{sh} = v_h$$

The same relations hold for acceleration, where a is substituted for v. Substitution of these relations into the expressions on Table 5-1 yields the expressions on Table 5-3.

5.3 Controlling Strain Combinations Due to Earthquakes and UNEs

For the design basis parameters recommended in Sections 2.0 and 3.0 for earthquakes and UNEs, it can be shown (see Appendix A-3) that of all the various incidence angles (0° to 30° for earthquakes and C to 90° for UNEs) that need to be evaluated with three possible combinations of P, S_v and S_h waves for design, only one case controls all aspects of the shaft design:

- Earthquake control motion
- 30° incidence angle
- 100 percent S_v peak effects plus 40 percent P and S_h peak effects (using the probabilistic combination rule specified in Section 4.0).

Both hoop stress or strain and total axial strain are controlled by earthquake waves emerging at an angle of 30° from the vertical. For the specified design basis motions, UNEs will never control the design. Hence, it is recommended that the designer use only the above combination for des.gn evaluation of the ES.

Table 5-1

Free Field and Bending Strains for Body Waves With Angle of Incidence θ

Wave Type	Free Field Strains						Bending Strains
	ϵ_{xx}	ϵ_{yy}	ϵ_{zz}	γ_{xy}	γ_{yz}	γ_{xz}	ϵ_b
P	$\frac{v_p}{C_p} \sin^2 \theta$	0	$\frac{v_p}{C_p} \cos^2 \theta$	0	0	$\frac{v_p}{C_p} \sin 2 \theta$	$\frac{R\, a_p}{C_p^2} \sin \theta \cos^2 \theta$ (in x-z plane)
SV	$\frac{v_{sv}}{C_s} \sin \theta \cos \theta$	0	$\frac{v_{sv}}{C_p} \sin \theta \cos \theta$	0	0	$\frac{v_{sv}}{C_s} \cos 2 \theta$	$\frac{R\, a_{sv}}{C_s^2} \cos^3 \theta$ (in x-z plane)
SH	0	0	0	$\frac{v_{sh}}{C_s} \sin \theta$	$\frac{v_{sh}}{C_s} \cos \theta$	0	$\frac{R\, a_{sh}}{C_s^2} \cos^2 \theta$ (in y-z plane)

Table 5-2

Free Field and Bending Strains in Terms of Ground Motion Control Parameters for Earthquakes

Wave Type	Free Field Strains						Bending Strains
	ϵ_{xx}	ϵ_{yy}	ϵ_{zz}	γ_{xy}	γ_{yz}	γ_{xz}	ϵ_b
P	$\frac{v_v}{C_P} \frac{\sin^2\theta}{\cos\theta}$	0	$\frac{v_v}{C_P} \cos\theta$	0	0	$\frac{v_v}{C_P} 2 \sin\theta$	$\frac{R\, a_v}{C_P^2} \sin\theta \cos\theta$ (in x-z plane)
SV	$\frac{v_h}{C_s} \sin\theta$	0	$\frac{v_h}{C_s} \sin\theta$	0	0	$\frac{v_h}{C_s} \frac{\cos 2\theta}{\cos\theta}$	$\frac{R\, a_h}{C_s^2} \cos^2\theta$ (in x-z plane)
SH	0	0	0	$\frac{v_h}{C_s} \sin\theta$	$\frac{v_h}{C_s} \cos\theta$	0	$\frac{R\, a_h}{C_s^2} \cos^2\theta$ (in y-z plane)

Note: These expressions are valid only for steeply emerging body waves, i.e., $\theta = 30°$ or less.

Table 5-3

Free Field and Bending Strains in Terms of Ground Motion Control Parameters for Body Waves With Shallow Angles of Incidence

Wave Type	Free Field Strains						Bending Strains
	ϵ_{xx}	ϵ_{yy}	ϵ_{zz}	γ_{xy}	γ_{yz}	γ_{xz}	ϵ_b
P	$\frac{v_h}{C_p} \sin \theta$	0	$\frac{v_h}{C_p} \frac{\cos^2 \theta}{\sin \theta}$	0	0	$\frac{v_h}{C_p} 2 \cos \theta$	$\frac{R\ a_h}{C_p^2} \cos \theta^2 \cos \theta$ (in x-z plane)
SV	$\frac{v_v}{C_s} \cos \theta$	0	$\frac{v_v}{C_s} \cos \theta$	0	0	$\frac{v_v}{C_s} \frac{\cos 2\theta}{\sin \theta}$	$\frac{R\ a_v}{C_s^2} \frac{\cos^3 \theta}{\sin \theta}$ (in x-z plane)
SH	0	0	0	$\frac{v_h}{C_s} \sin \theta$	$\frac{v_h}{C_s} \cos \theta$	0	$\frac{R\ a_h}{C_s^2} \cos^2 \theta$ (in y-z plane)

Note: These expressions are valid only for $\theta = 60°$ or $\theta = 90°$.

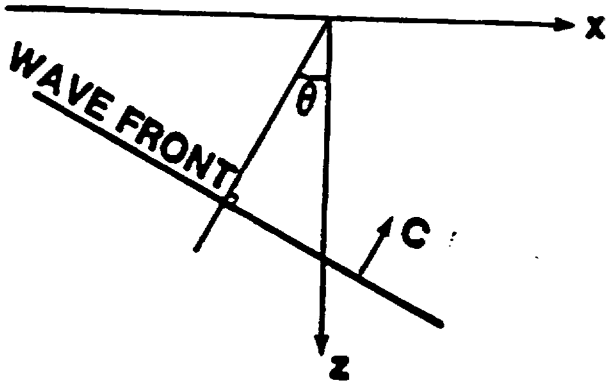
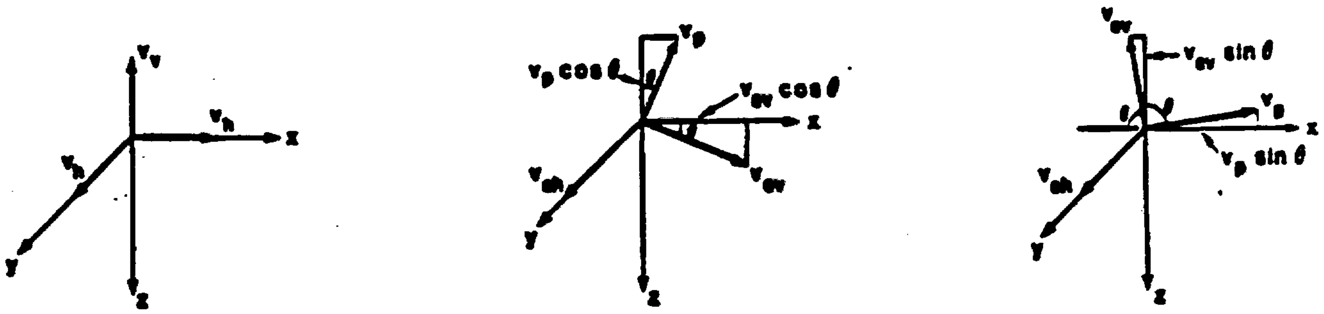


Figure 5-1. Orientation of Incident Waves with Respect to the Coordinate System



(a) DIRECTION OF CONTROL PARAMETERS (REPRESENTED BY PEAK GROUND MOTION VELOCITIES)

(b) DIRECTION OF PARTICLE MOTIONS IN STEEPLY EMERGING WAVES (REPRESENTED BY PARTICLE VELOCITY)

(c) DIRECTION OF PARTICLE MOTIONS IN SHALLOW EMERGING WAVES (REPRESENTED BY PARTICLE VELOCITY)

Figure 5-2. Relationship Between Peak Ground Motion Control Parameters and Particle Motions Due to Each Wave Type

6.0 DYNAMIC ROCK PROPERTIES

This section describes the procedure used to determine dynamic rock properties for use in analyses of underground openings at the ESF when subjected to transient free field strains caused by either earthquakes or underground nuclear explosions. The properties important to such analyses are as follows:

Velocity of compression waves, C_p
Velocity of shear waves, C_s
Dynamic deformation modulus, E_d
Dynamic Poisson's ratio, ν_d

These properties should be determined for each rock unit in which underground openings are located. Analyses of the openings for transient free field strains, based on the relative ground support to rock mass stiffness, must utilize the corresponding dynamic material properties. Static loadings may be analyzed independently, using static material properties, and the result superimposed over the results of the dynamic analyses.

Figure 6-1 illustrates the stratigraphy of the borehole nearest the ESF site (USW G-4), and includes plots of the measured in situ P-wave velocities, as presented in Reference 17, and of the measured laboratory P-wave velocities, as presented in Reference 18. The plot of in situ values also shows a smooth curve which represents the average of the measured values over each identified rock unit. The remaining plots on this figure represent the recommended P-wave and S-wave velocities as determined by the evaluation described herein.

The most recent Reference Information Base (RIB) for the NNWSI project (Reference 27) recommends the following rock mass bulk densities, rock mass Poisson's ratios, and intact Poisson's ratios.

Rock Unit	Bulk Density (g/cm^3)	Rock Mass Poisson's Ratio	Intact Rock Poisson's Ratio
TCw	2.31	0.10	0.24
PTn	1.58	0.19	0.16
TSw1[b]	1.84[c]	0.16	0.16
TSw1[a]	2.25	0.22	0.25
TSw2	2.32	0.22	0.24
TSw3	2.32	0.22[c]	0.24[c]
CHnlv	1.82	0.15	0.16
CHnlz	1.92	0.16	0.16

a. Lithophysal rich, devitrified.
b. Lithophysal rich, vapor phase.
c. Value shown is assumed, RIB indicates that value is not available.

The S-wave velocity (C_s) and the dynamic deformation modulus (E_d) can be determined from the bulk density (D), dynamic Poisson's ratio (v_d), and P-wave velocity (C_p) by the following elastic relationships:

$$C_s = C_p((1 - 2v_d)/(2 - 2v_d))^{0.5}$$
$$E_d = DC_p^2(1 + v_d)(1 - 2v_d)/(1 - v_d)$$

Based on the current, relatively limited, data on the rock properties, it is recommended that the rock mass Poisson's ratio, as given in the RIB, be used as the dynamic Poisson's ratio, and that the bulk density at in-situ saturation, as given in the RIB, be used.

The recommended P-wave velocities were determined as follows:

TCw: The in situ measurements differ significantly from the laboratory values. It is not possible to resolve this conflict with the data presently available. Therefore, the only recommendation provided for this unit is that the P-wave velocity of the underlying PTn unit represents a reasonable lower bound to the P-wave velocity of the TCw unit (i.e., PTn values are conservative for TCw unit).

PTn: The average of the in situ measurements over this unit is approximately 85 percent of the single laboratory measurement. This is considered to be a very reasonable correlation and the recommended P-wave velocity is specified as the average of the in situ measurements and equal to 1680 m/s.

TSw1[b], TSw1[a] and TSw2:

The average of the in situ measurements over each of these units varies between 75 and 90 percent of the corresponding laboratory measurements. As with the PT unit, the relative magnitude of the average in situ measurements as compared to the laboratory measurements is reasonable. Both sets of measurements indicate a slight increase in P-wave velocity with depth. Therefore, the recommended P-wave velocity is specified as a linear variation between the average in situ measurement for the TSw1[b] unit (2860 m/s) at the top of the TSw1 unit to the average in situ measurement for the TSw2 unit (3400 m/s) at the bottom of the TSw2 unit. This linear variation is further extended through the unnamed transition layer between the TSw2 and TSw3 units.

TSw3: There are no laboratory P-wave velocity measurements in the TSw3 material to use as confirmation of the in situ measurements. In addition, the thickness of the unit is less than the interval tested in situ, so the in situ measurement may be biased. Since the measured in situ value of P-wave velocity is the fastest recorded in the rock units of interest, it seems reasonable to assume that the actual unit velocity is greater than the recorded value. Therefore, the average in situ P-wave velocity measurement (5100 m/s) for the TSw3 unit is recommended as a conservative value.

CHnlv: The in situ measurement for this unit differs significantly from the single laboratory value. The in situ measurements of P-wave velocity for this thin unit appear to be biased by the underlying Chnlz unit. In lieu of better data, a value equal to the laboratory measurement (3850 m/s) is recommended.

CHnlz: The average in situ measurement for this unit is greater than the laboratory measurements. It seems reasonable that this nonwelded material is very sensitive to disturbance and/or confining pressure. Therefore, the average of in situ P-wave velocity (3010 m/s) is recommended.

Applying the aforementioned equations for S-wave velocity and dynamic deformation modulus to the recommended P-wave velocities, and summarizing the dynamic properties at the base of each unit yields the results given in Table 6-1.

As indicated earlier, these recommended properties are based on the currently available, but limited, site data, which have significant uncertainties. Hence, the WG recommends that additional data be obtained from the site at the earliest opportunity to supplement and confirm the available data and recommended properties.

Table 6-1

Recommended Rock Properties for the Different Rock Layers

Rock Unit	Dynamic Poisson's Ratio	P-wave Velocity (m/s)	S-wave Velocity (m/s)	Dynamic Deformation Modulus GPa
TCw	0.10	--	--	--
PTn	0.19	1680	1040	4.1
TSw1[b]	0.16	2940	1870	14.9
TSw1[a]	0.22	3078	1840	18.6
TSw2	0.22	3400	2040	23.5
TSw3	0.22	5100	3060	53.0
CHnlv	0.15	3850	2470	25.5
CHnlz	0.16	3010	1910	16.3

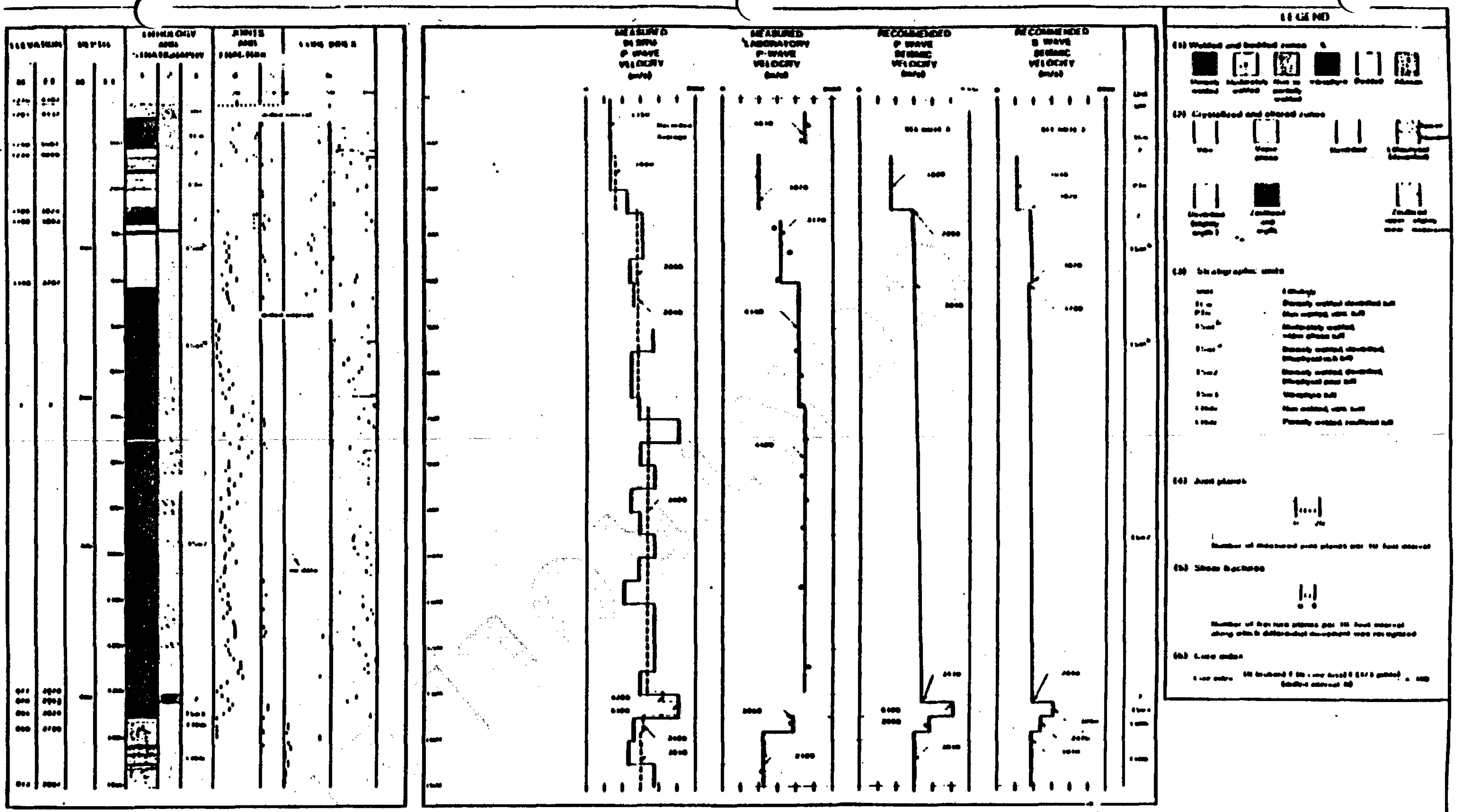


FIGURE 6-1

Interpretation of Seismic Velocities from USW-G4 Data

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7.0 FAULTING CONSIDERATIONS

7.1 Objectives

Several faults have been identified in the area of Yucca Mountain with evidence of movement during the Quaternary period. Hence, the possibility of faulting at the ES location and vicinity must be considered. None of the known faults with evidence of Quaternary movement intersect the exploratory shaft facilities. The potential hazard of a fault that may have thus far gone undetected can be assessed and bounded within reasonable limits. This assessment requires consideration of what is currently known about the characteristics of faulting in the surrounding area, including uncertainties. Considerations of the potential impact of faulting on the ESF provides a basis for assessing the relevance of possible undetected faults.

As discussed in Section 1.0, the exploratory shafts will not at any time be used to transport any high level waste materials. During the repository operations, the ESF shafts will be converted to serve as ventilation supply shafts. Exhausting fans on the emplacement exhaust shaft will at all times maintain negative pressure in the emplacement area relative to the development area, which is ventilated with forced ventilation. Hence, there is no potential for exploratory shafts to become an exhaust shaft rather than an intake shaft. Based on these discussions, any fault displacement through the ESF does not appear to impact public safety. It does not also seem to be a serious threat to operations or worker safety unless the fault offsets are significant. Fault displacements in excess of about 5 cm could possibly pose a threat to workers' safety during ESF operations.

The faulting hazard does not merit special design, provided there is reasonable assurance that fault displacement in excess of 5 cm is not likely to occur during the preclosure period. Limiting the possibility to less than one chance in 10 during the preclosure period is judged to be adequate to provide such an assurance. However, because of uncertainties in our present understanding of how the ESF would perform if subjected to significant fault displacement and because of uncertainties in our present understanding of the local tectonic conditions, the measure for adequate assurance is made more stringent by an additional factor of 10. Accordingly, faulting hazards need not be considered in the design of the ESF (which has a 100 year maintainable design life) if the annual probability for exceeding 5 cm of displacement is no greater than 10^{-4}/year. The characteristics of a fault that might pose a hazard can then be expressed as one that has moved during the Quaternary or late Quaternary at an average rate greater than 5 cm per 10,000 years or 0.005 mm per year.

7.2 Faulting Potential

Evidence of Quaternary displacement has not been identified on any fault that intersects the ESF or the underground area of waste storage. Except for the Ghost Dance fault, recognized offsets of faults within the repository block do not exceed 5 m (Reference 12, pp. 1-127). The Ghost Dance fault, which intersects the repository block but not the ESF, displaces Tertiary tuff units by 38 m and has a mapped length of 6 km (Reference 12). While evidence for movement on this fault during the Quaternary period has not been identified, the possibility cannot be ruled out from available data. However, it appears unlikely that repeated movements during the late Quaternary could have gone undetected.

The Ghost Dance fault is an obvious geologic feature, yet its potential for movement appears to be insignificant as compared with the faulting characteristics identified above in Section 7.1 to be of primary concern to the ESF. While the more significant faults that bound Yucca Mountain to the east and west do not intersect the ESF, their rates of movement are closer to the threshold of concern for the ESF. The Paintbrush Canyon fault appears to have the highest average rate of displacement during the late Quaternary, about 0.006 mm per year (Reference 12, Table 1-8). The average rate of late Quaternary displacement for the Windy Wash fault is estimated to be about 0.0015 mm per year. Similar faults in the proximity of the ESF would have been easily detected as they displace Tertiary tuff units by 200 m or more (Reference 12, Table 1-8).

7.3 Design Basis Faulting

No faults with evidence of Quaternary movement have been found in the immediate area of the ESF or in the larger area of the repository block. More distant faults that bound Yucca Mountain along the east and west flanks have moved repeatedly during the Quaternary period. Significant movement on these faults appears unlikely during a typical 100-year time period, and sympathetic displacement in excess of a few centimeters through the shaft is an unlikely response to a local earthquake. The annual probability that faulting in excess of a few centimeters will occur in the ESF shafts is judged to be well below 10^{-4} per year. Therefore, faulting need not be considered in the design of the ESF.

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APPENDIX A-1: INCIDENCE ANGLE OF SEISMIC BODY WAVES

INTRODUCTION

Strong ground shaking is primarily the result of seismic body waves that propagate through the earth along ray paths. The ray paths curve or refract in response to gradual or abrupt changes in material velocity. As illustrated in Figure A1-1, the inherent velocity of materials in the earth generally increases with depth. This causes the ray paths for emerging seismic waves to steepen as they approach the earth's surface. The curvature of ray paths is explained by Snell's Law which requires a constant phase velocity in directions that are parallel to the interface of two different materials as waves pass from one material to the other. Snell's Law is used to examine the range of incidence angles to be expected at the ESF from local earthquakes.

EARTH PROPERTIES

The velocity structure in the Great Basin increases rather dramatically with depth (Figure A1-1). The average P and S wave velocities for the Tertiary tuff units at Yucca Mountain are about 3 km/s and 1.8 km/s, respectively (see Section 6.0). At a depth of about 3 km below mean sea level, the respective values have increased to about 6.15 km/s and 3.6 km/s (Rogers, et al., 1983-References A1-1).

This increase of a factor of two or more in the velocity of rock with depth is indicative of significant increases in the stiffness and strength properties of rock with depth. The capacity of rock to support large tectonic stresses also increases with depth, at least to a depth of several kilometers. Consequently, earthquake rupture of most importance to ground motion hazards originates at a depth of a few kilometers or more. Also, the relatively large stiffness and strength properties of rock at these depths are required to efficiently transmit the largest amplitude waves away from the immediate source area.

INCIDENCE ANGLE

A local earthquake of unspecified location is postulated for estimating the range of incidence angles that would be expected for the largest amplitude body waves. As illustrated in Figure A1-2, the analysis uses the following notation:

V_S = Velocity of rock at the source depth responsible for the largest amplitude waves.

V_{ESF} = Velocity of rock at the ESF (approximately = 1/2 V_s).

θ_S = Take off angle at the source, measured from vertical, for body waves enroute to the ESF.

θ_{ESF} = Incidence angle at the ESF, measured from vertical.

The largest variations in velocity occur with depth. For simplicity, the earth is assumed to be comprised of horizontal layers of homogeneous material, i.e., vertically stratified. Repetitious application of Snell's Law to ray paths passing from one layer to the next indicates that the horizontal phase velocity would be constant along the entire ray path (Richtar, 1958, Reference A1-2). Equating the horizontal phase velocity for waves transmitted at the source with those emerging at the ESF location gives:

$$\frac{V_s}{\text{Sin}\theta_S} = \frac{V_{ESF}}{\text{Sin}\theta_{ESF}}$$

The incidence angle at the ESF is then obtained from:

$$\text{Sin}\theta_{ESF} = \frac{V_{ESF}}{V_S}\text{Sin}\theta_S$$

$$\leq 1/2$$

assuming V_S = 2 V_{ESF} for both P and S waves at the source depth responsible for the predominant earthquake waves was noticed previously.

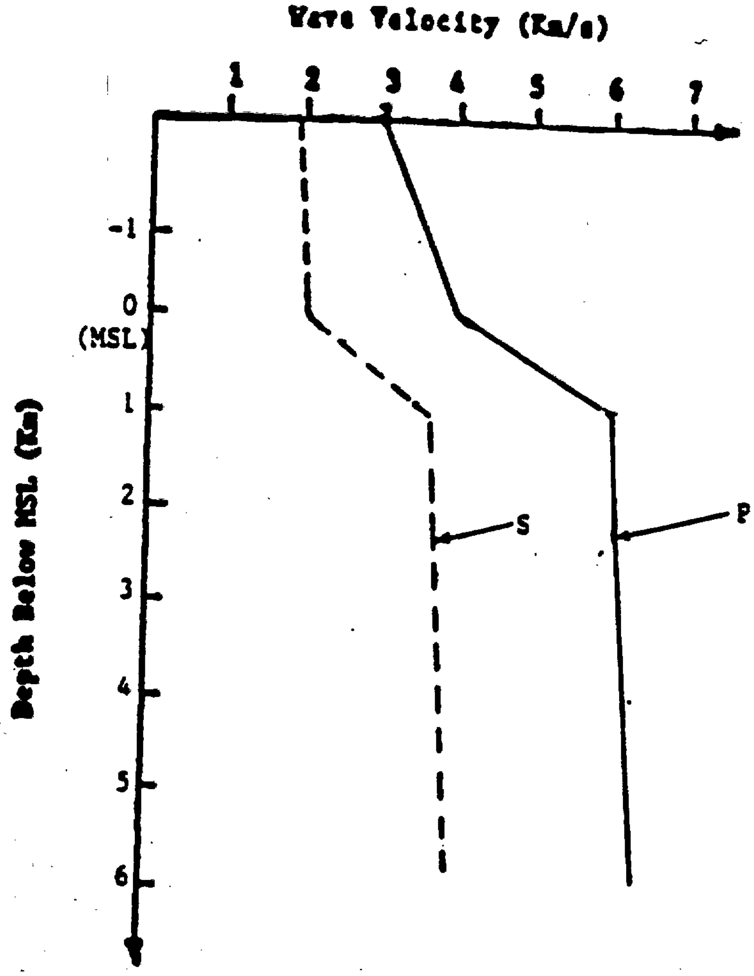

Figure A1-1: Approximate Velocity Structure for the Southern Great Basin, after Rogers et al. (1981).

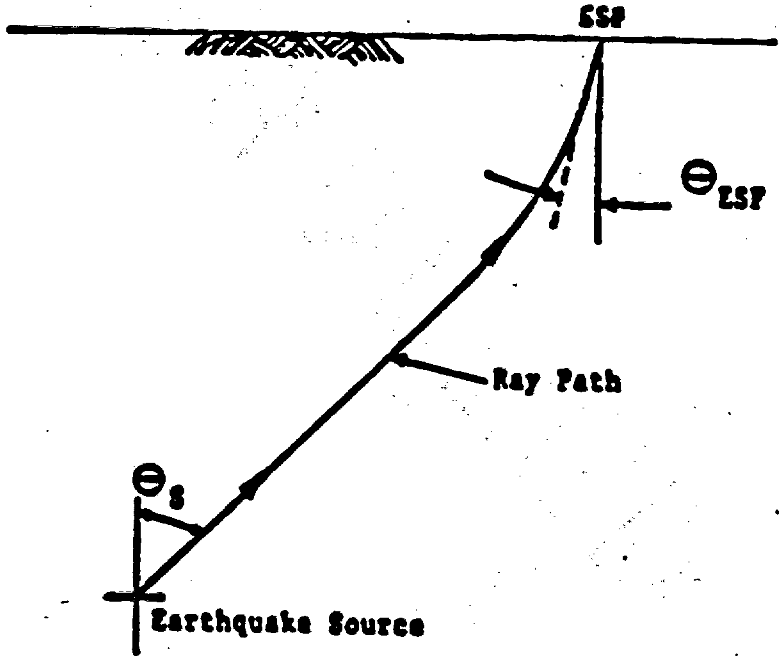

Figure A1-2: Depiction of the Ray Path for the Largest Amplitude Waves to Emerge at the ESF From a Potential Earthquake Source.

Thus, the largest amplitude body waves are expected to emerge at the ESF steeper than about 30° from vertical. Intervening heterogeneities and alternate wave paths are not expected to significantly alter this conclusion.

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APPENDIX A-2: DISCUSSION OF THE PREDICTION OF UNE GROUND MOTIONS

This appendix summarizes the background information concerning the prediction equations given in Table A2-1 and used for the prediction of UNE ground motions. This background information includes discussions on how the design basis UNE was selected, the data used in the development of the equations (including the rationale used in the analysis of the data and the recommended prediction equations) and a brief discussion on wave propagation from a UNE. Additional detail on the development of the prediction equations may be found in References A2-1 through A2-3.

Table A2-1: Prediction Equations for Stations on Rock(1)

Component	Equation	Mean Value	1.65 σ Value
Vert. Accel. (g)	$0.487\ W^{0.491}\ R^{-1.792}$	0.05	0.2
Rad. Accel. (g)	$0.239\ W^{0.382}\ R^{-1.425}$	0.03	0.1
Trans. Accel. (g)	$0.246\ W^{0.326}\ R^{-1.371}$	0.03	0.1
Vector Accel. (g)	$0.511\ W^{0.482}\ R^{-1.717}$	0.06	0.2
Vert. Vel. (cm/s)	$8.390\ W^{0.679}\ R^{-1.684}$	4	9
Rad. Vel. (cm/s)	$6.861\ W^{0.544}\ R^{-1.352}$	4	12
Trans. Vel. (cm/s)	$5.873\ W^{0.458}\ R^{-1.208}$	3	12
Vector Vel. (cm/s)	$12.04\ W^{0.628}\ R^{-1.593}$	5	10
Vert. Disp. (cm)	$1.319\ W^{0.737}\ R^{-1.699}$	1	2
Rad. Disp. (cm)	$1.024\ W^{0.719}\ R^{-1.486}$	1	3
Trans. Disp. (cm)	$0.598\ W^{0.603}\ R^{-1.165}$	1	4
Vector Disp. (cm)	$2.683\ W^{0.675}\ R^{-1.640}$	1	2

Note 1: The vector values at the 1.65 σ level for acceleration, velocity and displacement are less than the maximum individual component because (i) the standard deviation for the vector quantities are much smaller than that of the individual components, and (ii) of the round-off effects.

Selection of the Design Basis UNE

Locations of present and proposed testing areas were shown in Figure 3-1. Testing areas in present use are those at Pahute Mesa, Rainier Mesa and Yucca Flats. Possible future sites have been defined (Reference A2-4) as they are required in the event that existing sites are consumed. The two possible future sites of concern are the Buckboard area and Mid Valley.

The upper limits on yield for each of the testing areas have been defined (Reference A2-5) based on offsite damage with special emphasis on potential damage in Las Vegas. These limits are:

Pahute Mesa	1300 kt
Yucca Flats	300 kt
Frenchman's Flat	300 kt
Buckboard Area	750 kt
Mid Valley	*

(Note, the yield limit for Mid Valley was not specifically addressed because the geology will restrict yields to well below the other sites.)

Using the information given above, predictions were made for UNEs in the closest testing area (to the Yucca Mountain) with the highest yield limits (Pahute Mesa and Buckboard Area - Reference A2-6). The smallest possible distance between these particular testing areas and Yucca Mountain were scaled from a map at this distance and was used in the prediction equations. The design basis UNE was selected as the UNE which produced the largest ground motions at Yucca Mountain. This was a 700 kt event in the Buckboard area at 22.8 km away (note 700 kt was used instead of 750 kt because of the small differences in the predicted values and the already conservative approach of assuming the closest point for the largest yield). Although the yield limit for Pahute Mesa is greater, it is sufficiently far away that the ground motion at the repository site would be less than that from the nearest location in the Buckboard area.

Development of the UNE Prediction Equations

The major objectives for the analyses included in References A2-1 through A2-3 were: (1) to develop a regional prediction model for the Nevada Test Site alone; and (2) to identify and quantify the differences in ground motion behavior at Yucca Mountain when compared to NTS. To this end, data from a number of UNEs were analyzed.

The data set used to develop the prediction equations includes ground motions recorded from a total of 34 UNEs. These events were conducted between 1966 and 1984. The yield variation in the data set is from 80 kt to 1400 kt (9 UNEs had yields > 500 kt; 7 UNEs had yields between 150 and 500 kt; 18 UNEs had yields between 80 and 150 kt). Ground motion has been recorded at about 50 different locations. Of these 50 locations, ten have been located in the Yucca Mountain area. Ground motion from a total of eight of these events were recorded at Yucca Mountain stations. This data set was chosen based on the need for a reasonable variation in yield and distance (from the source) to obtain general prediction equations. The fact that there are a limited number of events recorded at Yucca Mountain included in the data set is due to the fact that these stations were first installed in only mid 1980. All events were conducted in the Pahute Mesa testing area of NTS (see Fig. 3-1). Station geologies may be placed in two broad categories - rock and alluvium.

The prediction equations that were developed in References A2-1 and A2-2 are empirical. The major assumptions made in the development of these equations are: (1) source geology is considered to be the same; (2) differences in travel path geology are ignored; and (3) station geology differences are accounted for by providing separate equations for rock and alluvium. In addition, the data are assumed to be lognormally distributed and linearly correlated in a log-log space (i.e., fit with a power curve). These assumptions and approach are not original. Past studies (Reference A2-7) have shown this to be a reasonable approach in describing the behavior of UNE ground motions. The equations are developed from multiple linear regressions in which yield and distance are considered to be the independent variables and the ground motion parameter (acceleration, velocity or displacement) is the dependent variable. The data were subdivided into three major groups (Reference A2-1). Group I included all data in the data set. Data from known anomalous stations (e.g., NRDS area, Rainier Mesa, Climax Stock, etc.)(Reference A2-8) were excluded to form Group II. The Group III data set was Group II minus the data from the Yucca Mountain stations available at the time of the analyses. In addition to these three major groups, three subdivisions of these groups were made based on the station geology. These subdivisions were: (i) all stations regardless of geology; (ii) only stations on rock; and (iii) only stations on alluvium.

The recommendations from References A2-1 and A2-2 were to use the Group III equations for the appropriate station geology as the prediction equations at NTS. These recommendations were based on the fact that inclusion of the anomalous stations would bias the predictions in an unfavorable fashion for a procedure that is meant to predict general NTS ground motions. Inclusion of the Yucca Mountains stations would bias the predictions to lower yields and greater distances (most UNEs are between 40 and 50 km away from Yucca Mountain).

The recommended prediction equations from References A2-1 and A2-2 were evaluated in Reference A2-3. This study used all data recorded at Yucca Mountain stations between mid 1980 and the end of FY 1986. These events were "predicted" with the recommended equations and these predicted values were compared to the measured values at Yucca Mountain. Ratios of measured/predicted ground motions were calculated for each event at each Yucca Mountain station and average ratios for each station were determined. In the analysis of these average station ratios, it was observed that the predicted values were generally less than those measured. The average ratios calculated for each station were always less than the 1σ value of the prediction equation. The individual ratios calculated for each event at a particular station seldom exceeded the 2σ values calculated from the equations (1σ corresponds to the 68% confidence interval for the mean of all the observations at the site or the 84% nonexceedance probability level while 2σ corresponds to the 95% confidence interval or the 98% nonexceedance probability level). The conclusion of this analysis was that the prediction equations from References A2-1 and A2-2 provided reasonably accurate results given the statistics of the fits. To attempt to correct for possible site effects with this data set, would imply a level of accuracy that does not exist in the data.

As discussed in Section 3.0 of the main body of this report, the predicted ground motions provided for the design of the exploratory shaft were specified at the 95% nonexceedance probability level. This corresponds to 1.65σ. These values are also listed in Table A2-1 with the equations.

Wave Propagation from UNEs

The UNE produces a radially expanding compressional shock front at the point of the explosion. As the distance increases from the source, this compressional front is converted to a complex wave train of various seismic signals. These signals are the result of tectonic release, rarefactions from layering in the earth, free surface effects at the ground surface and material anisotropies. At distances of interest to the exploratory shaft, the primary wave types present in the ground motions are the body waves and surface waves. Body waves are composed of compression (P) waves, horizontally polarized shear waves (S_h) and the vertically polarized shear waves (S_v). Surface waves are composed of Rayleigh and Love waves. The wave types that carry the majority of the energy are the P, S_h and S_v waves. Because of the depth of the UNE and the radial nature of the explosion, the following assumptions are made about which wave types are responsible for the component acceleration and velocities observed at distances of interest to the exploratory shaft.

- Peak radial motions are the result of the P wave.

- Peak transverse motions are the result of the S_h wave.

- Peak vertical motions are the result of the S_V wave.

The peak displacements observed at these distances from a UNE are associated with the surface waves.

References

A2-1. Vortman, L. J., Ground Motion Produced at Yucca Mountain from Pahute Mesa Underground Nuclear Explosions, SAND85-1605, Sandia National Laboratories, February 1986.

A2-2. Long, J. W., Component Ground Motion at the Nevada Test Site from Pahute Mesa Underground Nuclear Explosions, SAND86-0439, Sandia National Laboratories, October 1986, In Review.

A2-3. Phillips, J. S., Evaluation of Equations Used for the Prediction of Peak Ground Motions at Yucca Mountain from Underground Nuclear Explosions in Pahute Mesa, SAND87-1811, Sandia National Laboratories, October 1987, In Review.

A2-4. Fernald, A. T., Coordinator, Real Estate Availability Study, Potential New Test Areas, Nevada Test Site, USGS, January 1977.

A2-5. Minutes of the Ground Motion and Seismic Evaluation Subcommittee of October 11, 1977, dated October 19, 1977.

A2-6. Vortman, L. J., "Prediction of Ground Motion From Underground Nuclear Weapons Test as It Relates to Siting a Nuclear Waste Storage Facility at NTS and Compatibility With the Weapons Test Program," SAND80-1020/1, Sandia Naitonal Laboratories, April 1980.

A2-7. Environmental Research Corporation, Prediction of Ground Motion Characteristics of Underground Nuclear Detonations, NVO-1163-239, U.S. Atomic Energy Commission, Nevada Operations Office, March 1974.

A2-8. Vortman, L. J., Long, J. W., "Effects of Repository Depths on Ground Motion - Pahute Mesa Data," SAND82-0174, Sandia National Laboratories, May, 1982

APPENDIX A-3: DETERMINATION OF CONTROLLING STRAIN COMBINATION FOR DESIGN

CONDITIONS AND ASSUMPTIONS

1. Earthquake Control Motion

   Horizontal: $V = 30$ cm/sec $\quad a = 0.3\ g$

   Vertical : $V_v = 2/3\ V \quad a_v = a$

2. UNE Control Motion

   Horizontal: $V' = 12$ cm/sec $= 0.40\ V \quad a' = 0.1\ g = 0.33\ a$

   Vertical : $V'_v = 9$ cm/sec $= 0.30\ V \quad a'_v = 0.2\ g = 0.67\ a$

   Note 1: All results will be normalized in terms of V and a.

3. Earthquake incident angles between 0° (vertical) and 30° (maximum) and free field strains are given by Table A3-2 which was derived from Table A3-1 using:

   $$V_P = V_v/\cos\theta \qquad V_{SV} = V/\cos\theta \qquad V_{SH} = V$$
   $$a_P = a_v/\cos\theta \qquad a_{SV} = a/\cos\theta \qquad a_{SH} = a$$

4. UNE incident angles can range from 0° (vertical) to 90° (horizontal).

   For $0° \leq \theta \leq 45°$: Use same assumptions as for Condition 3 and Table A3-2

   For $45° < \theta \leq 90°$: Use Table A3-3 derived from Table A3-1 using:

   $$V_P = V'/\sin\theta \qquad V_{SV} = V'_v/\sin\theta \qquad V_{SH} = V'$$

These assumptions are very conservative for $30° \leq \theta \leq 60°$ as they lead to the following wave particle velocities and accelerations.

Table A3-1

Free Field and Bending Strains Due to Earthquakes

Wave Type	Free Field Strains						Bending Strains
	ϵ_{xx}	ϵ_{yy}	ϵ_{zz}	γ_{xy}	γ_{yz}	γ_{xz}	ϵ_b
P	$\frac{v_p}{C_p} \sin^2 \theta$	0	$\frac{v_p}{C_p} \cos^2 \theta$	0	0	$\frac{v_p}{C_p} \sin 2\theta$	$\frac{R\, a_p}{C_p^2} \sin \theta \cos^2 \theta$ (in x-z plane)
SV	$\frac{v_{sv}}{C_s} \sin \theta \cos \theta$	0	$\frac{v_{sv}}{C_p} \sin \theta \cos \theta$	0	0	$\frac{v_{sv}}{C_s} \cos 2\theta$	$\frac{R\, a_{sh}}{C_s^2} \cos^3 \theta$ (in x-z plane)
SH	0	0	0	$\frac{v_{sh}}{C_s} \sin \theta$	$\frac{v_{sh}}{C_s} \cos \theta$	0	$\frac{R\, a_{sh}}{C_s^2} \cos^2 \theta$ (in y-z plane)

Table A3-2

Free Field and Bending Strains in Terms of Ground Motion Control Parameters for Earthquakes

Wave Type	Free Field Strains						Bending Strains
	ϵ_{xx}	ϵ_{yy}	ϵ_{zz}	γ_{xy}	γ_{yz}	γ_{xz}	ϵ_b
P	$\frac{v_v}{C_p} \frac{\sin^2 \theta}{\cos \theta}$	0	$\frac{v_v}{C_p} \cos \theta$	0	0	$\frac{v_v}{C_p}\, 2 \sin \theta$	$\frac{R\, a_v}{C_p^2} \sin \theta \cos \theta$ (in x-z plane)
SV	$\frac{v_h}{C_s} \sin \theta$	0	$\frac{v_h}{C_p} \sin \theta$	0	0	$\frac{v_h}{C_s} \frac{\cos 2\theta}{\cos \theta}$	$\frac{R\, a_h}{C_s^2} \cos^2 \theta$ (in x-z plane)
SH	0	0	0	$\frac{v_h}{C_s} \sin \theta$	$\frac{v_h}{C_s} \cos \theta$	0	$\frac{R\, a_h}{C_s^2} \cos^2 \theta$ (in y-z plane)

Note: These expressions are valid only for steeply emerging body waves, i.e., θ = 30° or less.

	cm/sec				"g"			
θ	V_P	V_{SV}	V' (1)	V'_v (1)	a_P	a_{SV}	a' (1)	a'_v (1)
0°	9.0	12.0	12.0	9.0	0.2	0.1	0.1	0.2
37°	11.3	15.0	14.7	12.6	0.25	0.125	0.19	0.23
45°	12.7	17.0	15.6	15.6	0.282	0.141	0.24	0.24
53°	15.0	11.3	14.7	12.6	0.125	0.25	0.19	0.23
90°	12.0	9.0	12.0	9.0	0.1	0.2	0.1	0.2

(1) - Probabilistic combination rule of 100% to 40% used to generate these values.

The table above shows that the computed values of V and a are very conservative as compared to the design basis UNE values. Despite this excessive conservatism, UNE will not govern.

5. Effects of P, S_V, and S_H will be vector summed using 100%-40%-40% combination rule based on random phasing. For instance bending strain ϵ_b due to S_H wave is 90° to ϵ_b from P and S_V waves.

   Thus, $\epsilon_b = \sqrt{(\epsilon_{b_P} + 0.4\ \epsilon_{b_{SV}})^2 + 0.4\ \epsilon_{b_{SH}}{}^2}$, etc.

6. Designer is concerned with total axial strain and either maximum hoop strain or maximum hoop stress.

   a) Elastic computed maximum hoop stress σ_h at unlined opening will serve as a measure of hoop effects.

   b) Total axial strain, ϵ_a, is given by:

$\epsilon_a = \epsilon_{zz} + \epsilon_b$

c) Earthquake and UNE incident angles and component combinations which maximize σ_h and ϵ_a must be determined.

7. <u>Properties Used</u>:

Poisson's Ratio: $\nu = 0.19$ (Results insensitive for $0.13 \leq \nu \leq 0.24$)

Wave Speed Ratios: $C_p/C_s = 1.62$ (Results insensitive for $1.53 \leq C_p/C_s \leq 1.71$)

Shear Wave Speed: $C_S \geq 800$ m/sec

Shaft Radius: $R \leq 5$ m

References

A3-1. Timoshenko, S. and Goodier, J. N., "Theory of Elasticity," McGraw-Hill Publication, 1951.

Table A3-3

Wave Type	ϵ_{xx}	ϵ_{zz}	γ_{xy}	ϵ_b
P	$\frac{V'}{C_p}\sin\theta$	$\frac{V'}{C_p}\frac{\cos^2\theta}{\sin\theta}$	0	$\frac{R\,a'}{C_p^2}\cos^2\theta$ (x-z plane)
SV	$\frac{V'_v}{C_s}\cos\theta$	$\frac{V'_v}{C_s}\cos\theta$	0	$\frac{R\,a'_v}{C_s^2}\frac{\cos^3\theta}{\sin\theta}$ (x-z plane)
SH	0	0	$\frac{V'}{C_s}\sin\theta$	$\frac{R\,a'}{C_s^2}\cos^2\theta$ (y-z plane)

ELASTIC HOOP STRESS FOR UNLINED OPENING

Free Field:

$$\left.\begin{aligned}(\sigma_x/G) &= 2\epsilon_{xx} + (\lambda/G)(\epsilon_{xx} + \epsilon_{zz})\\ (\sigma_y/G) &= (\lambda/G)(\epsilon_{xx} + \epsilon_{zz})\\ (\tau_{xy}/G) &= \gamma_{xy}\end{aligned}\right\}$$

-- Lame's Equation (Reference A3-1)

Principal Stresses $\sigma_{1,3} = \dfrac{\sigma_x + \sigma_y}{2} \pm \sqrt{\left[\dfrac{\sigma_x - \sigma_y}{2}\right]^2 + \tau_{xy}^2}$

$$\therefore (\sigma_{1,3}/G) = \epsilon_{xx} + (\lambda/G)(\epsilon_{xx} + \epsilon_{zz}) \pm \sqrt{\epsilon_{xx}^2 + \gamma_{xy}^2}$$

Maximum Hoop Stress: $(\sigma_h/G) = 3\,(\sigma_1/G) - (\sigma_3/G)$ -- Kirsch's Equation (Reference A3-1)

$$\therefore (\sigma_h/2G) = \epsilon_{xx} + (\lambda/G)(\epsilon_{xx} + \epsilon_{zz}) + 2\sqrt{\epsilon_{xx}^2 + \gamma_{xy}^2} \qquad \text{Equ. 1}$$

where $(\lambda/G) = \dfrac{2\nu}{1-2\nu} = \dfrac{2(0.19)}{1-2(0.19)} = 0.61$ for $\nu = 0.19$

Note 2: For both earthquake and UNE, incident angle, and component combination which maximizes $(\sigma_h/2G)$ will maximize hoop effects on shaft

Note 3: Normalize all results in terms of $\epsilon_N = \dfrac{V}{C_s}$

Axial Strain: $\epsilon_a = \epsilon_{zz} + \epsilon_b$

Normalize ϵ_b by $\epsilon_{BN} = \left[\dfrac{Ra}{C_s^2}\right]$

$$\therefore (\epsilon_a/\epsilon_N) = \left(\frac{\epsilon_{zz}}{\epsilon_N}\right) + \left(\frac{\epsilon_b}{\epsilon_{BN}}\right)\left(\frac{\epsilon_{BN}}{\epsilon_N}\right)$$

For $R \le 5$ m and $C_s \ge 800$ m/s

$$(\epsilon_{BN}/\epsilon_N) = \frac{Ra}{VC_s} \le \frac{(5_m)(0.3g)(980\ cm/sec^2 g)}{30\ cm/sec\ (800\ cm/sec)} = 0.061$$

$$\therefore (\epsilon_a/\epsilon_N) \le (\epsilon_{zz}/\epsilon_N) + 0.061\ (\epsilon_b/\epsilon_{BN}) \qquad \text{Equ. 2}$$

Note 4: Axial effects on shaft will be maximized when (ϵ_a/ϵ_N) maximized

FOR EARTHQUAKE CONTROL MOTION

$\theta = 0°$	ϵ_{xx}/ϵ_N	ϵ_{zz}/ϵ_N	λ_{xy}/ϵ_N	ϵ_b/ϵ_{BN} (*)	$\sigma_h/2G\epsilon_N$	ϵ_a/ϵ_N
P	0	0.41	0	0		
SV	0	0	0	1.0		
SV	0	0	0	1.0		
100% P+40% (S_V+S_H)	0	0.41	0	0.57	0.25	0.44
100% S_V+40% (P+S_H)	0	0.16	0	1.08	0.10	0.23
100% S_H+40% (P+S_V)	0	0.16	0	1.08	0.10	0.23

$\theta = 30°$	ϵ_{xx}/ϵ_N	ϵ_{zz}/ϵ_N	λ_{xy}/ϵ_N	ϵ_b/ϵ_{BN} (*)	$\sigma_h/2G\epsilon_N$	ϵ_a/ϵ_N
P	0.12	0.36	0	0.16		
SV	0.50	0.50	0	0.75		
SH	0	0	0.50	0.75		
100% P + 40% (S_V+S_H)	0.32	0.56	0.20	0.55	0.61	0.59
100% S_V + 40% (P+S_H)	0.55	0.64	0.20	0.87	2.45**	0.69**
100% S_H + 40% (P+S_V)	0.25	0.34	0.50	0.83	1.73	0.39

*Vectorially combined per Condition 5.

**Controls

FOR UNE CONTROL MOTION:

1 = 100% $\underline{P}$ + 40% ($\underline{S}_v$ + $\underline{S}_H$)

2 = 100% $\underline{S}_v$ + 40% ($\underline{P}$ + $\underline{S}_H$)

3 = 100% $\underline{S}_H$ + 40% ($\underline{P}$ + $\underline{S}_v$)

$\theta = 0°$	ϵ_{xx}/ϵ_N	ϵ_{zz}/ϵ_N	λ_{xy}/ϵ_N	ϵ_b/ϵ_N	$\sigma/2G\epsilon_N$	ϵ_a/ϵ_N
P	0	0.19	0	0		
SV	0	0	0	0.33		
SH	0	0	0	0.33		
1	0	0.19	0	--	0.12	0.19
2	--	0.08	--	0.36	--	0.10
3	--	0.08	--	0.36	--	0.10

$\theta = 37°$	ϵ_{xx}/ϵ_N	ϵ_{zz}/ϵ_N	λ_{xy}/ϵ_N	ϵ_b/ϵ_{BN}	$\sigma_h/2G\epsilon_N$	ϵ_a/ϵ_N
P	0.09	0.15	0	0.12		
SV	0.24	0.24	0	0.21		
SH	0	0	0.24	0.21		
1	0.19	0.25	0.10	--	--	--
2	0.28	0.30	0.10	0.27	1.23	0.32
3	0.13	0.16	0.24	--	--	--

$\theta = 45°$	ϵ_{xx}/ϵ_N	ϵ_{zz}/ϵ_N	λ_{xy}/ϵ_N	ϵ_b/ϵ_{BN}	$\sigma_h/2G\epsilon_N$	ϵ_a/ϵ_N
P	0.08	0.08	0	0.13		
SV	0.28	0.28	0	0.17		
SH	0	0	0.28	0.17		
1	0.19	0.19	0.11	--	0.86	--
2	0.31	0.31	0.11	0.23	1.35*	0.32*
3	0.14	0.14	0.28	--	0.94	--

$\theta = 53°$	ϵ_{xx}/ϵ_N	ϵ_{zz}/ϵ_N	λ_{xy}/ϵ_N	ϵ_b/ϵ_{BN}	$\sigma_h/2G\epsilon_N$	ϵ_a/ϵ_N
P	0.20	0.11	0	0.05		
SV	0.18	0.18	0	0.18		
SH	0	0	0.32	0.12		
1	0.27	0.18	0.13	--	1.14	--
2	0.26	0.22	0.13	--	--	--
3	0.15	0.12	0.32	--	1.02	--

$\theta = 90°$	ϵ_{xx}/ϵ_N	ϵ_{zz}/ϵ_N	λ_{xy}/ϵ_N	ϵ_b/ϵ_{BN}	$\sigma_h/2G\epsilon_N$	ϵ_a/ϵ_N
P	0.25	0	0	0		
SV	0	0	0	0		
SH	0	0	0.40	0		
1	0.25	0	0.16	0	1.00	0
2	--	0	--	0	--	0
3	0.10	0	0.40	0	0.99	0

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*Controls

--By observation, this cannot control; so not computed.

Conclusions

1. Earthquake Control Motion, with $\theta = 30°$ and a combination of 100% S_V + 40% (P + S_H) } Controls

   For this case, $\sigma_h/2G\epsilon_N = 2.45$ and

   $$\epsilon_a/\epsilon_N \leq 0.69$$

2. Largest UNE effect is at $\theta = 45°$, for 100% S_V + 40% ($P + S_H$)

   For this case, $\sigma_h/2G\epsilon_N = 1.35 = (0.55 * \text{value for earthquake control motion})$

   $\epsilon_a/\epsilon_N = 0.32 = (0.46 * \text{value for earthquake control motion})$

3. Need to double UNE Control Motion for UNE to govern.

APPENDIX A-4: DEPTH ATTENUATION BEHAVIOR OF UNE GROUND MOTIONS AT YUCCA MOUNTAIN

The objective of this appendix is to describe the observed attenuation behavior of ground motions at Yucca Mountain with depth. The ideal approach to achieve this objective would be to record ground motions from the design basis UNE in the hole of interest, at several depths, and develop attenuation curves for the pertinent parameters (Figure A4-1). However, data in this form do not exist at the repository site. The data set which is available for this task consists of ground motions from a total of 17 UNEs (conducted from mid 1980 through mid 1987) recorded at a total of six different surface/downhole stations located in the vicinity of Yucca Mountain but none of which are at the ESF location. Each one of these stations have instruments at the surface and at one downhole location. The stations are in similar geologies (not identical geologies) and they are separated by distances of as much as 8 km (Figure A4-2). The distances from the UNEs included in the data base to the ground motion stations range from 40 to 50 km and the UNE yields range from 80 to 150 kt (as compared to the design basis UNE of 700 kt at a distance of 22.8 km).

Two different studies were conducted. The first was to study the attenuation of absolute peak ground motions with depth. The second was to study the depth attenuation behavior of the pseudo relative velocity response spectra (PSRV) at characteristic earthquake frequencies of 1, 2 and 5 Hz. These two studies will be discussed below.

Assumptions and Approach

The approach used to develop the depth attenuation behavior is to calculate ratios of surface and downhole ground motion and plot the log of these ratios versus depth. This approach assumes that the geologic differences, as well as the separation distances between the individual stations, are insignificant. In addition, differences in yield, shot point geology, station-to-source distance and travel path geology are also assumed to be insignificant. Finally, by only considering the absolute peak ground motions, the individual wave types that make up the total ground motion are ignored. All of these assumptions will have the effect of increasing the data scatter and hence the uncertainty in this analysis. In the analysis of the PSRV ratios, the degree of uncertainty will be reduced because the same wave type will be compared at both the surface and downhole locations.

Considerations that went into the determination of the various fits were as follows:

1. Distance attenuation rates for a specific wave type will be different on the surface versus downhole and distance attenuation rates of different wave types will be different. This is due to geometrical factors as well as material property differences in the surface and downhole media. Although these factors are not used explicitly in the development of the depth attenuation curves, they are taken into consideration in the "judgment factor" applied to the derived fits.

2. The surface materials at the ground motion stations are different. These differences will artificially influence the surface/downhole ratios because there will only be one surface material at the ESF site.

3. Station W30 was the farthest station from the UNEs. Surface/downhole ratios for this station are generally less than the other stations at Yucca Mountain. Based on observations of the UNE data, the amount of attenuation observed at depth decreases with increasing distance from the source (Reference A4-1). A possible explanation may be that the peak amplitudes at greater distances are driven by surface waves which do not attenuate significantly (for the wavelengths of the UNE motions) with depth. Because the primary objective here is to predict attenuation behavior for

a larger yield at a closer range, the data from W30 were not given much weight in the derived fit.

4. Transverse and radial acceleration data recorded at Station W28 were not heavily weighted in the fit because the anomalous behavior observed there is too sporadic to quantify at this time (Reference A4-1).

5. Singular events that appear to be outside of the norm were essentially ignored in the fitting process.

6. The derived fit is an "eyeball" fit. Blind regression of these data produces results with poor correlation coefficients and imply a degree of accuracy or understanding (from these data) that is not present.

7. The fits were determined from the average ratios at each station and compared to the complete data set and modified where it was judged to be necessary.

Absolute Peak Attenuation

The surface/downhole ratios for peak values of acceleration, velocity and displacement for all UNEs recorded at the Yucca Mountain site were calculated and plotted versus depth of the station. Note that some of the events were included in Reference A4-1, others were conducted after the data for that study had been gathered. Table A4-1 shows the events, stations, station depths and calculated surface/downhole ratios for each ground motion component. Table A4-2 repeats the information of Table A4-1 and includes the actual data values from the events not included in the study in Reference A4-1. The plots of these ratios are included in Figures A4-3 through A4-11. The equations determined for the lines shown on these figures are given in Table A4-3. The amount of depth attenuation predicted for various depths by these equations is summarized in Table A4-4. All accelerations, velocities and displacements decreased with increasing depth with the exception of vertical displacement.

In an attempt to evaluate these attenuation curves with an event more similar to the design basis event, another UNE recorded at a closer range was studied. The event was Nebbiolo and the station was W-9 located at a distance of 15.9 km from surface ground zero. This combination roughly approximates the design basis UNE and the geology at Yucca Mountain (W-9 is located on Rainier Mesa). The depth of the station is 432 m. The surface/downhole ratios calculated for this event and station are also shown on Figures A4-3 through A4-11. This shows that the surface/downhole ratios from this event were all greater than what the equations in Table A4-3 would predict.

PSRV Attenuation

Similar depth attenuation ratios were developed for the PSRV data at 1, 2 and 5 Hz. Table A4-5 shows the ratios calculated for each station. Table A4-6 shows the actual PSRV values for the events not included in the study in Reference A4-1. These ratios were plotted with depth and are shown in Figures A4-12 through A4-20. The same considerations as used for the peak ground motion parameters were used in deriving the depth attenuation curves. The results are similar. The data scatter in the ratios were generally less, because the same ground motion wave types were compared in the ratios. As would be expected, the 1 Hz signal attenuates at a slower rate than the higher frequencies. The equations determined for these fits are given in Table A4-7. The amount of attenuation predicted from these equations at various depths is summarized in Table A4-8.

Conclusion

With the exception of the vertical displacement, all absolute peak values of the ground motion components decreased with increasing depth (accelerations at 400 m depth varied between 40% and 60% of the surface value while velocities at this depth varied between 60% and 70% of the surface value). The PSRV data also exhibited a similar decrease in amplitude with increasing depth. All of the frequencies examined had values at the 400 m depth that were between 40% and 60% of the surface values. The conclusion of this study, based on the data recorded at Yucca

Mountain, is that UNE ground motions will attenuate with depth at the exploratory shaft. The amount of attenuation is subject to a large amount of uncertainty for the reasons stated earlier. The specification of the design basis for the ES has not taken depth attenuation into account and for this reason the approach is conservative.

Reference

A4-1. Phillips, J. S., "Analysis of Component Surface/Downhole Ground Motions at Yucca Mountain for Underground Nuclear Explosions in Pahute Mesa," SAND87-2381, Sandia National Laboratories, October 1987 (In Review).

Table A-4.1

Ratio of Peak Surface and Downhole Ground Motions

Ratios of Peak Surface and Downhole Vertical Accelerations

Station	#27	#29	#12/30	#25	#25	#28	#26	#24
Depth - m	35	83	352	[illegible]	[illegible]	[illegible]	[illegible]	564
Event								
Chancellor			1.53	3.58				
Cabra			1.41					[illegible]
Kappeli	1.21		1.92	5.15				
Salut		1.52	1.31	4.21		3.16		
Serena		2.12	1.64	4.09		2.37		
Egmont				2.41				
Gibne								3.32
Tierra				3.34		2.41		
Towanda		1.76	1.49	2.85				
Goldstone		2.74	1.57	3.90		2.31		
Jefferson		1.57	1.54	4.59		2.09		
Darwin		2.12	1.23	4.07		1.92		
Labquark		1.89	1.50	3.75		2.25		
Belmont		1.95	1.32	2.97		1.68		
Bodie		1.73	1.75			0.54		
Delamar		1.74	1.84					
Hardin		3.76	1.77		1.48		2.45	
Average	1.21	2.07	1.80	3.92		2.08		3.50

Ratios of Peak Surface and Downhole Vertical Velocities

Station	#27	#29	#12/30	#25	#25	#28	#26	#24
Depth - m	35	83	352	358	365	375	358	564
Event								
Chancellor			1.05	1.47				1.32
Cabra			0.97					
Kappeli	1.12		1.50	2.74				
Salut		1.15	1.08	1.31		2.06		
Serena		1.09	1.01	1.74		1.33		
Egmont				1.40				
Gibne								1.78
Tierra				1.98		1.21		
Towanda		1.13	0.99	1.10				
Goldstone		1.23	1.12	2.27		1.37		
Jefferson		1.31	1.34	1.91		1.45		
Darwin		1.06	0.97	1.14		1.40		
Labquark		1.15	1.07	1.17		1.30		
Belmont		1.19	1.01	1.68		1.14		
Bodie		1.26	0.95			0.44		
Delamar		1.01	[illegible]					
Hardin		1.29	[illegible]		0.86		1.60	
Average	1.12	1.12	[illegible]	1.52		1.34		1.55

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Table A-4.1

Ratio of Peak Surface and Downhole Ground Motions (Continued)

Ratios of Peak Surface and Downhole Vertical Displacements

Station	#27	#29	#12/30	#25	#25	#28	#28	#24
Depth - m	35	83	352	358	305.00	375	358	564
Event								
Chancellor			1.02	1.10				
Cabra			0.97					1.17
Kappeli	0.99		1.00	1.11				
Salut		1.05	0.98	1.08		1.08		
Serena		1.04	1.02	1.13		1.09		
Egmont				1.13				
Gibne								1.14
Tierra				0.85		1.04		
Towanda		1.02	0.98	1.08				
Goldstone		1.02	0.98	1.09		1.05		
Jefferson		1.02	0.99	1.10		1.07		
Darwin		1.05	1.00	1.08		1.02		
Labquark		1.05	0.99	1.13		1.13		
Belmont		1.06	0.95	1.08		1.05		
Bodie		1.03	0.95			0.28		
Delamar		1.02	1.00					
Hardin		0.95	0.99		0.44		1.13	
Average	0.99	1.03	0.99	1.08		0.98		1.16

Ratios of Peak Surface and Downhole Radial Accelerations

Station	#27	#29	#12/30	#25	#25	#28	#28	#24
Depth - m	35	83	352	358	305	375	358	564
Event								
Chancellor			1.03	2.70				2.74
Cabra			1.24					
Kappeli	1.36		1.06	4.45				
Salut		2.09	1.70	3.67		1.04		
Serena		2.23	1.34	3.31		0.66		
Egmont								
Gibne								3.58
Tierra				4.83		0.60		
Towanda		1.23	1.49	3.94				
Goldstone		2.52	1.11	2.60		0.96		
Jefferson		2.09	0.87	2.35		1.24		
Darwin		1.72	1.65	3.10		2.25		
Labquark		1.52	1.33	3.53		2.27		
Belmont		2.04	1.50	3.30		1.40		
Bodie		2.65	1.59			0.34		
Delamar		2.14	1.41					
Hardin		2.92	1.21		1.19		2.12	
Average	1.36	2.10	1.72	3.48		1.19		6.16

Table A-4.1

Ratio of Peak Surface and Downhole Ground Motions (Continued)

Ratios of Peak Surface and Downhole Radial Velocities

Station	#27	#29	#12/30	#25	#25	#28	#28	#24
Depth - m	35	83	352	358	305	375	358	564
Event								
Chancellor			1.42	2.22				
Cabra			1.77					2.07
Kappeli	1.04		1.68	2.25				
Salut		1.22	1.59	2.30		2.39		
Serena		1.16	1.39	2.65		2.23		
Egmont				2.05				
Gibne								1.77
Tierra				2.56		2.07		
Towanda		1.12	1.83	2.32				
Goldstone		1.35	1.54	2.92		2.46		
Jefferson		2.31	1.61	2.55		3.25		
Darwin		1.32	1.56	2.77		2.44		
Labquark		1.15	1.08	2.32		2.01		
Belmont		1.17	1.19	2.13		2.81		
Bodie		1.30	1.36			0.72		
Delamar		1.06	1.50					
Hardin		1.08	1.44		0.65		2.50	
Average	1.04	1.19	1.55	2.59		2.32		1.92

Ratios of Peak Surface and Downhole Radial Displacements

Station	#27	#29	#12/30	#25	#25	#28	#28	#24
Depth - m	35	83	352	358	305	375	358	564
Event								
Chancellor			1.42	1.55				
Cabra			1.61					1.68
Kappeli	0.85		1.64	2.63				
Salut		1.22	1.66	1.72		2.14		
Serena		1.09	1.15	3.98		1.93		
Egmont				2.32				
Gibne								
Tierra				2.79				0.95
Towanda		1.10	1.81	2.45		1.50		
Goldstone		1.14	1.33	1.41		2.21		
Jefferson		2.48	1.38	1.79		2.22		
Darwin		1.05	1.65	2.15		2.26		
Labquark		1.12	1.07	[illegible]		1.63		
Belmont		1.10	1.17	1.56		2.54		
Bodie		1.06	1.74			0.44		
Delamar		0.36	1.84					
Hardin		1.03	1.54		0.57		1.96	
Average	0.85	1.21	[illegible]	[illegible]		1.87		[illegible]

Table A-4.1

Ratio of Peak Surface and Downhole Ground Motions (Continued)

Ratios of Peak Surface and Downhole Transverse Accelerations

Station	#27	#29	#12/30	#25	#25	#28	#28	#24
Depth - m	75	83	352	358	305	375	358	564
Event								
Chancellor			1.77	9.22				
Cabra			1.99					7.35
Kappeli	1.58		2.11	5.74				
Salut		1.44	1.97	4.79		1.11		
Serena		1.47	2.34	9.01		0.51		
Egmont				7.58				
Gibne								2.72
Tierra				7.82		0.30		
Towanda		1.37	2.20	4.16				
Goldstone		1.94	2.73	6.92		1.03		
Jefferson		1.69	2.54	6.54		0.89		
Darwin		1.28	2.95	7.33		2.05		
Labquark		1.36	2.29	5.80		1.17		
Belmont		1.75	2.02	8.31		0.82		
Bodie		1.67	2.66			0.27		
Delamar		1.28	2.17					
Hardin		1.69	4.64		2.69		1.57	
Average	1.56	1.53	2.54	6.90		0.92		5.29

Ratios of Peak Surface and Downhole Transverse Velocities

Station	#27	#29	#12/30	#25	#25	#28	#29	#24
Depth - m	75	83	352	358	305	375	358	564
Event								
Chancellor			1.79	3.28				
Cabra			1.08					2.11
Kappeli	1.07		1.21	1.44				
Salut		1.15	2.10	2.18		2.47		
Serena		1.13	1.27	1.66		2.12		
Egmont				1.38				
Gibne								2.5
Tierra				1.56		1.30		
Towanda		1.15	1.70	1.46				
Goldstone		1.13	1.85	2.37		1.82		
Jefferson		1.08	1.14	1.25		2.11		
Darwin		1.11	1.73	1.72		1.95		
Labquark		1.16	2.01	1.93		2.37		
Belmont		1.03	1.77	1.27		1.79		
Bodie		1.10	1.54			0.45		
Delamar		1.09	1.49					
Hardin		1.13	1.75		0.79		1.38	
Average	1.07	[illegible]	[illegible]	[illegible]		1.32		1.54

Table A-4.1

Ratio of Peak Surface and Downhole Ground Motions
(Continued)

Ratios of Peak Surface and Downhole Transverse Displacements

Station	#27	#29	#12/30	#25	#25	#28	#23	#24
Depth - m	75	83	352	358	[illegible]	275	258	5[illegible]4
Event								
Chancellor			1.33	1.47				
Cabra			1.09					1.39
Kappeli	1.06		1.21	1.05				
Salut		1.05	1.96	1.64		1.94		
Serena		1.04	1.17	1.17		1.51		
Egmont				1.51				
Gibne								2.38
Tierra				1.05		1.42		
Towanda		1.09	1.46	1.38				
Goldstone		1.11	1.69	1.37		1.79		
Jefferson		1.01	1.36	1.44		1.59		
Darwin		1.06	1.43	1.40		1.38		
Labquark		1.06	1.78	1.40		1.57		
Belmont		1.04	1.65	1.40		1.56		
Bodie		1.06	1.44			0.39		
Delamar		1.10	1.26					
Mardin		1.08	1.57		0.48		1.27	
Average	1.06	1.06	1.45	1.35		1.46		2.24

Table A-4.2

Values Used to Determine Ratios of Surface and Downhole Ground Motions

Vaules Used to Determine Ratios of Peak Surface and Downhole Vertical Acceleration

Station	M27	M29	M12/30	M25	M25	M28	M28
Depth - m	35	83	352	358	305	375	358
Event							
Chancellor			1.58	3.55			
Cabra			1.41				
Kappeli	1.21		1.97	5.15			
Salut		1.62	1.31	4.21		3.16	
Serena		2.13	1.64	4.09		2.37	
Egmont				3.41			
Gibne							
Tierra			-	3.84		2.41	
Towanda		1.36	1.49	2.85			
Goldstone		0.08884/0.03243	0.04418/0.02879	0.1947/0.05319		0.09425/0.04082	
Jefferson		0.04426/0.02822	0.04029/0.0261	0.1336/0.02972		0.08289/0.03965	
Darwin		0.05782/0.02729	0.04157/0.03237	0.09713/0.02389		0.05032/0.02617	
Labquark		0.04103/0.02473	0.0309/0.02062	0.08752/0.02332		0.07905/0.03521	
Belmont		0.08817/0.04527	0.04694/0.03547	0.2071/0.05213		0.09635/0.05729	
Bodie		0.05543/0.03212	0.0392/0.02236			0.04941/0.09127	
Delamar		0.05322/0.0305	0.05156/0.028				
Hardin		0.2484/0.06598	0.1673/0.09473		0.16/0.1084		0.1926/0.07852
Average	1.21	2.03	1.60	3.92		2.08	

Vaules Used to Determine Ratios of Peak Surface and Downhole Vertical Velocities

Station	M27	M29	M12/30	M25	M25	M28	M28
Depth - m	35	83	352	358	305	375	358
Event							
Chancellor			1.05	1.47			
Cabra			0.97				
Kappeli	1.12		1.5	2.74			
Salut		1.15	1.06	1.31		2.06	
Serena		1.09	1.01	1.74		1.33	
Egmont				1.4			
Gibne							
Tierra				0.98		1.21	
Towanda		1.13	0.99	1.1			
Goldstone		0.004279/0.003476	0.00461/0.004468	0.006936/0.00305		0.005606/0.003001	
Jefferson		0.003762/0.003711	0.003956/0.003796	0.006011/0.003152		0.005011/0.003465	
Darwin		0.003875/0.003648	0.005705/0.00586	0.005284/0.004626		0.004895/0.003497	
Labquark		0.003103/0.002707	0.00566/0.005481	0.006609/0.005672		0.006729/0.005607	
Belmont		0.00525/0.004793	0.006099/0.006035	0.006792/0.004032		0.006434/0.005635	
Bodie		0.003909/0.003705	0.004531/0.004621			0.002545/0.00581	
Delamar		0.004111/0.004069	0.006322/0.006233				
Hardin		0.006579/0.005081	0.00694/0.006753		0.004142/0.004818		0.00698/0.004955
Average	1.12	1.12	1.05	1.58		1.34	

Table A-4.2

Values Used to Determine Ratios of Surface and Downhole Ground Motions (Continued)

Vaules Used to Determine Ratios of Peak Surface and Downhole Vertical Displacements

Station	#27	#29	#12/30	#25	#25	#28	#28
Depth - m	35	83	352	358	305	375	358
Event							
Chancellor			1.02	1.1			
Cabra			0.97				
Kappeli	0.99		1	1.11			
Salut		1.05	0.98	1.08		1.08	
Serena		1.04	1.02	1.13		1.09	
Egmont				1.13			
Gibne							
Tierra				0.85		1.04	
Towanda		1.02	0.98	1.08			
Goldstone		0.112/0.11	0.1483/0.1514	0.1074/0.09893		0.1081/0.1028	
Jefferson		0.1108/0.109	0.1249/0.1264	0.105/0.09525		0.1071/0.09963	
Darwin		0.118/0.1123	0.2006/0.2012	0.1561/0.145		0.1237/0.1213	
Labquark		0.09823/0.09327	0.1862/0.1882	0.2056/0.182		0.186/0.1643	
Belmont		0.152/0.1439	0.2001/0.2112	0.1711/0.1583		0.1857/0.1762	
Bodie		0.1089/0.1061	0.1406/0.1474			0.0449/0.1577	
Delamar		0.1147/0.1124	0.2122/0.2124				
Hardin		0.1563/0.1571	0.2043/0.2071		0.07026/0.1614		0.173/0.1528
Average	0.99	1.03	0.99	1.08		0.98	

Vaules Used to Determine Ratios of Peak Surface and Downhole Radial Accelerations

Station	#27	#29	#12/30	#25	#25	#28	#28
Depth - m	35	83	352	358	305	375	358
Event							
Chancellor			1.03	2.7			
Cabra			1.24				
Kappeli	1.36		1.06	4.45			
Salut		2.09	1.7	3.67		1.04	
Serena		2.23	1.34	3.31		0.66	
Egmont							
Gibne							
Tierra				4.83		0.6	
Towanda		1.23	1.49	3.94			
Goldstone		0.08349/0.03315	0.0312/0.02817	0.09765/0.03754		0.06244/0.0653	
Jefferson		0.0577/0.02762	0.0248/0.02843	0.08018/0.03025		0.05006/0.0405	
Darwin		0.05811/0.03381	0.03081/0.01866	0.07624/0.02462		0.05991/0.02657	
Labquark		0.0326/0.02147	0.03319/0.02497	0.07833/0.02216		0.06318/0.0278	
Belmont		0.07586/0.03725	0.04049/0.02693	0.1532/0.04382		0.07954/0.05701	
Bodie		0.06069/0.02291	0.03496/0.02197			0.02636/0.0784	
Delamar		0.05849/0.02727	0.03152/0.02234				
Hardin		0.1775/0.06085	0.08188/0.06788		0.1078/0.09089		0.1602/0.07568
Average	1.36	2.10	1.32	3.48		1.19	

Table A-4.2

Values Used to Determine Ratios of Surface and Downhole Ground Motions (Continued)

Vaules Used to Determine Ratios of Peak Surface and Downhole Radial Velocities

Station Depth - m Event	N27 35	N29 83	N12/30 352	N25 358	N25 305	N28 375	N28 358
Chancellor			1.42	2.22			
Cabra			1.77				
Kappeli	1.04		1.66	2.25			
Salut		1.22	1.59	3.3		2.89	
Serena		1.16	1.39	2.65		2.23	
Egmont				3.05			
Gibne							
Tierra				2.56		2.07	
Towanda		1.12	1.83	2.32			
Goldstone		0.003816/0.002826	0.005512/0.003589	0.005294/0.001816		0.004694/0.001912	
Jefferson		0.008551/0.003708	0.004865/0.003013	0.004281/0.001679		0.005116/0.001575	
Darwin		0.005118/0.004186	0.008371/0.005378	0.005421/0.001958		0.005381/0.002208	
Labquark		0.004227/0.00367	0.005286/0.004898	0.005774/0.00249		0.006026/0.002992	
Belmont		0.005094/0.004366	0.008333/0.007047	0.005275/0.002477		0.008672/0.003091	
Bodie		0.004286/0.003308	0.006688/0.003587			0.003134/0.004375	
Belmar		0.00445/0.004194	0.0082/0.004535				
Hardin		0.00604/0.005615	0.009206/0.006384		0.002759/0.004267		0.009711/0.003882
Average	1.04	1.18	1.55	2.59		2.32	

Vaules Used to Determine Ratios of Peak Surface and Downhole Radial Displacements

Station Depth - m Event	N27 35	N29 83	N12/30 352	N25 358	N25 305	N28 375	N28 358
Chancellor			1.42	1.55			
Cabra			1.61				
Kappeli	0.85		1.64	2.63			
Salut		1.22	1.66	1.72		2.14	
Serena		1.09	1.15	2.98		1.93	
Egmont				2.32			
Gibne							
Tierra				2.78			
Towanda		1.1	1.81	2.45		1.5	
Goldstone		0.095/0.08315	0.1913/0.144	0.08143/0.05783		0.1258/0.05688	
Jefferson		0.2581/0.104	0.1668/0.0993	0.1002/0.05438		0.104/0.04686	
Darwin		0.1484/0.1411	0.2854/0.1716	0.1054/0.04902		0.147/0.06507	
Labquark		0.1021/0.09115	0.1925/0.18	0.2058/0.0959		0.2014/0.1233	
Belmont		0.1446/0.1319	0.2855/0.2432	0.1347/0.08461		0.2256/0.08887	
Bodie		0.1174/0.1105	0.2275/0.1304			0.08256/0.1895	
Belmar		0.1266/0.1319	0.3138/0.1708				
Hardin		0.1804/0.1745	0.3204/0.2074		0.06805/0.1197		0.2573/0.1314
Average	0.85	1.21	1.52	2.12		1.87	

Table A-4.2

Values Used to Determine Ratios of Surface and Downhole Ground Motions (Continued)

Vaules used to Determine Ratios of Peak Surface and Downhole Transverse Accelerations

Station	W27	W29	W12/30	W25	W25	W28	W28
Depth - m	35	83	352	358	305	375	358
Event							
Chancellor			3.37	8.22			
Cabra			1.99				
Kappeli	1.68		2.11	5.34			
Salut		1.44	1.97	4.79		1.11	
Serena		1.47	2.34	9.01		0.61	
Egmont				7.58			
Gibne							
Tierra				7.82		0.3	
Towanda		1.37	2.2	4.16			
Goldstone		0.04923/0.0268	0.03457/0.01483	0.1539/0.02558		0.06017/0.05852	
Jefferson		0.0405/0.02393	0.03422/0.01347	0.1384/0.01993		0.04342/0.04854	
Darwin		0.05048/0.03946	0.03763/0.01274	0.09191/0.01254		0.05915/0.02884	
Labquark		0.03816/0.02806	0.02883/0.01262	0.07754/0.0114		0.04343/0.03709	
Belmont		0.05646/0.03233	0.03667/0.01818	0.2365/0.02685		0.05045/0.06186	
Bodie		0.05017/0.03008	0.03895/0.01467			0.02519/0.09315	
Delamar		0.04426/0.03469	0.02919/0.01344				
Hardin		0.1184/0.07014	0.1685/0.03628		0.1476/0.05483		0.0842/0.05352
Average	1.68	1.53	2.54	6.90		0.92	

Vaules Used to Determine Ratios of Peak Surface and Downhole Transverse Velocities

Station	W27	W29	W12/30	W25	W25	W28	W28
Depth - m	35	83	352	358	305	375	358
Event							
Chancellor			1.79	3.28			
Cabra			1.08				
Kappeli	1.07		1.21	1.44			
Salut		1.15	2.1	2.18		2.47	
Serena		1.13	1.27	1.66		2.12	
Egmont				1.88			
Gibne							
Tierra				1.56		1.3	
Towanda		1.15	1.7	1.48			
Goldstone		0.005696/0.005047	0.004878/0.002638	0.006163/0.002599		0.005192/0.002856	
Jefferson		0.005039/0.004666	0.00435/0.003818	0.004868/0.002637		0.004834/0.002292	
Darwin		0.006773/0.006116	0.005195/0.002917	0.004688/0.002726		0.006692/0.003437	
Labquark		0.005052/0.004347	0.008124/0.004034	0.004539/0.002476		0.00605/0.002553	
Belmont		0.007286/0.007047	0.008112/0.004525	0.007039/0.004213		0.009423/0.005264	
Bodie		0.007052/0.006418	0.007011/0.004567			0.003119/0.006894	
Delamar		0.008947/0.008214	0.007461/0.0050[illegible]				
Hardin		0.008122/0.007184	0.009393/0.005361		0.003614/0.004547		0.007866/0.[illegible]04664
Average	1.07	1.11	1.61	1.91		1.82	

Table A-4.2

Values Used to Determine Ratios of Surface and Downhole Ground Motions (Continued)

Vaules Used to Determine Ratios of Peak Surface and Downhole Transverse Displacements

Station	N27	N29	N12/30	N25	N25	N28	N28
Depth - m	35	83	352	358	305	375	358
Event							
Chanceller			1.33	1.43			
Cabra			1.09				
Kappeli	1.06		1.21	1.05			
Salut		1.05	1.86	1.64		1.94	
Serena		1.04	1.17	1.17		1.51	
Egmont				1.51			
Gibne							
Tierra				1.05		1.42	
Towanda		1.09	1.46	1.38			
oldstone		0.1521/0.1373	0.1813/0.107	0.1156/0.08425		0.1705/0.0952	
Jefferson		0.151/0.1495	0.1724/0.1264	0.1433/0.09934		0.1324/0.08308	
Darwin		0.2669/0.2516	0.1877/0.1311	0.168/0.1201		0.1753/0.1267	
Labquark		0.1405/0.1321	0.294/0.1655	0.1507/0.1079		0.1606/0.1024	
Belmont		0.2807/0.269	0.3291/0.1995	0.2249/0.1605		0.2891/0.1848	
Bodie		0.1808/0.1705	0.2926/0.203			0.09659/0.2473	
Delamar		0.3319/0.303	0.2598/0.2057				
Hardin		0.2594/0.2406	0.3274/0.2084		0.09403/0.1979		0.2428/0.1917
Average	1.06	1.06	1.45	1.35		1.46	

Table A4-3

Summary of Depth Attenuation Curves for Peak UNE Ground Motions

Component	Equation
Peak Vertical Accel.	$a_d = a_s / (e^{1.8E-3\ z})$
Peak Vertical Vel.	$v_d = v_s / (e^{7.4E-4\ z})$
Peak Vertical Disp.	$d_d = d_s$
Peak Radial Accel.	$a_d = a_s / (e^{1.2E-3\ z})$
Peak Radial Vel.	$v_d = v_s / (e^{1.2E-3\ z})$
Peak Radial Disp.	$d_d = d_s / (e^{4.4E-4\ z})$
Peak Transverse Accel.	$a_d = a_s / (e^{2.3E-3\ z})$
Peak Transverse Vel.	$v_d = v_s / (e^{1.2E-3\ z})$
Peak Transverse Disp.	$d_d = d_s / (e^{7.8E-4\ z})$

Note: subscript d is for downhole, s is for surface, z is depth in m

Table A4-4

Depth Attenuation of Component Ground Motions

Depth	Vertical			Radial			Transverse		
m	Accel	Vel	Disp	Accel	Vel	Disp	Accel	Vel	Disp
0	1	1	1	1	1	1	1	1	1
100	0.8	0.9	1	0.9	0.9	1	0.8	0.9	0.9
200	0.7	0.9	1	0.8	0.8	0.9	0.6	0.8	0.9
300	0.6	0.8	1	0.7	0.7	0.9	0.5	0.7	0.8
400	0.5	0.7	1	0.6	0.6	0.8	0.4	0.6	0.7
500	0.4	0.7	1	0.6	0.6	0.8	0.3	0.6	0.7

Table A4-5

Ratios of Surface and Downhole PSRVS 1,2 & 5 H2

Station #25

	Vertical			Radial			Transverse		
Event	1 Hz	2 Hz	5 Hz	1 Hz	2 Hz	5 Hz	1 Hz	2 Hz	5 Hz
Labquark	1.7	3.1	2.7	1.2	2.9	3.5	2.5	8.6	7.2
Chancellor	1.5	2.8	2.9	2.4	2.1	3.5	1.8	5.1	8.3
Salut	1.7	3.8	3.8	3.8	2.2	4.9	2.6	5.5	6.0
Kappeli	1.6	5.4	3.8	2.3	1.7	3.5	1.8	6.4	9.3
Jefferson	1.7	5.2	4.7	2.1	2.8	2.9	3.1	4.7	8.6
Serena	1.3	5.1	4.4	2.3	2.2	3.7	1.6	4.8	11.2
Goldstone	1.8	4.0	4.6	3.2	2.8	2.8	1.7	4.5	9.6
Egmont	1.6	2.5	5.7	2.6	4.5	4.5	2.0	5.0	9.5
Towanda	1.5	2.6	2.7	1.6	2.9	4.6	2.5	4.0	5.7
Darwin	1.6	2.1	5.3	3.2	4.4	4.5	2.1	4.3	6.7
Belmont	1.7	4.7	4.5	2.9	2.9	1.7	2.0	3.9	13.0
Hardin 8	0.6	1.8	1.7	0.7	1.0	1.2	0.8	1.5	2.3
Average	1.6	3.8	4.1	2.5	2.9	3.6	2.2	5.2	8.7

Station #12/30

	Vertical			Radial			Transverse		
Event	1 Hz	2 Hz	5 Hz	1 Hz	2 Hz	5 Hz	1 Hz	2 Hz	5 Hz
Labquark	1.5	3.6	1.4	1.2	2.5	0.8	2.8	2.3	3.1
Chancellor	1.5	2.7	1.7	1.9	2.7	0.8	3.0	2.1	2.3
Salut	1.5	3.1	1.5	1.5	1.4	1.3	2.1	2.5	1.6
Kappeli	1.5	2.6	1.4	1.4	1.5	1.0	1.6	2.8	1.4
Jefferson	1.5	2.1	1.5	1.3	1.3	0.8	2.4	1.8	1.5
Serena	1.4	2.9	1.6	1.4	1.6	0.7	1.7	2.5	1.6
Goldstone	1.5	3.1	1.3	1.7	1.1	0.8	3.4	2.4	1.9
Cabra	1.5	3.0	1.3	0.9	1.3	1.3	3.3	2.6	1.6
Towanda	1.4	1.8	1.3	1.7	1.9	0.8	2.4	2.0	2.0
Darwin	1.6	2.2	1.5	1.8	1.7	1.1	2.8	2.7	2.3
Delamar	1.4	2.2	1.8	1.8	1.4	1.1	2.2	1.6	1.9
Belmont	1.4	2.8	1.6	1.5	1.4	0.7	2.9	2.7	1.6
Bodie	1.5	1.9	1.4	1.1	1.5	0.8	1.7	2.2	1.7
Hardin	1.5	3.0	1.6	1.6	1.3	0.7	1.6	1.7	1.6
Average	1.5	2.6	1.5	1.5	1.6	0.9	2.4	2.3	1.9

Station #20

	Vertical			Radial			Transverse		
Event	1 Hz	2 Hz	5 Hz	1 Hz	2 Hz	5 Hz	1 Hz	2 Hz	5 Hz
Labquark	1.9	5.0	2.1	3.5	2.9	2.5	2.8	2.2	1.7
Tierra	1.7	3.9	2.5	4.8	3.8	1.1	3.1	1.4	0.8
Salut	2.9	4.0	3.1	3.3	1.9	2.3	4.0	2.6	2.0
Jefferson	2.6	4.2	2.6	5.8	2.3	2.0	2.8	2.9	2.3
Serena	1.4	3.1	2.1	3.3	3.5	1.2	3.2	1.7	1.5
Goldstone	2.9	3.9	2.4	3.3	3.3	1.5	4.1	2.8	2.2
Darwin	2.3	3.3	4.2	4.0	4.0	2.6	4.1	3.8	3.1
Belmont	2.1	3.4	3.3	4.0	3.2	2.2	3.6	1.9	1.9
Bodie	0.7	1.1	0.6	1.0	0.9	0.6	0.8	0.5	0.5
Hardin 8	2.1	3.0	2.6	2.9	4.0	2.2	3.6	2.2	1.5
Average	2.1	3.5	2.5	3.7	2.9	1.8	3.2	2.2	1.8

Table A4-5

Ratios of Surface and Downhole PSRVS 1,2 & 5 H2 (Continued)

Station #29

	Vertical			Radial			Transverse		
Event	1 Hz	2 Hz	5 Hz	1 Hz	2 Hz	5 Hz	1 Hz	2 Hz	5 Hz
Labquark	1.1	1.2	1.4	1.1	1.8	1.4	1.2	1.2	1.8
Salut	1.1	1.3	1.3	1.2	1.6	1.6	1.3	1.9	1.0
Jefferson	1.1	1.3	1.2	.4	2.4	2.5	1.2	1.1	1.3
Serena	1.1	1.4	2.5	1.2	1.3	1.4	1.2	1.4	1.3
Goldstone	1.1	1.4	1.6	1.1	1.5	2.5	1.2	1.5	1.5
Towanda	1.1	1.4	2.1	1.1	1.7	1.7	1.1	1.8	1.1
Darwin	1.2	1.3	1.3	1.1	1.4	1.7	1.3	1.2	1.2
Delamar	1.2	1.3	1.8	1.2	2.0	2.0	1.3	1.4	1.9
Belmont	1.1	1.3	2.1	1.1	1.8	1.6	1.1	1.6	1.5
Bodie	1.1	1.4	1.6	1.1	2.1	2.4	1.3	1.7	1.2
Hardin	1.1	1.4	3.7	1.2	1.6	1.8	1.2	2.4	1.4
Average	1.1	1.3	1.9	1.3	1.7	1.9	1.2	1.6	1.4

Station #24

	Vertical			Radial			Transverse		
Event	1 Hz	2 Hz	5 Hz	1 Hz	2 Hz	5 Hz	1 Hz	2 Hz	5 Hz
Gibne	3.1	4.2	2.9	4.0	5.8	13.8	1.1	2.5	3.2
Cabra	2.4	3.8	4.6	1.3	2.3	2.3	2.5	6.2	10.0
Average	2.8	4.0	3.8	2.6	4.0	8.1	1.8	4.3	6.6

Station #27

	Vertical			Radial			Transverse		
Event	1 Hz	2 Hz	5 Hz	1 Hz	2 Hz	5 Hz	1 Hz	2 Hz	5 Hz
Kappelli	1.0	1.1	1.2	0.9	1.1	1.6	1.0	1.3	1.8

Table A4-6

Values Used to Determine Ratios of Surface and Downhole PSRVS for 1,2, & 5 HZ

Station M25

	Vertical			Radial			Transverse		
Event	1 Hz	2 Hz	5 Hz	1 Hz	2 Hz	5 Hz	1 Hz	2 Hz	5 Hz
Labquark	1.7	3.1	2.7	1.2	2.9	3.5	[illegible].5	8.6	7.2
Chancellor	1.5	2.8	2.9	2.4	2.1	3.5	1.8	5.1	8.3
Salut	1.7	3.8	3.8	3.8	2.2	4.9	2.6	5.5	6.6
Kappeli	1.6	5.4	3.8	2.3	1.7	3.5	1.8	6.4	9.3
Jefferson	1.7	5.2	4.7	2.1	2.8	2.9	[illegible].1	4.7	8.6
Serena	1.3	5.1	4.4	2.3	2.2	3.7	1.6	4.8	11.2
Goldstone	1.8	4	4.6	3.2	2.8	2.8	1.7	4.5	9.6
Egmont	1.6	2.5	5.7	2.6	4.5	4.5	2	5	9.5
Towanda	1.5	2.6	2.7	1.6	2.9	4.6	2.5	4	5.7
Darwin	1.6/0.97	0.79/0.3	0.95/0.1	2/0.62	1.2/0.27	0.9/0.2	1/0.48	0.95/0.22	1/0.15
Belmont	1.2/0.7	1.5/0.32	1.9/0.42	1.2/0.42	1.7/0.58	1.1/0.64	0.7/0.35	1.5/0.38	3/0.23
Hardin &	0.72/1.3	0.6/0.33	1/0.58	0.72/1.1	0.43/0.4	0.6/0.5	0.47/0.5	0.52/0.35	1/0.43
Average	1.61	3.75	4.10	2.51	2.86	3.65	2.15	5.17	8.70

Station M12/30

	Vertical			Radial			Transverse		
Event	1 Hz	2 Hz	5 Hz	1 Hz	2 Hz	5 Hz	1 Hz	2 Hz	5 Hz
Labquark	1.5	3.6	1.4	1.2	2.5	0.8	2.8	2.3	3.1
Chancellor	1.5	2.7	1.7	1.9	2.7	0.8	3	2.1	2.3
Salut	1.5	3.1	1.5	1.5	1.4	1.3	2.1	2.5	1.6
Kappeli	1.5	2.6	1.4	1.4	1.5	1	1.6	2.8	1.4
Jefferson	1.5	2.1	1.5	1.3	1.3	0.8	2.4	1.8	1.5
Serena	1.4	2.9	1.6	1.4	1.6	0.7	1.7	2.5	1.6
Goldstone	1.5	3.1	1.8	1.7	1.1	0.8	3.4	2.4	1.9
Cabra	1.5	3	1.3	0.9	1.3	1.3	3.3	2.6	1.6
Towanda	1.4	1.8	1.3	1.7	1.9	0.8	2.4	2	2
Darwin	2.8/1.8	0.5/0.23	0.3/0.2	1.8/1	0.38/0.2	0.19/0.1	0.9/0.32	0.38/0.14	0.2/0.08
Delamar	2.1/1.5	0.6/0.27	0.44/0.2	1.5/0.85	0.55/0.4	0.22/0.2	0.8/0.36	0.42/0.26	0.25/0.1
Belmont	2.1/1.5	0.85/0.3	0.3/0.19	1.2/0.8	0.58/0.4	0.2/0.28	1/0.34	0.65/0.24	0.24/0.1
Bodie	2/1.3	0.52/0.2	0.27/0.1	1.1/0.98	0.5/0.33	0.16/0.2	1/0.6	0.67/0.3	0.17/0.1
Hardin	2.1/1.4	0.9/0.3	0.8/0.5	1.8/1.1	0.59/0.4	0.48/0.6	1.6/1	0.63/0.37	0.55/0.3
Average	1.48	2.65	1.53	1.49	1.61	0.91	2.42	2.28	1.86

Station M28

	Vertical			Radial			Transverse		
Event	1 Hz	2 Hz	5 Hz	1 Hz	2 Hz	5 Hz	1 Hz	2 Hz	5 Hz
Labquark	1.9	5	2.1	3.5	2.9	2.3	2.8	2.2	1.7
Tierra	1.7	3.9	2.5	4.8	3.8	1.1	3.1	1.4	0.8
Salut	2.9	4	3.1	3.3	1.9	2.3	4	2.6	2
Jefferson	2.6	4.2	2.6	5.8	2.3	2	2.8	2.9	2.3
Serena	1.4	3.1	2.1	3.3	3.5	1.2	3.2	1.7	1.5
Goldstone	2.9	3.9	2.4	3.3	3.3	1.5	4.1	2.8	2.2
Darwin	1.8/0.78	1/0.3	0.67/0.1	2/0.5	1.2/0.3	0.36/0.1	1.9/0.46	0.8/0.21	0.34/0.1
Belmont	1.6/0.75	1.7/0.5	1/0.3	2/0.5	1.5/0.47	0.65/0.3	1.8/0.5	1/0.53	0.34/0.1
Bodie	0.3/1.2	0.98/0.9	0.28/0.4	0.8/0.8	0.7/0.76	0.19/0.3	0.7/0.85	0.43/0.8	0.16/0.3
Hardin &	1.8/0.86	1.8/0.6	1.5/0.58	2/0.7	1.7/0.42	0.92/0.4	2.5/0.7	1.1/0.5	0.41/0.2
Average	2.06	3.55	2.54	3.67	2.87	1.77	3.17	2.20	1.77

Table A4-6

Values Used to Determine Ratios of Surface and Downhole PSRVS for 1,2, & 5 HZ (Continued)

Station #29

Event	Vertical 1 Hz	Vertical 2 Hz	Vertical 5 Hz	Radial 1 Hz	Radial 2 Hz	Radial 5 Hz	Transverse 1 Hz	Transverse 2 Hz	Transverse 5 Hz
Labquark	1.1	1.2	1.4	1.1	1.8	1.4	1.2	1.2	1.8
Salut	1.1	1.3	1.3	1.2	1.6	1.6	1.3	1.9	1
Jefferson	1.1	1.3	1.2	2.4	2.4	2.5	1.2	1.1	1.3
Serena	1.1	1.4	2.5	1.2	1.3	1.4	1.2	1.4	1.3
Goldstone	1.1	1.4	1.6	1.1	1.5	2.5	1.2	1.5	1.5
Towanda	1.1	1.4	2.1	1.1	1.7	1.7	1.1	1.8	1.1
Darwin	1.7/1.4	0.58/0.4	0.24/0.1	0.98/0.9	0.49/0.3	0.3/0.18	1.3/1	0.56/0.45	0.35/0.3
Delamar	1.4/1.2	0.9/0.7	0.3/0.17	1/0.85	1/0.5	0.38/0.1	1/0.75	0.7/0.5	0.4/0.21
Belmont	1.7/1.6	1.3/1	0.4/0.19	1/0.9	0.75/0.4	0.5/0.31	1/0.91	1/0.62	0.4/0.27
Bodie	1.2/1.1	1/0.72	0.26/0.1	0.75/0.6	0.82/0.4	0.4/0.17	1.9/1.5	0.85/0.5	0.44/0.3
Hardin	1.6/1.4	1.1/0.78	0.73/0.2	1.4/1.2	0.82/0.5	0.8/0.45	2.2/1.9	1.2/0.5	0.8/0.58
Average	1.12	1.33	1.87	1.25	1.74	1.86	1.21	1.57	1.38

Station #24

Event	Vertical 1 Hz	Vertical 2 Hz	Vertical 5 Hz	Radial 1 Hz	Radial 2 Hz	Radial 5 Hz	Transverse 1 Hz	Transverse 2 Hz	Transverse 5 Hz
Gibne	0.9/0.29	1.3/0.31	1.4/0.48	0.8/0.2	1.1/0.19	1.8/0.13	0.53/0.5	1/0.4	1.6/0.5
Cabra	0.48/0.2	0.75/0.2	0.55/0.1	0.4/0.32	0.5/0.22	0.3/0.13	0.6/0.24	0.8/0.13	0.52/0.0
Average	2.75	3.97	3.75	2.63	4.03	8.08	1.78	4.33	6.60

Station #27

Event	Vertical 1 Hz	Vertical 2 Hz	Vertical 5 Hz	Radial 1 Hz	Radial 2 Hz	Radial 5 Hz	Transverse 1 Hz	Transverse 2 Hz	Transverse 5 Hz
Kappelli	0.82/0.8	0.9/0.85	0.29/0.2	0.6/0.69	0.8/0.71	0.35/0.2	0.65/0.6	1/0.8	0.39/0.2

Table A4-7

Summary of PSRV Depth Attenuation Curves for 1, 2 and 5 HZ

Component	Equation
Vertical @ 1 Hz	downhole = surface / ($e^{1.2E-3\ z}$)
Vertical @ 2 Hz	downhole = surface / ($e^{1.8E-3\ z}$)
Vertical @ 5 Hz	downhole = surface / ($e^{2.3E-3\ z}$)
Radial @ 1 Hz	downhole = surface / ($e^{1.2E-3\ z}$)
Radial @ 2 and 5 Hz	downhole = surface / ($e^{1.8E-3\ z}$)
Transverse @ 1 Hz	downhole = surface / ($e^{1.1E-3\ z}$)
Transverse @ 2 & 5 Hz	downhole = surface / ($e^{1.8E-3\ z}$)

Table A4-8

Depth Attenuation of PSRVS at 1, 2 and 5 HZ

Depth	Vertical			Radial			Transverse		
m	1 Hz	2 Hz	5 Hz	1 Hz	2 Hz	5 Hz	1 Hz	2 Hz	5 Hz
0	1	1	1	1	1	1	1	1	1
100	0.9	0.8	0.8	0.9	0.8	0.8	0.9	0.8	0.8
200	0.8	0.7	0.6	0.8	0.7	0.7	0.8	0.7	0.7
300	0.7	0.6	0.5	0.7	0.6	0.6	0.7	0.6	0.6
400	0.6	0.5	0.4	0.6	0.5	0.5	0.6	0.5	0.5
500	0.6	0.4	0.3	0.6	0.4	0.4	0.6	0.4	0.4

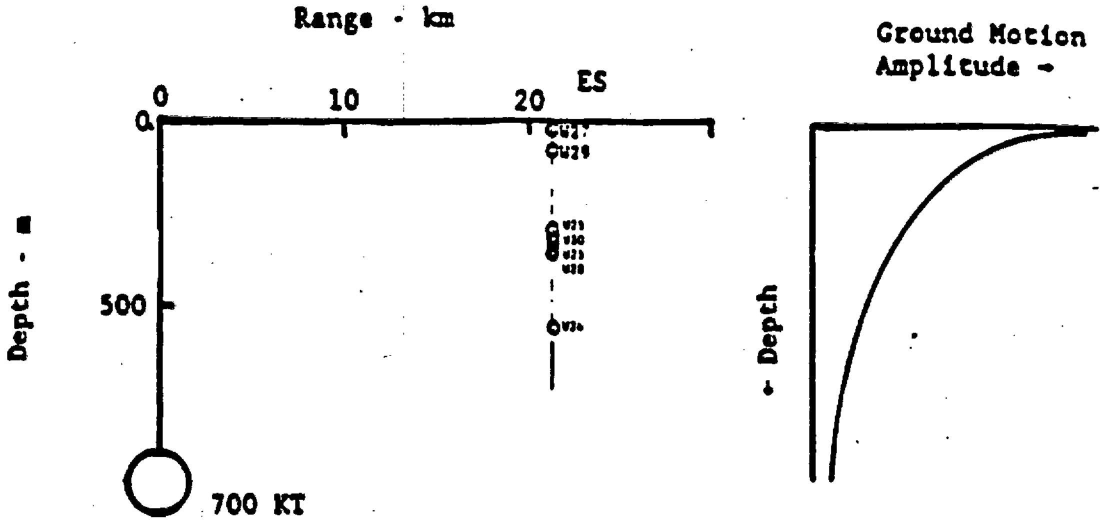
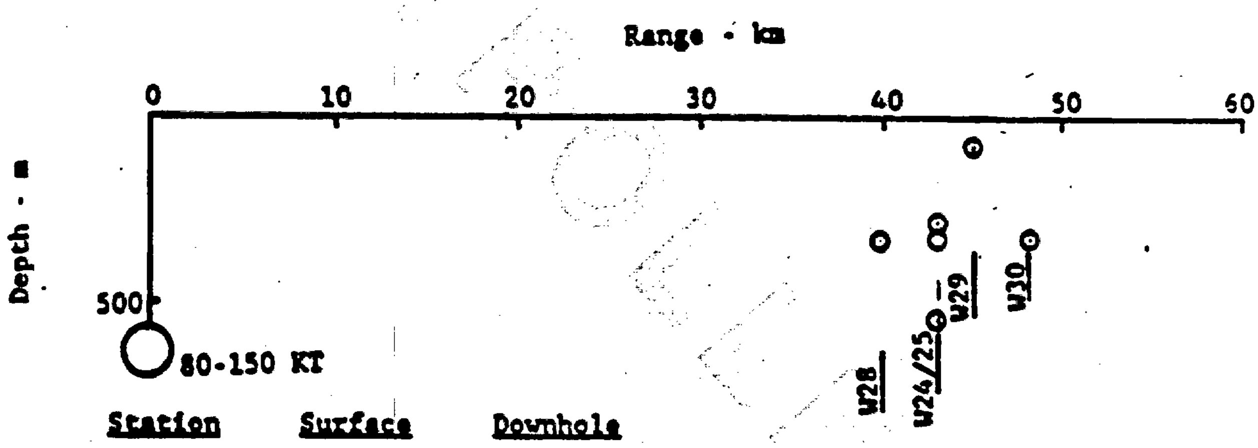
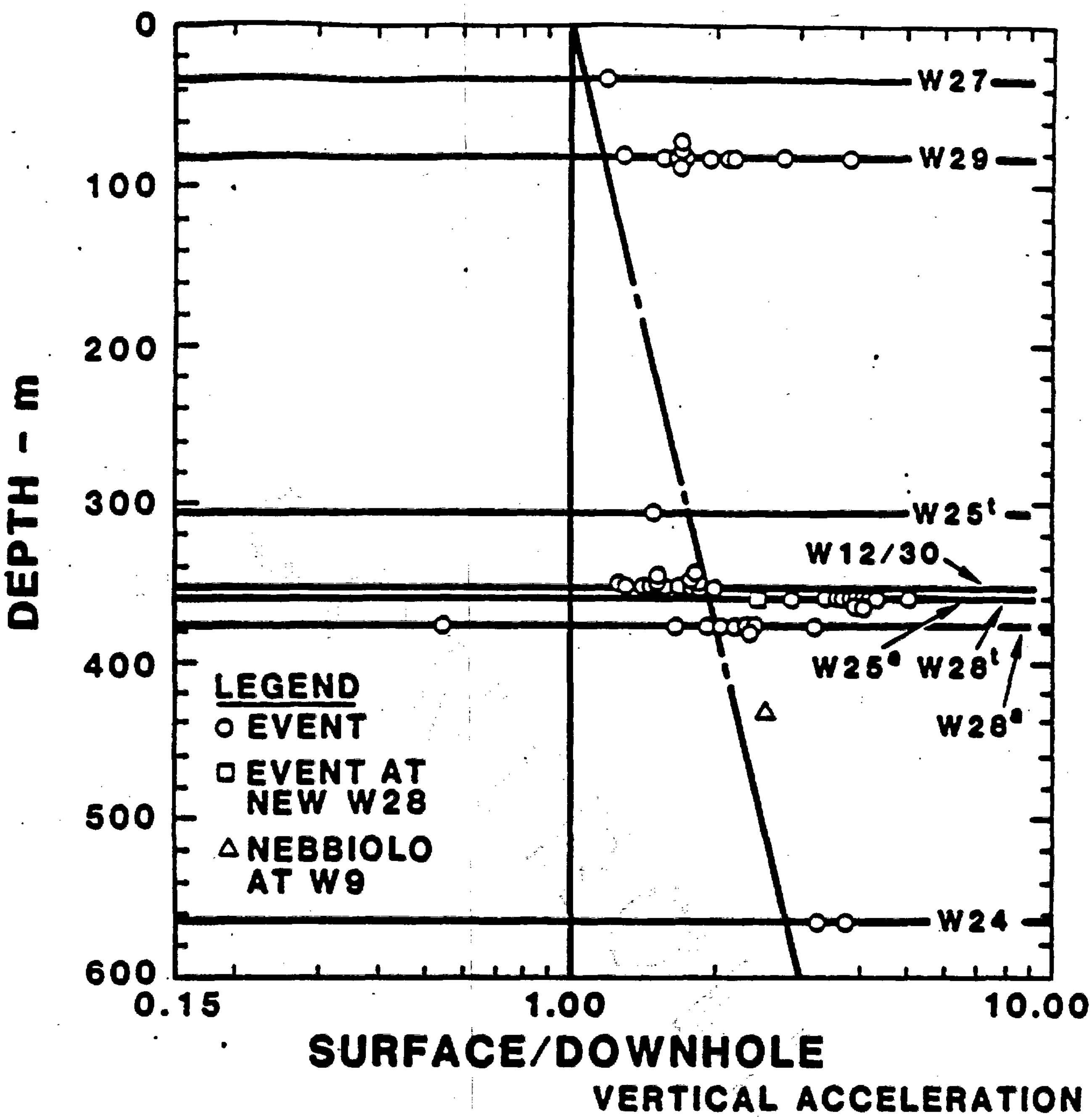


Figure A-4.1. Ideal Situation for Determining Depth Attenuation Behavior



Station	Surface	Downhole
W28	TCW	TSW1
W24	UO	CHn2
W25	UO	TSW2
W29	UO	UO
W30	TCW	TSW2

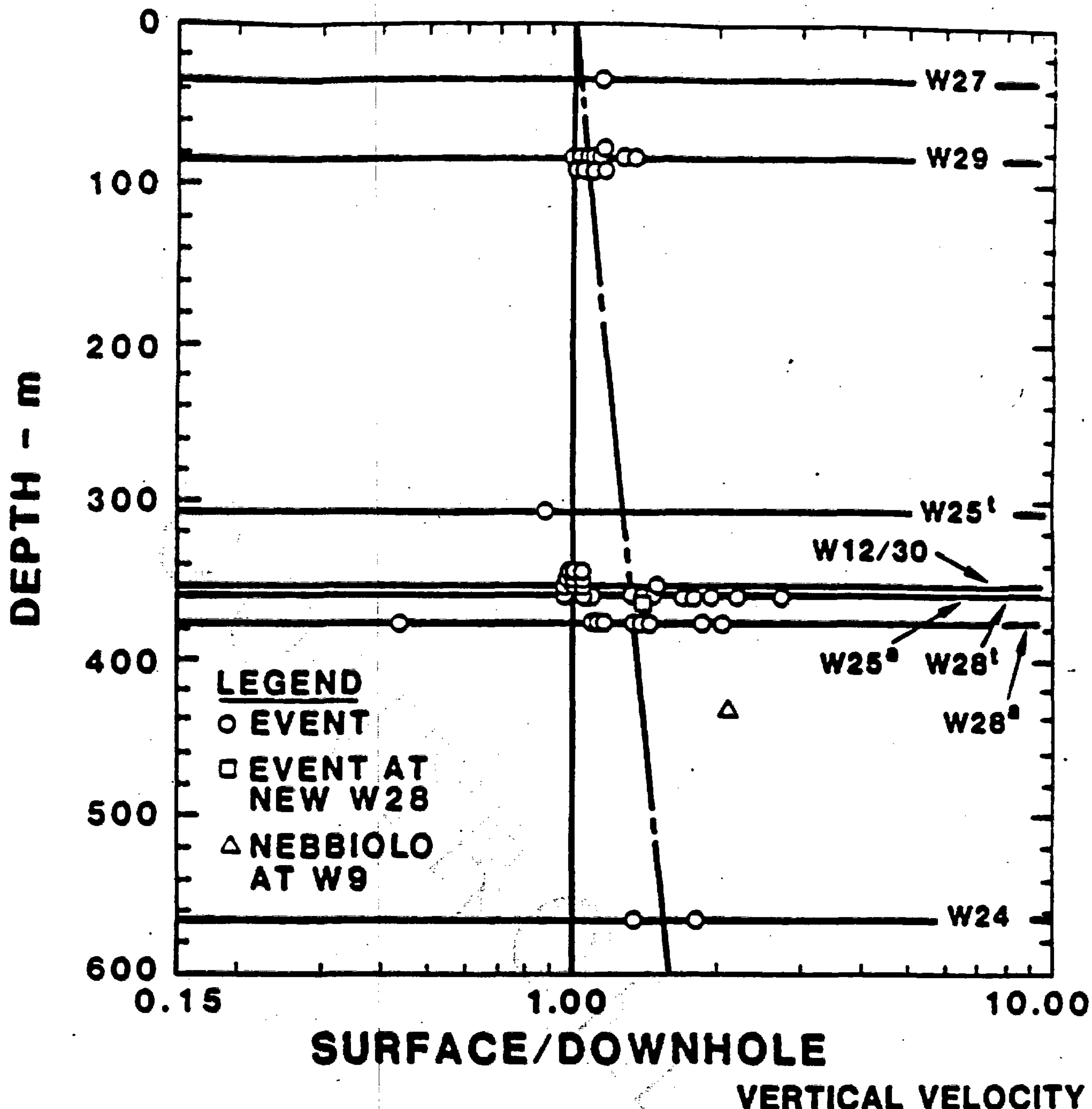
Figure A-4.2. Actual Situation for Determining Depth Attenuation Behavior



NOTES: 1. DOWNHOLE STATIONS AT W25 and W28 HAVE BEEN INSTALLED AT TWO DIFFERENT DEPTHS. "a" DENOTES THE INITIAL DEPTH. "t" DENOTES THE MOST RECENT DEPTH. THE NEW DEPTH FOR W28 IS THE SAME AS OLD W25.

2. THE LINE SHOWN IS THE FIT DISCUSSED IN THE TEXT.

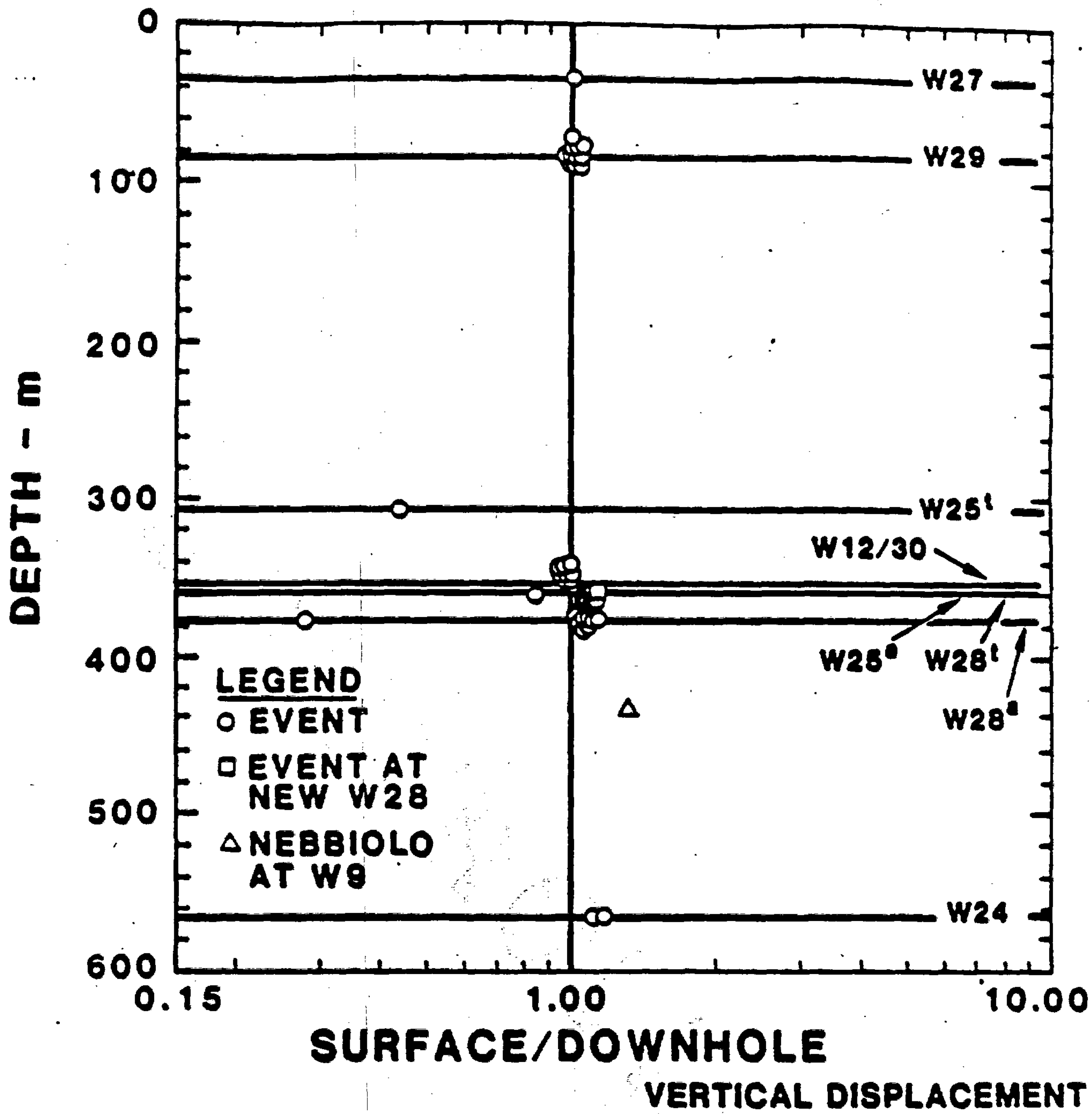
Figure A-4.3. Surface/Downhole Ratios vs Depth for Vertical Acceleration



NOTES: 1. DOWNHOLE STATIONS AT W25 and W28 HAVE BEEN INSTALLED AT TWO DIFFERENT DEPTHS. "a" DENOTES THE INITIAL DEPTH. "t" DENOTES THE MOST RECENT. THE NEW DEPTH OF W28 IS THE SAME AS THE OLD FOR W25.

2. THE LINE SHOWN IS THE FIT DISCUSSED IN THE TEXT.

Figure A-4.4. Surface/Downhole Ratios vs Depth for Vertical Velocity



NOTES:

1. DOWNHOLE STATIONS AT W25 and W28 HAVE BEEN INSTALLED AT TWO DIFFERENT DEPTHS. "a" DENOTES ORIGINAL DEPTH. "t" DENOTES NEW DEPTH. NEW DEPTH OF W28 IS THE SAME AS OLD W25.
2. THE FIT FOR THESE DATA IS A VERTICAL LINE AT A RATIO OF 1.

Figure A-4.5. Surface/Downhole Ratios vs Depth for Vertical Displacement

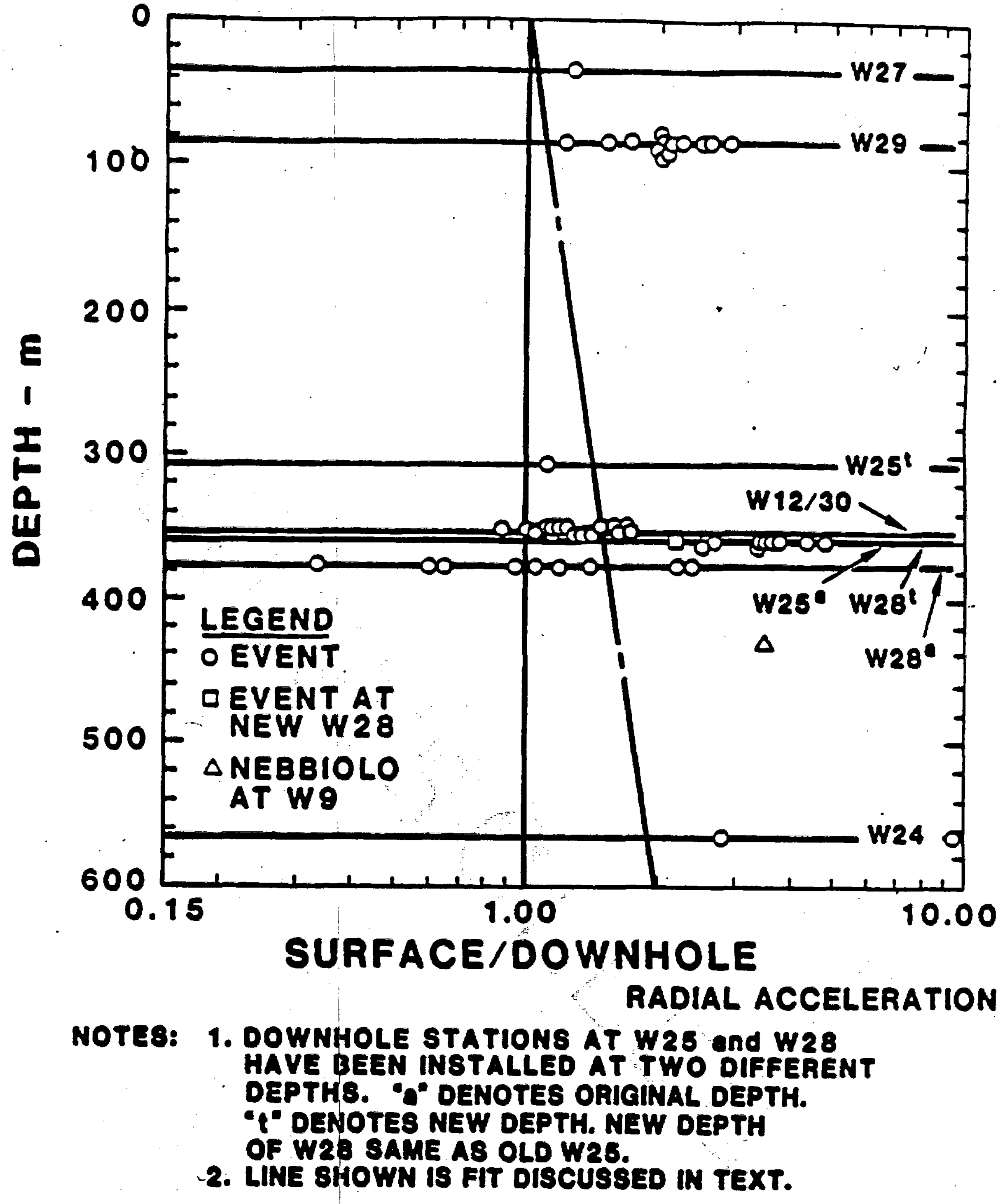
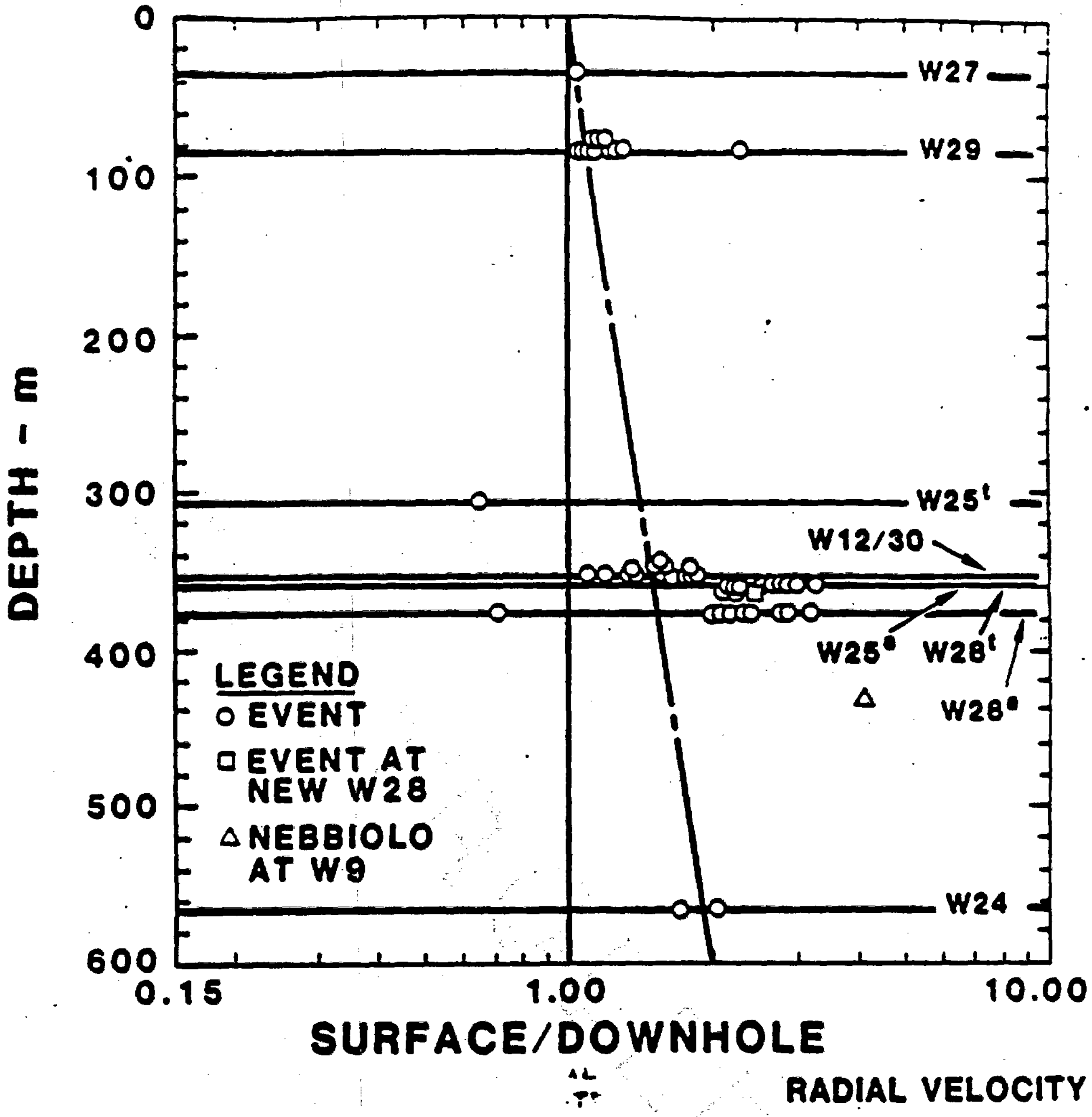


Figure A-4.6. Surface/Downhole Ratios vs Depth for Radial Acceleration



NOTES: 1. DOWNHOLE STATIONS AT W25 and W28 HAVE BEEN INSTALLED AT TWO DIFFERENT DEPTHS. "a" DENOTES ORIGINAL DEPTH. "t" DENOTES NEW DEPTH. NEW DEPTH OF W28 SAME AS OLD W25.
2. LINE SHOWN IS FIT DISCUSSED IN THE TEXT.

Figure A-4.7. Surface/Downhole Ratios vs Depth for Radial Velocity

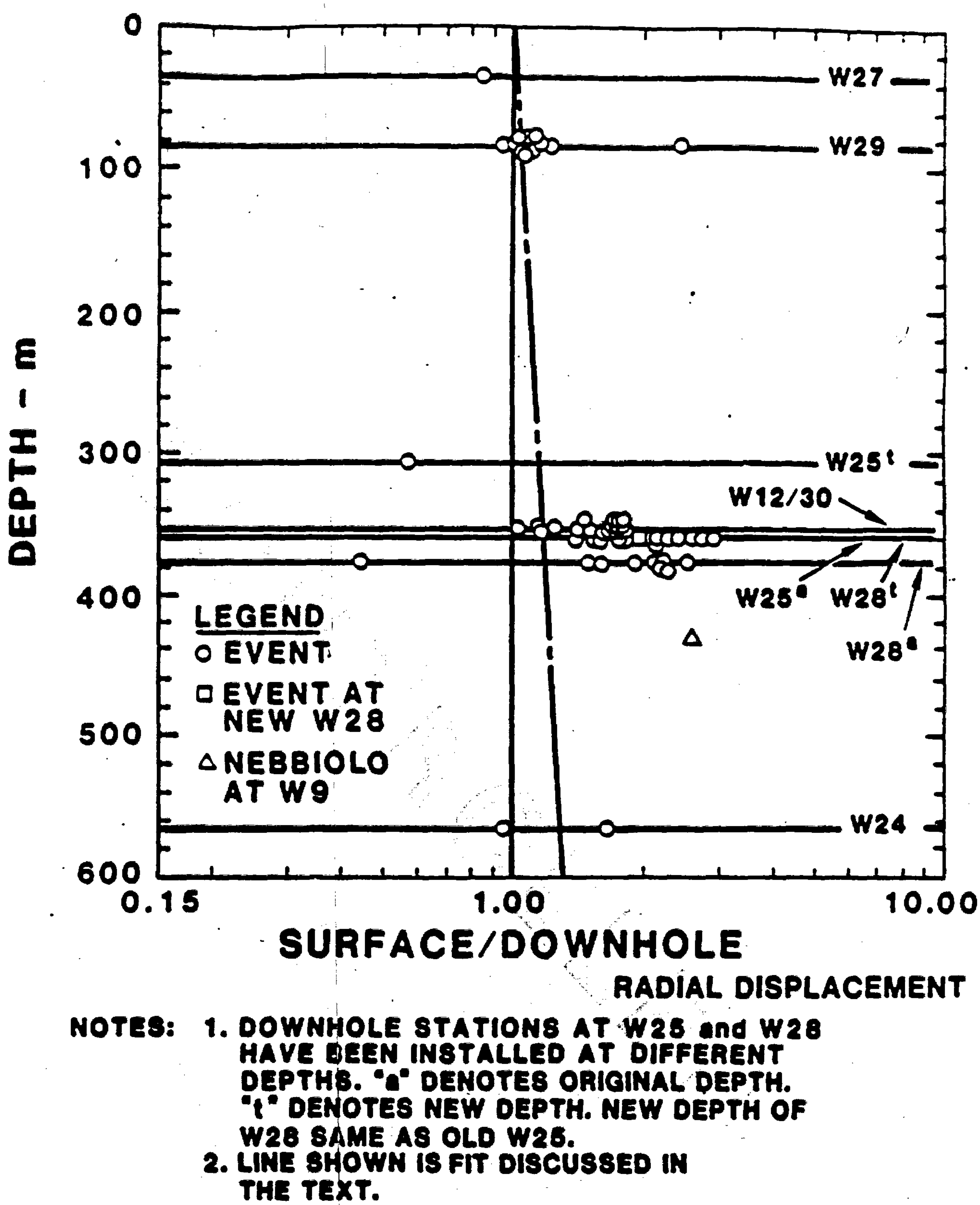
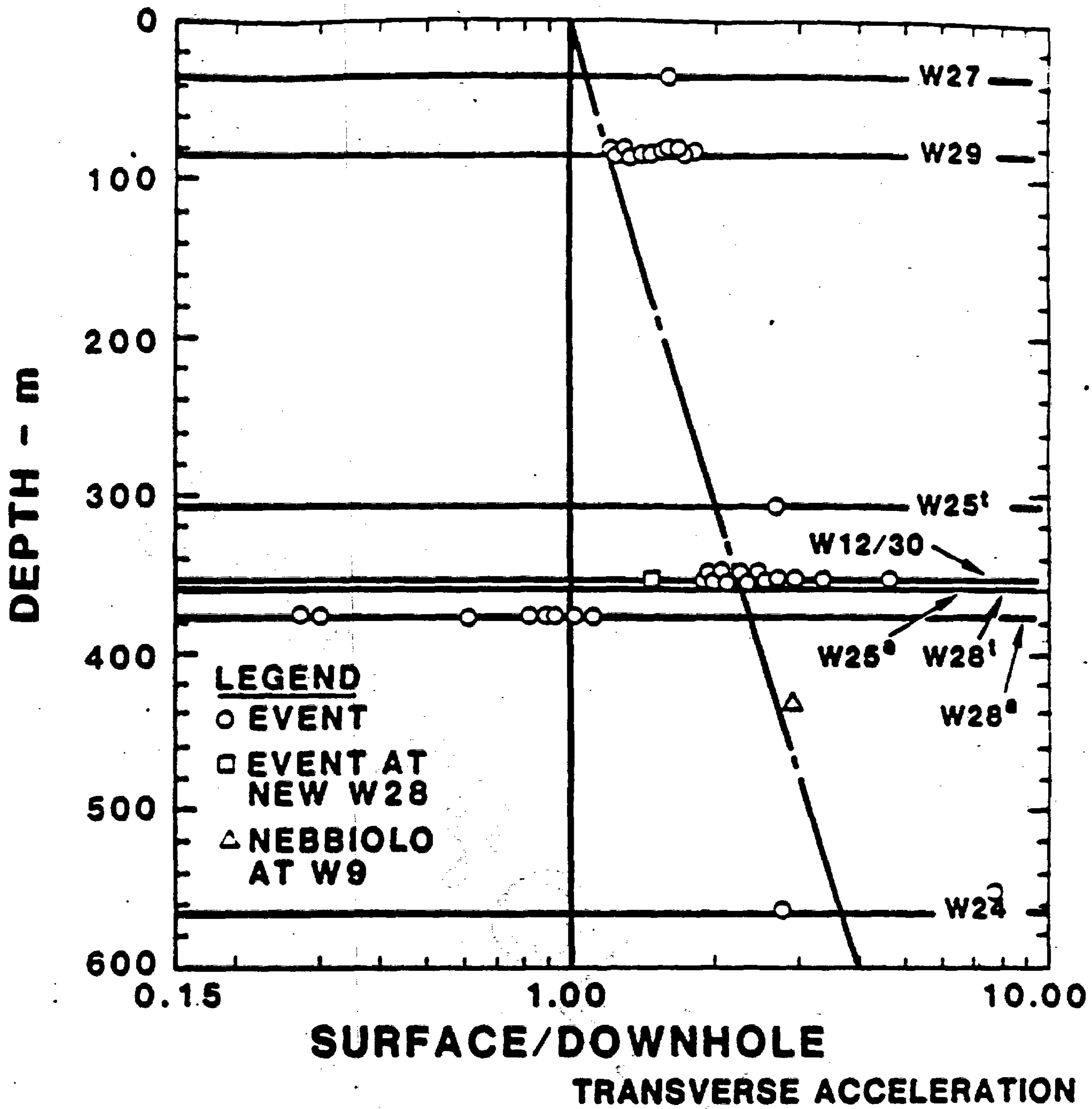


Figure A-4.8. Surface/Downhole Ratios vs Depth for Radial Displacement



NOTES: 1. DOWNHOLE STATIONS AT W25 and W28 HAVE BEEN INSTALLED AT DIFFERENT DEPTHS. "a" DENOTES ORIGINAL DEPTH. "t" DENOTES NEW DEPTH. NEW DEPTH OF W28 SAME AS OLD W25.
2. LINE SHOWN IS FIT DISCUSSED IN TEXT.

Figure A-4.9. Surface/Downhole Ratios vs Depth for Transverse Acceleration

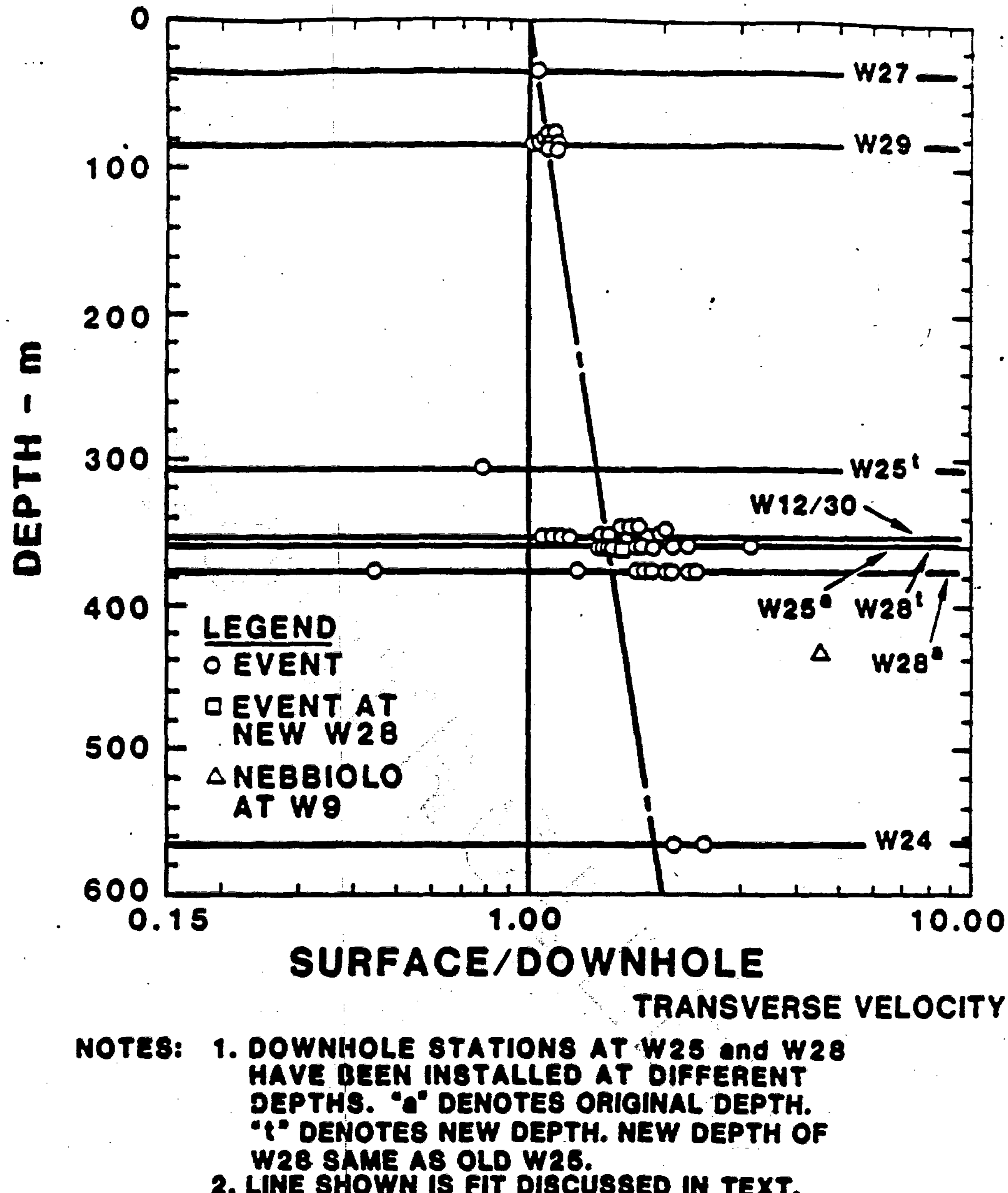
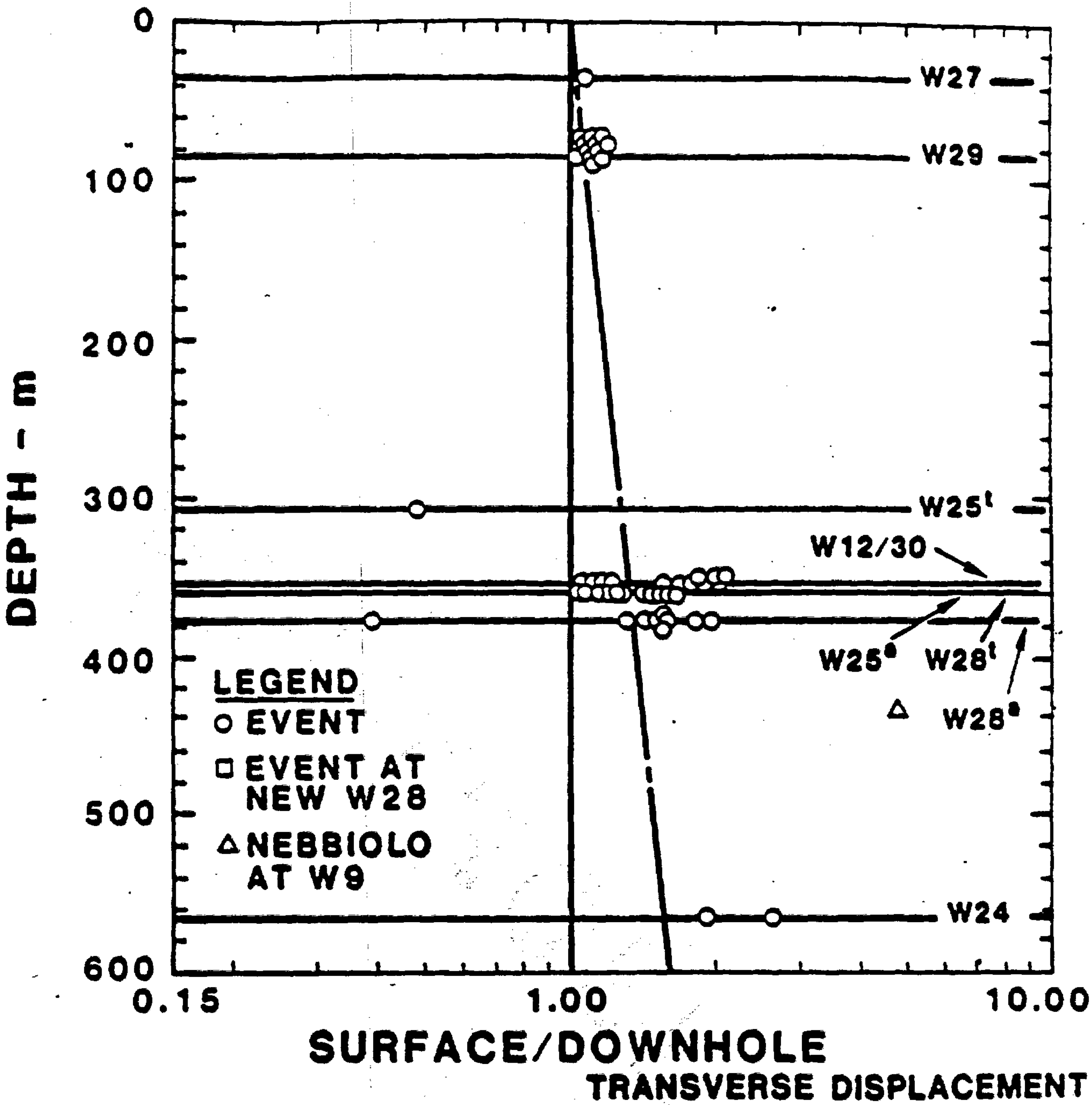
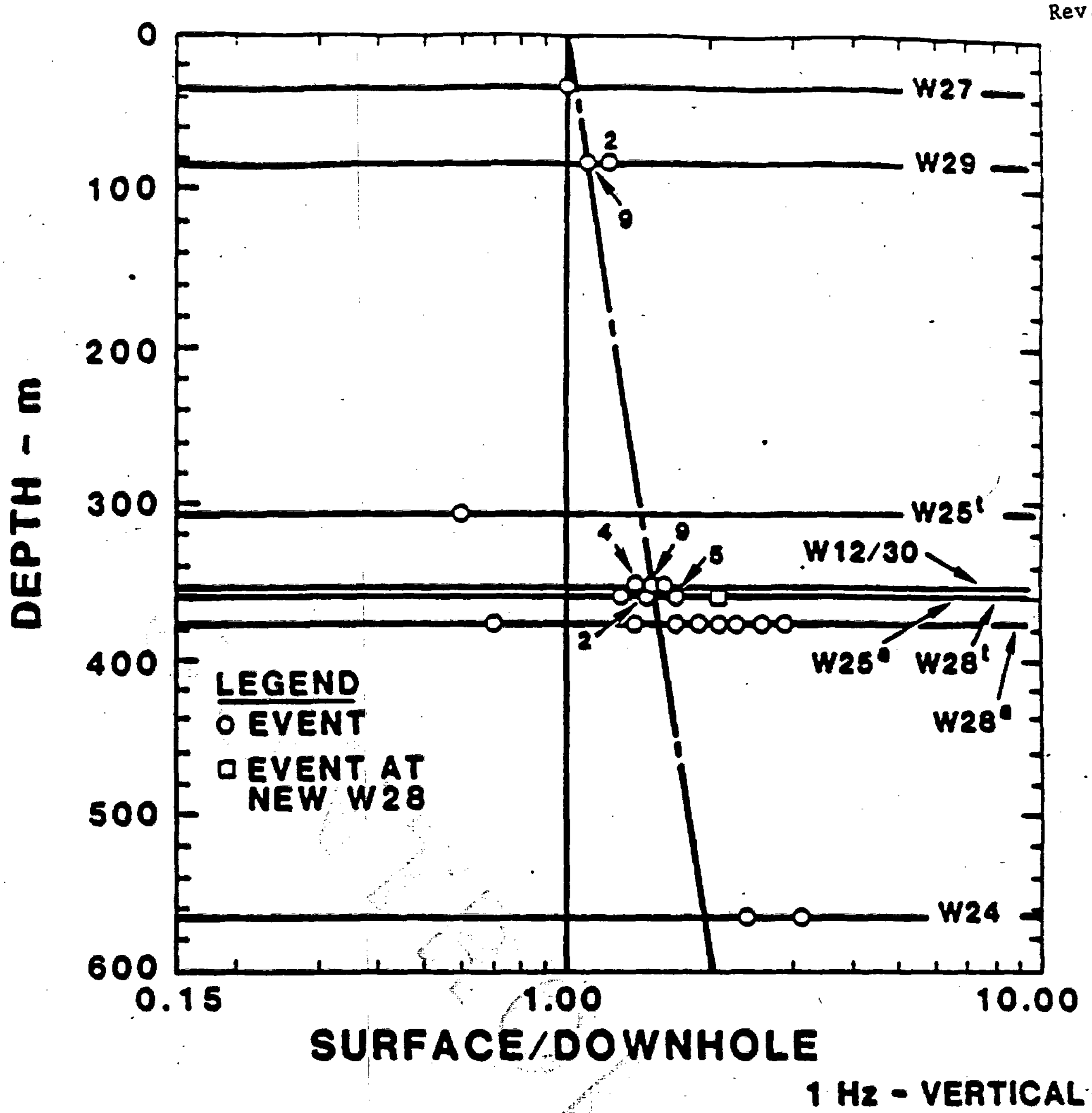


Figure A-4.10. Surface/Downhole Ratios vs Depth for Transverse Velocity



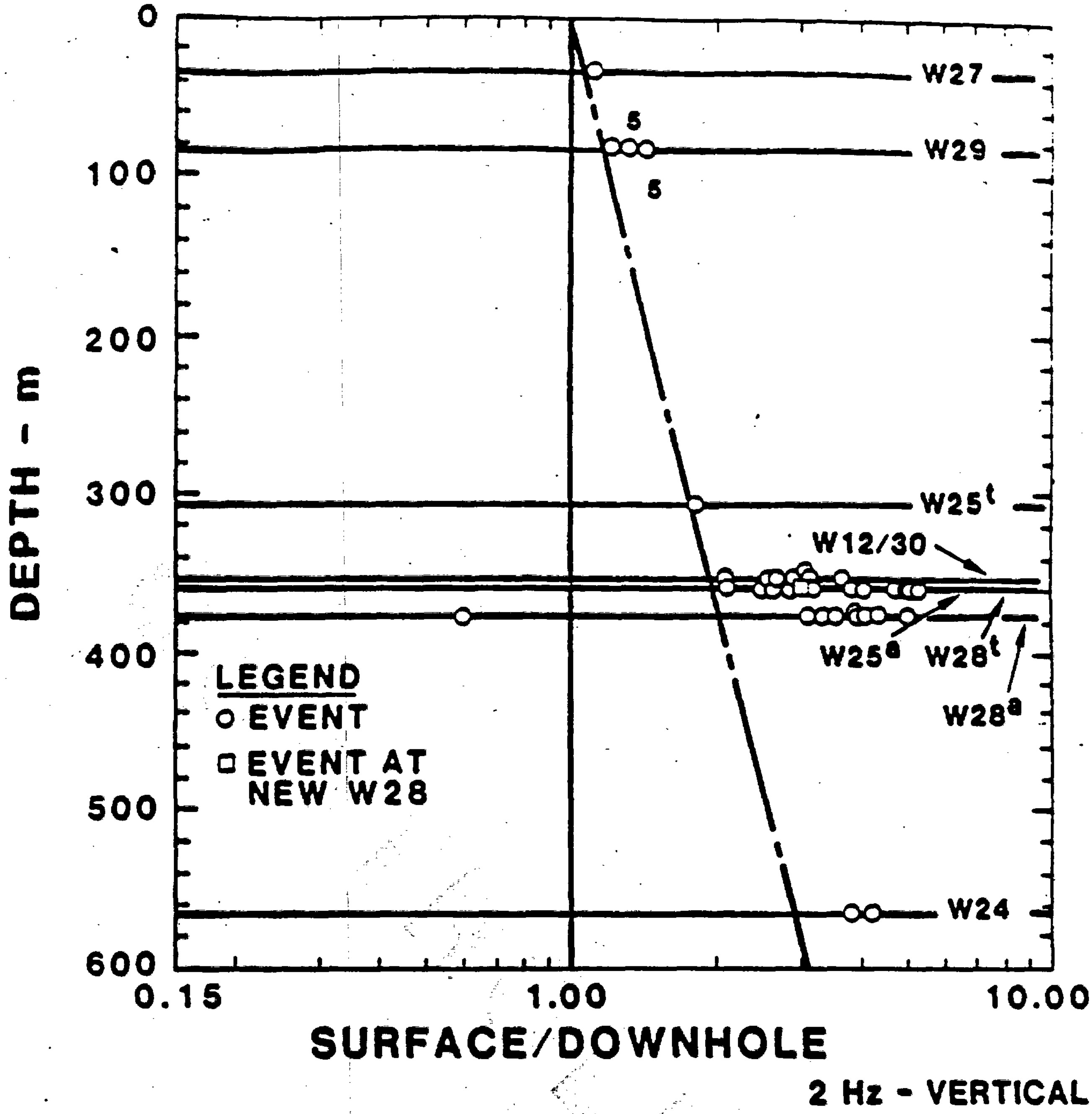
NOTES: 1. DOWNHOLE STATIONS AT W25 and W28 HAVE BEEN INSTALLED AT DIFFERENT DEPTHS. "o" DENOTES ORIGINAL DEPTH. "t" DENOTES NEW DEPTH. NEW DEPTH OF W28 SAME AS OLD W25.
2. LINE SHOWN IS FIT DISCUSSED IN TEXT.

Figure A-4.11. Surface/Downhole Ratios vs Depth for Transverse Displacement



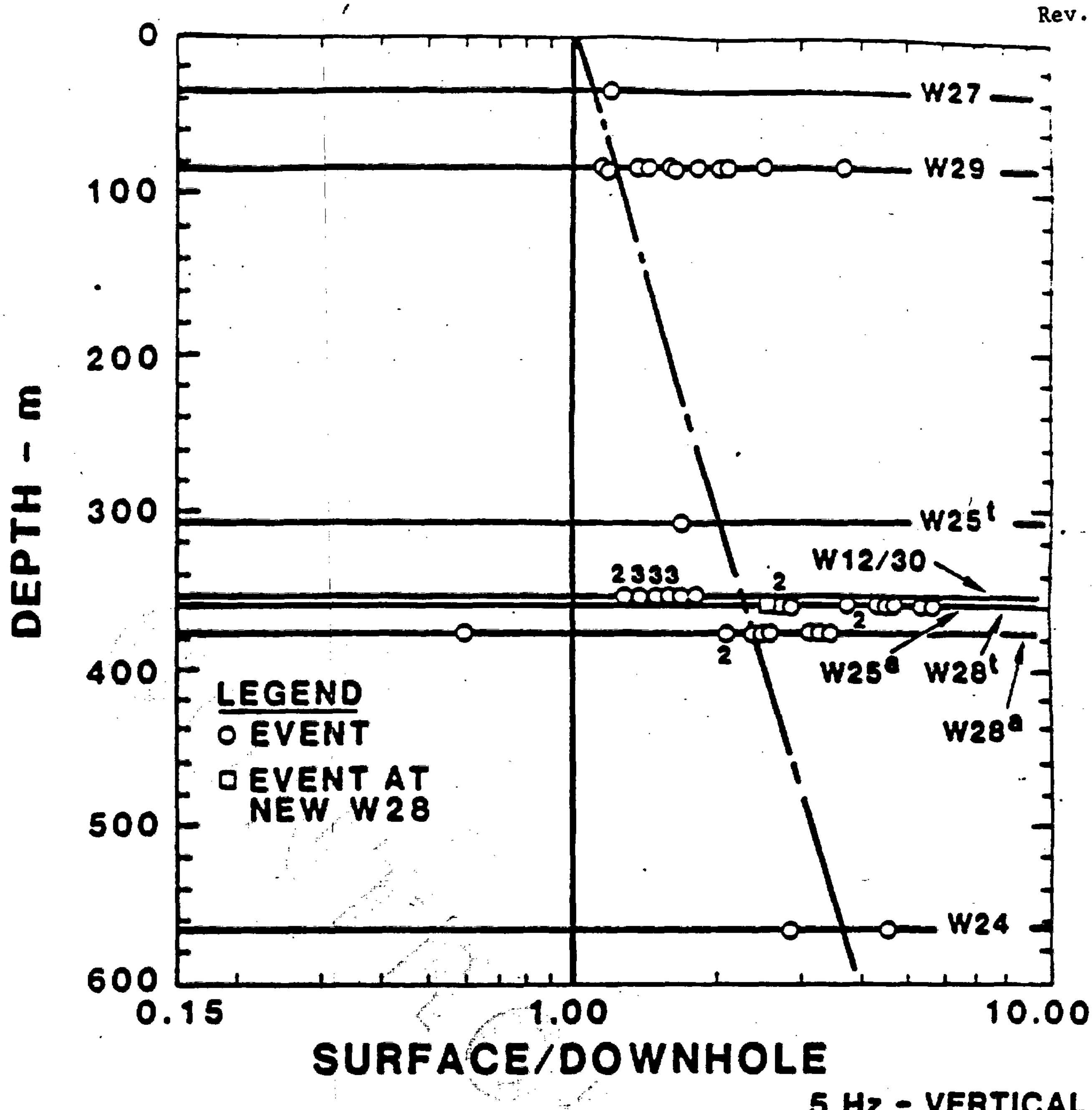
NOTES:
1. DOWNHOLE STATIONS AT W25 and W28 HAVE BEEN INSTALLED AT TWO DIFFERENT DEPTHS. "a" DENOTES THE INITIAL DEPTH. "t" DENOTES THE MOST RECENT DEPTH. THE NEW DEPTH OF W28 IS THE SAME AS THE OLD DEPTH FOR W25.
2. NUMBERS ABOVE THE POINTS INDICATE SEVERAL OF THE EVENTS HAD THE SAME RATIO.
3. THE LINE SHOWN IS THE FIT DISCUSSED IN THE TEXT.

Figure A-4.12. Surface/Downhole Ratios vs Depth for PSRVs of Vertical Motions at 1 Hz



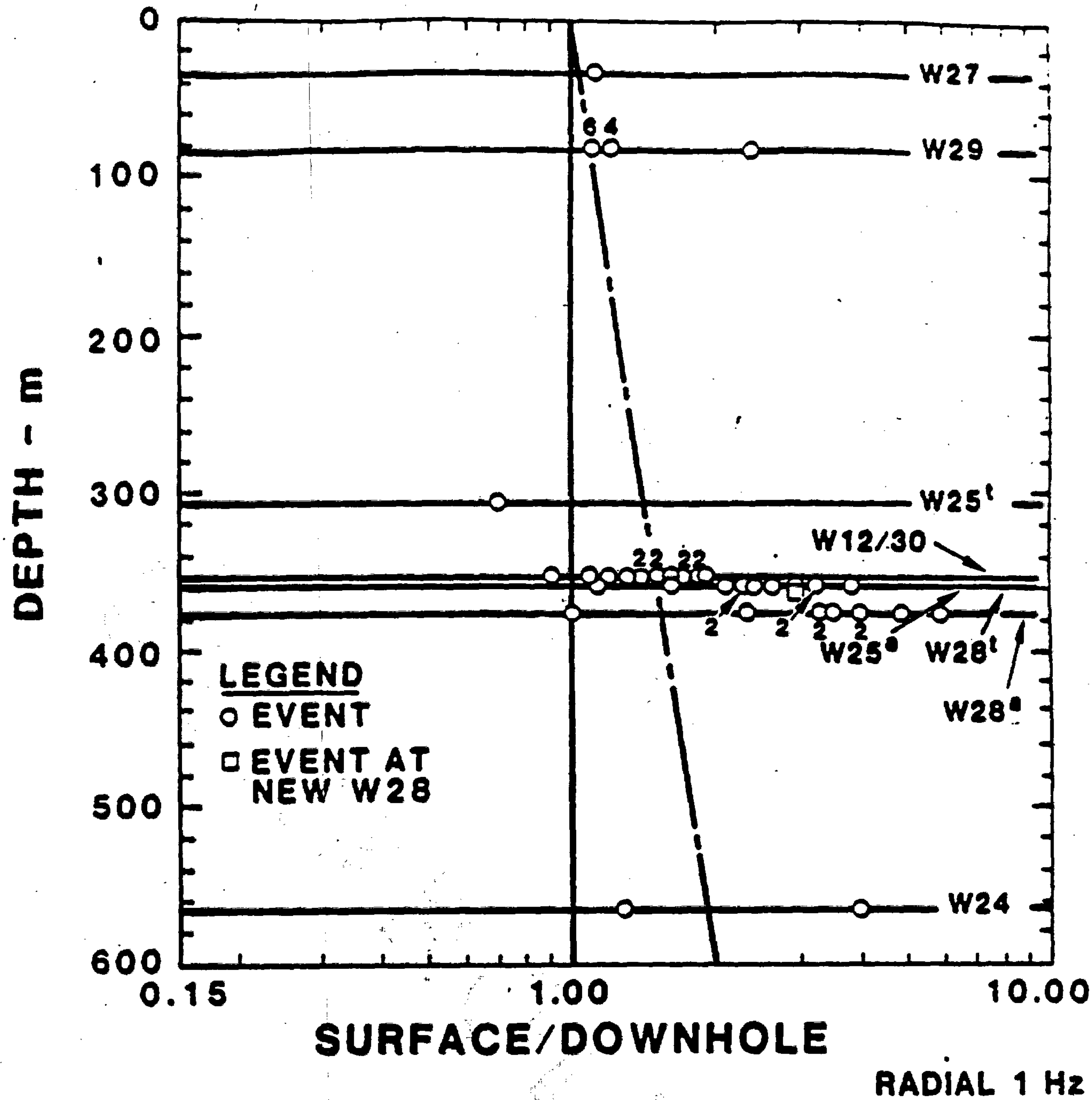
NOTES:
1. DOWNHOLE STATIONS AT W25 and W28 HAVE BEEN INSTALLED AT DIFFERENT DEPTHS. "a" DENOTES OLD DEPTH. "t" DENOTES NEW DEPTH. NEW DEPTH OF W28 SAME AS OLD W25.
2. NUMBER ABOVE POINTS INDICATE SEVERAL EVENTS WITH SAME RATIO.
3. LINE SHOWN IS FIT DISCUSSED IN TEXT.

Figure A-4.13. Surface/Downhole Ratios vs Depth for PSRVs of Vertical Motions at 2 Hz



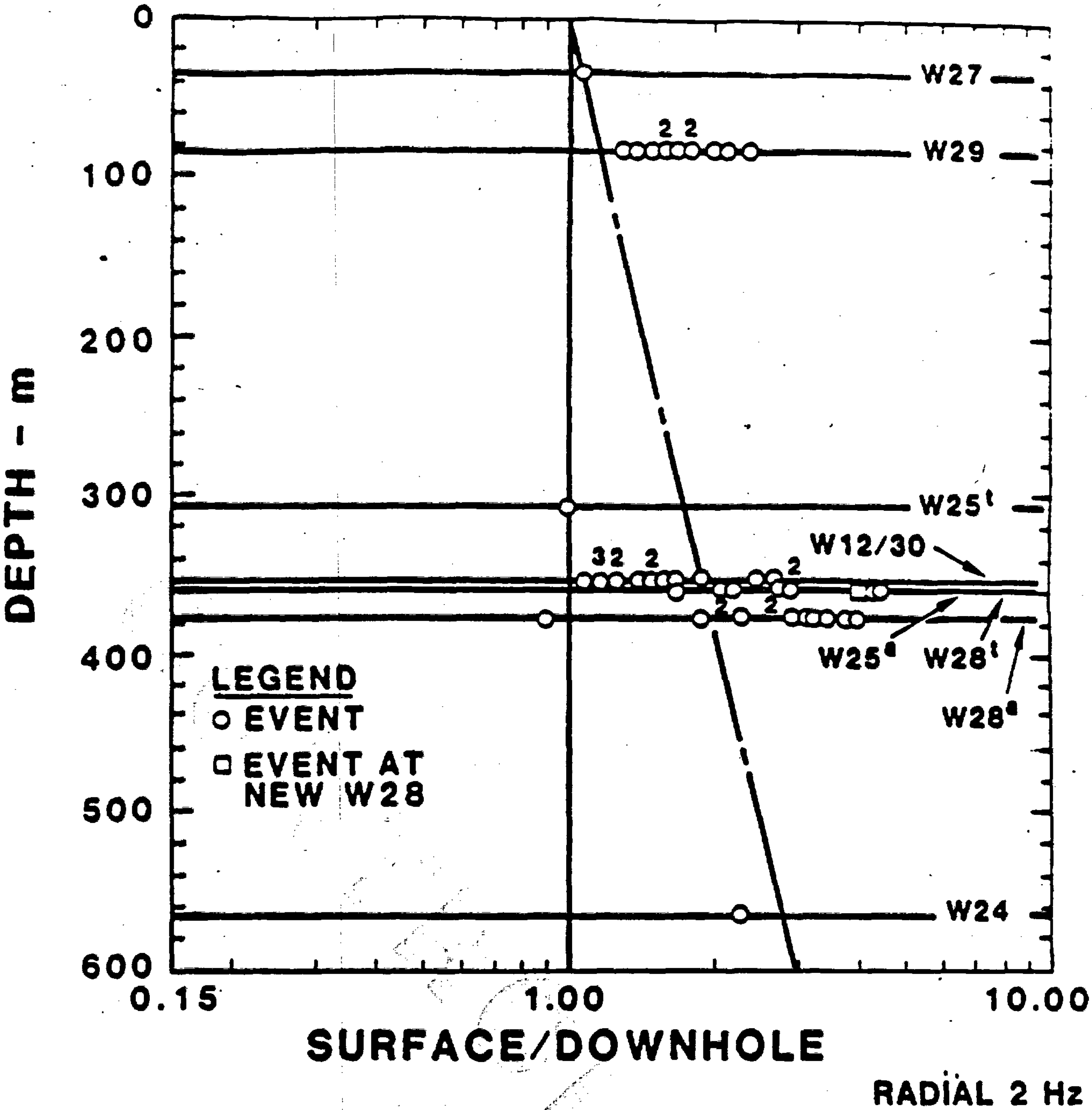
NOTES:
1. DOWNHOLE STATIONS AT W25 and W28 HAVE BEEN INSTALLED AT DIFFERENT DEPTHS. "a" DENOTES OLD DEPTH. "t" DENOTES NEW DEPTH. NEW W28 IS AT SAME DEPTH AS OLD W25.
2. NUMBERS ABOVE POINTS INDICATE SEVERAL EVENTS WITH SAME RATIO.
3. LINE SHOWN IS FIT DISCUSSED IN TEXT.

Figure A-4.16. Surface/Downhole Ratios vs Depth for PSRVs of Vertical Motions at 5 Hz



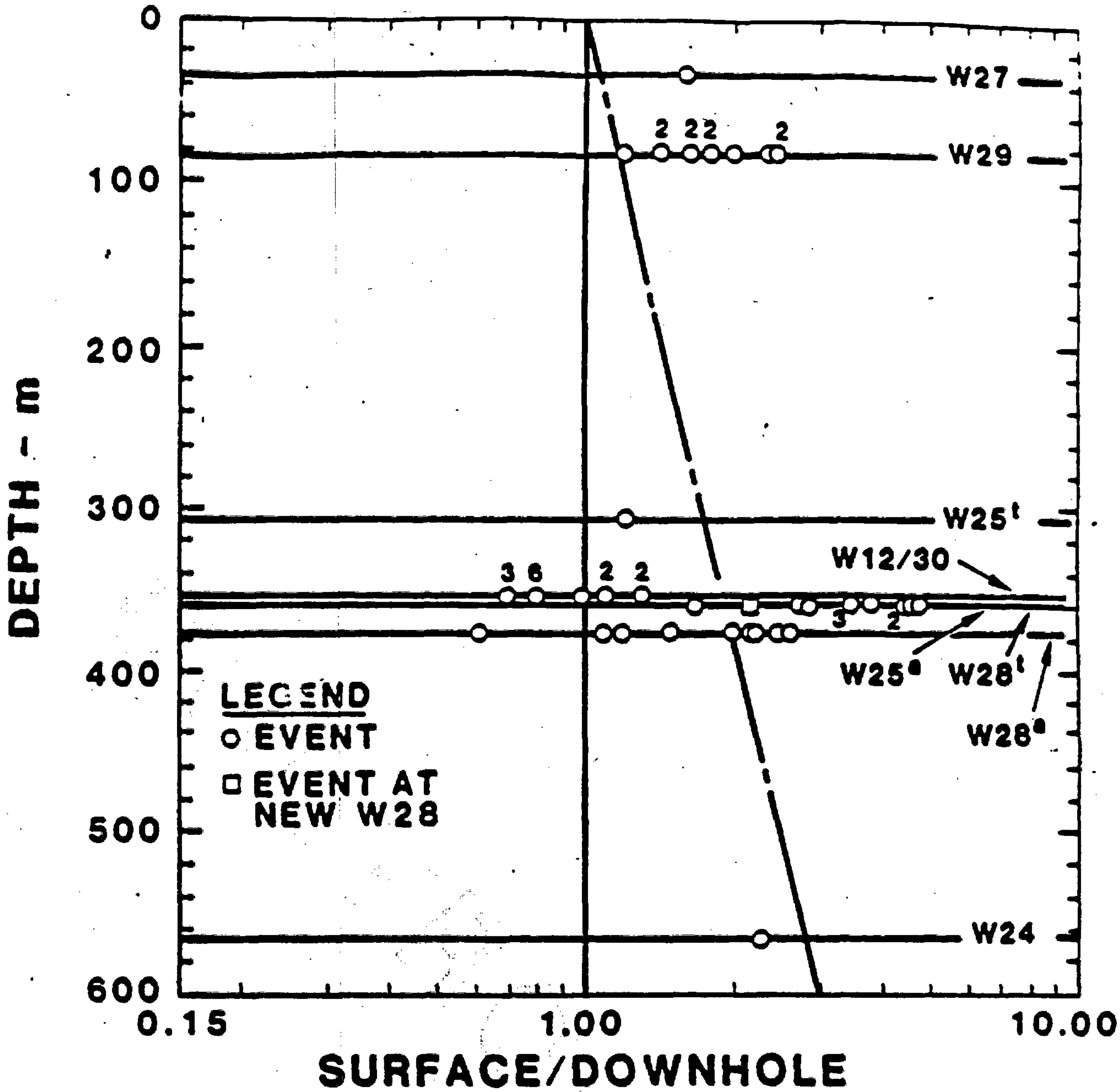
NOTES:
1. DOWNHOLE STATIONS AT W25 and W28 HAVE BEEN INSTALLED AT DIFFERENT DEPTHS. "a" DENOTES ORIGINAL DEPTH. "t" DENOTES OLD DEPTH. NEW DEPTH OF W28 SAME AS OLD W25.
2. NUMBERS ABOVE POINTS INDICATE SEVERAL EVENTS WITH SAME RATIO.
3. LINE SHOWN IS FIT DISCUSSED IN TEXT.

Figure A-4.15. Surface/Downhole Ratios vs Depth for PSRVs of Radial Motions at 1 Hz



NOTES:
1. DOWNHOLE STATIONS AT W25 and W28 HAVE BEEN INSTALLED AT DIFFERENT DEPTHS. "a" DENOTES ORIGINAL DEPTH. "t" DENOTES NEW DEPTH. NEW DEPTH OF W28 SAME AS OLD W25.
2. NUMBERS ABOVE POINTS INDICATE SEVERAL EVENTS WITH SAME RATIO.
3. LINE SHOWN IS FIT DISCUSSED IN TEXT.

Figure A-4.16. Surface/Downhole Ratios vs Depth for PSRVs of Radial Motions at 2 Hz



RADIAL 5 Hz

NOTES: 1. DOWNHOLE STATIONS AT W25 and W28 HAVE BEEN INSTALLED AT DIFFERENT DEPTHS. "a" DENOTES ORIGINAL DEPTH. "t" DENOTES NEW DEPTH. NEW DEPTH OF W28 SAME AS OLD W25.
2. NUMBERS ABOVE POINTS INDICATE SEVERAL EVENTS WITH SAME RATIO.
3. LINE SHOWN IS FIT DISCUSSED IN TEXT.

Figure A-4.17. Surface/Downhole Ratios vs Depth for PSRVs of Radial Motions at 5 Hz

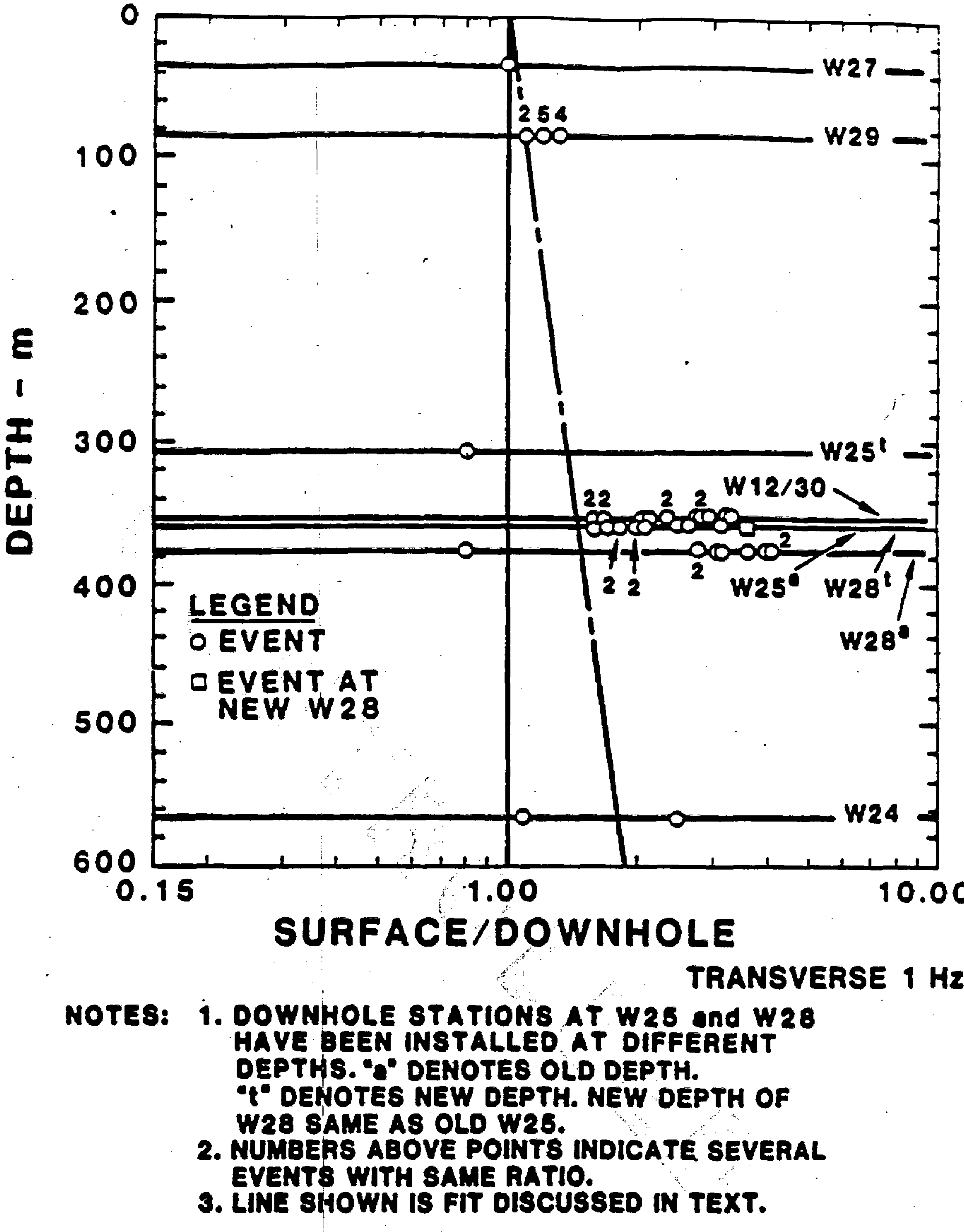
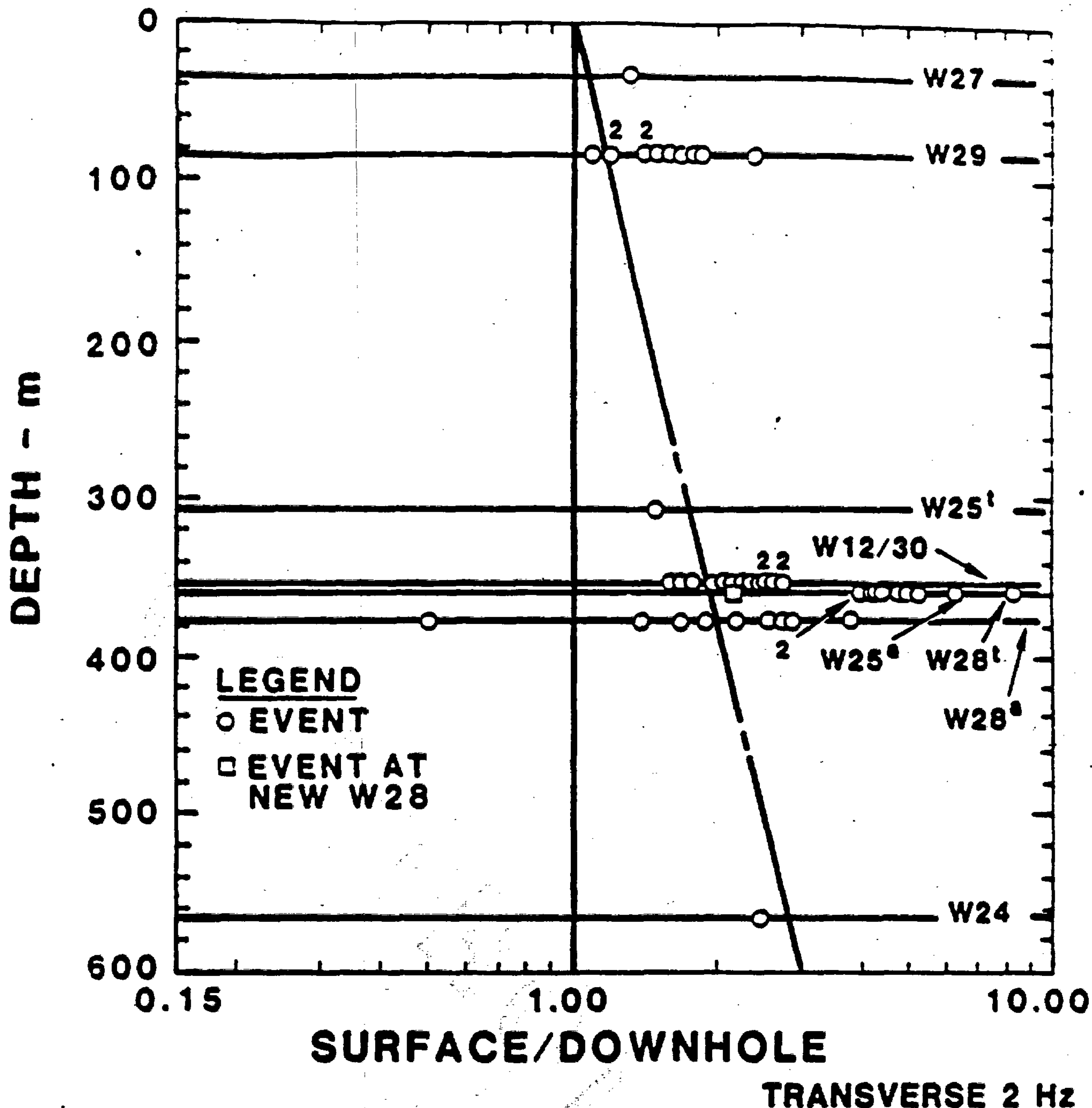
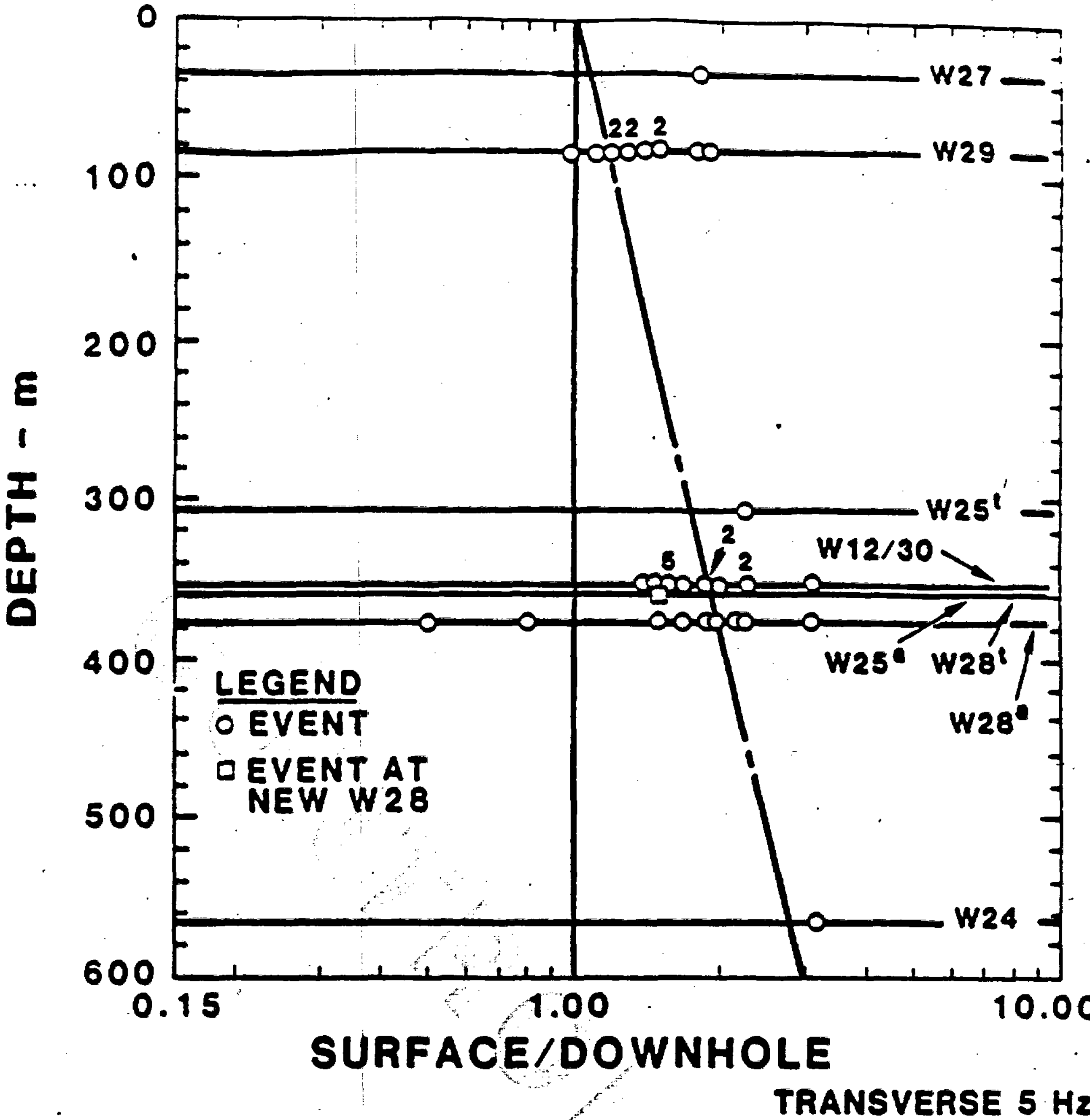


Figure A-4.18. Surface/Downhole Ratios vs Depth for PSRVs of Transverse Motions at 1 Hz



NOTES: 1. DOWNHOLE STATIONS AT W25 and W28 HAVE BEEN INSTALLED AT DIFFERENT DEPTHS. "a" DENOTES OLD DEPTH. "t" DENOTES NEW DEPTH. NEW DEPTH OF W28 SAME AS OLD W25.
2. NUMBERS ABOVE POINTS INDICATE SEVERAL EVENTS WITH SAME RATIO.
3. LINE SHOWN IS FIT DISCUSSED IN TEXT.

Figure A-4.19. Surface/Downhole Ratios vs Depth for PSRVs of Transverse Motions at 2 Hz



NOTES:

1. DOWNHOLE STATIONS AT W25 and W28 HAVE BEEN INSTALLED AT DIFFERENT DEPTHS. "a" DENOTES OLD DEPTH. "t" DENOTES NEW DEPTH. NEW DEPTH W28 SAME AS OLD W25.
2. NUMBERS ABOVE POINTS INDICATE SEVERAL EVENTS WITH SAME RATIO.
3. LINE SHOWN IS FIT DISCUSSED IN TEXT.

Figure A-4.20. Surface/Downhole Ratios vs Depth for PSRVs of Transverse Motions at 5 Hz

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EXPLORATORY SHAFT FACILITY

SUBSYSTEM DESIGN REQUIREMENTS DOCUMENT

TABLE OF CONTENTS

FULL TEXT ASCII SCAN

N1103 102

1.2.6.0 GENERAL EXPLORATORY SHAFT FACILITY

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1.2.6.3 Surface Facilities
1.2.6.4 First Shaft
1.2.6.5 Second Shaft
1.2.6.6 Underground Excavations
1.2.6.7 Underground Utility Systems
1.2.6.8 Underground Tests

Definition of Subsystem Elements

The Exploratory Shaft Facility (ESF) is defined by those systems, subsystems, and components used for in situ site characterization and performance confirmation testing of a candidate site for a repository. The ESF is defined as the surface and underground facilities (including shafts and connecting drifts) and supporting systems required to support site characterization testing at depth. (See Appendix A, Sketches 1, 2, 3, 4, and 5.)

Applicable Regulations, Codes, and Specifications

It is the responsibility of the Architect-Engineer (A/E) to identify which specific regulations, codes, and standards apply from the regulations, orders, codes, and specifications listed in this document. Citations can be found in each section of this document as applicable. Specific citations for the applicable regulations, codes, and specifications can be found in the ESF Basis for Design Documents. Appendix E contains a listing of some additional commonly used regulations, codes, and standards. Except for the 12/25/87 Draft Department of Energy Order DOE 6430.1A, the latest edition or revison of a regulation, code or standard in effect as of October 1, 1987, is to be used. In the event of conflicting requirements, the most stringent shall be applied. The Director of the Waste Management Project Office (WMPO), or his designee, shall be requested in writing to approve or obtain any required waivers.

Functional Requirements

1. Support in situ site characterization for the Mined Geologic Disposal System and provide testing facilities for in situ site characterization as required by DOE/OGR milestones and the Site Characterization Plan.

2. Provide an ESF whose permanent items can be incorporated into the repository and which can be used to support phase I repository construction. Those items, listed below, are the ESF permanent systems, structures, and components that shall be designed, procured, and constructed to be incorporated into the repository. The

permanent items must be designed to have a maintainable life and quality as specified for the repository.

a. Underground Opening(s) — space created by mining or drilling, including those zones within the rock altered by that process.

b. Shaft Liner(s) — all components placed between the inside limits of the shaft and the accessible extent of the underground opening.

c. Ground Support — any means used to reinforce rock and/or control the movement of rock except for removable or replaceable hardware.

3. Provide a suitable location for in situ site characterization.

4. Provide equipment and facilities for ensuring a safe, healthful, and productive working environment.

5. Provide the facilities to alert on-site personnel of possibly dangerous situations.

6. Provide design and construction methods that will demonstrate licensability and constructability for the candidate repository.

Performance Criteria

1. The ESF shall be designed to support site characterization by providing facilities to meet the needs of in situ site characterization testing.

2. Underground openings shall be developed to meet the needs of in situ site characterization, including basic needs for the initially planned tests. Additionally an allowance for uncertainties for the test area needs at the main test level has been set at 100 percent; i.e., all major systems for ventilation, utilities, emergency egress, rock handling, personnel support, and others shall be analyzed to determine the need for and the impact associated with this uncertainty allowance. If it can be demonstrated that critical parts of the allowance would require excessive costs, schedule, test disruption, or other program impacts to design, procurement, and/or construction later (after the basic test plan needs are completed), consideration shall be given to designing, procuring, and/or constructing these critical items as part of the initial facility. The uncertainty allowance for each of the major ESF systems shall be determined by an analysis of the following systems:

Description	Uncertainty Allowance
Underground test area at the main test level	100 percent
Systems - Site - Utilities - Surface facilities - First shaft - Second shaft - Underground excavations	DETERMINED BY ANALYSES IN THE TITLE I DESIGN PHASE

- Underground utility systems
- Underground tests

Specific allowances for each major system shall be identified and incorporated prior to the start of Title II design (detailed design).

3. in situ and in-shaft testing shall satisfy the requirements of the DOE/OGR milestones and the Site Characterization Plan (SCP).

4. Those ESF structures, systems, and components that are incorporated into the repository shall be designed and constructed to meet the requirements of 10 CFR Part 60. Compliance with the requirements of 10 CFR Part 60 will be demonstrated in the license application.

5. ESF permanent structures, systems, and components that will be incorporated into the repository shall be designed and constructed with the same criteria, standards, and Quality Assurance levels as required for the repository, to the extent known at the time of ESF design.

6. Drill cores from USW G-4 and other existing geologic data shall be used to design the ESF shafts and underground openings.

7. Quality and quantity of uncontaminated ventilation air supplied to the subsurface facilities of the ESF system shall provide a safe, healthy, and productive working environment to operating personnel.

8. Alarm systems shall indicate when the various monitored conditions exceed predetermined specified limits. Redundant systems shall be installed as required by applicable regulations.

9. Monitoring of conditions such as noise, noxious or flammable gas, and radon shall be conducted in accordance with applicable federal, state, and local regulations.

10. ESF openings, boreholes, and their seals shall be designed so that they do not become pathways that compromise the repository's ability to meet the performance objectives of 10 CFR Part 60. Compliance with this criterion will be demonstrated in the license application.

11. Shafts and other underground excavations shall be designed and constructed with reasonably available technology similar to or corresponding with the techniques planned for the candidate repository.

12. All geotechnical information and assumptions used in the design of underground features (including seismic criteria) shall be consistent with information contained in the baselined repository Reference Information Base (RIB) or traceable to NNWSI Project published information. See Appendix D for the indexes and cross references to other applicable and referenceable Project documentation.

13. The ESF shall be designed to include on-site facilities and services that ensure a safe and timely response to emergency conditions and that facilitate the use of available off-site services (such as fire, police, medical, and ambulance service) that may aid in recovery from emergencies.

Interface Control Requirements

1. The basic interface control requirements are established by the NNWSI Project ESF Interface Control Procedure (ICP), Standard Operating Procedure (SOP) 03-05. This procedure is applicable to all work to be performed by participating organizations and contractors during the engineering phases for the ESF. This is an interim procedure and, as such, shall apply until the NNWSI Project Systems Engineering Management Plan (SEMP) and the NNWSI Project Configuration Management Plan (CMP) with appropriate implementing procedures have been finalized, approved, and implemented within the NNWSI Project. Specific working groups may be formed, as required, to coordinate Project-specific interfaces.

Constraints

1. The ESF system shall comply with all applicable federal environmental regulations and with state and local environmental regulations consistent with the DOE's responsibilities under the Nuclear Waste Policy Act of 1982 (NWPA). Such compliance could include the following:

   a. The designs for systems which contain point-source discharges of treated waste waters into surface-water systems shall comply with the provisions of the Clean Water Act (as amended) as implemented through the National Pollutant Discharge Elimination System (NPDES) permit process.

   b. The design for the management and disposal of solid and any hazardous wastes (excluding any radioactive wastes) shall be conducted in accordance with the requirements of the Resource Conservation and Recovery Act (RCRA) (as amended) which could include RCRA permitting for the hazardous wastes.

   c. The design for systems which handle, use, and/or dispose of any toxic substances shall comply with the requirements of the Toxic Substances Control Act (TSCA), as amended. Federal regulations implementing TSCA are coded in Title 40, Chapter I, Subchapter R.

   d. The design of systems shall ensure that the noise levels of those systems shall be controlled in accordance with the requirements of the Noise Control Act of 1972.

   e. The design for any system or activity involving underground injections shall comply with the provision of the Safe Drinking Water Act (as amended) which could require an Underground Injection Control (UIC) permit.

2. The ESF shall be designed so that the effects of credible disruptive events as defined in the RIB (e.g., flooding, fires, and explosions) shall be limited from spreading through the facility.

3. The engineered barrier system must be designed such that other systems, structures, and components of the ESF and the candidate repository do not eventually become

ground-water flow paths and do not promote the release of radionuclides to the accessible environment.

4. The structures, systems, and components important to safety shall be designed so that natural phenomena and environmental conditions anticipated at the ESF and candidate repository will not interfere with necessary safety functions.

5. The structures, systems, and components important to safety shall be designed and located to withstand the effects of credible fires and explosions as well as all other postulated design basis accidents as defined in the RIB.

6. The ESF permanent systems, structures, and components important to safety shall be designed to ensure continued safe repository operation or safe repository shutdown and personnel evacuation, if necessary, under conditions resulting from the effects of natural phenomena and design-basis accidents.

7. To the extent practicable, the ESF shall be designed to incorporate the use of non-combustible and heat-resistant materials.

8. The predicted thermal and thermomechanical response of the host rock and surrounding strata, and the ground-water system shall be considered in the ESF design.

9. To the extent practicable and consistent with procurement regulations, consideration of surplus government equipment shall be given to fulfill the requirements for the support services and equipment.

10. The ESF shall be designed, constructed, and operated to meet decommissioning and closure requirements of applicable federal, state, and local codes.

11. The design shall allow for fugitive and stationary source dust control at potential dust generation areas such as roads and earth moving sites to minimize airborne particulates, as required by applicable federal, state, and local codes.

Assumptions

1. The site shall be located such that, based on expected ground-water conditions, it will be unlikely that engineering measures beyond reasonably available technology will be required for ESF construction, operation, or closure.

2. The responsibilities of the NNWSI Project ESF participants are defined in the ESF Project Management Plan.

3. The design shall assume that the shaft subcontractor will be totally self-sufficient with respect to the physical mine plant, except for government-furnished utilities, equipment, and facilities.

1.2.6.1 SITE

Subparts are:

1.2.6.1.1 Main Pad
1.2.6.1.2 Auxiliary Pads
1.2.6.1.3 Access Roads
1.2.6.1.4 Site Drainage

Definition of Subsystem Elements

The ESF site is defined as the systems, subsystems and components located on Government-owned land necessary for the development of the surface and underground facilities and supporting systems required to support site characterization testing at depth. The site is comprised of the main pad, auxiliary pads, access roads, and drainage system contained within the boundaries of the ESF.

The ESF will be located in Coyote Wash on the eastern side of Yucca Mountain at an elevation of about 4,130 feet and placed on a cut-and-fill rock shelf located on the side of the hill that bounds the wash on the northeast.

Applicable Regulations, Codes, and Specifications

The design shall be in accordance with:

1. Draft DOE 6430.1A dated 12/25/87, Division 1 General Requirements except for the seismic requirements in 0111.2.7, Earthquake Loads, Division 2, Site and Civil Engineering, Division 3, Concrete and Division 5, Metals.
2. Nevada Revised Statues - Chapter 445, para. 705, item 8.
3. State of Nevada Department of Highways Section 201 through 212.

In addition, see Section 1.2.6.0, Applicable Regulations, Codes, and Specifications.

Functional Requirements

1. Site systems, subsystems, and components are composed of general civil improvements. This includes but is not limited to clearing, grading, excavations, filling, parking areas, flood protection, drainage systems, temporary roads, laydown areas, and top soil storage areas adequate to support construction and operation of the shafts, underground workings, and testing program.

2. Roads, building pads, utility corridors, and rock-storage areas shall be cleared, graded, and stabilized.

3. The surface layout (site plan) must accommodate future expansion as determined by the uncertainty allowance (see Section 1.2.6.0, Performance Criteria item #2).

Performance Criteria

1. The site systems, subsystems, and components shall provide a safe, healthful, and productive working environment.

2. Site systems, subsystems, and features related to drainage ponds and rock storage areas shall be designed and constructed for a maintainable 25-year life.

3. Site preparation for shaft collars shall be designed and constructed for a maintainable 100-year life.

4. Dust control shall be provided at potential dust-generation areas such as roads and earth moving sites in order to minimize airborne particulates, as required by federal, state, and local codes.

5. The shafts and shaft collar areas shall be located and/or graded to protect them from the probable maximum flood as defined in the RIB.

Interface Control Requirements

The ESF designers shall coordinate with repository designers on ESF site location and layout and on permanent ESF structures, systems, and components, and shall make available all design information pertaining to the permanent ESF components during formal program design reviews.

In addition, see Section 1.2.6.0, Interface Control Requirements.

Constraints

1. The design and construction of the site (civil improvements) for the permanent ESF structures, systems, and components shall not significantly increase the preferential pathways for groundwater or radioactive waste migration to the accessible environment.

2. The site systems, subsystems, and components shall incorporate environmental impact considerations with respect to ground disturbance, dust control, etc. (See Section 1.2.6.0, Constraints item #1.)

3. All storm-water runoff shall be controlled in an environmentally acceptable manner.

4. The design life for all ESF systems, components, and structures shall be as follows:

a. Permanent ESF structures, systems, and components shall be designed and constructed for a 100-year maintainable life.

b. Drainage ponds and rock storage (muck pile) liners shall be designed and constructed for a maintainable 25-year life.

c. The design life for all other ESF systems, components, and structures shall be maintainable for 5 years unless otherwise specified.

5. The first shaft, ES-1, shall be located at the intersection of the following coordinates: E563,630 and N766,255, as defined by the Nevada Coordinate System.

6. The second shaft, ES-2, shall be located at the intersection of the following coordinates: E563,918 and N766,337, as defined by the Nevada Coordinate System.

7. Access to the ESF site pad from the east shall be controlled by a chain-link fence and gates.

8. Existing roads, utilities, and structures shall be incorporated into the ESF if this incorporation can be shown to be cost effective.

9. The area within the site boundaries shall be cleared of unusable roads, utilities, and structures that interfere with the ESF.

10. The designs for site preparation shall ensure that construction activities disturb only the minimum amount of land necessary to accomplish the project.

11. Topsoil shall be stored in an environmentally acceptable manner.

12. The ESF shall be designed to operate on a 3-shift-per-day, 7-days-per- week schedule throughout both the ESF construction and operation phases.

13. Lighting in operations areas shall support security requirements.

14. The design shall include considerations for site restoration.

Assumptions

1. Surface characteristics such as topography, meteorological conditions, and flood potential are important factors in the process of designing surface facilities. It is incumbent upon the designers to include these factors during the design process.

2. All necessary civil work to support the site systems, subsystems, and components will be completed in order to meet the schedule of approved in situ site characterization activities.

3. The natural terrain will provide a barrier to vehicle access from elsewhere on the site.

1.2.6.1.1 MAIN PAD

Definition of Subsystem Elements

The main pad consists of the structures, systems, and components defined by the area prepared to accommodate shaft collars, headframes, hoist systems, substations, offices, laboratories, warehouse, contractor's temporary facilities, as well as other normal facilities such as parking space.

Functional Requirements

The main pad shall provide an area of adequate size and shape to support all anticipated structures, systems, and components that will be located near the shafts. This includes the following items:

1. Roads (muck haulage and access)
2. ES-1 (plus standoff distances)
3. ES-2 (plus standoff distances)
4. Permanent hoist house(s) (plus standoff distances)
5. Headframes and back legs
6. Muck handling facilities
7. First aid
8. Shop (plus equipment storage)
9. Deleted
10. Substation (69 kV)
11. Compressor(s)
12. Ventilation fans (plus standoff distances)
13. Standby generator(s) (plus fuel tanks)
14. Utilities (power, water, sewage, communications)
15. Change house(s)
16. Subcontractor facilities (offices, change house, shop)
17. Trailers and parking
18. Integrated data acquisition system/communications building

Performance Criteria

1. The main pad shall be designed to handle potential runoff in the existing natural drainage channels from a probable maximum flood.

2. Site preparation for the shaft collars shall be designed and constructed for a maintainable 100-year life.

Constraints

1. The main pad shall facilitate the safe and efficient flow of material and personnel within the ESF site.

2. Buildings shall be so spaced as to allow sufficient room for construction and maintenance of the facilities.

Assumptions

1. The graded area for the ESF site does not need to be contiguous or even on a single level if such an arrangement is cost effective (considering construction, operation, and maintenance) or provides for efficient operations.

1.2.6.1.2 AUXILIARY PADS

Definition of Subsystem Elements

The auxiliary pads consist of the areas prepared to support the ESF construction and operation. These pads include the G-4 laydown pad, explosives magazine pad, muck storage pad, topsoil storage pad, batch plant pad, water tank pad, lower storage pads, and other areas defined as the design progresses.

Functional Requirements

The auxiliary pads shall provide areas of adequate size and shape to support all anticipated functions. This includes the following:

1. Parking
2. Utilities (power, water, sewage, communications)
3. Materials storage
4. Storage and equipment (subcontractor and REECo)
5. Fuel and lubricants storage/tank
6. Explosive storage plus access roads
7. Batch plant
8. Borrow pit
9. Water tank and access
10. Muck storage
11. Stock pile of topsoil
12. Sewage disposal
13. Mine wastewater disposal
14. Booster pump station
15. Warehouse (plus storage area)

Performance Criteria

1. All auxiliary pads shall be designed to handle potential runoff of a 100 year storm unless otherwise specified. The following pads shall be designed to the runoff potential shown.

Batch Plant Pad	10 year storm
Lower Storage Pads	10 year storm
G-4 Pad	25 year storm
Booster Pump Bldg. Pad	50 year storm

2. Drainage ponds and muck storage pile liners shall be designed and constructed for a maintainable 25-year life. All other civil improvements for auxiliary pads shall be designed and constructed for a maintainable 5-year life.

Constraints

1. The auxiliary pads shall facilitate the safe and efficient flow of material and personnel within and around their respective areas.

2. The muck storage pad design shall ensure that the capacity includes allowances for excavation overbreak and swell of broken rock.

3. The location and size of the explosives storage area shall be determined by the current California and Mine Health and Safety Administration (MSHA) regulations and the MSHA table of distances.

4. The auxiliary pad design and construction shall ensure considerations for expansion (uncertainty allowance).

Assumptions

1. The graded areas for the auxiliary pad(s) do not need to be contiguous or even on a single level if such an arrangement is cost effective (considering construction, operation, and maintenance) or provides for efficient operations.

1.2.6.2 UTILITIES

Subparts are:

1.2.6.2.1 Power systems
1.2.6.2.2 Water Systems
1.2.6.2.3 Sewage Systems
1.2.6.2.4 Communication System
1.2.6.2.5 Mine Wastewater System
1.2.6.2.6 Compressed Air System

Definition of Subsystem Elements

The utilities systems, subsystems, structures, and components include provisions for power, water, sewage, communications, mine wastewater, and compressed air.

Applicable Regulations, Codes, and Specifications

The power systems shall be designed in accordance with the following:

Electrical Power

1. Draft DOE 6430.1A dated 12/25/87 Division 16 Electrical
2. ANSI NFPA-70
3. ANSI C-2

Lighting

1. Draft DOE 6430.1A dated 12/25/87, Division 16, Electrical

Stand-by Power

1. Draft DOE 6430.1A dated 12/25/87 Division 16 Electrical

Uninterruptible Power

1. Draft DOE 6430.1A dated 12/25/87 Division 16 Electrical
2. IEEE-485
3. IEEE-650

The water systems shall be designed in accordance with the following:

1. Draft DOE 6430.1A dated 12/25/87 Division 2 Site and Civil Engineering and Division 15, Mechanical
2. Nevada Revised Statutes, Chapter 445, paragraphs .121 through .139
3. NEPA 20.22, 24

The sewage systems shall be designed in accordance with the following:

1. Draft DOE 6430.1A dated 12 25 87 Division 2, Site and Civil Engineering
2. Nevada Revised Statutes, Chapter 445, paragraph .121 through .139

The communications system design shall be in accordance with the following:

1. Draft DOE 6430.1A dated 12/25/87 Division 16 Electrical

The mine wastewater system shall be designed in accordance with the following:

1. 30 CFR, Chapter 1
2. Nevada mining law and California mine and tunnel safety orders
3. Nevada Revised Statutes, Chapter 445
4. DOE order 5480.1A

The compressed air system shall be designed in accordance with the following:

1. Draft DOE 6430.1A dated 12/25/87 Division 2 Site and Civil Engineering
2. 30 CFR, Chapter 1
3. Nevada mining law
4. California mine and tunnel safety orders

In addition, see Section 1.2.6.0, Applicable Regulations, Codes, and Specifications.

Functional Requirements

1. The utility systems, subsystems, and facilities shall provide electrical power, water, sewer, mine wastewater disposal, telephone, communications, compressed air, and area lighting to the ESF adequate to support construction and operation of the shafts, underground workings, and the ESF testing program during site characterization.

Performance Criteria

1. The utility services, such as power, water, and communications, shall have the capability of meeting ESF needs and be constructed and made available to meet all of the requirements for construction and operation of the ESF.

2. Utilities such as electric power, compressed air, and water systems shall be provided to underground construction, operations, and in situ site characterization areas. When installed, these systems shall not restrict foot, vehicular, or shaft conveyance traffic; obstruct ventilation; or cause health and safety concerns.

Interface Control Requirements

1. The A/E must recognize that interfaces with Central Telephone Company of Nevada for communications and the Nevada Test Site (NTS) for utility supply will be required. Also see Section 1.2.6.0, Interface Control Requirements.

Constraints

1. The offsite utilities shall be considered as extending from the closest tie-in point off the ESF site to its designated point on the ESF site.

Assumptions

1. Solid refuse will be hauled to an existing landfill on the NTS.

1.2.6.2.1 POWER SYSTEMS

Definition of Subsystem Elements

The power systems are defined as those systems, subsystems, components, and structures that supply electrical power to the ESF site. These systems include, but are not limited to, the ESF site substation, extension of the existing 69-kV overhead power line, a secondary power line (to the booster pump station), surface lighting, a stand-by power generation system, and an uninterruptable power system (UPS).

Functional Requirements

Electrical power systems shall provide all of the necessary power, during both normal and peak demands, for the construction and operation of the ESF.

Standby power systems shall provide all of the necessary power to systems and subsystems that have been identified as required to operate in the event of a power outage based on safety, operational, or security requirements, for the construction and operation of the ESF.

The UPS shall provide all of the necessary power to systems and subsystems that cannot tolerate a loss of power incident.

Performance Criteria

1. The UPS, consisting of standby batteries and inverter, shall ensure continuity of power to the Integrated Data System (IDS), safety instruments and controls, and communications that cannot tolerate a power interruption.

2. Power distribution for the ESF, including the primary and secondary substations, transmission lines, and feeder cables, shall be adequately designed, with sufficient redundancy to meet load requirements at points of usage throughout the operations areas. Suitable switching and protective devices shall be provided in the electrical system to prevent damage to the equipment in case of power failure or faults. Sufficient metering shall be provided to establish the demand and consumption of power. Adequate primary surge protection and a well-engineered separate "safety" grounding system shall be provided in order to maximize personnel and equipment safety.

3. A 69-kV overhead power line shall be designed to be routed from the existing 69-kV line (at the NTS boundary) to a main substation at the ESF site to accommodate all of the anticipated electrical loads during the construction and operation of the ESF. In addition, the main substation at the ESF site shall be designed to accommodate all of the anticipated electrical loads during the construction and operations of the ESF.

4. The power distribution system shall provide adequate services from the main ESF substation to the surface and subsurface facilities.

5. The surface facilities power distribution system shall include the appropriate services to surface-mounted equipment. Surface-mounted equipment (permanent and temporary) includes, but is not limited to:

   a. Hoists and controls
   b. Air compressor(s)
   c. Ventilation fans
   d. Communication equipment, as required
   e. Main water supply pump(s)
   f. Shaft-work-deck winches and miscellaneous motors
   g. Trailers
   h. Shops
   i. Lights

6. The electrical system shall be designed to withstand windblown dust and other natural phenomena.

7. The subsurface facilities power distribution system shall be defined in Section 1.2.6.7.1.

8. The standby power system shall provide standby power for safety and security lighting.

9. The standby power system shall include generators, fuel tanks, transfer switches, necessary fuel piping, conduit and wire, cutouts, concrete work, and weatherproof enclosures. The generators shall have sufficient output to provide power for the hoists (to allow for evacuation of all underground personnel within the time allowed), ventilation, area lighting, and surface computer equipment that would be damaged by a power failure. The allowable delay time between the loss of primary power and the availability of standby power will be dictated by safety considerations of the mining operation.

10. Standby generators shall be installed and have the capability to support the hoisting systems when the hoist(s) become operational.

Constraints

1. The normal supply of electrical power shall be provided by a substation to be constructed at the ESF site. Power for this substation shall be supplied from an existing 69-kV overhead power line extending from Canyon Substation in Jackass Flats to the NTS boundary 6.2 miles away.

2. The design of the electrical system shall include the modifications that are required to accommodate the tie-in of the proposed 69-kV transmission line between the Canyon Substation and the main substation to be located at the ESF site.

3. The design shall incorporate existing NNWSI Project transformers and switch gear as much as practicable.

4. A power supply shall be available as soon as possible but no later than the start of shaft construction.

Assumptions

None.

1.2.6.3 SURFACE FACILITIES

Subparts are:

1.2.6.3.1 Ventilation System
1.2.6.3.2 Test Support Facilities
1.2.6.3.3 Trailer Spaces
1.2.6.3.4 Parking Areas
1.2.6.3.5 Materials Storage Facilities
1.2.6.3.6 Shop
1.2.6.3.7 Warehouse
1.2.6.3.8 Trailers
1.2.6.3.9 A&E Building (Area 25)
1.2.6.3.10 Communications/Data Building

Definition of Subsystem Elements

The surface facilities system and subsystem includes all the facilities, systems, and services for the surface buildings and trailers that are required for the support of ESF operations and in situ site characterization.

Applicable Regulations, Codes, and Specifications

The designs shall be in accordance with:

1. Draft DOE 6430.1A, dated December 25, 1987, except for Seismic Requirements, 0111-2.7, Earthquake Loads.

In addition, see Section 1.2.6.0, Applicable Regulations, Codes, and Specifications.

Functional Requirements

1. Provide buildings and supporting equipment for the following functions:

   a. Ventilation system
   b. Test support facilities
      1) Test apparatus assembly pad
   c. Trailer spaces
   d. Parking areas
      1) Surface mobile equipment
      2) Personnel parking
      3) Visitor parking
   e. Materials storage facilities
   f. Shop
   g. Warehouse

3) Visitor parking
e. Materials storage facilities
f. Shop
g. Warehouse
h. Trailers
1) Offices for Principal Investigators (PIs)
2) Offices for site security
3) Offices for site operations staff
4) Offices for site administration and training
5) Offices for Quality Assurance
6) Offices for support of shaft and facility construction
7) Laboratories, etc.
8) Change trailers
9) First aid trailer
10) Test support trailer
11) NRC and State offices
i. A&E building (Area 25)
1) DELETED
2) DELETED
3) DELETED
4) DELETED
5) DELETED
6) DELETED
7) DELETED
8) DELETED
9) DELETED
j. Communications and data building
1) Computer/control system
2) Data acquisition (IDS)
3) Communications equipment

2. Provide air quality monitoring.

3. Provide water quality monitoring (including the physical, chemical, and biological characteristics of ESF wastewater, the receiving water body, and any other water bodies that could be affected by ESF operations).

4. Provide dust control and/or collection facilities.

5. Provide for the detection of and protection from fires and explosions.

6. Provide onsite transportation facilities for equipment, materials, and rock.

Performance Criteria

1. The surface facilities shall meet the operational requirements of the users.

2. The surface facilities shall be designed and constructed for a nominal 5-year life, unless otherwise noted.

3. The surface facilities and their locations shall (a) facilitate the flow of material and personnel within the ESF site and (b) provide adequate ESF site security, including controlled access and emergency response.

4. The facilities shall be complete with Heating Ventilation and Air Conditioning (HVAC), compressed air, plumbing and sanitary facilities, lighting, communications, and fire protection systems, as appropriate for the intended use.

5. Surface facilities shall combine functions when the combinations are cost effective.

6. The surface facilities shall be located away from potential dust generating areas to the extent practicable.

Interface Control Requirements

See Section 1.2.6.0, Interface Control Requirements.

Constraints

1. The general layout of the surface facilities shall be designed to minimize disturbance to the existing area.

2. To the extent practicable and economical, modular, relocatable, or portable structures shall be considered for surface facilities.

3. To the extent practicable and consistent with procurement regulations, consideration of surplus government equipment shall be given to fulfill the requirements for the surface facilities and equipment.

4. Each inhabited structure shall have rest rooms, water heating, space heating, and air conditioning, as required for the intended use.

Assumptions

None.

1.2.6.3.7 WAREHOUSE

Definition of Subsystem Elements

The warehouse shall include all the facilities, systems, and services for the safe storage and dispensing of materials within the ESF.

Functional Requirements

Provide facilities for general warehousing in support of the ESF construction and operations.

Performance Criteria

1. The warehouse shall meet the operational requirements of the users.
2. Space and equipment shall support the functions of purchasing, storing, and dispensing equipment and materials, and shall be sized to accommodate the inventory needed for ESF operations and in situ site characterization.
3. Storage of critical components shall be under controlled access.
4. The warehouse shall provide a chemical storage area.

Constraints

1. The warehouse will be designed and constructed as a prefabricated metal building.
2. The warehouse shall contain a rest room and offices.
3. The warehouse shall be insulated and heated. In addition, the office areas and rest rooms shall be air conditioned.

Assumptions

(deleted)

1.2.6.3.8 TEMPORARY FACILITIES

Definition of Subsystem Elements

The temporary facilities are defined by the facilities, systems, and services that will be utilized for the offices, change rooms, first aid, and test support required to support ESF construction, operations, and maintenance personnel for the site characterization program.

Functional Requirements

1. Temporary facilities may be provided for office spaces.
2. Temporary facilities may be provided for change rooms of sufficient size to provide all necessary personnel a place to change clothes.
3. A temporary facility may be provided for the first aid center.
4. Temporary facilities may be provided for test support functions.

Performance Criteria

1. The first aid facility shall provide at least 200 square feet for the first aid facility, plus 50 square feet for storage.

Constraints

1. Office spaces shall be based on a minimum of 100 square feet per office.
2. Overhead baskets and locker facilities in the change room facility shall be sized to accommodate the ESF underground personnel for both operations and underground testing.

Assumptions

1. The government-owned change facility may satisfy the requirements for the change room trailers.

1.2.6.3.9 A&E BUILDING (AREA 25)

Section Deleted

1.2.6.4 FIRST SHAFT

Subparts are:

1.2.6.4.1 Collar
1.2.6.4.2 Lining
1.2.6.4.3 Stations
1.2.6.4.4 Furnishings
1.2.6.4.5 Hoist System
1.2.6.4.6 Sump

Definition of Subsystem Elements

The first shaft system is defined by the vertical engineered openings, within an 11-foot radius of the shaft centerline, that connect the surface with the targeted horizons, provide safe and controlled access to the targeted horizons for personnel, equipment, underground service systems, and includes the materials required for development of the underground drifts and excavations, as well as underground testing operations.

Applicable Regulations, Codes, and Specifications

See Section 1.2.6.0, Applicable Regulations, Codes, and Specifications.

Functional Requirements

1. Provide safe access between the ESF surface and the underground portion of the ESF to meet the needs of underground site characterization testing (at two levels). The flexibility to sink shafts in Calico Hills will be maintained.

2. Provide for testing in the shaft as required.

3. Provide for water drainage and/or control in the shaft.

4. Provide means for emergency egress.

Performance Criteria

1. The shaft shall be designed and constructed such that it meets the requirements of personnel, equipment, materials, utilities, excavated rock, and ventilation.

2. Permanent shaft structures, systems, and components shall be designed and constructed for a maintainable 100-year design life.

3. Structures, systems, and components shall be provided for effective water and ground control.

4. Muck handling systems shall be sized and designed for operation and in-situ site characterization needs and shall minimize the spillage of rock during rock handling. This system shall provide capabilities for gathering and cleaning out rock spillage from the shaft bottom.

5. The location of openings for rock handling shall be selected to minimize effects on the integrity of any other openings.

6. Appropriate gravity drainage and/or pumping systems shall be incorporated into the shaft for draining water away from testing and other working areas to suitable collection point(s) for further treatment and/or disposal.

7. The shaft and its drainage systems shall control standing water and air/water contact surfaces where ventilation air will be flowing through in order to control the humidity in the air and to maintain the quality of the ventilation air being supplied.

8. The size and shape of the shaft shall be adequate to supply and exhaust the required volumes of air for underground construction, operation, and in situ site characterization.

9. The size and depth of the shaft shall be sufficient for in situ site characterization needs in terms of testing, personnel, materials, equipment, utilities, and schedule.

10. The size and layout of the shaft shall be adequate for in-situ site characterization needs and capable of supporting the excavation allowances determined under General Exploratory Shaft Facility requirements, Section 1.2.6.0, Performance Criteria item #2.

11. Shaft design and construction shall provide for ESF design and construction testing, performance confirmation, and in situ site characterization testing to the extent necessary.

12. Necessary shaft facilities and equipment required for handling excavated rock, materials, equipment, and supplies shall support construction, operations, and in situ site characterization testing.

13. Water handling and control in the shaft shall be sized for credible water inflows.

14. Support facilities, utilities, and equipment shall be designed and constructed to accommodate conventional shaft sinking techniques (i.e., drill and blast).

15. Shaft instrumentation will be protected from physical damage.

16. The shaft shall be excavated and structurally lined using methods and materials based upon conventional shaft construction technology for the shaft diameter and depth under consideration.

17. Functional requirements of the shafts may be assigned to either of the shafts.

Interface Control Requirements

See Section 1.2.6.0, Interface Control Requirements.

Constraints

1. The shaft and its furnishings shall be designed to minimize air resistance to the extent practicable.
2. Techniques used for shaft excavation shall control overbreak of rock and minimize disturbance to the integrity of the adjoining rock mass.
3. The shaft will be designed to provide stability and to minimize the potential for deleterious rock movement or fracturing that may create a pathway for radionuclide migration.
4. The use of blasting agents, explosives, and water shall be controlled so that in situ site characterization is not adversely affected.
5. Rock support and other structural anchoring materials shall be compatible with waste isolation and shall neither interfere with radionuclide containment nor enhance radionuclide migration.
6. Ventilation air velocities in the shaft shall not exceed 2,000 feet per minute.
7. Ventilation capacity, shaft design, and air velocities in the shaft shall be optimized with respect to the NNWSI Project objectives.
8. The predicted thermal and thermomechanical response of the host rock and surrounding strata and groundwater system shall be designed to withstand the anticipated effects.
9. The centerline coordinate location of ES-1 (science shaft) shall be N766,255, E563,630 as defined by the Nevada Coordinate System.
10. The shaft shall be connected with ES-2 (second shaft) prior to full-scale in situ testing on the Main Test Level (1020 level).
11. Utility lines, shaft steel, etc., shall be designed such that the underground electrical grounding system is electrically bonded to the surface electrical "safety" grounding system.
12. The shaft shall be designed and constructed such that its nominal finished inside diameter is 12 feet.
13. Shaft permanent structures shall be designed and constructed to withstand the effects of the seismic events as defined in the RIB.

Assumptions

None.

1.2.6.4.5 HOIST SYSTEM

Definition of Subsystem Elements

The Hoist system is defined as those systems and components for the transportation of personnel and equipment between the surface and subsurface to meet the needs of ESF shaft sinking, construction, and underground site characterization testing. The hoist system includes the structural steel members used to support the hoisting conveyance, the headframes, and the hoist house.

The hoist house is defined as those facilities to accommodate one hoist operator and the necessary equipment and instrumentation for the hoist, air compressor system, control room, electrical and motor control centers, and an area for repairs and lay down.

Functional Requirements

The hoist system shall provide for the transport and support of personnel, materials, and construction equipment, and serve as the emergency egress from the underground during shaft sinking, ESF construction (mining operations), and underground testing.

Performance Criteria

1. The ESF hoisting system capacities shall be consistent with the requirements of ESF construction, operation, and underground site characterization needs.
2. The hoisting conveyance shall be designed to permit the inspection of shaft performance monitoring instrumentation, as well as other shaft inspection and maintenance activities.
3. The conveyance system shall consist of a cage and sinking bucket in an out-of-balance arrangement operated by a ground-mounted hoist.
4. The cage shall be designed to act as a crosshead for the sinking bucket.
5. The hoist shall be designed with a separate and independent power distribution system.
6. The hoisting systems shall have a rated capacity sufficient for emergency egress.

7. Headframe shall elevate the hoist sheaves sufficiently above the collar level to provide room for normal conveyance unloading and over-travel allowances.

8. A hoist foundation shall be provided to accommodate the hoist dimensions and mounting details, independent of the hoist house foundation.

9. The hoist house control and operator's room shall be complete with a heating and air conditioning system.

10. The headframe shall provide sufficient facilities for dumping buckets during shaft construction.

11. The headframe shall be designed and constructed to serve subsurface construction and underground test operations.

12. Clearances in the headframe directly above the collar shall be designed to accommodate the rigging of all anticipated underground equipment.

13. The hoisting systems shall be designed and constructed for the evacuation of all underground personnel to safety within one hour.

14. Area flood lighting and lightning protection shall be provided atop the shaft headframe.

Constraints

1. The hoisting system shall be designed to have all necessary safety features.

2. The hoist shall be designed to accommodate the uncertainty allowance (see Section 1.2.6.0, Performance Criteria item =2.)

Assumptions

1. DELETED

2. The existing GFE 900 HP hoist shall be used for shaft sinking and ESF construction and operation activities.

1.2.6.5 SECOND SHAFT

Subparts are:

1.2.6.5.1	Collar
1.2.6.5.2	Lining
1.2.6.5.3	Station
1.2.6.5.4	Furnishings
1.2.6.5.5	Hoist System
1.2.6.5.6	Sump

Definition of Subsystem Elements

The second shaft system is defined by those systems, subsystems, and components that are comprised of vertical engineered openings, within 11 feet of the shaft centerline, that connects the surface with the targeted repository horizon. The system provides safe and controlled access to the targeted repository horizon for personnel, equipment, underground service systems, and materials required for development of the underground drifts and excavations, as well as underground testing operations. The second shaft will serve as the primary muck hoisting shaft for test area development.

Applicable Regulations, Codes, and Specifications

See Section 1.2.6.0, Applicable Regulations, Codes, and Specifications.

Functional Requirements

1. Provide safe access between the ESF surface and the candidate repository horizon to meet the needs of site characterization testing, emergency egress, ventilation intake and exhaust, major muck handling, and primary transport of heavy equipment.

2. Provide for water drainage and/or control in the shaft.

3. Provide for testing in the shaft as required.

Performance Criteria

1. The shaft shall be designed and constructed such that it meets the emergency egress, ventilation, mining and testing requirements.

2. Permanent shaft structures, systems, and components shall be designed and constructed for a maintinable 100-year design life.

3. The shaft shall serve as the primary rock hoisting and construction support shaft.

4. Muck handling systems shall be sized and designed for ESF operations and in situ site characterization needs and shall minimize the spillage of rock during rock handling. This system shall provide capabilities for gathering and cleaning out rock spillage from the shaft bottom.

5. Structures, systems, and components shall be provided for effective water and ground control.

6. Appropriate gravity drainage and/or pumping systems shall be incorporated into the shaft for draining water away from testing and other working areas to suitable collection point(s) for further treatment and/or disposal.

7. The shaft and its drainage systems shall control standing water and air/water contact surfaces where ventilation air will be flowing through in order to control the humidity in the air and to maintain the quality of the ventilation air being supplied.

8. The size and shape of the shaft shall be adequate to supply and exhaust the required volumes of air for underground construction, operation, and in situ site characterization.

9. The shaft and its furnishings shall be designed to minimize air resistance to the extent practicable.

10. The size and depth of the shaft shall be sufficient for in-situ site characterization needs in terms of testing, personnel, materials, equipment, utilities, and schedule.

11. The size and layout of the shaft shall be adequate for in-situ site characterization needs and capable of supporting the excavation allowances determined under General Exploratory Shaft Facility requirements Section 1.2.6.0, Performance Criteria 2.

12. Shaft design and construction shall provide for ESF design and construction testing, performance confirmation, and in situ site characterization testing to the extent necessary.

13. Shaft design and construction shall provide for ESF design and construction testing, performance confirmation, and in situ site characterization testing to the extent necessary.

14. Necessary shaft facilities and equipment required for handling excavated rock, materials, equipment, and supplies shall support construction, operations, and in situ site characterization testing.

15. Water handling and control in the shaft shall be sized for credible water inflows.

16. Support facilities, utilities, and equipment shall be designed and constructed to accommodate conventional shaft sinking techniques (i.e., drill and blast).

17. The shaft shall be excavated and structurally lined using methods and materials based upon conventional shaft construction technology for the shaft diameter and depth under consideration.

Interface Control Requirements

See Section 1.2.6.0, Interface Control Requirements.

Constraints

1. The functional requirements of the shafts may be assigned to either of the shafts.
2. Techniques used for shaft excavation shall control overbreak of rock and minimize disturbance to the integrity of the adjoining rock mass.
3. The shaft will be designed to provide stability and to minimize the potential for deleterious rock movement or fracturing that may create a pathway for radionuclide migration.
4. The use of blasting agents, explosives and water shall be controlled so that in situ site characterization is not adversely affected.
5. Rock support and other structural anchoring materials shall be compatible with waste isolation and shall neither interfere with radionuclide containment nor enhance radionuclide migration.
6. Ventilation air velocities in the shaft shall not exceed 2,000 feet per minute.
7. Ventilation capacity, shaft design, and air velocities in the shaft shall be optimized with respect to the NNWSI Project objectives.
8. The predicted thermal and thermomechanical response of the host rock and surrounding strata and groundwater system shall be considered in the ESF design as defined in the RIB. Phased construction techniques shall be employed to accommodate post-construction thermal stresses.
9. The shaft shall be designed and constructed such that its nominal finished diameter is 12 feet.
10. The centerline coordinate location of the ES-2 (second shaft), in the Nevada Coordinate System, shall be N766,337; E 563,918.
11. The shaft shall be connected with ES-1 (science shaft) prior to full-scale in situ testing on the Main Test Level (1020-level).
12. The location of openings for rock handling shall be selected to minimize effects on the integrity of any other openings.
13. Utility lines, shaft steel, etc., shall be designed such that the the underground electrical grounding system is electrically bonded to the surface electrical "safety" grounding system."
14. Shaft permanent structures shall be designed and constructed to accommadate seismic events as defined in the RIB.

Assumptions

None.

1.2.6.6 UNDERGROUND EXCAVATIONS

Subparts are:

1.2.6.6.1 Operations Support Areas
1.2.6.6.2 Test Areas

Definition of Subsystem Elements

The underground excavations are defined as those underground openings 5 feet beyond the shaft liner that extend away from the shaft stations and which comprise the excavations at the proposed test levels and the preferred repository horizon, based on the needs for underground site characterization.

Functional Requirements

1. Provide underground openings in welded and nonwelded tuff for in situ site characterization construction, operations, and maintenance.

2. Provide compatibility with the repository conceptual design so that the test level development does not adversely impact future repository development.

3. Provide the specific excavation required for shaft stations, muck storage, refuge chambers, power centers, shop and storage areas, fueling, sanitation, ventilation, utilities, drifts, test levels, test rooms and alcoves, communications, IDS, service, special function, and other areas as determined by the in situ site characterization program.

4. Provide a system for removing excavated rock to the shaft.

Performance Criteria

1. Underground openings shall be designed and constructed to minimize impacts on underground site characterization.

2. Underground openings within the Topopah Spring welded and non-welded tuff shall be designed and constructed to meet testing, personnel, equipment, utility, and ventilation requirements.

3. Underground openings within the Topopah Spring unit shall be designed to provide stability and to minimize the potential for deleterious rock movement or fracturing that may create a pathway for radionuclide migration.

4. Rock support and other structural anchoring materials used in rock support systems shall be compatible with waste isolation operations and shall neither interfere with radionuclide containment nor enhance radionuclide migration.

5. The design of underground openings and their supports shall utilize pillar and opening geometries that limit stress concentration to acceptable levels.

6. The size, shape, excavation and support of underground openings shall be adequate to meet transfer requirements for excavated rock, personnel, equipment, ventilation, utilities and the underground test plan.

7. A station landing and test drifts will be constructed as part of the ES-1 shaft at the Upper Demonstration Breakout Room. The flexibility to drift in the Calico Hills will be maintained.

8. Underground openings shall be designed to minimize air resistance to the extent practicable.

9. Underground excavated areas shall be designed for safe and maintainable ground support and control where required.

10. The test level development will be accomplished by conventional mining (drill, blast, muck).

11. Full face, blast hole drilling will be accomplished by using a multi-boom drill jumbo.

12. The testing requirements outlined in Appendix B will serve as the basis for the test level development.

13. Dry air coring will be required for some tests.

14. Permanent (as defined in Section 1.2.6.0, Functional Requirements item =2.) ESF structures, systems, and components shall be designed and constructed with a 100-year maintainable life.

15. Nonpermanent underground facilities shall be designed and constructed with a maintainable 5-year life.

16. Instrument cables shall be separated from power cables in drifts to minimize electrical interference. Instrument and IDS cables shall be contained in overhead runs to protect them from damage.

17. The size and layout of the openings excavated on the test levels shall be adequate for in situ site characterization needs and capable of supporting additional excavation beyond the initially planned test areas (see Section 1.2.6.0, Performance Criteria item #2.).

18. Appropriate gravity drainage and/or pumping systems shall be incorporated in underground openings for draining water away from testing and other working areas to suitable collection point(s) for further treatment and/or disposal.

19. During in situ site characterization testing, facilities shall be provided for at least 10 visitors underground at any one time.

20. The maintenance, refueling, and equipment storage areas shall be designed and located to minimize the fire and safety risks.

21. A refuge chamber(s) shall be provided with sufficient capacity and facilities to accommodate personnel underground.

22. The equipment and facilities required for excavating and handling rock shall meet the needs of construction and testing activities and shall be capable of supporting the uncertainty allowance (see Section 1.2.6.0. Performance Criteria item #2.).

23. Excavation techniques shall control overbreak of rock and minimize disturbance to the integrity of the adjoining rock mass.

24. The chemical content of the blasting agents and explosives shall be controlled to preclude adverse effects on in situ site characterization.

Constraints

1. The underground test and operations support areas shall be parallel to the dip of the tuff stratigraphy to the extent practicable and safe.

2. The proposed Main Test Level floor within the Topopah Spring Member at the first shaft will be defined as the 1020 level.

3. The ventilation system shall be designed to provide an air cooling power greater than or equal to 400 watts per square meter.

4. Targets to be utilized in the design and construction of the underground drifts can be found on Sketch Number 5, Appendix A.

Assumptions

1. Mucking will be accomplished by using rubber-tired, diesel-powered equipment.

2. Groundwater inflow will not be an adverse factor during mining operations.

3. The use of water in the development of underground openings shall be minimized to the extent practicable.

1.2.6.6.2 TEST AREAS

Definition of Subsystem Elements

The test areas are defined as those openings excavated in ES-1 (science shaft) at the Upper Demonstration Breakout Room and the Main Test Level for conducting underground site characterization tests at the potential repository horizon and other geologic horizons.

Functional Requirements

The test areas shall provide excavated space of adequate size and appropriate opening geometry to conduct the necessary underground site characterization test activities.

Performance Criteria

1. The number and the size of openings shall satisfy underground testing needs in terms of personnel, materials, equipment, and utilities as found in the Underground Test Requirements in Appendix B.

2. ESF structures, systems, components, and operations must accommodate additional tests and monitoring if required (see Section 1.2.6.0, Performance Criteria item =2.).

3. Underground test areas shall have a minimum excavation width of 14 feet and a minimum height of 12 feet.

Constraints

1. Test areas shall be separated so they are not affected by the excavation disturbed zone, geotechnical edge effects, thermal, mechanical, chemical, and hydrological interactions.

Assumptions

None.

1.2.6.7 UNDERGROUND UTILITY SYSTEMS

Subparts are:-

1.2.6.7.1 Power Distribution System
1.2.6.7.2 Communications System
1.2.6.7.3 Lighting System
1.2.6.7.4 Ventilation System
1.2.6.7.5 Water Distribution System
1.2.6.7.6 Mine Wastewater Collection System
1.2.6.7.7 Compressed Air Distribution System
1.2.6.7.8 Fire Protection System
1.2.6.7.9 Muck Handling Systems
1.2.6.7.10 Sanitary Facilities
1.2.6.7.11 Monitoring and Warning Systems

Definition of Subsystem Elements

The underground utility systems, subsystems, and components include provisions for power, communications, lighting, ventilation, water, mine wastewater, compressed air, fire protection, excavation and muck handling, sanitary, and monitoring and warning systems required to meet the needs of the underground site characterization testing program during construction and operation.

Applicable Codes, Regulations, and Specifications

General

1. 30 CFR Part 57
2. Nevada Mining Law
3. California Mine and Tunnel Safety Orders

Electrical

1. Draft DOE 6430.1A dated 12/25/87 Division 16 Electrical
2. ANSI/NFPA-70
3. ANSI C-2

Lighting

1. Draft DOE 6430.1A dated 12/25/87, Division 16 Electrical

Stand-by power

1. Draft DOE 6430.1A dated 12/25/87, Division 16 Electrical

Uninterruptible power

1. Draft DOE 6430.1A dated 12/25/87, Division 16 Electrical
2. IEEE-485
3. IEEE-650

Water systems

1. Draft DOE 6430.1A dated 12/25/87, Division 2 Site and Civil Engineering and Division 15 Mechanical
2. NRS Chapter 445, paragraphs .121 through .139

Mine wastewater system

1. Draft DOE 6430.1A dated 12/25/87 Division 2 Site and Civil Engineering

Ventilation system and dust control

1. American Institute of Government Hygienists, Industrial Ventilation, Manual of Recommended Practice

In addition, see Section 1.2.6.0, Applicable Codes, Regulations, and Specifications.

Functional Requirements

1. Provide utilities for underground ESF operations, in situ site characterization, and monitoring activities.

2. Provide facilities and equipment for the installation and maintenance of the underground utilities.

3. Provide for the distribution of utilities around the operations area of the Main Test Level in such a manner to allow for flexibility in the siting and construction of the final testing locations.

Performance Criteria

1. The underground utility systems and service facilities shall have suitable utilities, including power, lights, water and compressed air, as required for construction, operations, and in situ site characterization, and shall be capable of supporting the uncertainty allowances as defined in Section 1.2.6.0, Performance Criteria item #2.

2. The utility services shall include minimal backup units for primary power lines, primary pumps, shaft conveyances, primary ventilation fans, and primary communications and testing equipment to allow testing continuity based upon NNWSI Project analysis.

3. Cranes, lifting equipment, and shop machinery shall be consistent with maintenance needs.

Interface Control Requirements

See Section 1.2.6.0, Interface Control Requirements.

Constraints

1. Utility systems (i.e., electric power, air, water, etc.), when installed, shall not restrict foot, vehicular, or shaft conveyance traffic; obstruct ventilation; or cause safety hazards.
2. In the selection of equipment that will require maintenance, consideration shall be given to:
   a. The availability and cost of replacement materials and parts.
   b. The need for equipment manufacturer's technical services.

Assumptions

None.

1.2.6.8 UNDERGROUND TESTS

Subparts are:

Definition of Subsystem Elements

The underground test systems are defined by those activities associated with test equipment installation, test execution, test data recording, and test analysis for in situ site characterization to be performed within the Yucca Mountain ESF.

Applicable Regulations, Codes, and Specifications

The design requirements and criteria for the Integrated Data System (IDS) can be found in the Technical Requirements for the Integrated Data System of the NNWSI Project Exploratory Shaft Facility. See SDRD Volume II, Appendix D, Reference Project Documentation.

See Section 1.2.6.0, for additional Applicable Regulations, Codes, and Specifications.

Functional Requirements

The underground tests shall provide the means for the implementation of site characterization testing plans and provide data to support performance confirmation testing.

Performance Criteria

1. In situ site characterization shall meet applicable requirements of 10 CFR part 60 and 10 CFR part 960.
2. In situ site characterization shall meet the applicable requirements of the Site Characterization Plan (SCP).
3. Testing plans must provide for feedback and modification as a result of initial and ongoing tests and monitored results.

4. Testing instrumentation hardware, cables, computer equipment, and data acquisition and monitoring systems, shall be designed to withstand the expected underground environment.

5. Reports shall contain adequate visual and diagrammatic information to make the conduct, setup, and objectives of all the tests clear to readers outside the NNWSI Project.

6. In situ site characterization shall provide reliable information with specified accuracy and uncertainty as determined by the NNWSI Project.

7. Measurements, tests, and analyses shall be sufficient to determine the performance of the ESF and the effects of ESF construction on in situ site characterization.

8. An uninterruptable power supply system shall be available to ensure continuous operation of equipment and instrumentation related to critical testing as determined by the NNWSI Project through analysis.

9. Written procedures shall be developed for the procurement, construction, installation, maintenance, and operation of testing instruments, and data collection facilities.

10. Performance confirmation testing shall be carried out to meet the requirements of 10 CFR 60, Subpart F.

Constraints

1. Tests shall be designed and located within the facility to ensure that thermal, mechanical, chemical, and hydrological interactions will not endanger the structural stability of the ESF or adversely affect tests conducted in adjacent areas.

2. Testing shall not affect overall site integrity of the Mined Geologic Disposal System as required by 10 CFR 60.112.

3. Testing equipment requirements, including design life, shall be based on the performance goals of the tests.

4. Tests shall be classified according to primary information needs (i.e., site characterization, ESF site characterization, ESF design confirmation, repository design, or performance confirmation) and defined with respect to duration, scale, and space requirements. This classification and definition shall be the basis for equipment design, underground layout, ventilation, personnel, and utility requirements.

5. The ESF shafts shall be connected prior to initiation of full-scale in situ testing.

Interface Control Requirements

See Section 1.2.6.0, Interface Control Requirements.

Assumptions

1. Planned testing and monitoring will be conducted in the ES-1 (science) shaft, the Upper Demonstration Breakout Room and the Main Test Level. The flexibility to drift in the Calico Hills will be maintained.

2. The development of the underground testing program at the ESF has been based upon the qualitative derivation of information needs to satisfactorily address key issues in the Issues Hierarchy. The number of tests may change as site characterization proceeds and more variable or unexpected conditions are encountered. See Section 1.2.6.0, Performance Criteria item #2.

3. The underground utility system at the Main Test Level shall be sufficient to accommodate drifting and testing at any point surrounding the immediate operations area. See Section 1.2.6.7, Underground Utility Systems.

1.2.6.8.5 HYDROLOGIC AND TRANSPORT PHENOMENA TESTS

Definition of Subsystem Elements

The hydrologic and transport phenomena tests are defined as those tests that are required to characterize the hydrologic and transport phenomena of the welded and nonwelded tuff. These properties are an integral part of the information needed to:

1. supplement and complement the surface-based hydrologic information needed to characterize the Yucca Mountain site; and

2. provide information for analyzing fluid flow and the potential for radionuclide transport through unsaturated tuff.

Functional Requirements

Provide the test plans, test data, equipment, and instrumentation to access and record the detailed hydrologic and transport phenomena characteristics of the potential repository site.

Performance Criteria

1. Field and laboratory methods shall be used to measure the rock-matrix hydrologic properties on large-rock samples collected from selected horizons during excavation of the Exploratory Shaft (ES-1).

2. Fluid flow and chemical transport measurements shall be conducted in the laboratory on variably saturated single fractures. Samples will be obtained from the main test level and the breakout levels by bolting perpendicular to a fracture and then overcoring.

3. In situ fluid flow and chemical transport measurements shall be made through fracture networks in variably saturated welded tuff. This test will be an infiltration test performed by trickling tracer-tagged water onto the floor of a specially designed drift.

4. In situ bulk (rockmass) permeability measurements shall be made within bounded rock mass blocks of the Topopah Spring welded unit at the main test level. This test will utilize a test chamber and parallel boreholes.

5. In situ rockmass hydrologic properties measurements shall be made at 12 depth locations in ES-1 using two radial boreholes at each depth drilled perpendicular to the shaft and perpendicular to each other.

6. Measurements shall be made to determine the effect excavating and lining ES-1 will have on the hydrologic properties of the unsaturated welded tuff. The tests will be conducted in vertical boreholes drilled in radial arrangements in the floors of the two breakout rooms and will consist of air-permeability, deformation, and moisture content measurements.

7. DELETED

8. If perched-water zones are encountered during construction of ES-1, then borehole hydrological measurements and geologic characterization shall be conducted to detect the occurrence and estimate the properties of the perched-water zones.

9. Hydrochemistry analysis of the unsaturated zone water shall be made on pore-water samples obtained from bulk rock samples taken from the walls of ES-1 at various horizons and from fracture water samples taken directly from the shaft where inflow is observed.

10. The rate of water movement downward through the unsaturated zone to the water table beneath Yucca Mountain shall be determined by conducting Chlorine-36 tracer measurements of pore or fracture water from blast rubble rock obtained at various depths within ES-1.

11. In situ diffusion test measurements shall be made on nonsorbing tracers in the Topopah Spring welded unit. Tracers will be introduced into boreholes and later overcoring will be conducted to obtain tracer concentrations as a function of distance from the borehole.

Constraints

See Section 1.2.6.8, Constraints.

Assumptions

None.

Pg 2 TOC App B

ESF TEST DESCRIPTION AND REQUIREMENTS

Rev. 6

1. TEST PLAN TITLE (ESTP) INTEGRATED DATA SYSTEM	2. PREVIOUS ISSUE DATE 2/18/88	3. DATE 5/2/88	PAGE 1 of 28
4. KEY ISSUE Provide QA Level I System For Collecting and Archiving ESF Test Data.	5. TEST PLAN NUMBER (WBS) 1.2.6.9.3	6. LOG NUMBER	

7. PRINCIPAL INVESTIGATOR (PI) APPROVAL: Robert J. Crowley	8. TECHNICAL PROJECT OFFICER (TPO) APPROVAL: Donald T. Oakley	9. WASTE MANAGEMENT PROJECT OFFICE (WMPO) STAFF APPROVAL: Lester P. Skousen, Chief Tech. Dev. & Eng. Branch
7a ADDRESS/PHONE Los Alamos Nat'l Lab. P.O. Box 1663, MS G787 Los Alamos, NM 87545 FTS 843-7459	8a ADDRESS/PHONE Los Alamos Nat'l Laboratory P. O. Box 1663, MS J521 Los Alamos, NM 87545 FTS 843-1310	9a ADDRESS/PHONE Waste Management Project Office U.S. Dept. of Energy Box 14100, LV., NV 89114 FTS 544-7929

10. TECHNICAL DESCRIPTIONS

	Attached	Will Be Provided	Deliverable Date
a. Equipment Requirements/specification	☐	☒	* 10/88
b. Equipment Data Sheets	☐	☒	10/88
c. Equipment Catalog Sheets	☐	☒	10/88
d. Installation Requirements & Space Allocation	☒	☐	See Attachments 1 thru 6
e. Operational Requirements & Space Allocation	☐	☒	10/88
f. Maintenance Requirements & Space Allocation	☐	☒	10/88
g. System Interfaces	☐	☒	10/88
h. Utility Interfaces	☐	☒	10/88
i. Utility Requirements	☒	☐	See Attachment 8
j. Deliverables, Milestones, & Schedule	☒	☐	See Attachment 9

* For IDS Phase I only; For Phase II, see attachments 1 thru 7.

11. TEST PACKAGE COSTS

TOTAL ESTIMATE TO DATE	UNCERTAINTY ON ESTIMATE TO COMPLETE
TBD	

12. REFERENCES

Nevada Nuclear Waste Storage Investigations Project, Exploratory Shaft Facility, Integrated Data System Title I, Preliminary Design, March 2, 1988. Prepared by EG&G Energy Measurements, Las Vegas Operations.

REV. NO.	DATE	DESCRIPTION	PI	TPO	WMPO
1	5/3/88				

TEST PLAN TITLE (ESTP)	DATE	Page
INTEGRATED DATA SYSTEM	5/2/88	2 Of 28

13. GENERAL DESCRIPTION OF TEST PLAN

- Provide a Data Acquisition System to collect ESF Site Characterization Data throughout the ES-1 and drift space.
- Provide interfaces to the various equipments used by the Experimenters to allow timely control and data gathering functions.
- To periodically distribute QA Level I data to the Experimenters and to archive all data collected by the IDS in a secure location.

14. SYSTEM INTERFACES

- Data acquisition and calibration to all test sensors.
- Test controllers furnished by SNL, LANL, LLNL, and USGS.
- Communications Systems between the IDS main computer facility, downhole test locations and the testing organizations at Los Alamos, Livermore, Albuquerque and Denver.
- Utility systems in the ES-1 shaft and drift spaces.

ESF TEST DESCRIPTION AND REQUIREMENTS

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TEST PLAN TITLE (ESTP)	DATE	Page
INTEGRATED DATA SYSTEM	5/2/88	3 Of 28

15. SUMMARY OF TEST PLAN ITEMS AND RESPONSIBILITIES

Test Item	Primary Responsibility	Designed by	Procured by	Fabricated by	Date Req.
IDS	LANL	EG&G	EG&G	EG&G	* 4/89
UPS System	LANL	A & E	REECO	VENDOR	* 4/89
Power	LANL	A & E	REECO	REECO	* 4/89
IDS Data Communication	LANL	EG&G	EG&G	EG&G	* 4/89
External IDS Communication	LANL	A & E	REECO	REECO	* 4/89
Telephones & Intercoms	LANL	A & E	REECO	CENTEL	* 4/89
IDS Space	LANL	A & E	REECO	REECO	* 4/89

* IDS Phase I only; For Phase II, see attached schedule.

TEST PLAN TITLE (ESTP) INTEGRATED DATA SYSTEM	DATE 5/2/88	Page 4 Of 28

16. MAXIMUM TEST AREA REQUIRED AND SPACE ALLOCATION

See Attachments 1 thru 7. These sketches are for reference only. Exact dimensions, placement and utility requirement will be provided as the information is developed.

TEST PLAN TITLE (ESTP) INTEGRATED DATA SYSTEM	DATE 5/2/88	Page 5 Of 28

17. TEST DIMENSIONAL OUTLINE

See Attachments 1 thru 7

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18. PLANS, SECTIONS, AND ELEVATIONS

See Attachments 1 thru 7.

TEST PLAN TITLE (ESTP) INTEGRATED DATA SYSTEM	DATE 5/2/88	Page 7 Of 28

19. UTILITY INTERFACES - LIST QUANTITIES, CONSUMPTIONS, INPUTS, OUTPUTS, ETC.

A. AIR NONE

B. WATER Fire sprinkler system at IDS Surface Bldg. and at IDS Data Alcove on main test level. Domestic water at Main Surface Bldg. Fire protection requirements TBD.

C. POWER See attached NNWSI IDS equipment lists. See Attachment 8.

D. VENTILATION Sufficient to remove heat from all spaces containing computer equipment. See Attachment 8.

E. DATA LINK TBD

F. OTHER (SPECIFY) Phones, Intercom

20. DESIGN CONSTRAINTS

The minimum separation between power cabling and signal cabling (of) either twisted shielded pair or coax type) should be 5 ft. if the power wiring is in conduit (not open raceways) and 10 ft. if the power wiring is not in conduit. All crossings of power and signal cabling should be at right angles with the maximum practical separation. Separation of power wiring and fiber optic cabling is not critical with respect to distance.

21. DESIGN ASSUMPTIONS

See approved QALAS for the IDS.

ESF TEST DESCRIPTION AND REQUIREMENTS

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TEST PLAN TITLE (ESTP)	DATE	Page
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22. DELIVERABLES

DESCRIPTION	DELIVER TO	Estimated DATE
TBD		

23. MILESTONES

DESCRIPTION	(Estimated) TARGET DATE	(Estimated) COMPLETION DATE
See Attachment 9.		

ESF TEST DESCRIPTION AND REQUIREMENTS

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TEST PLAN TITLE (ESTP)	21. STATUS DATE	PLAN DATE	Page
INTEGRATED DATA SYSTEM	5/2/88		9 Of 28
24. TEST PLAN NUMBER	23. PRINCIPAL INVESTIGATOR Robert J. Crowley		
25. MILESTONE ACTIVITY DELIVERABLES See Attachment 9	25. CALENDER TIME (Estimated)		

ESF TEST OPERATIONAL DESCRIPTION AND REQUIREMENTS SUMMARY

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TEST PLAN TITLE (ESTP)	DATE	Page
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26. REFERENCE OPERATING PROCEDURE NUMBER AND TITLE	27. DURATION OF TEST
	______ Calendar Days

28. DESCRIPTION OF MEN/CRAFTS REQUIRED TO INSTALL, CHECKOUT, OPERATE AND DISMANTLE TEST

PHASE	CRAFT	NUMBER	DURATION
INSTALL			
CHECKOUT			
OPERATE			
DISMANTLE			

Information TBD

29. TOTAL MANPOWER AND SCHEDULE REQUIREMENTS

PHASE	MAN-DAYS	CALENDAR TIME	DATES
INSTALLATION			
CHECKOUT			
OPERATE			
DISMANTLE			

30. TOTALS

31. DESCRIPTION OF MATERAILS (CONSUMABLES, OPERATING, ETC.) REQUIRED TO CHECK OUT AND PERFORM THE TEST(S).

DESCRIPTION	COST(S)

32. ESTIMATED CONSUMABLE MATERIAL COSTS $ TBD

ESF TEST OPERATIONAL DESCRIPTION AND REQUIREMENTS SUMMARY

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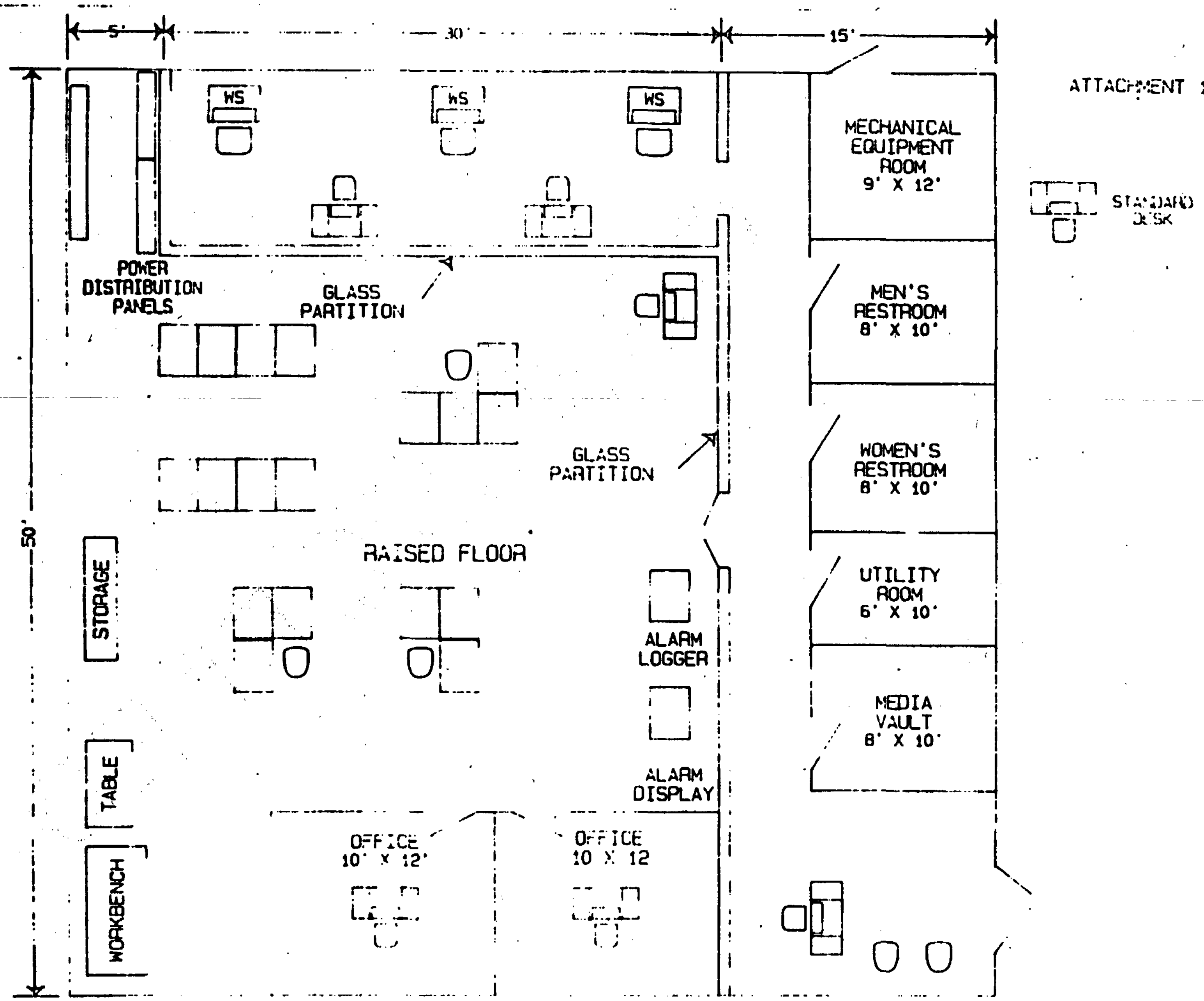
TEST PLAN TITLE (ESTP) INTEGRATED DATA SYSTEM	DATE 5/2/88	Page 11 of 28

33. OPERATIONAL MILESTONE ACTIVITY/ DELIVERABLES	25. CALENDER TIME (Estimated)
See Attached Schedule.	

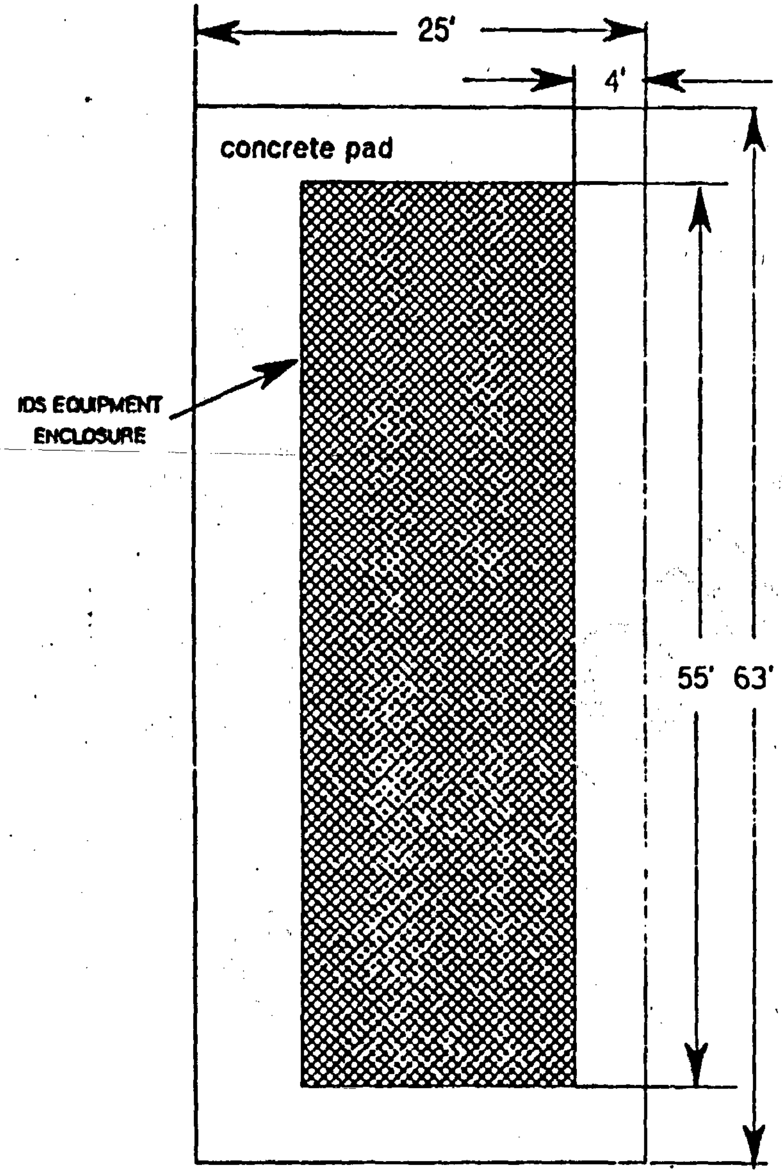
ATTACHMENT 1

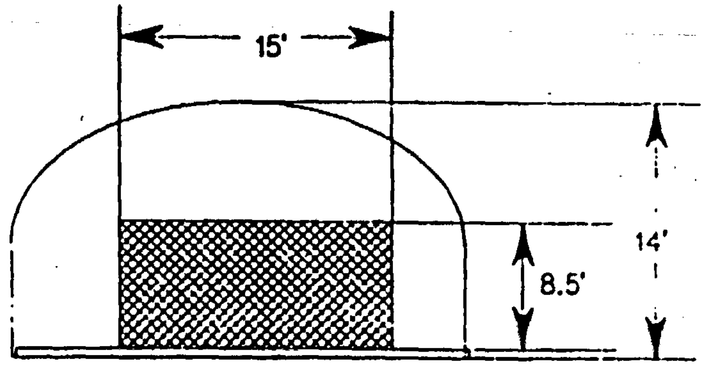


NNWSI PROJECT

IDS SURFACE FACILITY

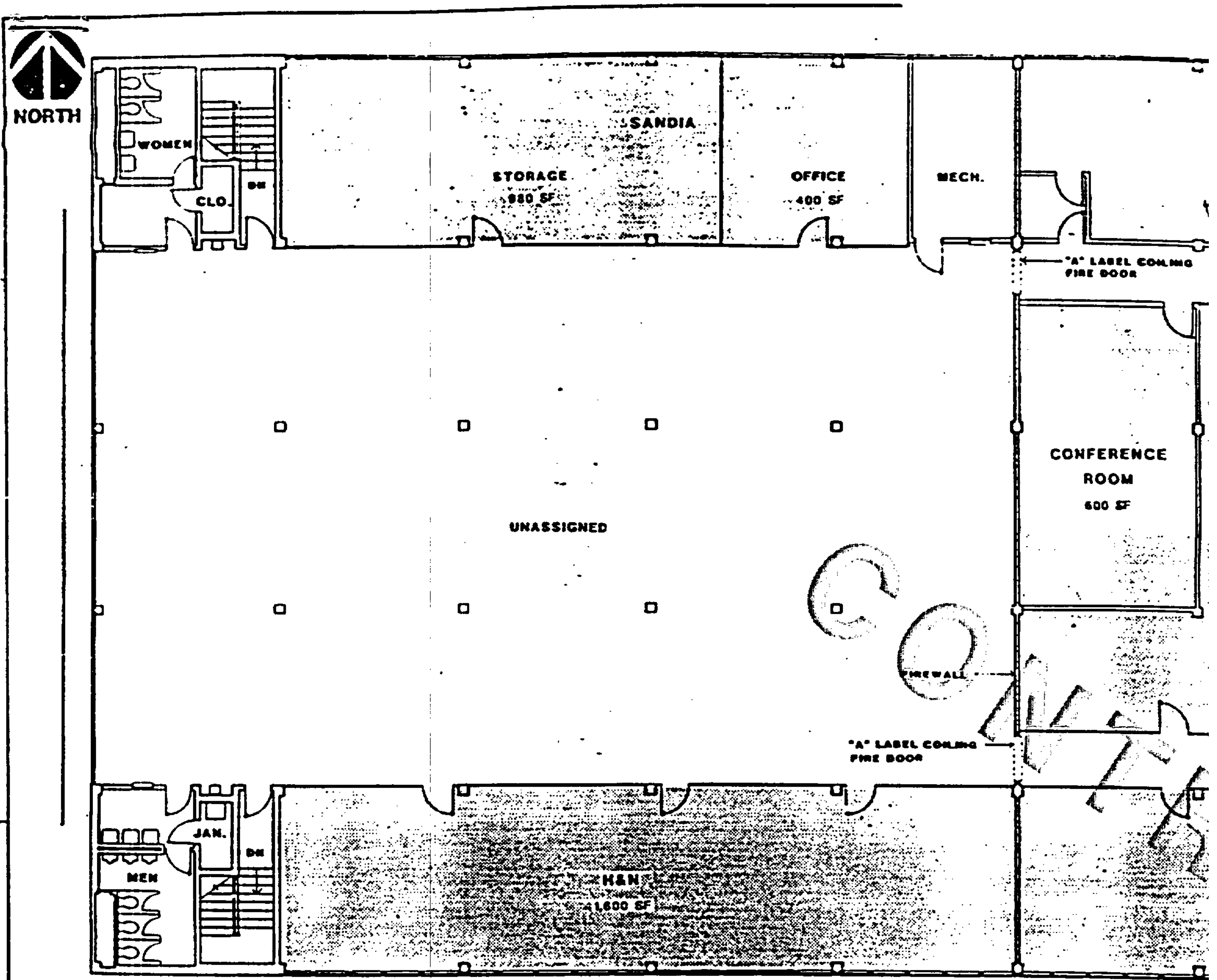
ATTACHMENT 2





NNWSI MTL IDS ALCOVE

D. Hall
4/29/88



ADMINISTRATION AND ENGINEERING BUIL

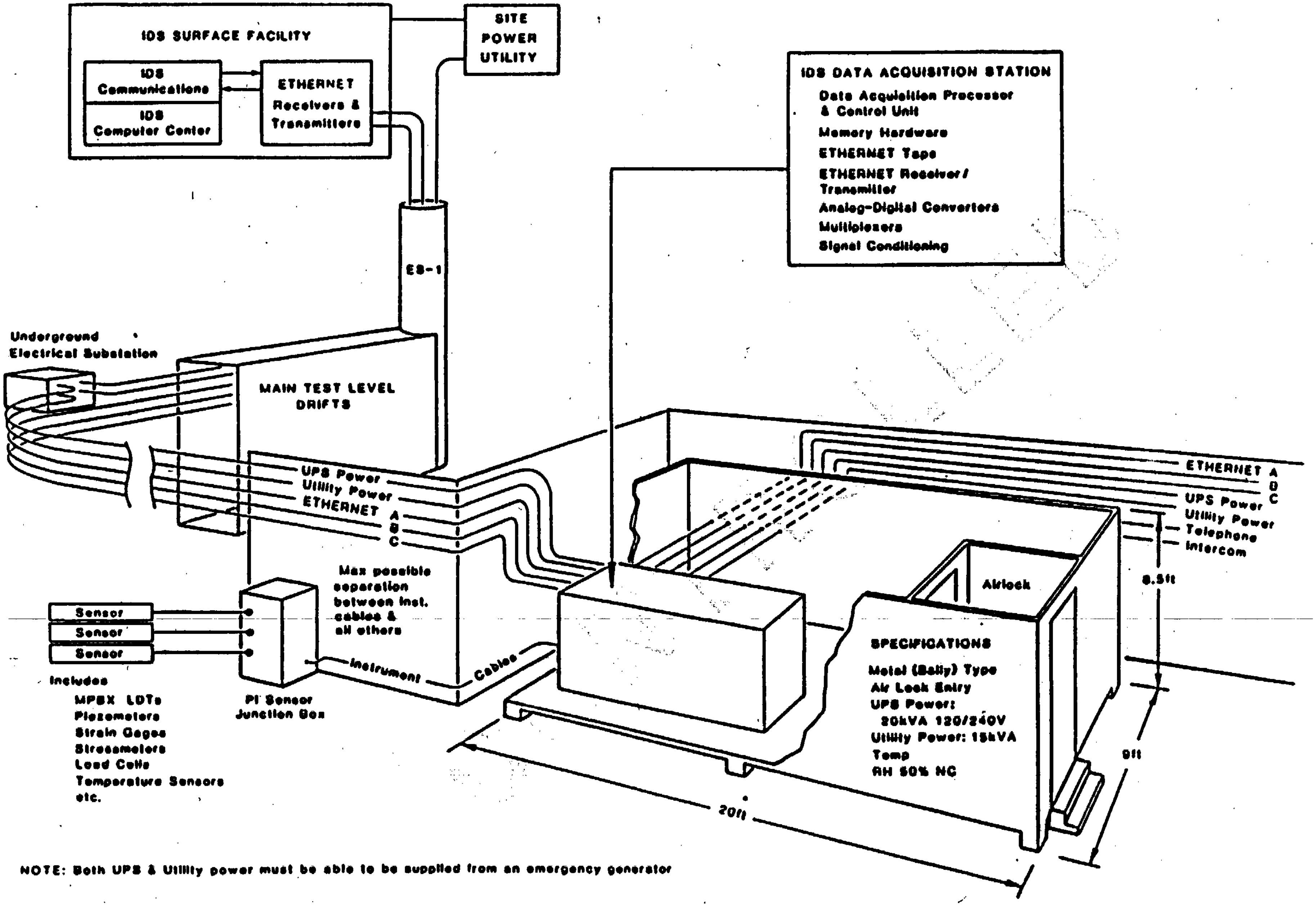
SCALE: 1/8" = 1'-0"

1/8"=1'-0"

INTEGRATED I
SPACE REQUIR

ATTACHMENT 3

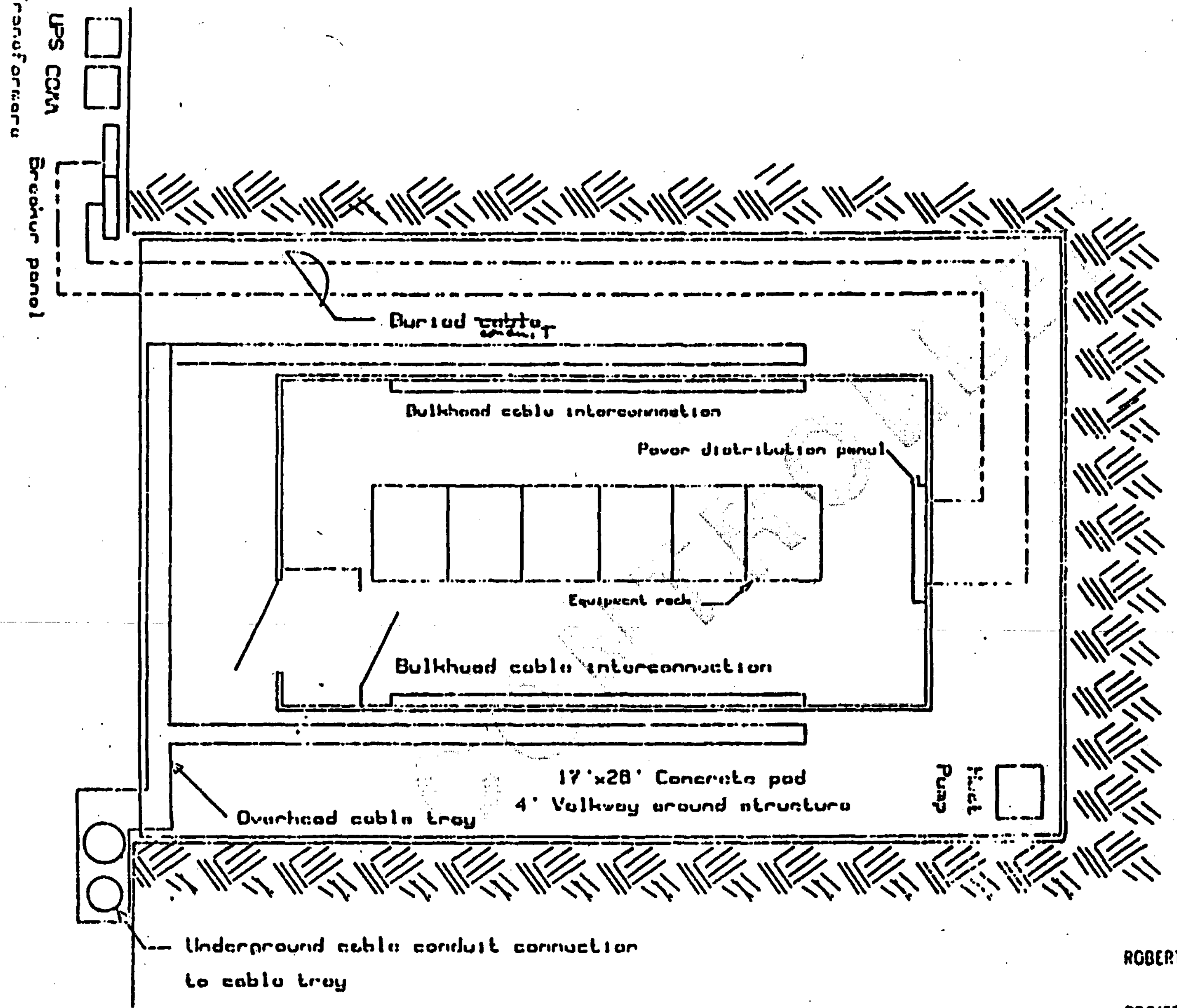
ATTACHMENT 4



NOTE: Both UPS & Utility power must be able to be supplied from an emergency generator

IDS Data Acquisition Station

ATTACHMENT 5

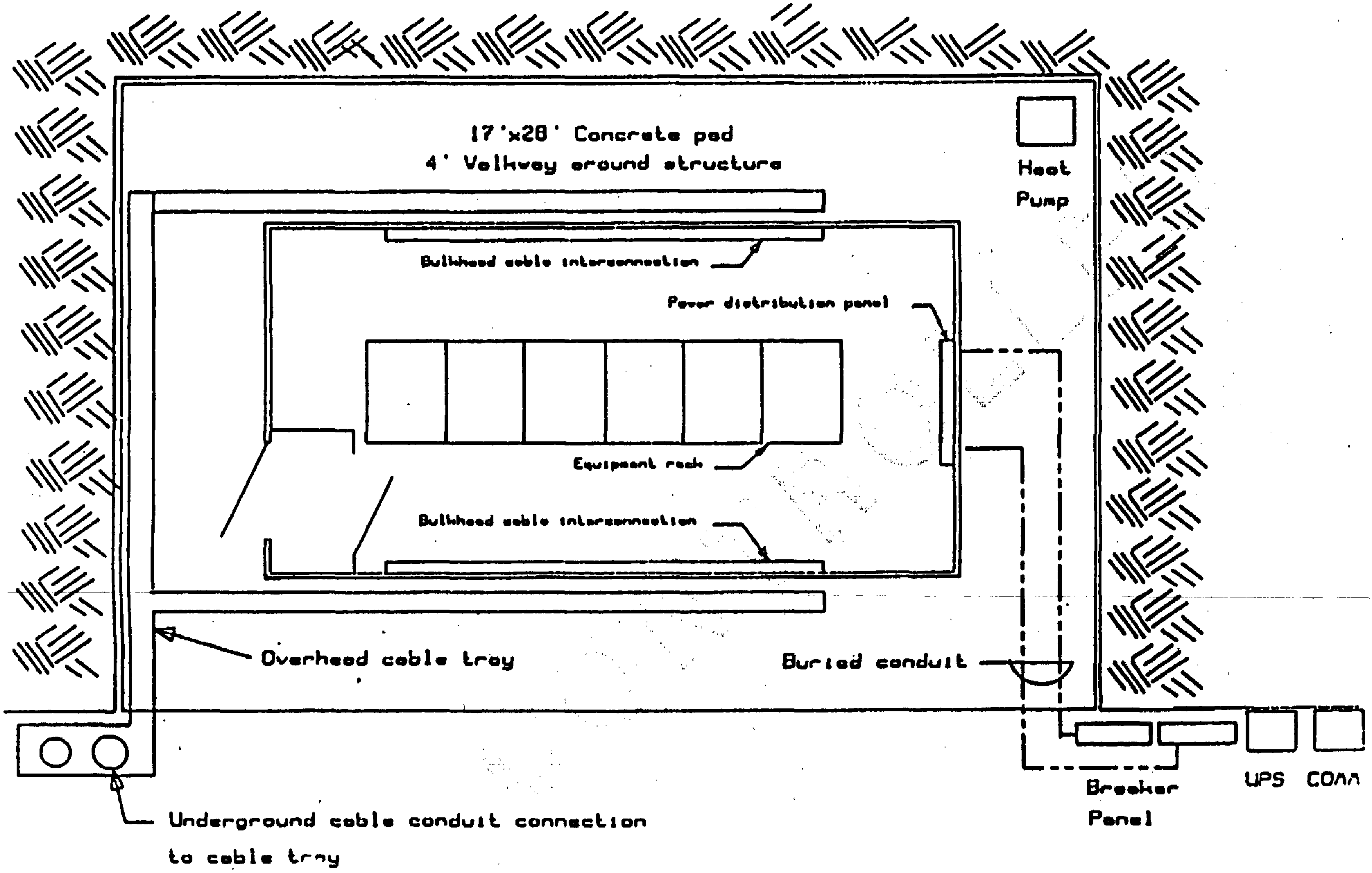


ROBERT J. CROWLEY

PROJECT IDS

DATE 2-19-88

ATTACHMENT 6



ROBERT J. CROWLEY

PROJECT IDS

DATE 2-19-88

ATTACHMENT 7

MTL IDS EQUIPMENT LOCATIONS

The sketch for the IDS Data Alcove and the IDS Data Acquisition Stations at the main test level will be revised and coodinated through the ICWG.

ATTACHMENT 8

Rev. 6

05-03-88

NNWSI IDS EQUIPMENT

COMPONENT NAME: DATA ACQUISITION STATION #1
SUPPORTED TESTS: DIFFUSION, INFILTRATION

SENSOR TYPES: NUMBER:
LOCATION: MAIN TEST LEVEL, ACROSS DRIFT FROM INFILTRATION TEST
SIZE: 9x20x8.5 feet, 4 ft. CLEARANCE
CONSTRUCTION: METAL (BALLY) TYPE, AIR LOCK ENTRY
MOUNTING: CONCRETE PAD
POWER REQ. UPS:20 KVA, 120/240, 3 WI. UTILITY: 15 KVA (BOTH ON EMERG)
ENVIRONMENTAL REQ.: COMPUTER GRADE, 12 KW COMPUTER HEAT LOAD
FIRE REQ.: HALON SAFETY: COMPUTER SHUTDOWN
COMMUNICATIONS: 2 ETHERNET LOOP-THRU, TELEPHONE, INTERCOM
CABLING: IDS: SENSOR:
NOTES: 1000 CHANNEL CAPACITY, NON-REDUNDANT

COMPONENT NAME: DATA ACQUISITION STATION #2
SUPPORTED TESTS: BULK PERMEABILITY

SENSOR TYPES: NUMBER:
LOCATION: MAIN TEST LEVEL, ADJACENT TO BULK PERMEABILITY TEST
SIZE: 9x20x8.5 feet, 4 ft. CLEARANCE
CONSTRUCTION: METAL (BALLY) TYPE, AIR LOCK ENTRY
MOUNTING: CONCRETE PAD
POWER REQ. UPS:20 KVA, 120/240, 3 WI. UTILITY: 15 KVA (BOTH ON EMERG)
ENVIRONMENTAL REQ.: COMPUTER GRADE, 12 KW COMPUTER HEAT LOAD
FIRE REQ.: HALON SAFETY: COMPUTER SHUTDOWN
COMMUNICATIONS: 2 ETHERNET LOOP-THRU, TELEPHONE, INTERCOM
CABLING: IDS: SENSOR:
NOTES: 1000 CHANNEL CAPACITY, NON-REDUNDANT

NNWSI IDS EQUIPMENT

COMPONENT NAME: DATA ACQUISITION STATION #3
SUPPORTED TESTS: LOWER DEMONSTRATION BREAKOUT ROOM TESTS

SENSOR TYPES: NUMBER:
LOCATION: MAIN TEST LEVEL, ADJACENT TO LDBR
SIZE: 9x20x8.5 feet, 4 ft. CLEARANCE
CONSTRUCTION: METAL (BALLY) TYPE, AIR LOCK ENTRY
MOUNTING: CONCRETE PAD
POWER REQ. UPS:20 KVA, 120/240, 3 WI. UTILITY: 15 KVA (BOTH ON EMERG)
ENVIRONMENTAL REQ.: COMPUTER GRADE, 12 KW COMPUTER HEAT LOAD
FIRE REQ.: HALON SAFETY: COMPUTER SHUTDOWN
COMMUNICATIONS: 2 ETHERNET LOOP-THRU, TELEPHONE, INTERCOM
CABLING: IDS: SENSOR:
NOTES: 1000 CHANNEL CAPACITY, NON-REDUNDANT

COMPONENT NAME: DATA ACQUISITION STATION #4
SUPPORTED TESTS: SEQUENTIAL DRIFT MINING

SENSOR TYPES: NUMBER:
LOCATION: MAIN TEST LEVEL, ADJACENT TO SEQUENTIAL DRIFT MINING TEST
SIZE: 9x20x8.5 feet, 4 ft. CLEARANCE
CONSTRUCTION: METAL (BALLY) TYPE, AIR LOCK ENTRY
MOUNTING: CONCRETE PAD
POWER REQ. UPS:20 KVA, 120/240, 3 WI. UTILITY: 15 KVA (BOTH ON EMERG)
ENVIRONMENTAL REQ.: COMPUTER GRADE, 12 KW COMPUTER HEAT LOAD
FIRE REQ.: HALON SAFETY: COMPUTER SHUTDOWN
COMMUNICATIONS: 2 ETHERNET LOOP-THRU, TELEPHONE, INTERCOM
CABLING: IDS: SENSOR:
NOTES: 1000 CHANNEL CAPACITY, NON-REDUNDANT

Rev. 6

05-03-89

NNWSI IDS EQUIPMENT

COMPONENT NAME: DATA ACQUISITION STATION #5
SUPPORTED TESTS: WASTE PACKAGE HORIZONTAL TEST

SENSOR TYPES: NUMBER:
LOCATION: MAIN TEST LEVEL, ACROSS DRIFT FROM WP HORIZONTAL TEST
SIZE: 9x20x8.5 feet, 4 ft. CLEARANCE
CONSTRUCTION: METAL (BALLY) TYPE, AIR LOCK ENTRY
MOUNTING: CONCRETE PAD
POWER REQ. UPS:20 KVA, 120/240, 3 WI. UTILITY: 15 KVA (BOTH ON EMERG)
ENVIRONMENTAL REQ.: COMPUTER GRADE, 12 KW COMPUTER HEAT LOAD
FIRE REQ.: HALON SAFETY: COMPUTER SHUTDOWN
COMMUNICATIONS: 2 ETHERNET LOOP-THRU, TELEPHONE, INTERCOM
CABLING: IDS: SENSOR:
NOTES: 1000 CHANNEL CAPACITY, NON-REDUNDANT

COMPONENT NAME: DATA ACQUISITION STATION #6
SUPPORTED TESTS: WASTE PACKAGE VERTICAL TEST

SENSOR TYPES: NUMBER:
LOCATION: MAIN TEST LEVEL, ACROSS DRIFT FROM WP VERTICAL TEST
SIZE: 9x20x8.5 feet, 4 ft. CLEARANCE
CONSTRUCTION: METAL (BALLY) TYPE, AIR LOCK ENTRY
MOUNTING: CONCRETE PAD
POWER REQ. UPS:20 KVA, 120/240, 3 WI. UTILITY: 15 KVA (BOTH ON EMERG)
ENVIRONMENTAL REQ.: COMPUTER GRADE, 12 KW COMPUTER HEAT LOAD
FIRE REQ.: HALON SAFETY: COMPUTER SHUTDOWN
COMMUNICATIONS: 2 ETHERNET LOOP-THRU, TELEPHONE, INTERCOM
CABLING: IDS: SENSOR:
NOTES: 1000 CHANNEL CAPACITY, NON-REDUNDANT

NNWSI IDS EQUIPMENT

COMPONENT NAME: DATA ACQUISITION STATION #7
SUPPORTED TESTS: UPPER DEMONSTRATION BREAKOUT ROOM TESTS

SENSOR TYPES: NUMBER:
LOCATION: UDBR
SIZE: 9x20x8.5 feet, 4 ft. CLEARANCE
CONSTRUCTION: METAL (BALLY) TYPE, AIR LOCK ENTRY
MOUNTING: CONCRETE PAD
POWER REQ. UPS:20 KVA, 120/240, 3 WI. UTILITY: 15 KVA (BOTH ON EMERG)
ENVIRONMENTAL REQ.: COMPUTER GRADE, 12 KW COMPUTER HEAT LOAD
FIRE REQ.: HALON SAFETY: COMPUTER SHUTDOWN
COMMUNICATIONS: 2 ETHERNET LOOP-THRU, TELEPHONE, INTERCOM
CABLING: IDS: SENSOR:
NOTES: 1000 CHANNEL CAPACITY, NON REDUNDANT

COMPONENT NAME: DATA ACQUISITION STATION #8
SUPPORTED TESTS: CALICO HILLS TESTS

SENSOR TYPES: NUMBER:
LOCATION: CALICO HILLS
SIZE: 9x20x8.5 feet. 4 ft. clearance
CONSTRUCTION: METAL (BALLY) TYPE, AIR LOCK ENTRY
MOUNTING: CONCRETE PAD
POWER REQ. UPS:20 KVA, 120/240, 3 WI. UTILITY: 15 KVA (BOTH ON ENERG)
ENVIRONMENTAL REQ.: COMPUTER GRADE, 12 KW COMPUTER HEAT LOAD
FIRE REQ.: HALON SAFETY: COMPUTER SHUTDOWN
COMMUNICATIONS: 2 ETHERNET LOOP-THRU, TELEPHONE, INTERCOM
CABLING: IDS: SENSOR:
NOTES: 1000 CHANNEL CAPACITY, NON-REDUNDANT

Rev. 6

05-03-88

NNWSI IDS EQUIPMENT

COMPONENT NAME: IDS ALCOVE COMPUTER SYSTEM
SUPPORTED TESTS: HEATED BLOCK, CANISTER SCALE HEATER

SENSOR TYPES: NUMBER:
LOCATION: IDS ALCOVE, MAIN TEST LEVEL
SIZE: 825 SQ. FT. 20x40x8
CONSTRUCTION: METAL, AIR LOCK ENTRY, RAISED FLOOR
MOUNTING: CONCRETE PAD
POWER REQ. UPS:35 KVA, 3 PH, 208/120 UTILITY: 30 KVA (BOTH ON EMERG)
ENVIRONMENTAL REQ.: COMPUTER GRADE, INCOMING AIR HIGHLY FILTERED
FIRE REQ.: HALON, SPRINKLER BACKUP SAFETY: COMPUTER SHUTDOWN
COMMUNICATIONS: 2 ETHERNET LOOP-THRU, TELEPHONE, INTERCOM
CABLING: IDS: VARIOUS ETHERNET SENSOR:
NOTES:

COMPONENT NAME: IDS MAIN COMPUTER SYSTEM
SUPPORTED TESTS: ALL

SENSOR TYPES: NUMBER:
LOCATION: IDS MAIN SURFACE FACILITY
SIZE: 2600 SQ. FT.
CONSTRUCTION: METAL (BUTLER) TYPE
MOUNTING: CONCRETE PAD
POWER REQ. UPS:50 KVA, 2-200A,30CKT P UTILITY: 50 KVA, 3 PH, 208/120
ENVIRONMENTAL REQ.: RAISED FLOOR, 74 +/-3 DEG, RH 50%NC, 40 KW HEAT
FIRE REQ.: HALON, SPRINKLER BACKUP SAFETY: COMPUTER SHUTDOWN
COMMUNICATIONS: 3 ETHERNET, TELEPHONE, INTERCOM
CABLING: IDS: 3 ETHERNETS SENSOR:IDS SURF. COMMON DATA
NOTES:

NNWSI IDS EQUIPMENT

COMPONENT NAME: IN-SHAFT DATA ACQUISITION STATION #1
SUPPORTED TESTS: RADIAL BOREHOLE #1

SENSOR TYPES: NUMBER:
LOCATION: ES-1, 10 FEET ABOVE BOREHOLE #1
SIZE: 3x3x6 FEET
CONSTRUCTION: HEAVY DUTY NEMA-12 (SEE ATTACHED SKETCH)
MOUNTING: RECESSED IN SHAFT WALL, MUST BE ABLE TO RACK OUT
POWER REQ. UPS:120 VAC, 1.5 KVA UTILITY: NONE
ENVIRONMENTAL REQ.: FILTERED AIR, POSSIBLE TEMPERATURE CONTROL
FIRE REQ.: NONE SAFETY: NONE
COMMUNICATIONS: DATA TO SURFACE AND/OR DATA ALCOVE, INTERCOM
CABLING: IDS: SENSOR:
NOTES:

COMPONENT NAME: IN-SHAFT DATA ACQUISITION STATION #2
SUPPORTED TESTS: RADIAL BOREHOLE #2

SENSOR TYPES: NUMBER:
LOCATION: ES-1, 10 FEET ABOVE BOREHOLE #2
SIZE: 3x3x6 FEET
CONSTRUCTION: HEAVY DUTY NEMA-12 (SEE ATTACHED SKETCH)
MOUNTING: RECESSED IN SHAFT WALL, MUST BE ABLE TO RACK OUT
POWER REQ. UPS:120 VAC, 1.5 KVA UTILITY: NONE
ENVIRONMENTAL REQ.: FILTERED AIR, POSSIBLE TEMPERATURE CONTROL
FIRE REQ.: NONE SAFETY: NONE
COMMUNICATIONS: DATA TO SURFACE AND OR DATA ALCOVE, INTERCOM
CABLING: IDS: SENSOR:
NOTES:

NNWSI IDS EQUIPMENT

COMPONENT NAME: IN-SHAFT DATA ACQUISITION STATION #3
SUPPORTED TESTS: RADIAL BOREHOLE #3

SENSOR TYPES: NUMBER:
LOCATION: ES-1, 10 FEET ABOVE BOREHOLE #3
SIZE: 3x3x6 FEET
CONSTRUCTION: HEAVY DUTY NEMA-12 (SEE ATTACHED SKETCH)
MOUNTING: RECESSED IN SHAFT WALL, MUST BE ABLE TO RACK OUT
POWER REQ. UPS:120 VAC, 1.5 KVA UTILITY: NONE
ENVIRONMENTAL REQ.: FILTERED AIR, POSSIBLE TEMPERATURE CONTROL
FIRE REQ.: NONE SAFETY: NONE
COMMUNICATIONS: DATA TO SURFACE AND OR DATA ALCOVE, INTERCOM
CABLING: IDS: SENSOR:
NOTES:

COMPONENT NAME: IN-SHAFT DATA ACQUISITION STATION #4
SUPPORTED TESTS: RADIAL BOREHOLE #4

SENSOR TYPES: NUMBER:
LOCATION: ES-1, 10 FEET ABOVE BOREHOLE #4
SIZE: 3x3x6 FEET
CONSTRUCTION: HEAVY DUTY NEMA-12 (SEE ATTACHED SKETCH)
MOUNTING: RECESSED IN SHAFT WALL, MUST BE ABLE TO RACK OUT
POWER REQ. UPS:120 VAC, 1.5 KVA UTILITY: NONE
ENVIRONMENTAL REQ.: FILTERED AIR, POSSIBLE TEMPERATURE CONTROL
FIRE REQ.: NONE SAFETY: NONE
COMMUNICATIONS: DATA TO SURFACE AND OR DATA ALCOVE, INTERCOM
CABLING: IDS: SENSOR:
NOTES:

NNWSI IDS EQUIPMENT

COMPONENT NAME: IN-SHAFT DATA ACQUISITION STATION #5
SUPPORTED TESTS: RADIAL BOREHOLE #5

SENSOR TYPES: NUMBER:
LOCATION: ES-1, 10 FEET ABOVE BOREHOLE #5
SIZE: 3x3x6 FEET
CONSTRUCTION: HEAVY DUTY NEMA-12 (SEE ATTACHED SKETCH)
MOUNTING: RECESSED IN SHAFT WALL, MUST BE ABLE TO RACK OUT
POWER REQ. UPS:120 VAC, 1.5 KVA UTILITY: NONE
ENVIRONMENTAL REQ.: FILTERED AIR, POSSIBLE TEMPERATURE CONTROL
FIRE REQ.: NONE SAFETY: NONE
COMMUNICATIONS: DATA TO SURFACE AND OR DATA ALCOVE, INTERCOM
CABLING: IDS: SENSOR:
NOTES:

COMPONENT NAME: IN-SHAFT DATA ACQUISITION STATION #6
SUPPORTED TESTS: RADIAL BOREHOLE #6

SENSOR TYPES: NUMBER:
LOCATION: ES-1, 10 FEET ABOVE BOREHOLE #6
SIZE: 3x3x6 FEET
CONSTRUCTION: HEAVY DUTY NEMA-12 (SEE ATTACHED SKETCH)
MOUNTING: RECESSED IN SHAFT WALL, MUST BE ABLE TO RACK OUT
POWER REQ. UPS:120 VAC, 1.5 KVA UTILITY: NONE
ENVIRONMENTAL REQ.: FILTERED AIR, POSSIBLE TEMPERATURE CONTROL
FIRE REQ.: NONE SAFETY: NONE
COMMUNICATIONS: DATA TO SURFACE AND OR DATA ALCOVE, INTERCOM
CABLING: IDS: SENSOR:
NOTES:

NNWSI IDS EQUIPMENT

COMPONENT NAME: IN-SHAFT DATA ACQUISITION STATION #7
SUPPORTED TESTS: RADIAL BOREHOLE #7

SENSOR TYPES: NUMBER:
LOCATION: ES-1, 10 FEET ABOVE BOREHOLE #7
SIZE: 3x3x6 FEET
CONSTRUCTION: HEAVY DUTY NEMA-12 (SEE ATTACHED SKETCH)
MOUNTING: RECESSED IN SHAFT WALL, MUST BE ABLE TO RACK OUT
POWER REQ. UPS:120 VAC, 1.5 KVA UTILITY: NONE
ENVIRONMENTAL REQ.: FILTERED AIR, POSSIBLE TEMPERATURE CONTROL
FIRE REQ.: NONE SAFETY: NONE
COMMUNICATIONS: DATA TO SURFACE AND OR DATA ALCOVE, INTERCOM
CABLING: IDS: SENSOR:
NOTES:

COMPONENT NAME: IN-SHAFT DATA ACQUISITION STATION #8
SUPPORTED TESTS: RADIAL BOREHOLE #8

SENSOR TYPES: NUMBER:
LOCATION: ES-1, 10 FEET ABOVE BOREHOLE #8
SIZE: 3x3x6 FEET
CONSTRUCTION: HEAVY DUTY NEMA-12 (SEE ATTACHED SKETCH)
MOUNTING: RECESSED IN SHAFT WALL, MUST BE ABLE TO RACK OUT
POWER REQ. UPS:120 VAC, 1.5 KVA UTILITY: NONE
ENVIRONMENTAL REQ.: FILTERED AIR, POSSIBLE TEMPERATURE CONTROL
FIRE REQ.: NONE SAFETY: NONE
COMMUNICATIONS: DATA TO SURFACE AND OR DATA ALCOVE, INTERCOM
CABLING: IDS: SENSOR:
NOTES:

ATTACHMENT 7

IDS PHASE 1 PROJECT SCHEDULE, Revision 1, 12/21/87, File 89WPAS01.DAT
Prepared by R.J.CROWLEY

IDS PHASE 1 PROJEC
Revision 1, 12/21/

```
                                    Oct 87              Nov               Dec                      Jan 88                Feb          FebMar
Job Description                     1  8  15 22 29  5  12 19 26  3  10 17 24 31  7  14 21 28  4  11 18 25  3  10 17 24 31
                                    0  1  2  3  4   5  6  7  8   9  10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26
 1 TITLE I, PH. 1&2 DESIGN          0=======================>  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
 2 REVISED TITLE I DESIGN DOC.      .  .  .  .  .  .  .  .  .  >========================X  .  .  .  .  .  .  .  .  .  .
 3 IDS COMMITTEE MEETING            .  .  .  .  .  .  .  .  .  X  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
 4 TITLE II, PHASE 1 DESIGN         .  .  .  .  .  .  .  .  .  >=========================================================
 5 PHASE I INSTALLATION             .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .

 6 PH. 1 DEV. SYSTEM TEST REPORT    .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  X
 7 PH. 1 S/W INTERIM DES. REPORT    .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  X
 8 PH. 1&2 FACIL. RQMTS. DOCUMENT   .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
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12 PH. 1 S/W VER. & VAL. REPORT     .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
13 PH. 1 H/W ACCEPT. TEST REPORT    .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
14 INSTALL IN-SHAFT STATIONS        .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
15 PH. 1 TITLE III ENGRG. REPORT    .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .

16 END OF IDS PHASE 1               .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
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Sorting order is Current order
From the first job to the last job
Jobs using all skills

Symbol-Explanation

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>-->    Duration of a normal job
>..>    Slack time for a normal job
>==>    Duration of a critical path job
>::>    Duration of a completed job
*       Job with zero duration
+       Job deadline
0-->    Job with no prerequisites
>--X    Job with no successors
!       Time break due to holiday or week-off
```

Rev. 6

JULE
le 89WPAS01.DAT

IOS PHASE 1 PROJECT SCHEDULE
Revision 1, 12/21/87, File 89WPAS01.DAT

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      May          Jun                 Jul            Aug            Sep                 OctOct          Nov            Dec               Jan 89         Fe
21 28 5  12 19 26 2  9  16 23 30 7  14 21 28 4  11 18 25 1  8  15 22 29 6  13 20 27 3  10 17 24 1  8  15 22 29 5  12 19 26 2
29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70
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Rev. 6

IDS PHASE 1 PROJECT SCHEDULE
Revision 1, 12/21/87, File 89WPAS01.DAT

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>        Mar                 Apr             May                 Jun                 Jul                 Aug                     Sep             Oct             Nov
9  16 23 2  9  16 23 30 6  13 20 27 4  11 18 25 1  8  15 22 29 6  13 20 27 3  10 17 24 31 7  14 21 28 5  12 19 26 2  9  16 2
71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100   102   104   106   108   110   1

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Rev. 6

IOS PHASE 1 PROJECT SCHEDULE
Revision 1, 12/21/87, File 89WPAS01.DAT

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Dec           Jan90 Jan     Feb        Mar           Apr          May             Jun          Jul          Aug 90
7  14 21 28 4  11 18 25 1  8  15 22 1  8  15 22 29 5  12 19 26 3  10 17 24 31 7  14 21 28 5  12 19 26 2
114   116   118   120   122   124   126   128   130   132   134   136   138   140   142   144   146   148
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Item	Title	Prepared by
24.	Stratigraphic and Structural Characteristics of Volcanic Rock in Core Hole USW G-4, Yucca Mountain, Nye County, Nevada	D. C. Muller, J. E. Kibler
25.	Analysis of the Elastic and Strength Properties of Yucca Mountain Tuff, Nevada	R. H. Price, S. J. Bauer
26.	Implication about In Situ Stress at Yucca Mountain	S. J. Bauer, J. F. Holland, D. K. Parrish
27.	Conceptual Hydrologic Model of Flow in the Unsaturated Zone, Yucca Mountain, Nevada	U. S. Geological Survey
28.	Technical Requirements For The Integrated Data System Of The NNWSI Project Exploratory Shaft Facility	EG&G Las Vegas Support Operations
29.	Repository Design Requirements Shaft Collars and Linings Preclosure Period	Sandia National Laboratories (Rev. 2)
30.	Exploratory Shaft Seismic Design Basis	ESF ICWG Working Group