Y-12

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OAK RIDGE Y-12 PLANT

MARTIN MARIETTA

Y-12 SITE-SPECIFIC EARTHQUAKE RESPONSE ANALYSIS AND SOIL LIQUEFACTION ASSESSMENT

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September 29, 1995

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FOR THE UNITED STATES
DEPARTMENT OF ENERGY

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Y/EN-5444

Central Engineering Services Division

**Y-12 SITE-SPECIFIC EARTHQUAKE
RESPONSE ANALYSIS AND
SOIL LIQUEFACTION ASSESSMENT**

Date Issued--September 1995

Prepared by
Central Engineering Services
Oak Ridge K-25 Site
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SUMMARY AND CONCLUSIONS

A site-specific earthquake response analysis and soil liquefaction assessment were performed for the Oak Ridge Y-12 Plant. The main purpose of these studies was to use the results of the analyses for evaluating the safety of the performance category -1, -2, and -3 facilities against the natural phenomena seismic hazards.

Earthquake response was determined for seven (7), one dimensional soil columns (Fig. 12) using two horizontal components of the PC-3 design basis 2000-year seismic event.

The computer program SHAKE 91 (Ref. 7) was used to calculate the absolute response accelerations on top of ground (soil/weathered shale) and rock outcrop. The SHAKE program has been validated for horizontal response calculations at periods less than 2.0 second at several sites and consequently is widely accepted in the geotechnical earthquake engineering area for site response analysis.

Geotechnical data available from the past investigations at the Y-12 site (Refs. 15 through 28) was used to develop forty two (42) soil columns. A relatively wide range of site conditions in terms of height of soil layer and weathered (rock) shale were encountered at the site. From the forty-two (42) soil columns, seven (7) representative one dimensional soil columns were selected to represent the Y-12 Plant site. Although the locations of the borings and the monitoring wells are scattered, the range of subsurface conditions like stratigraphy, depth to groundwater and rock; and type of overburden materials are judged to be adequately represented by the soil columns and the engineering properties of the materials used in the response analysis.

The range of soil thickness used in the analysis was 10 to 30 ft. Weathered shale underlying the soil varied from 10 to 20 ft. The highest column used in the analysis was 50 ft (30 ft soil + 20 ft weathered shale) and the shortest being 10 ft. weathered shale overlying fresh rock. A fairly wide spectrum of shear wave velocities for soil (500, 700 and 1000 fps) and weathered shale (1300, 1800 and 2,500 fps) were used to bracket soft, stiff and very dense materials. Therefore, the ranges of subsurface parameters modeled in the SHAKE 91 program are considered to be adequate.

For each soil column, free-field response spectra was determined using six (6) damping values; 2, 5, 7, 10, 12 and 15 percent. Amplification ratio, defined as the ratio between the absolute response accelerations at top of ground (soil/weathered shale) and rock outcrop, was calculated for all seven profiles using the lower bound, mean and upper bound shear wave velocities (Tables 6 through 11).

Considering the mean range soil properties and 5 percent damping, the peak soil amplification ratio varied from 3.8 to 4.5 at periods ranging between .06 and .2 second. For weathered shale, the peak amplification ratio varied from 1.2 to 1.4 at .04 second.

Based on the amplification ratios, site-specific earthquake design response spectra for horizontal soil motion and weathered rock motion were developed for use in the seismic evaluation of the PC -1, -2, and -3 facilities at the Y-12 Plant (Figures 16 through 27).

Results of the liquefaction study indicate that the soils encountered at the Y-12 site are not susceptible to liquefaction (Figures 28 and 29). Consequently, it is concluded that the PC -1, -2, and -3 soil-supported facilities at the Y-12 Plant should remain stable against liquefaction during and after the design seismic events.

The Y-12 Plant, owned by the U.S. Department of Energy (DOE) and operated by Lockheed Martin Energy Systems (LMES), is located about three (3) miles from the center of Oak Ridge, Tennessee. The Y-12 Plant, situated in eastern Bear Creek Valley, is bounded on the south by Chestnut Ridge and on the north by Pine Ridge (Fig. 1). The plant was originally constructed in the early 1940's as part of the Manhattan Project. The primary mission has been production of nuclear weapon components and now the mission is to maintain the production capacity and dismantle nuclear weapon components.

The facilities at Y-12 are currently being evaluated for safety in response to natural seismic hazards. Design and evaluation guidelines to evaluate the effects of earthquakes and other natural hazards on DOE facilities are defined in DOE Order 5480.28, *Natural Phenomena Hazards Mitigation* (Ref. 1) and the following five DOE Standards:

DOE-STD-1020-94, *Natural Phenomena Hazards Design and Evaluation Criteria for Department of Energy Facilities* (Ref. 2)

DOE-STD-1021-93, *Natural Phenomena Hazards Performance Categorization Guidelines for Structures, Systems, and Components* (Ref. 3)

DOE-STD-1022-94, *Natural Phenomena Hazards Site Characterization Criteria* (Ref. 4)

DOE-STD-1023 (Draft, November 1994), *Natural Phenomena Hazards Assessment Criteria* (Ref. 5)

DOE-STD-1024-92, *Guidelines for Use of Probabilistic Seismic Hazard Curves at Department of Energy Sites* (Ref. 6)

These DOE guidelines establish natural phenomena performance categories for structures, systems, and components (SSCs) in facilities as PC-0, PC-1, PC-2, PC-3, and PC-4. PC-0 SSCs do not require any natural phenomena considerations. The guidelines also establish the annual probability of exceedance of the seismic hazard input for each PC category. These annual probabilities of exceedance for each PC category are as follows:

<u>PC CATEGORY</u>	<u>ANNUAL PROBABILITY</u>	<u>RETURN PERIOD</u>
PC-1	2×10^{-3}	500 yrs.
PC-2	1×10^{-3}	1000 yrs.
PC-3	5×10^{-4}	2000 yrs.
PC-4	1×10^{-4}	10000 yrs.

There are PC-0, PC-1, PC-2, and PC-3 SSCs at Y-12, but no facilities have been classified as PC-4 to date.

The map illustrates the Oak Ridge Reservation and its surrounding environment. Key features include:

- Geographical Features:** Clinch River, Melton Hill Lake, Melton Hill Dam, and various smaller lakes and ponds.
- Road Network:** Emory Valley Road, Union Valley Road, Chestnut Ridge Road, Pine Ridge Road, Bear Road, and others.
- Facilities and Landmarks:** Y-12, Y-25, and other industrial or research structures.
- Administrative Boundaries:** Oak Ridge City, Doe Oak Ridge Reservation, and county boundaries (Anderson, Knox, Loudon, Roane).
- Infrastructure:** Highways (e.g., 58, 62, 64) and a railroad line.

FIG. 1 LOCATION OF Y-12 PLANT

The PC structures are supported by foundations bearing on sound (fresh) rock or weathered rock (shale) or soil. The seismic evaluation requires the ground motion characteristics of the foundation bearing stratum. The top of ground motion, i.e. soil and weathered shale spectra are not available for the evaluation of the structures supported on soil or weathered shale deposit. Additionally, there is also a need to determine if the soil-supported structures are safe against soil liquefaction during and after the seismic event.

2.0 PURPOSE

There are two main purposes of this study:

- (1) To calculate a reasonable range of expected site-specific free-field soil earthquake responses at Y-12 for the 2000-year return period earthquake, using geotechnical and geophysical information collected at the site during previous investigations for facilities at the site. The response will be calculated independently for two components of horizontal motion at the 2000-year hazard level. The emphasis on evaluating the 2000-year event is because there are no PC-4 SSCs at Y-12 and because the 1000 and 500-year hazard levels can be scaled from the 2000-year event. The calculated responses will be used to define free-field ground response spectra for the different soil and weathered shale conditions at Y-12. The free-field ground response spectra will be used for the seismic designs/evaluations of SSCs at Y-12.
- (2) To assess the liquefaction potential of the foundation soils at Y-12 site in order to assure the stability of those SSCs supported on soil deposit against liquefaction during and after the seismic event.

3.0 SCOPE

A site-specific response analysis will be conducted using SHAKE 91 computer program (Ref. 7). Soil profiles will be developed at several locations at or in the vicinity of PC-3 SSCs 9204-2, 9204-2E, 9212, 9215, 9720-5, 9995, 9996 and 9998 (Fig. 2). A wide range of engineering properties covering unit weights, shear wave velocities, normalized shear moduli and damping ratios will be evaluated for soil, weathered shale, and fresh rock. Free-field earthquake response will be calculated for a 2000-year event which represents the Design Basis Earthquake (DBE) for the PC-3 facilities. The response will be determined for two components of horizontal motion. It was decided that the earthquake time history for fresh rock originally determined by Risk Engineering for 1000-year return period (Ref. 8) could be used for 2000-year period for this study. The two horizontal components of the time history of acceleration (Figs. 8 and 9) will be used as input ground motion in the SHAKE analysis.

SHAKE program will generate the absolute response spectral accelerations at the top of soil, weathered shale, and fresh rock. Amplification ratios will be calculated by dividing the response spectral acceleration at the top of soil/weathered shale by the response spectral acceleration at the top of fresh rock.

Design spectra curves for horizontal ground motion will be developed for PC-3, PC-2, and PC-1 facilities supported on weathered (rock) shale, or soil by applying the amplification ratios to the top of fresh rock response spectra.

FIG. 2 LOCATION OF PC-3 STRUCTURES (CONSIDERED IN THIS STUDY)

Vertical ground motion calculations will not be performed. The vertical ground motion will be assumed to be two-thirds of the horizontal ground motion (same ratio as rock).

Additionally, the soils present at the Y-12 site will be assessed for liquefaction potential using simplified procedures recommended by Seed, et. al. (Ref. 9). These procedures are based upon soil index properties, grain size distribution, standard penetration test (SPT) blow counts (N) and cyclic stress ratio (CSR) for a given magnitude of earthquake and peak ground acceleration. If sandy soils are encountered, computer program SLIQ (Ref. 10) will be used. SLIQ is based upon Seed's procedures (Ref. 11 and 12) employing the relationship between CSR and N for evaluating liquefaction potential for sands and silty sands.

4.0 GEOLOGY

4.1 REGIONAL GEOLOGY

The Oak Ridge Reservation (ORR) is located in the western part of the Valley and Ridge Province at the narrowest part of the Appalachian foreland fold-thrust belt. Here, the Valley and Ridge Province is dominated by several west-directed thrust faults that formed when the huge Blue Ridge sheet to the east pushed the Valley and Ridge sedimentary succession in front of it. The ORR contains a variety of geologic structures. The map-scale structure of the ORR is dominated by a uniform southeast dip of sedimentary layering interrupted only by the two large thrust faults, the Copper Creek and the White Oak Mountain faults, and the East Fork Ridge (and Pilot Knob) syncline in the footwall of the White Oak Mountain thrust. A simplified map of the ORR showing the valleys, ridges and the faults is presented in Fig. 3.

The bedrock geology exposed in the ORR is composed entirely of sedimentary rocks that range in age from Early Cambrian to Early Mississippian. This stratigraphy formed as part of the early Paleozoic drift (ocean opening) succession. The carbonate bank was developed. Uplift and erosion of the carbonate bank occurred in early Middle Ordovician time forming the regional post-Knox unconformity, and the carbonate bank was reestablished during the middle Ordovician only to be destroyed later in the Ordovician by development of a clastic wedge in the Late Ordovician and Silurian. This was followed by erosion and formation of another unconformity, then by the deposition of the Upper Devonian-Early Carboniferous clastic wedge.

Nine major stratigraphic units have been recognized previously in the ORR: Rome Formation, Conasauga Group, Knox Group, Chickamauga Group, Reedsville Shale, Sequatchie Formation, Rockwood Formation, Chattanooga Shale, and Fort Payne Formation. Detailed studies of surface geology and core over the past decade have permitted subdivision of the Conasauga, Knox, and Chickamauga Groups. The Conasauga, and to a much lesser extent, the Knox and Chickamauga Groups, have served as the principal units for disposal of radionuclides and other waste materials in the ORR.

Outcrop-scale structures consist of inclined, faulted, and folded bedding, and joints. Joints (systematic fractures) are the most common structures present here, and several sets of joints with different orientations have been recognized. The dominant joint sets are oriented northeast and northwest, with lesser north-south and east-west sets. These structures are probably the most

North

5 kilometers

0 1 2

miles

Fig. 3 Locations of Ridges, Valleys and Faults on the Oak Ridge Reservation

important in the ORR because they, along with bedding and local karst, form the conduit system that controls groundwater movement.

The mantle of unconsolidated residual materials, or regolith, derived by in situ weathering of bedrock, is composed mostly of silty clays and clayey silts. The water table typically is near the interface between regolith and bedrock. In a normal year, the water table is lowest during September-October and highest during February-March.

A detailed geology of the ORR is described in Ref. 13.

4.2 AREA GEOLOGY

The ORR consists of approximately 36,000 acres bounded by the Clinch River on the east and south and to the west and north, at approximately 5 to 10 km, by the Cumberland Mountains. The reservation is situated in the Valley and Ridge Province.

Faulting in the Valley and Ridge is quite extensive, with a southeast to northwest trend. The White Oak mountain fault, an inactive fault, crosses the ORR at the Oak Ridge Gaseous Diffusion Plant (ORGDP). The ORGDP, Oak Ridge National Laboratory (ORNL), and Y-12 facilities are all located in long, narrow, northeasterly trending valleys bordered by narrow ridges. Ridge levels average 200 to 300 feet above the elevation of the valleys and have steep northwest slopes and flattened southeast slopes which reflect the southeast dip of the underlying rock.

The Y-12 facility is in Bear Creek Valley. It is flanked on the northwest by Pine Ridge and on the southeast by Chestnut Ridge. Bedrock is southeast dipping limestone, dolomite, and argillaceous shale of the Conasauga Group of Cambrian age which, in turn, overlies sandy shales and sandstones of the Cambrian Rome Formation. At the base of the unit, the Conasauga rocks are predominantly shales, with an increase in the percentage of limestone layers toward the top of the unit. The bed strike is approximately N 55 E, and the dip is about 45 to 60 SE. Along the westside of Pine Ridge is a prominent southeast dipping thrust fault which indicates that the Y-12 Plant is located on the southeast dipping limb of a syncline that contains a sequence of Cambrian and Ordovician rocks. The Rome Formation is the bottom portion of a thrust fault sheet, and the entire sequence of rocks has been thrust westward over Silurian and Ordovician rocks. A number of similar folded and faulted geologic structures occur parallel to Pine Ridge and constitute the structural pattern of the area.

5.0 SEISMOLOGY

5.1 GENERAL SEISMOLOGY

Seismic activity in the vicinity of the ORR has primarily occurred in the Valley and Ridge Province, although some historical activity has occurred in the Cumberland Plateau. To the east of the Valley and Ridge province, a similar amount of seismic activity has occurred in the Blue Ridge province, and some scattered activity has occurred in the Piedmont province. Major historical activity has occurred in a northwesterly band of the Atlantic Coastal Plain province centered in South Carolina. The seismic activity described here is shown in Fig. 4. Additionally, the earthquake epicenters in east Tennessee, as recorded from 1977 to 1991 are shown on Fig. 5.

FIG. 4 EARTHQUAKE EPICENTERS IN EASTERN U.S.

FIG.5 EARTHQUAKE EPICENTERS IN EAST TENNESSEE,
AS RECORDED ON SEISMIC NETWORK, 1977 - 1991

5.2 EARTHQUAKES AFFECTING THE OAK RIDGE RESERVATION

Of the earthquakes that are known to have occurred in the above regions, only three may have had any significant impact on the ORR. In 1886, the Charleston, South Carolina, earthquake occurred 520 km (325 miles) from the Reservation. This earthquake has been estimated to have had a Modified Mercalli Intensity (MMI) of X at the epicenter, and the effects at the ORR area have been estimated to have been an MMI of VI.

Following the 1886 Charleston, South Carolina, earthquake, an earthquake occurred in Giles County, Virginia, on May 31, 1897, 360 km (228 miles) from the ORR. This earthquake has been estimated to have an epicentral MMI from VII to VIII and at the ORR an MMI somewhere between V and VII.

The third earthquake was nearest the ORR, occurring just northwest of Knoxville on March 28, 1913, approximately 60 km (37 miles) from the Reservation. It has been estimated to have had an epicentral MMI of VII and an MMI of V to VI in the ORR.

The most recent significant earthquake to occur in the Appalachian area occurred on November 30, 1973, at Maryville, 34 km (21 miles) southeast of the ORR. This earthquake was estimated as having an epicentral MMI of VI and an MMI of IV in the ORR. Instrumental seismograph readings of this earthquake placed the magnitude at a value of 4.6 m_b . The recording instrument at the Y-12 Plant recorded a peak acceleration of 0.024 g. No damage occurred at the Y-12 Plant facilities from this earthquake. Two other earthquakes are worthy of discussion that did not occur in the above provinces. The first is the series of earthquakes that occurred near New Madrid, Missouri, 450 km (280 miles) west of the area of ORR during the months of December 1811, January 1812, and February 1812. Three of these earthquakes have been estimated as having an epicentral MMI of X to XII and an MMI of V to VI at the ORR.

The second earthquake to discuss is significant because of its recent occurrence, June 27, 1980. This earthquake occurred in Northern Kentucky approximately 290 km (180 miles) north of the ORR. The earthquake was estimated to have had an epicentral MMI of VII and a magnitude from instrumental records of 5.2 m_b . Some areas of the ORR experienced an MMI of I to II.

5.3 SEISMIC SOURCE ZONE

A recent seismic hazard study has indicated that the major potential for earthquake damage to the ORR is the seismic source zone of the Valley and Ridge province. Although there is considerable micro-earthquake activity occurring in the area, none of the activity can be attributed to known faulting.

5.4 DESIGN EARTHQUAKES

The determination of the earthquake hazard and the selection or derivation of appropriate design time history records for the rock outcrop at Y-12 represent the first step of a site response analysis. Based on the DOE Order 5480.28, DOE-STD-1020, 1022, 1023, and 1024, probabilistic

methods of hazard analysis were used to derive parameters defining the design events and to develop corresponding synthetic records.

The probabilistic assessment of seismic hazard was conducted by Risk Engineering, Inc. (Ref. 8). The results from Risk Engineering were used to define the rock outcrop seismic hazard and rock outcrop design response spectra. The results are summarized in report ES/CNPE-95/2, (Ref. 14). The seismic hazard results for peak rock acceleration are as follows:

<u>PC CATEGORY</u>	<u>RETURN PERIOD</u>	<u>PEAK ROCK ACCELERATION</u>
PC-1	500	0.06 G
PC-2	1000	0.08 G
PC-3	2000	0.12 G
PC-4	10000	0.26 G

The seismic hazard curve for the peak rock acceleration versus annual probability of exceedance is shown in Figure 6. The design response spectra for 5 percent damping are shown in Figure 7.

Synthetic earthquake records were developed by Risk Engineering, Inc. to represent rock outcrop motions. Two components of horizontal motion were provided. The time histories of acceleration for these horizontal components for the 2000-year earthquake are shown in Figures 8 and 9. The acceleration response spectra of these records are shown in Figs. 10 and 11 compared to the rock outcrop spectra. The acceleration response spectra from these time histories envelop the rock outcrop spectra in the frequency range of the Y-12 soil deposits and therefore are considered adequate to determine amplification ratios which can be used to scale the rock spectra to represent the free-field soil spectra.

6.0 GEOTECHNICAL INVESTIGATIONS

Geotechnical data available from the past site investigations were used in this study. New geotechnical explorations or laboratory testing for determining the soil and weathered shale response spectra and soil liquefaction potential were not performed because it was judged that the existing data was sufficient to define the ground motions and evaluate liquefaction potential.

The main sources of the past geotechnical data are the (1) Y-12 Updated Subsurface Data Base for Bear Creek Valley, Chestnut Ridge, and Parts of Bethel Valley, October, 1993 (Ref. 15), (2) Y-12 Plant, Groundwater Quality Report for the Upper East Fork Poplar Creek Hydrologic Regime Feb. 1994 (Ref. 16), and (3) The subsurface Investigation reports listed in Refs. 17 through 28.

Since the past geotechnical investigation programs were not designed for the purpose of this study, the above referenced reports did not contain all the information needed to define the

FIG. 6 SITE SPECIFIC EARTHQUAKE HAZARD
CURVE FOR OAK RIDGE RESERVATION

FIG. 7 OAK RIDGE-SITE SPECIFIC
RESPONSE SPECTRA FOR HORIZONTAL
ROCK MOTION

Fig. 8 Oak Ridge Reservation
Y-12 Plant Site
Amplification Study
Time History of Acceleration

Fig. 9 Oak Ridge Reservation
Y-12 Plant Site
Amplification Study
Time History of Acceleration

Oak Ridge Reservation

Fig. 10 Y-12 Plant Site - Horizontal 1 - 2000 YR Spectrum - 5% Damping
Comparison of Original Oak Ridge with Current 2000 YR Smooth Spectrum

Oak Ridge Reservation

Fig. 1.1 Y-12 Plant Site - Horizontal 2 - 2000 YR Spectrum - 5% Damping
Comparison of Original Oak Ridge with Current 2000 YR Smooth Spectrum

required response spectra and assess the soil liquefaction potential. The gaps in the data and the soil properties were filled in using engineering judgement based upon information available in published literature on similar materials.

Pertinent data from the past geotechnical reports were compiled. Information relating to depths of fresh rock and weathered rock (shale) were generally obtained from References 15 and 16. Engineering properties and profiles were basically derived from subsurface investigation reports (Refs. 17 through 28). Dynamic properties like normalized shear moduli and damping ratios, and shear strain were obtained from published literature.

6.1 PREPARATION OF DRAWINGS

The following drawings were prepared to show the locations of soil borings, soundings, and monitoring wells, and incorporate the geotechnical information, e.g., depths to fresh rock and weathered rock (shale), soil stratification, groundwater elevation, and original ground contours.

(1)	Drawing Y-12 SARUP SUPPORT	- Boring Location Plan, C2E 900000A952
(2)		- 1943 Contours, C2E 900000A953
(3)		- Top of fresh rock Contours, C2E 900000A954
(4)		- Groundwater Contours, C2E 900000A955
(5)		- Top of Weathered Rock (Shale) Contours, C2E 900000A956
(6)		- Soil Profiles (Columns), Bldg. 9212, C2E 900000A957
(7)		- Soil Profiles (Columns), Bldgs. 9998, 9996, 9215, 9204-2 & -2E, 9720-5, C2E 900000A958
(8)		- Soil Profiles (Columns), Bldg. 9995, C2E 900000A959

Drawing 1 presents the locations of soil borings, soundings, and groundwater monitoring wells. Original ground contours depicting the site topography in 1943, prior to the construction of Y-12 Plant are shown on Drawing 2. References 15 and 16 provided a significant amount of data relating to the depths of fresh rock and weathered rock (shale). This data was used to generate top of fresh rock and weathered rock (shale) contours shown on Drawings (3) and (5). Groundwater information was taken directly from Ref. 16. In areas where the information was not available, groundwater contours were extrapolated based on the trend of the watertable. Drawing 4 shows the groundwater contours generated at the site. All (8) drawings are included in Appendix C of this report.

6.2 SUBSURFACE PROFILES

Subsurface profiles were developed using field exploratory data from several geotechnical investigations listed in Refs. 17 through 28. Elevations of fresh rock, weathered rock (shale) and groundwater were derived from the contours discussed in Section 6.1. Subsurface profiles consisting of soil and weathered shale strata overlying fresh rock were designated as soil columns for use in the seismic response analysis and soil liquefaction assessment.

For the purpose of this study, a given height of soil deposit was treated as a single layer of homogeneous soil mass for the following reasons:

- (1) The geotechnical investigations revealed that the overburden soils are predominantly silty clays or clayey silts. Coarse-grained soils are generally not present at the site. Consequently, we are dealing with only one major type of soil i.e fine-grained soil.
- (2) Variation in shear strength of the overburden soil (soft, medium, stiff, very stiff and hard) can be estimated to a reasonable degree by assigning a wide spectrum of shear wave velocities, i.e., lower bound, mean, and upper bound in the response analyses using the criteria recommended by the Nuclear Regulatory Commission (Ref. 29).
- (3) The soil overburden is shallow, generally, not exceeding 30 ft.
- (4) The single layer assumption will simplify the analyses specially when detailed (layer by layer) soil properties are not available since the referenced geotechnical investigations were not designed for the purpose of this study.

Weathered (rock) shale was also considered as a single layer due to similar reasons discussed above. The subsurface profiles were simplified to constitute columns of soil overlying weathered shale. A total of forty-two (42) simplified subsurface profiles were developed at several locations in the vicinity of the PC-3 structures. For the purpose of this report the subsurface profiles will be referred to as the soil columns. The 42 soil columns are presented on Drawings 6, 7, and 8. Grade elevation, bottom of foundations of the structures, groundwater table, top of weathered shale and fresh rock are marked on individual soil columns.

In order to simplify the analysis, seven representative soil columns were modelled for the SHAKE 91 computer input. Thicknesses of soil and weathered shale for each soil column (model) are listed in Table 1. Each model is pictorially presented on Fig. 12. It is believed that the seven models should be sufficient to cover the ranges of soil and weathered rock (shale) thicknesses encountered at the Y-12 SSCs.

6.3 MATERIAL PROPERTIES

Material properties required to calculate the amplification ratios by SHAKE analysis and for determining liquefaction potential of soils are discussed below.

6.3.1 SHAKE 91 PROGRAM

The SHAKE 91 analysis requires unit weight, shear wave velocity or shear modulus, normalized shear modulus vs. shear strain, and damping ratio vs. shear strain.

Table 2, presents unit weights and shear wave velocities for soil, weathered shale and fresh rock. Unit weight for soil is calculated from the laboratory test results reported in refs. 18, 19, 20, 24, 25, and 26. Shear wave velocities for the soils at the Y-12 site are not available. The most extensive testing performed in East Tennessee relating to shear wave velocity and shear modulus on soils similar to those at Y-12 has been at TVA Watts Bar Nuclear Plant (Ref. 30). Therefore,

Table 1
Representative Soil Columns For
SHAKE Analysis

Soil Column No.	1	2	3	4	5	6	7
Soil Thickness (Ft.)	10	10	20	20	30	30	0
Weathered Rock (Shale) Thickness (Ft.)	10	20	10	20	10	20	10
Fresh Rock	Half-Space Elastic

FIG. 12 REPRESENTATIVE SOIL COLUMNS FOR SHAKE ANALYSIS

FIG. 13 SEAR WAVE VELOCITY VS DEPTH
WHEATHERED ROCK (SHALE) AND FRESH
ROCK

the mean shear wave velocity of soil = 700 fps was calculated from the data reported in Ref. (30).

For weathered (rock) shale, shear wave velocity is determined from the geophysical Cross Hole Tests conducted in the vicinity area of Building 9206 at Y-12. Fig. 13 presents a plot of shear wave velocity vs. depth for weathered (rock) shale. The unit weight for weathered (rock) shale was obtained from Ref. 30.

There may be areas where the weathered rock could be shaly limestone. The SHAKE analysis, however, requires only the shear wave velocity and does not distinguish between the rock types. The range of shear wave velocities used in the analysis covers the types of weathered rock in the area.

Unit weight and shear wave velocity for fresh rock listed in Table 2 were estimated from Ref. 30 and 28, respectively.

The lower and upper bound values of shear wave velocities are computed in accordance with the recommendations made by Nuclear Regulatory Commission (Ref. 29). The lower bound, mean and upper bound properties shown in Table 2 should cover a wide range of overburden soil/weathered (rock) shale deposits varying from soft to very dense consistencies.

The normalized moduli and damping ratio vs. shear strain data for soil, weathered shale and fresh rock are presented in Tables 3 and 4. For soil, this data has been adequately determined by using the curve for a Plasticity Index of 10-15 given in Ref. 32. At the Y-12 site, the computed mean value of Plasticity Index of soil is on the order of 14.

In the absence of tests on weathered shale and fresh rock at the Y-12 site, the dynamic moduli and damping ratios are assumed from the recommendations made in Ref. 30. The assumptions are justified in view of the similarity between the materials encountered at the Y-12 site and the Watts Bar Nuclear Plant.

6.3.2 SOIL LIQUEFACTION POTENTIAL

Liquefaction analysis will be performed by using the simplified methods presented by Seed et. al., (Ref. 9) for cohesive soils and sandy soils with varying percentages of fines. These procedures require the following engineering properties: Natural water content, Atterberg limits, Grain size distribution, Unit weight, N values and CSR.

Table 5 presents the soil properties collected from various geotechnical investigation reports (Refs. 18, 20, 24, 27, and 28). These properties include natural water content, Atterberg limits, plasticity index, grain size distribution (percent finer than .005mm) and soil classification. Although the information on grain size distribution is very limited, Atterberg limits and natural water content data should be sufficient to assess the liquefaction potential of the cohesive soils.

Cyclic triaxial, resonant column, or simple shear tests were not conducted on the soils at the Y-12 site since the past geotechnical investigation programs were not designed for soil liquefaction analysis. Empirical formulation for calculating the CSR have been used in the SLIQ computer program. N value is generally used for liquefaction analysis of sandy soils by field performance

procedures. Sands and sandy soils are generally not present at Y-12 site. Out of several soil investigations' results considered in this study, only one boring (Ref. 27) indicated a small pocket of silty sand (approximately 18 in. thick) with a N value of 8. This information will be used as input to the SLIQ Program.

7.0 SITE-SPECIFIC EARTHQUAKE RESPONSE ANALYSIS

7.1 METHODOLOGY

A site response analysis, sometimes referred to as soil amplification analysis, involves the determination of components of ground motion for seismic design or evaluation. Typically, as in this study, that determination is made for a "free-field", i.e., the response at ground surface of an ideal soil deposit (horizontal layers extending to infinity) to a spatially-uniform, horizontal motion applied at the base. The conceptual relationship between free-field response with respect to two other primary control points, rock outcrop and base rock in a site response analysis is shown in Fig. 14. The motions at these points, as well as any other point in the vertical profile are unique.

Design earthquake motions are most often specified as corresponding to rock outcrop. Mathematical expressions (transfer functions) are then used to find the equivalent motion for the base rock and then seismic waves are propagated through the soil column to determine the free-field motion at the surface.

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

- a. Determination of earthquake hazard and the selection or derivation of design motions.
- b. Idealization of stratigraphy and selection of material properties.
- c. Calculation and evaluation of site response.

For this study, step (a) was conducted by Risk Engineering, Inc. (Ref. 8) and is summarized in ES/CNPE-95/2 (Ref. 14). This study addresses steps (b) and (c).

The computer program, SHAKE 91 (Ref. 7), is used for this task to calculate the site responses. SHAKE 91 is a one dimensional, total stress code that solves the wave equation in the frequency domain (complex response technique). The soil profile is represented with an idealized soil column of homogeneous, visco elastic layers of infinite extent. SHAKE 91 can be used to determine the site responses from horizontal motions, but is not easily adapted for calculating vertical motions. Therefore, the vertical motions are assumed to be two-thirds of the horizontal ground motions, just like the vertical rock outcrop motions are assumed to be two-thirds of the horizontal rock outcrop motions.

Schematic representation of soil response analysis is depicted in Fig. 15.

Table 2

Engineering Properties Used in SHAKE Analysis

Stratum	Unit Weight (PCF)	Shear Wave Velocity (FPS)		
		Lower Bound	Mean	Upper Bound
Soil	120	500	700	1,000
Weathered Rock (Shale)	127	1,300	1,800	2,500
Fresh Rock	150	4,000		

Table 3
Normalized Shear Modulus &
Damping Vs. Shear Strain for Soil

<u>Shear Strain</u>	<u>$\frac{G}{G_{max.}}$</u>	<u>Damping %</u>
.0001	1.00	2.00
.001	0.997	2.50
.00316	0.974	3.50
.010	0.881	4.75
.0316	0.674	6.50
.1	0.425	9.25

Table 4

Normalized Shear Modulus & Damping Vs.
Shear Strain for Weathered Shale and Fresh Rock

<u>Shear Strain</u>	<u>$\frac{G}{G_{max}}$</u>	<u>Damping %</u>
.0001	1.00	0.40
.0003	1.00	
.001	0.9875	0.80
.003	0.9525	
.01	0.900	1.50
.03	0.810	
.10	0.725	3.00
1.00	0.550	4.60

TABLE 5 Index Properties and Soil Classification

#	Natural Water Content %	Liquid Limit %	0.9*LL	Plastic Limit %	Plasticity Index LL-PL (PI)	Soil Classification	Grain Size .005 mm (% Finer)	Reference
1	24.70	51.50	46.35	24.30	27.20	CH		Ref.18-Boring 11A
2	20.40	29.00	26.10	19.60	9.40	CL		↓
3	22.90	38.90	35.01	21.60	17.30	CL		Ref.20 -Boring 1
4	21.60	40.40	36.36	23.20	17.20	CL		↓
5	16.40	42.20	37.98	26.60	15.60	ML		↓
6	15.80	36.10	32.49	24.20	11.90	ML		↓
7	25.40	36.90	33.21	24.50	12.40	ML		Ref.20 -Boring 2
8	26.90	43.60	39.24	29.00	14.60	ML		↓
9	13.70	28.90	26.01	20.10	8.80	CL		↓
10	23.60	40.10	36.09	22.80	17.30	CL		Ref.20 -Boring 2A
11	29.80	41.80	37.62	25.00	16.80	ML		↓
12	29.90	38.60	34.74	21.80	16.80	CL		↓
13	18.60	37.50	33.75	21.20	16.30	CL		Ref.20 -Boring 3
14	21.50	38.10	34.29	22.00	16.10	CL		↓
15	22.40	32.80	29.52	23.10	9.70	ML		↓
16	22.60	39.20	35.28	25.00	14.20	ML		↓
17	34.90	43.10	38.79	30.90	12.20	ML		Ref.20 -Boring 4
18	21.70	38.60	34.74	21.90	16.70	CL		↓
19	22.10	36.90	33.21	22.40	14.50	CL		↓
20	23.20	39.80	35.82	21.10	18.70	CL		↓
21	15.00	40.20	36.18	26.60	13.60	ML		Ref.20 -Boring 5
22	17.50	42.10	37.89	26.50	15.60	ML		↓
23	19.20	36.30	32.67	22.40	13.90	CL		↓
24	11.90	32.20	28.98	25.00	7.10	ML		↓
25	24.70	39.80	35.82	23.00	16.80	CL		Ref.20 -Boring 6
26	23.50	37.40	33.66	25.20	12.20	ML		↓
27	33.90	36.00	32.40	20.60	15.40	CL		↓
28	11.90	39.90	35.91	24.00	15.90	CL		↓
29	17.60	41.60	37.44	26.40	15.20	ML		Ref.20 -Boring 7
30	28.10	36.40	32.76	21.10	15.30	CL		

TABLE 5 Index Properties and Soil Classification (cont'd.)

#	Natural Water Content %	Liquid Limit %	0.9*LL	Plastic Limit %	Plasticity Index LL-PL (PI)	Soil Classification	Grain Size .005 mm (% Finer)	Reference
31	24.30	40.70	36.63	21.90	18.80	CL		
32	25.30	28.20	25.38	25.40	2.90	ML		
33	6.80	28.80	25.92	22.60	6.20	ML		
34	18.80	35.60	32.04	23.00	12.60	CL		Ref.20 -Boring 8
35	19.20	36.10	32.49	24.50	11.60	ML		
36	20.50	34.10	30.69	22.80	11.30	ML		
37	15.30	36.90	33.21	20.00	16.90	CL		
38	5.90	27.30	24.57	20.90	6.40	ML		
39	24.90	38.80	34.92	23.80	15.00	ML		Ref.20 -Boring 9
40	22.70	41.10	36.99	25.20	15.90	ML		
41	22.70	40.40	36.36	26.00	14.40	ML		
42	8.20	28.00	25.20	21.10	6.90	ML		
43	25.10	38.90	35.01	28.00	10.90	ML		Ref.20 -Boring 10
44	24.90	41.20	37.08	28.80	12.40	ML		
45	25.50	43.10	38.79	26.40	16.70	ML		
46	11.30	34.20	30.78	26.10	8.10	ML		
47	8.70	27.80	25.02	22.10	5.70	CL		
48	22.10	41.20	37.08	23.10	18.10	CL		Ref. 24, Boring 1
49	17.40	34.20	30.78	19.40	14.80	CL		
50	16.10	34.80	31.32	21.20	13.60	CL		
51	28.70	41.60	37.44	24.30	17.30	CL		Ref. 24, Boring 2
52	21.80	43.60	39.24	25.00	18.60	CL		
53	19.10	36.10	32.49	16.70	19.40	CL		
54	22.70	37.20	33.48	19.10	18.10	CL		Ref. 24, Boring 3
55	20.60	39.80	35.82	22.90	16.90	CL		
56	18.40	36.80	33.12	19.80	17.00	CL		
57	11.60	36.20	32.58	19.00	17.20	CL		Ref.24, Boring 4
58	21.00	35.20	31.68	17.80	17.40	CL		
59	6.50	31.60	28.44	17.40	14.20	CL		
60	18.20	32.10	28.89	20.00	12.10	CL		Ref. 27, Boring 1

TABLE 5 Index Properties and Soil Classification (cont'd.)

#	Natural Water Content %	Liquid Limit %	0.9*LL	Plastic Limit %	Plasticity Index LL-PL (PI)	Soil Classification	Grain Size .005 mm (% Finer)	Reference	
	(WC)	(LL)		(PL)					
61	12.20	33.20	29.88	19.10	14.10	CL			
62	24.30	39.40	35.46	23.10	16.30	CL			
63	24.50	38.10	34.29	23.30	14.80	CL			
64	20.70	39.20	35.28	23.60	15.60	CL			
65	22.40	36.20	32.58	20.40	15.80	CL			
66	17.40	35.40	31.86	19.00	16.40	CL			
67	20.00	36.20	32.58	21.10	15.10	CL		Ref. 27	↓ Boring 2
68	18.80	34.20	30.78	21.60	12.60	CL			
69	26.70	37.50	33.75	27.30	10.20	ML			
70	15.60	34.60	31.14	21.50	13.10	CL			
71	25.00	37.20	33.48	20.10	17.10	CL			
72	17.90	34.40	30.96	19.40	15.00	CL			
73	16.30	32.10	28.89	17.70	14.40	CL		Ref. 27	↓ Boring 3
74	15.50	34.20	30.78	22.90	11.30	ML			
75	22.60	35.60	32.04	19.10	16.50	CL			
76	19.70	36.90	33.21	19.50	17.40	CL			
77	15.00	35.10	31.59	17.60	17.50	CL			
78	17.80	34.70	31.23	19.00	15.70	CL			
79	24.10	34.70	31.23	20.40	14.30	CL		Ref. 27	↓ Boring 4
80	23.00	35.10	31.59	22.90	12.20	CL			
81	22.90	28.80	25.92	17.40	11.40	CL			
82	17.50	27.80	25.02	15.90	11.90	CL			
83	24.10	32.60	29.34	16.50	16.10	CL			
84	21.50	33.30	29.97	18.30	15.00	CL			
85	22.10	32.60	29.34	18.40	14.20	CL			
86	16.50	44.00	39.60	29.00	15.00	ML	34	Ref. 28	↓ Boring V-1
87	18.80	33.00	29.70	32.00	1.00	ML			
88	12.80	29.00	26.10	24.00	5.00	ML	12		
89	27.70	42.00	37.80	21.00	21.00	CL		Ref. 28	↓ Boring V-2
90	20.30	50.00	45.00	23.00	27.00	CH		Ref. 28	↓ Boring V-3

TABLE 5 Index Properties and Soil Classification (cont'd.)

	Natural	Liquid		Plastic	Plasticity		Grain	
	Water Content	Limit		Limit	Index	Soil	Size	
#	%	%	0.9*LL	%	LL-PL	Classification	.005 mm	Reference
	(WC)	(LL)		(PL)	(PI)		(% Finer)	
91	12.20	35.00	31.50	29.00	6.00	ML		↓
92	11.40	29.00	26.10	22.00	7.00	CL	21	Ref. 28 , Boring V-4
93	11.10	32.00	28.80	23.00	9.00	ML	26	Ref. 28 , Boring V-6
94	10.10	34.00	30.60	28.00	6.00	ML	24	↓

ROCK OUTCROP
MOTION

FREE-FIELD
MOTION

STRUCTURE
OF INTEREST

BASE-ROCK
MOTION

FIG. 14 THREE PRIMARY CONTROL POINTS
FOR A SITE RESPONSE ANALYSIS

7.2 RESULTS

The primary focus of this study was to calculate the free field acceleration response spectra for the soil/weathered shale and determine the amplification ratios between the free field and rock outcrop motions. The scope of this study requires response analysis for damping ratios of 2, 5, 7, 10, 12, and 15 percent. For the purpose of this analysis, data is presented for spectral periods up to 10 seconds to define the peak response values.

The SHAKE 91 output consists of two files. The first file contains input information, the results of iteration of modulus reduction and damping ratios to arrive at the strain compatible materials properties, calculated maximum shear stresses and strains, peak accelerations, response spectrum and fourier spectrum, etc. The second output file contains all the time histories desired. Since the main objective of this study is to determine soil amplification ratios, this report will focus on the spectral accelerations and the amplification ratios considering the two components of the 2000-year seismic event, seven representative soil columns and six levels of damping values. Therefore, the second output file is not required and consequently it is not included in this report. The filing system for identifying the individual SHAKE runs are explained on page 35. Tables 6 through 11 present the summary of the amplification ratios for seven soil columns, two horizontal components of the earthquake and six damping ratios.

Plots of absolute response accelerations at top of ground (soil/weathered shale) and fresh rock are shown in Appendix A1. Plots of soil amplification ratios vs. spectral period are presented in Appendix A2.

Considering the mean values of material properties with 5 percent damping: (a) The peak soil amplification ratio varied between 3.8 and 4.5 at spectral periods ranging from .06 to .2 second, and (b) The peak weathered shale amplification ratio varied from 1.2 to 1.4 at .04 second.

For the same conditions as above with the exception of damping changed to 10 percent, the peak soil amplification ratio varied from 3.3 to 4.4 at periods ranging between .06 and .2 seconds, and the peak amplification ratio for weathered shale was on the order of 1.3 at an spectral period of .04 second.

Considering all seven soil columns, lower bound, mean and upper bound material properties, a general range of peak amplification ratios occurred at spectral periods between .04 and .3 second. The highest peak amplification ratio was 9.7 at spectral period of .1 second for soil column 1 (10 ft. soil over 10 ft. weathered shale), with a damping value of 2 percent for lower bound shear wave velocities and earthquake component 2.

ROCK OUTCROP

SURFACE

SURFACE

$$\text{AMP RATIO} = \frac{S_A \text{ SURFACE (PERIOD)}}{S_A \text{ ROCK OUTCROP (PERIOD)}}$$

FIG.15 SCHEMATIC REPRESENTATION OF SOIL RESPONSE ANALYSIS

Shake 91 Filing System

File Names

Y1M1	Y1L1	Y1U1
Y1M2	Y1L2	Y1U2
Y1M3	Y1L3	Y1U3
Y1M4	Y1L4	Y1U4
Y1M5	Y1L5	Y1U5
Y1M6	Y1L6	Y1U6
Y1M7	Y1L7	Y1U7

Y2M1	Y2L1	Y2U1
Y2M2	Y2L2	Y2U2
Y2M3	Y2L3	Y2U3
Y2M4	Y2L4	Y2U4
Y2M5	Y2L5	Y2U5
Y2M6	Y2L6	Y2U6
Y2M7	Y2L7	Y2U7

File Name System

Y = Y-12 SARUP

1,2 = Earthquake History 1000 yrs. Horiz. Component 1 or 2.

L,M,U = Lower Bound, Mean, Upper Bound Shear Wave Velocity

1,2,3,4,5,6,7 = Soil Column #1, 2, 3, 4, 5, 6, 7

Y2L3 = Y12 SARUP, EQ History Horiz. Comp 2, Lower Bound Shear wave Velocity,
Soil Column #3 [For damping ratios .02, .05, .07, .10, .12 & .15]

Y2L3.DAT = Data File

Y2L3.01 = Output File 1

Y2L3.02 = Output File 2

TABLE 6 Summary of Amplification Ratios

Damping = 2%

L = Lower Bound Properties, M = Median Properties, U = Upper Bound Properties

Profile	1						2						3						4					
Property	L		M		U		L		M		U		L		M		U		L		M		U	
History	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
Period, (sec)	Amplification Ratio at Period, (sec)																							
0.01	3.10	2.85	3.11	2.42	2.87	2.49	3.25	2.84	3.44	2.68	2.38	2.04	2.68	2.11	2.50	2.04	2.35	1.98	2.87	2.52	2.38	2.12	2.31	2.24
0.03	2.98	3.07	2.96	2.36	3.52	3.08	3.02	2.68	3.31	2.55	2.58	2.08	2.31	2.07	2.43	1.91	2.14	1.83	2.58	2.36	2.22	2.10	2.19	2.13
0.04	2.79	3.04	1.93	2.04	4.56	5.04	1.86	2.04	2.66	2.85	2.57	2.76	2.08	2.11	2.83	2.54	1.26	1.60	1.62	1.69	2.05	2.08	1.72	1.96
0.05	1.91	1.85	2.65	2.22	7.39	7.72	2.62	2.52	2.51	2.53	3.23	3.07	1.69	1.63	1.64	1.79	1.34	1.41	2.49	2.47	2.37	2.25	1.58	1.47
0.06	1.98	2.02	4.39	3.31	3.06	3.33	3.18	2.81	3.06	2.61	3.17	2.73	3.16	2.58	1.44	1.36	1.79	1.59	2.59	2.58	2.02	1.79	1.81	1.62
0.07	2.87	2.84	4.02	4.33	1.92	2.08	2.96	2.72	3.99	4.03	2.22	2.10	2.02	2.14	1.53	1.37	2.77	2.68	2.94	2.93	1.60	1.71	2.47	2.53
0.08	4.10	3.78	3.52	3.03	1.86	1.64	3.02	2.67	4.03	4.11	1.95	1.78	1.51	1.42	1.66	1.40	3.16	3.24	2.54	2.56	1.67	1.58	2.92	3.01
0.09	8.30	8.48	2.70	2.24	1.57	1.47	3.73	3.83	3.50	3.14	1.68	1.67	1.57	1.39	2.18	2.03	3.68	3.34	2.11	1.84	2.08	2.15	3.65	3.45
0.1	7.80	9.73	2.09	1.99	1.42	1.37	4.49	4.28	2.62	2.74	1.46	1.45	1.44	1.55	2.64	2.52	2.65	3.07	1.77	1.91	2.38	2.20	3.04	3.41
0.11	4.65	3.92	1.89	1.64	1.39	1.29	4.90	4.98	2.41	2.05	1.45	1.35	1.60	1.65	3.41	3.53	2.52	2.22	1.66	1.84	2.99	2.96	2.74	2.40
0.12	3.96	3.93	1.77	1.62	1.29	1.31	4.67	5.07	2.31	2.07	1.36	1.33	1.86	1.83	3.91	3.91	2.38	2.22	1.94	1.78	3.47	3.45	2.59	2.42
0.13	2.91	2.96	1.66	1.47	1.22	1.19	4.15	4.06	1.97	1.81	1.27	1.23	1.91	2.29	4.25	4.36	2.01	1.95	2.03	2.17	4.05	4.29	2.22	2.14
0.14	2.22	2.63	1.38	1.46	1.17	1.21	3.27	3.50	1.64	1.77	1.21	1.25	2.46	2.25	3.98	4.23	1.68	1.82	2.45	2.15	4.36	4.60	1.82	1.92
0.15	2.00	2.14	1.30	1.34	1.15	1.14	2.61	2.82	1.54	1.55	1.19	1.17	2.79	3.37	3.09	3.09	1.57	1.62	2.60	2.99	3.68	3.54	1.63	1.75
0.16	1.77	1.67	1.24	1.18	1.13	1.14	2.17	2.17	1.39	1.35	1.14	1.16	3.44	3.61	2.51	2.56	1.47	1.37	3.04	3.19	3.05	3.11	1.57	1.46
0.17	1.65	1.75	1.21	1.23	1.11	1.12	2.22	2.30	1.36	1.42	1.12	1.16	4.39	4.58	2.55	2.38	1.40	1.45	3.70	3.71	2.98	2.77	1.50	1.52
0.18	1.52	1.58	1.17	1.25	1.10	1.09	1.83	2.04	1.27	1.36	1.11	1.13	5.42	5.10	2.04	2.15	1.31	1.36	4.83	4.53	2.28	2.41	1.39	1.44
0.19	1.50	1.44	1.17	1.14	1.10	1.07	1.85	1.83	1.27	1.24	1.11	1.08	5.34	5.25	2.01	1.95	1.28	1.27	5.18	5.46	2.25	2.20	1.35	1.32
0.2	1.52	1.35	1.22	1.15	1.09	1.09	1.82	1.61	1.33	1.22	1.14	1.11	5.08	4.46	1.94	1.76	1.35	1.22	5.44	4.98	2.12	1.98	1.41	1.28
0.3	1.40	1.53	1.15	1.16	1.08	1.09	1.61	1.92	1.27	1.26	1.10	1.09	3.82	4.22	1.76	1.88	1.30	1.31	4.38	4.87	1.99	2.06	1.33	1.39
0.4	1.17	1.16	1.07	1.10	1.04	1.05	1.21	1.30	1.11	1.12	1.04	1.05	1.84	1.94	1.25	1.36	1.12	1.12	2.10	2.28	1.30	1.42	1.13	1.14
0.5	1.15	1.12	1.04	1.04	1.02	1.03	1.18	1.22	1.08	1.06	1.03	1.03	1.45	1.43	1.20	1.21	1.09	1.07	1.64	1.46	1.24	1.23	1.11	1.09
0.6	1.07	1.06	1.05	1.03	1.02	1.02	1.14	1.08	1.06	1.04	1.03	1.02	1.33	1.35	1.16	1.08	1.05	1.04	1.38	1.37	1.18	1.11	1.06	1.05
0.8	1.06	1.04	1.04	1.02	1.01	1.01	1.08	1.05	1.05	1.03	1.02	1.01	1.24	1.16	1.07	1.06	1.04	1.03	1.25	1.25	1.08	1.07	1.04	1.03
1	1.04	1.05	1.02	1.02	1.01	1.01	1.05	1.05	1.03	1.03	1.01	1.01	1.16	1.09	1.06	1.05	1.03	1.03	1.17	1.12	1.07	1.06	1.03	1.04
2	1.04	1.03	1.02	1.02	1.01	1.01	1.04	1.05	1.02	1.03	1.01	1.01	1.08	1.11	1.03	1.05	1.02	1.02	1.10	1.15	1.03	1.06	1.02	1.03

TABLE 6 Summary Amplification Ratios (Cont'd.)
Damping = 2%

L = Lower Bound Properties, M = Median Properties, U = Upper Bound Properties

Profile	5						6						7					
Property	L		M		U		L		M		U		L		M		U	
History	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
Period, (sec)	Amplification Ratio at Period, (sec)																	
0.01	2.35	2.14	2.32	1.79	2.10	1.81	2.60	2.01	2.53	2.11	2.00	1.73	1.35	1.34	1.12	1.12	1.04	1.03
0.03	2.11	1.98	2.06	1.74	2.06	1.69	2.27	1.78	2.30	1.94	1.90	1.74	1.52	1.37	1.14	1.13	1.04	1.03
0.04	2.02	1.89	1.62	1.77	2.48	2.23	1.35	1.55	1.81	1.97	1.98	2.20	1.93	2.01	1.33	1.30	1.14	1.09
0.05	1.84	1.43	1.45	1.38	1.48	1.58	2.09	1.89	1.97	1.95	1.88	2.07	1.58	1.65	1.23	1.25	1.10	1.10
0.06	1.76	1.79	2.78	2.24	1.30	1.23	2.34	1.75	2.72	2.18	1.51	1.25	1.51	1.30	1.26	1.11	1.15	1.03
0.07	1.35	1.46	1.78	1.98	1.42	1.28	2.26	2.23	2.31	2.51	1.34	1.38	1.32	1.22	1.16	1.08	1.09	1.02
0.08	1.81	1.57	1.39	1.31	1.51	1.29	2.26	1.94	1.85	1.72	1.43	1.33	1.19	1.17	1.09	1.08	1.04	1.03
0.09	2.98	2.52	1.42	1.27	1.99	1.85	2.83	2.66	1.60	1.45	1.88	1.90	1.18	1.13	1.09	1.05	1.04	1.01
0.1	2.07	2.40	1.30	1.43	2.35	2.23	2.84	2.86	1.43	1.57	2.15	2.05	1.09	1.13	1.03	1.07	1.00	1.04
0.11	1.54	1.50	1.40	1.51	2.90	2.96	2.06	2.00	1.36	1.56	2.68	2.73	1.09	1.07	1.03	1.03	1.00	1.00
0.12	1.27	1.35	1.65	1.63	3.28	3.17	1.81	1.89	1.66	1.55	3.07	2.99	1.10	1.08	1.05	1.03	1.02	1.00
0.13	1.15	1.26	1.75	1.99	3.38	3.51	1.58	1.51	1.77	1.95	3.32	3.48	1.08	1.08	1.05	1.04	1.03	1.02
0.14	1.58	1.34	2.21	2.01	3.34	3.55	1.73	1.43	2.22	1.94	3.40	3.66	1.07	1.08	1.04	1.04	1.02	1.02
0.15	1.23	1.64	2.44	2.87	2.81	2.76	1.33	1.66	2.32	2.67	3.00	2.92	1.05	1.04	1.02	1.02	1.01	1.01
0.16	1.52	1.67	3.06	3.04	2.38	2.41	1.51	1.77	2.83	2.84	2.60	2.64	1.04	1.04	1.01	1.02	1.00	1.01
0.17	1.37	1.26	3.77	3.78	2.39	2.24	1.42	1.28	3.40	3.37	2.55	2.44	1.02	1.04	1.01	1.02	1.00	1.01
0.18	1.70	1.58	4.53	4.33	1.91	2.01	1.61	1.59	4.28	3.99	2.03	2.14	1.04	1.04	1.02	1.02	1.01	1.01
0.19	1.69	2.06	4.51	4.54	1.93	1.87	1.66	2.05	4.41	4.60	2.03	1.99	1.02	1.02	1.01	1.01	1.00	1.00
0.2	1.89	1.68	4.47	3.96	1.87	1.72	1.74	1.66	4.58	4.13	1.95	1.80	1.04	1.04	1.02	1.02	1.01	1.01
0.3	4.88	5.22	3.42	3.83	1.72	1.83	4.61	5.44	3.67	4.11	1.82	1.91	1.03	1.03	1.02	1.01	1.01	1.01
0.4	3.49	4.85	1.78	1.94	1.24	1.33	4.13	5.28	1.92	2.10	1.26	1.36	1.02	1.01	1.01	1.01	1.01	1.01
0.5	2.21	2.45	1.45	1.40	1.17	1.19	2.41	2.55	1.55	1.40	1.20	1.21	1.01	1.01	1.00	1.00	1.00	1.00
0.6	1.60	1.70	1.31	1.32	1.14	1.08	1.72	1.82	1.33	1.33	1.16	1.09	1.01	1.01	1.00	1.00	1.00	1.00
0.8	1.43	1.46	1.21	1.17	1.06	1.06	1.52	1.50	1.22	1.21	1.07	1.07	1.01	1.01	1.00	1.00	1.00	1.00
1	1.21	1.29	1.14	1.09	1.05	1.05	1.23	1.32	1.15	1.10	1.06	1.05	1.00	1.00	1.00	1.00	1.00	1.00
2	1.12	1.31	1.08	1.12	1.03	1.05	1.13	1.34	1.09	1.14	1.03	1.05	1.00	1.00	1.00	1.00	1.00	1.00

TABLE 6 Summary Amplification Ratios (Cont'd.)

Damping = 2%

L = Lower Bound Properties, M = Median Properties, U = Upper Bound Properties

	Total	Average	Max	85%	Total	Average	Max	85%	Total	Average	Max	85%	Total	Average	Max	85%
Profile																
Property	L	L	L	L	M	M	M	M	U	U	U	U	All	All	All	All
History																
Period, (sec)																
0.01	34.00	2.43	3.25	3.10	31.67	2.26	3.44	3.11	28.38	2.03	2.87	2.49	94.05	2.24	3.44	2.87
0.03	32.12	2.29	3.07	3.02	30.15	2.15	3.31	2.96	29.02	2.07	3.52	3.08	91.29	2.17	3.52	2.98
0.04	27.99	2.00	3.04	2.79	28.77	2.06	2.85	2.83	32.59	2.33	5.04	4.56	89.35	2.13	5.04	2.79
0.05	27.67	1.98	2.62	2.52	27.19	1.94	2.65	2.53	36.41	2.60	7.72	7.39	91.27	2.17	7.72	2.62
0.06	31.35	2.24	3.18	3.16	32.26	2.30	4.39	3.31	26.59	1.90	3.33	3.17	90.20	2.15	4.39	3.16
0.07	31.25	2.23	2.96	2.94	33.41	2.39	4.33	4.03	26.30	1.88	2.77	2.68	90.96	2.17	4.33	2.94
0.08	31.56	2.25	4.10	3.78	29.42	2.10	4.11	4.03	27.19	1.94	3.24	3.16	88.17	2.10	4.11	3.24
0.09	44.57	3.18	8.48	8.30	27.89	1.99	3.50	3.14	30.19	2.16	3.68	3.65	102.65	2.44	8.48	3.65
0.1	45.33	3.24	9.73	7.80	27.00	1.93	2.74	2.64	28.68	2.05	3.41	3.07	101.01	2.41	9.73	3.07
0.11	34.49	2.46	4.98	4.90	28.78	2.06	3.53	3.41	28.63	2.05	2.96	2.90	91.90	2.19	4.98	3.41
0.12	33.52	2.39	5.07	4.67	31.10	2.22	3.91	3.91	29.43	2.10	3.28	3.17	94.05	2.24	5.07	3.91
0.13	30.14	2.15	4.15	4.06	33.40	2.39	4.36	4.29	28.97	2.07	3.51	3.48	92.51	2.20	4.36	4.05
0.14	29.16	2.08	3.50	3.27	33.89	2.42	4.60	4.36	28.08	2.01	3.66	3.55	91.13	2.17	4.60	3.55
0.15	29.28	2.09	3.37	2.99	31.48	2.25	3.68	3.54	24.72	1.77	3.00	2.92	85.48	2.04	3.68	3.00
0.16	29.59	2.11	3.61	3.44	30.20	2.16	3.11	3.06	22.47	1.61	2.64	2.60	82.27	1.96	3.61	3.05
0.17	31.70	2.26	4.58	4.39	32.25	2.30	3.78	3.77	22.00	1.57	2.55	2.44	85.95	2.05	4.58	3.70
0.18	35.41	2.53	5.42	5.10	33.10	2.36	4.53	4.33	20.03	1.43	2.14	2.03	88.54	2.11	5.42	4.33
0.19	37.36	2.67	5.46	5.34	33.30	2.38	4.60	4.54	19.40	1.39	2.03	1.99	90.05	2.14	5.46	4.54
0.2	35.31	2.52	5.44	5.08	31.89	2.28	4.58	4.47	19.04	1.36	1.95	1.87	86.24	2.05	5.44	4.46
0.3	45.95	3.28	5.44	5.22	29.60	2.11	4.11	3.83	18.98	1.36	1.91	1.83	94.53	2.25	5.44	4.38
0.4	32.77	2.34	5.28	4.85	19.50	1.39	2.10	1.94	15.90	1.14	1.36	1.33	68.18	1.62	5.28	2.10
0.5	22.28	1.59	2.55	2.45	16.91	1.21	1.55	1.45	15.24	1.09	1.21	1.20	54.43	1.30	2.55	1.55
0.6	18.63	1.33	1.82	1.72	16.02	1.14	1.33	1.33	14.76	1.05	1.16	1.14	49.41	1.18	1.82	1.37
0.8	17.04	1.22	1.52	1.50	15.22	1.09	1.22	1.21	14.44	1.03	1.07	1.07	46.71	1.11	1.52	1.25
1	15.79	1.13	1.32	1.29	14.82	1.06	1.15	1.14	14.39	1.03	1.06	1.05	45.00	1.07	1.32	1.16
2	15.52	1.11	1.34	1.31	14.69	1.05	1.14	1.12	14.30	1.02	1.05	1.05	44.51	1.06	1.34	1.12

TABLE 7 Summary of Amplification Ratios
Damping = 5%

L = Lower Bound Properties, M = Median Properties, U = Upper Bound Properties

Profile	1						2						3						4					
Property	L		M		U		L		M		U		L		M		U		L		M		U	
History	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
Period, (sec)	Amplification Ratio at Period, (sec)																							
0.01	3.10	2.85	3.11	2.42	2.87	2.49	3.26	2.83	3.44	2.68	2.38	2.04	2.68	2.11	2.50	2.04	2.35	1.98	2.87	2.52	2.38	2.12	2.31	2.24
0.03	3.00	3.10	2.96	2.36	3.47	3.10	3.02	2.69	3.33	2.57	2.60	2.08	2.32	2.08	2.42	1.90	2.16	1.85	2.59	2.36	2.22	2.10	2.20	2.14
0.04	2.64	3.00	2.12	2.51	4.79	4.88	2.27	2.37	3.06	3.01	2.93	2.72	2.11	2.12	2.56	2.52	1.73	1.96	1.98	2.12	2.16	2.31	1.87	2.16
0.05	2.19	2.16	2.77	2.36	5.94	5.17	2.60	2.90	2.50	2.43	2.93	2.97	1.79	1.98	1.63	1.75	1.41	1.47	2.48	2.37	2.08	2.28	1.69	1.58
0.06	2.46	2.01	4.15	3.25	2.93	3.31	2.98	2.73	3.03	2.50	2.85	2.65	2.77	2.67	1.51	1.46	1.98	1.56	2.54	2.67	1.91	1.74	2.05	1.61
0.07	2.83	3.23	3.95	3.84	1.82	1.89	2.90	2.78	3.86	3.74	2.03	2.11	1.88	2.00	1.52	1.59	2.59	2.77	2.75	2.62	1.63	1.74	2.40	2.59
0.08	3.65	3.95	3.48	2.79	1.89	1.78	3.30	2.92	4.08	3.78	1.94	1.73	1.51	1.56	1.80	1.68	3.03	3.02	2.67	2.45	1.92	1.82	2.87	2.85
0.09	7.05	7.85	2.66	2.17	1.56	1.53	3.86	3.57	3.57	3.05	1.72	1.59	1.73	1.55	2.43	2.10	3.58	3.16	2.42	1.94	2.23	2.16	3.39	3.34
0.1	6.23	6.71	2.21	2.08	1.42	1.43	4.56	4.09	2.74	2.75	1.53	1.58	1.74	1.77	2.79	2.63	2.77	3.07	2.16	2.19	2.53	2.43	2.85	3.11
0.11	4.81	3.82	2.03	1.74	1.36	1.28	4.69	4.89	2.47	2.12	1.43	1.40	1.81	1.87	3.45	3.43	2.57	2.23	1.82	2.00	2.98	3.06	2.73	2.50
0.12	4.07	3.44	1.89	1.63	1.30	1.23	4.83	5.30	2.33	2.16	1.44	1.29	2.04	2.30	3.90	3.88	2.47	2.16	2.12	2.11	3.42	3.64	2.64	2.49
0.13	2.95	2.56	1.68	1.44	1.23	1.17	4.23	3.89	2.04	1.65	1.32	1.19	2.41	2.47	3.84	3.85	1.96	1.74	2.33	2.42	3.89	3.64	2.23	1.93
0.14	2.18	2.40	1.36	1.41	1.15	1.24	3.40	3.48	1.55	1.71	1.17	1.23	2.70	3.11	3.82	3.89	1.63	1.78	2.61	2.96	4.05	4.19	1.76	1.91
0.15	1.95	1.90	1.32	1.34	1.17	1.18	2.64	2.91	1.46	1.61	1.21	1.20	3.08	3.58	2.74	3.04	1.52	1.66	2.81	3.36	3.20	3.16	1.62	1.76
0.16	1.82	1.77	1.31	1.28	1.14	1.17	2.48	2.54	1.46	1.41	1.18	1.19	3.74	3.89	2.68	2.81	1.50	1.45	3.02	3.37	2.97	2.94	1.62	1.59
0.17	1.74	1.72	1.26	1.27	1.10	1.13	2.38	2.31	1.42	1.39	1.15	1.16	4.51	4.47	2.74	2.49	1.47	1.40	3.68	3.81	3.16	2.77	1.56	1.49
0.18	1.49	1.66	1.19	1.28	1.11	1.11	1.92	2.11	1.27	1.38	1.13	1.13	5.00	4.74	2.11	2.31	1.27	1.37	4.81	4.12	2.42	2.47	1.34	1.47
0.19	1.46	1.61	1.17	1.22	1.12	1.09	1.78	2.07	1.27	1.30	1.11	1.15	5.00	4.95	1.92	2.35	1.29	1.34	5.09	4.97	2.14	2.62	1.33	1.39
0.2	1.58	1.35	1.22	1.12	1.12	1.09	1.85	1.60	1.35	1.17	1.14	1.10	5.08	3.90	1.92	1.70	1.37	1.17	5.23	4.40	2.12	1.90	1.45	1.23
0.3	1.50	1.53	1.18	1.18	1.09	1.09	1.74	1.87	1.31	1.26	1.10	1.11	4.41	3.87	1.81	1.87	1.33	1.31	4.45	4.48	2.03	2.11	1.37	1.37
0.4	1.22	1.16	1.09	1.08	1.05	1.06	1.26	1.30	1.14	1.11	1.06	1.06	2.00	2.09	1.31	1.39	1.14	1.11	2.20	2.46	1.38	1.45	1.16	1.13
0.5	1.09	1.19	1.07	1.06	1.03	1.03	1.20	1.28	1.09	1.11	1.03	1.04	1.53	1.52	1.26	1.26	1.08	1.12	1.74	1.56	1.30	1.28	1.08	1.13
0.6	1.08	1.12	1.08	1.04	1.03	1.04	1.17	1.19	1.08	1.08	1.04	1.04	1.43	1.53	1.20	1.23	1.06	1.09	1.47	1.55	1.22	1.25	1.07	1.09
0.8	1.08	1.05	1.05	1.02	1.02	1.01	1.10	1.06	1.05	1.04	1.03	1.02	1.25	1.19	1.09	1.07	1.04	1.03	1.27	1.27	1.10	1.09	1.05	1.03
1	1.07	1.06	1.04	1.03	1.01	1.01	1.08	1.07	1.05	1.04	1.02	1.02	1.23	1.14	1.08	1.05	1.04	1.04	1.25	1.18	1.09	1.05	1.05	1.04
2	1.06	1.06	1.03	1.03	1.01	1.02	1.05	1.07	1.04	1.04	1.01	1.02	1.12	1.13	1.05	1.05	1.04	1.04	1.14	1.17	1.06	1.06	1.04	1.04

TABLE 7 Summary of Amplification Ratios (Cont'd.)
Damping = 5%

L = Lower Bound Properties, M = Median Properties, U = Upper Bound Properties

Profile	5						6						7					
Property	L		M		U		L		M		U		L		M		U	
History	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
Period, (sec)	Amplification Ratio at Period, (sec)																	
0.01	2.35	2.14	2.32	1.79	2.10	1.81	2.59	2.01	2.53	2.11	2.00	1.73	1.35	1.34	1.12	1.12	1.04	1.03
0.03	2.11	1.98	2.06	1.74	2.06	1.68	2.27	1.78	2.30	1.95	1.89	1.74	1.51	1.35	1.13	1.12	1.04	1.03
0.04	1.96	1.93	1.76	1.86	2.28	2.24	1.60	1.71	2.27	2.10	2.14	2.22	1.77	2.05	1.23	1.42	1.07	1.22
0.05	1.90	1.67	1.54	1.61	1.40	1.56	2.05	1.81	1.97	1.78	1.58	1.92	1.58	1.44	1.20	1.16	1.06	1.05
0.06	1.72	1.79	2.42	2.32	1.36	1.32	2.25	1.77	2.78	2.15	1.41	1.47	1.35	1.35	1.11	1.14	1.02	1.05
0.07	1.27	1.73	1.72	1.83	1.40	1.48	2.11	2.25	2.18	2.18	1.37	1.46	1.32	1.20	1.16	1.06	1.10	1.01
0.08	1.83	1.58	1.39	1.39	1.63	1.50	2.14	1.91	1.94	1.74	1.63	1.56	1.22	1.22	1.10	1.10	1.05	1.05
0.09	2.78	2.21	1.54	1.41	2.19	1.87	2.64	2.42	1.75	1.51	2.08	1.90	1.18	1.14	1.08	1.06	1.03	1.02
0.1	2.16	2.31	1.59	1.63	2.43	2.23	2.78	2.58	1.76	1.72	2.22	2.17	1.11	1.09	1.04	1.03	1.01	1.00
0.11	1.50	1.44	1.56	1.69	2.89	2.91	2.09	2.05	1.50	1.69	2.60	2.70	1.08	1.11	1.03	1.06	1.01	1.04
0.12	1.22	1.54	1.80	2.04	3.18	3.20	1.82	2.00	1.80	1.96	3.03	3.17	1.11	1.12	1.05	1.06	1.01	1.03
0.13	1.36	1.28	2.06	2.19	3.14	3.24	1.67	1.60	1.94	2.20	3.19	3.20	1.09	1.06	1.05	1.03	1.03	1.01
0.14	1.80	1.61	2.38	2.67	3.18	3.19	1.92	1.68	2.33	2.57	3.21	3.25	1.04	1.06	1.02	1.02	1.01	1.01
0.15	1.48	1.83	2.68	3.11	2.51	2.70	1.55	1.87	2.42	2.93	2.69	2.82	1.05	1.08	1.02	1.04	1.01	1.03
0.16	1.56	1.71	3.19	3.26	2.48	2.53	1.57	1.77	2.79	3.01	2.58	2.58	1.05	1.05	1.03	1.02	1.01	1.01
0.17	1.55	1.31	3.83	3.76	2.49	2.25	1.58	1.43	3.38	3.41	2.71	2.36	1.05	1.03	1.03	1.01	1.02	1.00
0.18	1.83	1.49	4.26	3.93	1.98	2.13	1.70	1.52	4.12	3.61	2.10	2.19	1.03	1.04	1.01	1.02	1.00	1.01
0.19	1.73	2.33	4.30	4.21	1.84	2.19	1.60	2.32	4.29	4.14	1.95	2.29	1.02	1.02	1.01	1.00	1.00	1.00
0.2	1.93	2.04	4.39	3.51	1.87	1.64	1.82	2.08	4.47	3.63	1.97	1.74	1.04	1.03	1.02	1.01	1.01	1.00
0.3	4.29	4.46	3.79	3.54	1.74	1.79	4.26	4.69	3.78	3.74	1.86	1.89	1.03	1.03	1.02	1.01	1.01	1.01
0.4	3.67	4.08	1.91	2.07	1.30	1.34	3.94	4.37	1.99	2.26	1.33	1.38	1.02	1.02	1.01	1.01	1.00	1.00
0.5	2.19	2.58	1.53	1.48	1.23	1.23	2.36	2.65	1.63	1.48	1.26	1.25	1.01	1.01	1.01	1.01	1.00	1.00
0.6	1.67	1.91	1.39	1.48	1.18	1.20	1.74	2.10	1.41	1.50	1.19	1.21	1.01	1.01	1.00	1.01	1.00	1.00
0.8	1.44	1.47	1.22	1.19	1.08	1.07	1.55	1.51	1.24	1.23	1.09	1.07	1.01	1.01	1.00	1.00	1.00	1.00
1	1.26	1.35	1.20	1.13	1.07	1.05	1.30	1.41	1.21	1.16	1.08	1.05	1.00	1.00	1.00	1.00	1.00	1.00
2	1.17	1.30	1.11	1.12	1.04	1.05	1.18	1.32	1.12	1.14	1.05	1.05	1.00	1.00	1.00	1.00	1.00	1.00

TABLE 7 Summary of Amplification Ratios (Cont'd.)
Damping = 5%

L = Lower Bound Properties, M = Median Properties, U = Upper Bound Properties

	Total	Average	Max	85%	Total	Average	Max	85%	Total	Average	Max	85%	Total	Average	Max	85%
Profile																
Property	L	L	L	L	M	M	M	M	U	U	U	U	All	All	All	All
History																
Period, (sec)																
0.01	33.99	2.43	3.26	3.10	31.66	2.26	3.44	3.11	28.38	2.03	2.87	2.49	94.04	2.24	3.44	2.87
0.03	32.16	2.30	3.10	3.02	30.17	2.16	3.33	2.96	29.03	2.07	3.47	3.10	91.36	2.18	3.47	3.00
0.04	29.62	2.12	3.00	2.64	30.88	2.21	3.06	3.01	34.20	2.44	4.88	4.79	94.69	2.25	4.88	2.93
0.05	28.91	2.07	2.90	2.60	27.04	1.93	2.77	2.50	31.72	2.27	5.94	5.17	87.67	2.09	5.94	2.77
0.06	31.07	2.22	2.98	2.77	31.49	2.25	4.15	3.25	26.58	1.90	3.31	2.93	89.14	2.12	4.15	2.93
0.07	30.88	2.21	3.23	2.90	32.01	2.29	3.95	3.86	26.02	1.86	2.77	2.59	88.91	2.12	3.95	2.90
0.08	31.90	2.28	3.95	3.65	30.00	2.14	4.08	3.78	27.51	1.96	3.03	3.02	89.40	2.13	4.08	3.30
0.09	42.34	3.02	7.85	7.05	28.71	2.05	3.57	3.05	29.96	2.14	3.58	3.39	101.01	2.40	7.85	3.57
0.1	41.47	2.96	6.71	6.23	28.93	2.07	2.79	2.75	28.82	2.06	3.11	3.07	99.22	2.36	6.71	3.07
0.11	34.97	2.50	4.89	4.81	29.82	2.13	3.45	3.43	28.65	2.05	2.91	2.89	93.45	2.22	4.89	3.43
0.12	35.01	2.50	5.30	4.83	32.55	2.32	3.90	3.88	29.62	2.12	3.20	3.18	97.18	2.31	5.30	3.64
0.13	31.32	2.24	4.23	3.89	32.49	2.32	3.89	3.85	27.56	1.97	3.24	3.20	91.37	2.18	4.23	3.64
0.14	31.97	2.28	3.48	3.40	33.95	2.43	4.19	4.05	26.72	1.91	3.25	3.21	92.65	2.21	4.19	3.40
0.15	31.09	2.22	3.58	3.36	31.07	2.22	3.20	3.16	24.06	1.72	2.82	2.70	86.23	2.05	3.58	3.08
0.16	31.34	2.24	3.89	3.74	31.17	2.23	3.26	3.19	23.02	1.64	2.58	2.58	85.53	2.04	3.89	3.02
0.17	32.57	2.33	4.51	4.47	32.91	2.35	3.83	3.76	22.30	1.59	2.71	2.49	87.78	2.09	4.51	3.68
0.18	34.44	2.46	5.00	4.81	32.38	2.31	4.26	4.12	20.34	1.45	2.19	2.13	87.16	2.08	5.00	4.12
0.19	36.94	2.64	5.09	5.00	32.96	2.35	4.30	4.29	20.08	1.43	2.29	2.19	89.98	2.14	5.09	4.29
0.2	34.92	2.49	5.23	5.08	30.52	2.18	4.47	4.39	18.89	1.35	1.97	1.87	84.34	2.01	5.23	3.90
0.3	43.59	3.11	4.69	4.48	29.63	2.12	3.79	3.78	19.06	1.36	1.89	1.86	92.28	2.20	4.69	4.29
0.4	31.79	2.27	4.37	4.08	20.19	1.44	2.26	2.07	16.14	1.15	1.38	1.34	68.13	1.62	4.37	2.26
0.5	22.90	1.64	2.65	2.58	17.55	1.25	1.63	1.53	15.52	1.11	1.26	1.25	55.96	1.33	2.65	1.63
0.6	19.99	1.43	2.10	1.91	16.96	1.21	1.50	1.48	15.21	1.09	1.21	1.20	52.17	1.24	2.10	1.53
0.8	17.26	1.23	1.55	1.51	15.39	1.10	1.24	1.23	14.54	1.04	1.09	1.08	47.20	1.12	1.55	1.27
1	16.40	1.17	1.41	1.35	15.15	1.08	1.21	1.20	14.49	1.03	1.08	1.07	46.04	1.10	1.41	1.23
2	15.78	1.13	1.32	1.30	14.85	1.06	1.14	1.12	14.41	1.03	1.05	1.05	45.04	1.07	1.32	1.14

TABLE 8 Summary of Amplification Ratios
Damping = 7%

L = Lower Bound Properties, M = Median Properties, U = Upper Bound Properties

Profile	1						2						3						4					
Property	L		M		U		L		M		U		L		M		U		L		M		U	
History	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
Period, (sec)	Amplification Ratio at Period, (sec)																							
0.01	3.10	2.85	3.11	2.42	2.87	2.49	3.26	2.83	3.44	2.68	2.38	2.04	2.68	2.11	2.50	2.04	2.35	1.98	2.87	2.52	2.38	2.12	2.31	2.24
0.03	3.01	3.11	2.96	2.35	3.43	3.11	3.03	2.69	3.35	2.59	2.61	2.09	2.32	2.08	2.42	1.90	2.17	1.86	2.59	2.37	2.22	2.10	2.20	2.15
0.04	2.58	2.97	2.22	2.55	4.88	4.71	2.45	2.51	3.16	2.94	2.99	2.80	2.14	2.07	2.39	2.44	1.88	2.01	2.07	2.26	2.25	2.34	1.94	2.16
0.05	2.34	2.36	2.77	2.48	5.20	4.51	2.58	2.98	2.48	2.51	2.87	2.96	1.82	2.04	1.64	1.74	1.48	1.65	2.51	2.43	2.09	2.22	1.74	1.64
0.06	2.54	2.12	3.83	3.25	2.66	3.13	2.90	2.82	2.86	2.46	2.60	2.74	2.69	2.72	1.57	1.57	2.03	1.73	2.55	2.75	1.84	1.96	2.10	1.66
0.07	2.82	3.29	3.93	3.55	1.81	1.88	2.92	2.77	3.83	3.53	1.99	2.14	1.94	2.06	1.54	1.69	2.51	2.72	2.65	2.38	1.66	1.78	2.39	2.55
0.08	3.47	3.78	3.38	2.70	1.86	1.76	3.24	3.03	3.86	3.44	1.94	1.75	1.50	1.66	1.82	1.73	2.86	2.95	2.53	2.25	1.94	1.85	2.74	2.76
0.09	6.21	7.30	2.60	2.13	1.57	1.62	3.77	3.44	3.49	2.99	1.68	1.62	1.82	1.61	2.45	2.09	3.33	2.99	2.46	2.02	2.26	2.18	3.24	3.25
0.1	5.67	5.78	2.16	2.15	1.43	1.49	4.43	4.10	2.72	2.83	1.54	1.66	1.78	1.87	2.78	2.86	2.62	3.09	2.19	2.30	2.50	2.67	2.84	3.13
0.11	4.94	3.85	2.10	1.74	1.36	1.27	4.60	4.67	2.44	2.15	1.45	1.39	1.93	1.93	3.43	3.28	2.56	2.25	1.93	2.04	2.97	2.98	2.73	2.44
0.12	3.91	3.52	1.95	1.57	1.33	1.20	4.88	4.69	2.38	2.04	1.46	1.26	2.20	2.32	3.83	3.75	2.46	2.20	2.29	2.15	3.44	3.55	2.68	2.38
0.13	2.96	2.61	1.70	1.38	1.23	1.14	4.11	3.87	2.10	1.60	1.33	1.17	2.58	2.65	3.77	3.74	1.97	1.75	2.56	2.54	3.77	3.64	2.18	1.92
0.14	2.09	2.13	1.33	1.34	1.20	1.21	3.13	3.40	1.47	1.61	1.22	1.19	2.82	3.07	3.43	3.50	1.54	1.63	2.71	2.97	3.54	3.37	1.65	1.78
0.15	1.94	1.83	1.33	1.28	1.17	1.18	2.68	2.88	1.47	1.55	1.21	1.19	3.13	3.53	2.81	3.08	1.52	1.60	2.95	3.33	3.18	3.18	1.64	1.70
0.16	1.87	1.72	1.33	1.30	1.15	1.17	2.58	2.49	1.49	1.36	1.19	1.20	3.79	3.79	2.84	2.80	1.52	1.40	3.16	3.36	3.14	2.94	1.64	1.52
0.17	1.75	1.71	1.28	1.30	1.10	1.16	2.42	2.38	1.41	1.45	1.17	1.17	4.39	4.41	2.76	2.54	1.48	1.42	3.74	3.74	3.13	2.85	1.57	1.50
0.18	1.50	1.72	1.21	1.32	1.11	1.11	1.96	2.34	1.30	1.43	1.15	1.16	4.86	4.78	2.08	2.55	1.30	1.42	4.79	4.24	2.43	2.77	1.36	1.50
0.19	1.51	1.57	1.19	1.17	1.13	1.06	1.74	2.11	1.28	1.28	1.12	1.09	4.99	4.60	1.91	2.35	1.30	1.29	5.18	4.61	2.10	2.63	1.37	1.37
0.2	1.58	1.36	1.24	1.12	1.13	1.09	1.88	1.67	1.35	1.15	1.17	1.10	5.07	3.80	1.94	1.76	1.38	1.16	5.28	4.13	2.11	1.93	1.46	1.23
0.3	1.54	1.44	1.20	1.18	1.10	1.09	1.90	1.66	1.31	1.23	1.12	1.12	4.79	3.46	1.99	1.72	1.34	1.23	4.88	4.00	2.14	1.94	1.39	1.28
0.4	1.25	1.19	1.11	1.09	1.06	1.07	1.29	1.32	1.15	1.12	1.06	1.07	2.16	2.15	1.33	1.40	1.16	1.13	2.38	2.56	1.41	1.45	1.18	1.15
0.5	1.10	1.22	1.07	1.08	1.04	1.03	1.23	1.32	1.09	1.12	1.04	1.05	1.56	1.55	1.29	1.30	1.08	1.13	1.78	1.65	1.32	1.32	1.09	1.15
0.6	1.08	1.15	1.10	1.04	1.04	1.05	1.18	1.27	1.08	1.08	1.05	1.04	1.48	1.54	1.22	1.26	1.06	1.09	1.51	1.54	1.23	1.28	1.07	1.10
0.8	1.09	1.06	1.07	1.04	1.03	1.02	1.10	1.07	1.06	1.04	1.03	1.02	1.23	1.20	1.09	1.09	1.06	1.03	1.25	1.30	1.10	1.10	1.07	1.04
1	1.08	1.07	1.05	1.03	1.02	1.02	1.10	1.06	1.06	1.04	1.03	1.02	1.24	1.15	1.08	1.05	1.06	1.05	1.27	1.18	1.10	1.06	1.06	1.05
2	1.08	1.09	1.04	1.03	1.03	1.02	1.10	1.09	1.05	1.05	1.03	1.03	1.16	1.16	1.07	1.07	1.05	1.05	1.19	1.19	1.08	1.08	1.05	1.05

TABLE 8 Summary of Amplification Ratios (Cont'd.)
Damping = 7%

L = Lower Bound Properties, M = Median Properties, U = Upper Bound Properties

Profile	5						6						7					
Property	L		M		U		L		M		U		L		M		U	
History	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
Period, (sec)	Amplification Ratio at Period, (sec)																	
0.01	2.35	2.14	2.32	1.79	2.10	1.81	2.59	2.01	2.53	2.10	2.00	1.73	1.35	1.34	1.12	1.12	1.04	1.03
0.03	2.11	1.98	2.06	1.75	2.05	1.68	2.28	1.78	2.31	1.96	1.89	1.75	1.51	1.34	1.13	1.12	1.03	1.02
0.04	1.90	1.88	1.81	1.82	2.14	2.18	1.77	1.76	2.37	2.10	2.19	2.12	1.86	1.97	1.28	1.40	1.12	1.21
0.05	1.93	1.78	1.57	1.74	1.44	1.56	2.06	1.82	1.95	1.93	1.65	1.84	1.53	1.49	1.16	1.16	1.03	1.05
0.06	1.63	1.90	2.35	2.37	1.41	1.41	2.30	1.86	2.64	2.12	1.40	1.62	1.25	1.37	1.07	1.16	1.01	1.07
0.07	1.25	1.83	1.74	1.84	1.41	1.57	2.04	2.35	2.17	2.04	1.40	1.58	1.31	1.23	1.16	1.10	1.09	1.04
0.08	1.84	1.52	1.38	1.46	1.61	1.52	2.07	1.87	1.95	1.80	1.64	1.57	1.24	1.22	1.11	1.10	1.06	1.05
0.09	2.58	2.10	1.69	1.46	2.20	1.87	2.57	2.33	1.84	1.54	2.09	1.91	1.13	1.14	1.05	1.06	1.01	1.02
0.1	2.13	2.35	1.66	1.72	2.37	2.46	2.73	2.50	1.78	1.79	2.19	2.40	1.08	1.12	1.02	1.04	0.99	1.01
0.11	1.56	1.44	1.66	1.73	2.87	2.79	2.11	2.07	1.58	1.72	2.58	2.65	1.08	1.10	1.03	1.06	1.01	1.04
0.12	1.37	1.53	1.93	2.05	3.19	3.13	1.78	2.06	1.93	1.96	3.02	3.06	1.13	1.07	1.06	1.03	1.03	1.01
0.13	1.61	1.31	2.19	2.33	3.10	3.15	1.70	1.70	2.12	2.29	3.07	3.17	1.07	1.07	1.03	1.04	1.01	1.02
0.14	1.85	1.54	2.44	2.71	2.86	2.98	1.99	1.59	2.37	2.61	2.84	2.94	1.04	1.06	1.01	1.02	1.00	1.00
0.15	1.65	1.81	2.68	3.08	2.54	2.70	1.72	1.83	2.53	2.91	2.73	2.81	1.05	1.08	1.02	1.04	1.01	1.03
0.16	1.68	1.69	3.22	3.16	2.60	2.50	1.73	1.74	2.85	2.98	2.70	2.56	1.05	1.05	1.03	1.02	1.01	1.01
0.17	1.76	1.38	3.71	3.69	2.51	2.33	1.82	1.48	3.40	3.33	2.68	2.41	1.04	1.04	1.02	1.02	1.01	1.01
0.18	1.88	1.75	4.13	3.97	1.95	2.35	1.72	1.71	4.08	3.66	2.10	2.44	1.03	1.04	1.01	1.02	1.00	1.01
0.19	1.84	2.36	4.30	4.03	1.79	2.17	1.65	2.33	4.35	3.93	1.91	2.30	1.03	1.03	1.01	1.01	1.00	1.01
0.2	2.10	2.24	4.42	3.28	1.86	1.63	1.99	2.26	4.48	3.49	1.97	1.71	1.03	1.03	1.01	1.02	1.00	1.01
0.3	4.05	3.94	4.16	3.23	1.88	1.64	4.11	4.15	4.18	3.44	1.96	1.73	1.03	1.04	1.01	1.02	1.01	1.01
0.4	3.74	3.94	2.07	2.16	1.30	1.34	4.02	4.06	2.16	2.33	1.34	1.38	1.02	1.02	1.01	1.01	1.01	1.00
0.5	2.21	2.69	1.55	1.50	1.26	1.27	2.37	2.75	1.66	1.54	1.28	1.28	1.01	1.01	1.01	1.00	1.00	1.00
0.6	1.75	1.94	1.44	1.49	1.19	1.22	1.82	2.13	1.46	1.49	1.19	1.24	1.01	1.01	1.01	1.01	1.00	1.00
0.8	1.38	1.49	1.21	1.21	1.08	1.08	1.50	1.55	1.23	1.25	1.09	1.08	1.01	1.01	1.00	1.00	1.00	1.00
1	1.30	1.39	1.23	1.14	1.08	1.04	1.34	1.44	1.26	1.15	1.09	1.05	1.00	1.00	1.00	1.00	1.00	1.00
2	1.22	1.31	1.14	1.14	1.06	1.06	1.24	1.32	1.16	1.16	1.07	1.06	1.01	1.01	1.00	1.00	1.00	1.00

TABLE 8 Summary of Amplification Ratios (Cont'd.)
Damping = 7%

L = Lower Bound Properties, M = Median Properties, U = Upper Bound Properties

	Total	Average	Max	85%	Total	Average	Max	85%	Total	Average	Max	85%	Total	Average	Max	85%
Profile																
Property	L	L	L	L	M	M	M	M	U	U	U	U	All	All	All	All
History																
Period, (sec)																
0.01	33.99	2.43	3.26	3.10	31.66	2.26	3.44	3.11	28.39	2.03	2.87	2.49	94.04	2.24	3.44	2.87
0.03	32.21	2.30	3.11	3.03	30.21	2.16	3.35	2.96	29.04	2.07	3.43	3.11	91.45	2.18	3.43	3.01
0.04	30.19	2.16	2.97	2.58	31.06	2.22	3.16	2.94	34.32	2.45	4.88	4.71	95.57	2.28	4.88	2.94
0.05	29.67	2.12	2.98	2.58	27.44	1.96	2.77	2.51	30.62	2.19	5.20	4.51	87.73	2.09	5.20	2.77
0.06	31.42	2.24	2.90	2.82	31.05	2.22	3.83	3.25	26.58	1.90	3.13	2.74	89.04	2.12	3.83	2.82
0.07	30.83	2.20	3.29	2.92	31.54	2.25	3.93	3.83	26.10	1.86	2.72	2.55	88.47	2.11	3.93	2.92
0.08	31.23	2.23	3.78	3.47	29.51	2.11	3.86	3.44	27.08	1.93	2.95	2.86	87.82	2.09	3.86	3.24
0.09	40.46	2.89	7.30	6.21	28.81	2.06	3.49	2.99	29.38	2.10	3.33	3.25	98.66	2.35	7.30	3.33
0.1	40.01	2.86	5.78	5.67	29.69	2.12	2.86	2.83	29.22	2.09	3.13	3.09	98.92	2.36	5.78	3.09
0.11	35.26	2.52	4.94	4.67	29.88	2.13	3.43	3.28	28.39	2.03	2.87	2.79	93.52	2.23	4.94	3.28
0.12	34.92	2.49	4.88	4.69	32.49	2.32	3.83	3.75	29.39	2.10	3.19	3.13	96.80	2.30	4.88	3.55
0.13	32.32	2.31	4.11	3.87	32.70	2.34	3.77	3.77	27.22	1.94	3.17	3.15	92.23	2.20	4.11	3.64
0.14	31.39	2.24	3.40	3.13	31.75	2.27	3.54	3.50	25.04	1.79	2.98	2.94	88.18	2.10	3.54	3.13
0.15	31.40	2.24	3.53	3.33	31.13	2.22	3.18	3.18	24.03	1.72	2.81	2.73	86.56	2.06	3.53	3.08
0.16	31.71	2.26	3.79	3.79	31.45	2.25	3.22	3.16	23.17	1.65	2.70	2.60	86.32	2.06	3.79	3.16
0.17	33.08	2.36	4.41	4.39	32.91	2.35	3.71	3.69	22.52	1.61	2.68	2.51	88.50	2.11	4.41	3.69
0.18	35.31	2.52	4.86	4.79	32.97	2.36	4.13	4.08	20.97	1.50	2.44	2.35	89.26	2.13	4.86	4.08
0.19	36.53	2.61	5.18	4.99	32.55	2.33	4.35	4.30	19.91	1.42	2.30	2.17	88.99	2.12	5.18	4.30
0.2	35.43	2.53	5.28	5.07	30.29	2.16	4.48	4.42	18.90	1.35	1.97	1.86	84.62	2.01	5.28	3.80
0.3	41.99	3.00	4.88	4.79	29.76	2.13	4.18	4.16	18.91	1.35	1.96	1.88	90.65	2.16	4.88	4.11
0.4	32.10	2.29	4.06	4.02	20.79	1.49	2.33	2.16	16.24	1.16	1.38	1.34	69.13	1.65	4.06	2.38
0.5	23.45	1.68	2.75	2.69	17.85	1.27	1.66	1.55	15.70	1.12	1.28	1.28	57.00	1.36	2.75	1.66
0.6	20.43	1.46	2.13	1.94	17.19	1.23	1.49	1.49	15.34	1.10	1.24	1.22	52.96	1.26	2.13	1.54
0.8	17.24	1.23	1.55	1.50	15.50	1.11	1.25	1.23	14.63	1.05	1.09	1.08	47.37	1.13	1.55	1.25
1	16.63	1.19	1.44	1.39	15.25	1.09	1.26	1.23	14.56	1.04	1.09	1.08	46.44	1.11	1.44	1.26
2	16.12	1.15	1.32	1.31	15.08	1.08	1.16	1.16	14.57	1.04	1.07	1.06	45.77	1.09	1.32	1.19

TABLE 9 Summary of Amplification Ratios
Damping = 10%

L = Lower Bound Properties, M = Median Properties, U = Upper Bound Properties

Profile	1						2						3						4					
Property	L		M		U		L		M		U		L		M		U		L		M		U	
History	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
Period, (sec)	Amplification Ratio at Period, (sec)																							
0.01	3.10	2.85	3.11	2.42	2.88	2.49	3.26	2.83	3.43	2.68	2.38	2.04	2.68	2.11	2.50	2.04	2.35	1.98	2.87	2.52	2.38	2.12	2.31	2.24
0.03	3.02	3.12	2.97	2.35	3.37	3.09	3.04	2.71	3.37	2.61	2.63	2.09	2.33	2.09	2.41	1.89	2.19	1.88	2.61	2.37	2.22	2.09	2.21	2.16
0.04	2.57	3.01	2.42	2.56	4.76	4.50	2.64	2.67	3.32	2.89	3.03	2.79	2.15	2.03	2.36	2.32	2.06	2.05	2.31	2.39	2.31	2.32	2.05	2.17
0.05	2.51	2.70	2.74	2.70	4.58	3.87	2.65	3.08	2.51	2.78	2.74	2.85	1.86	2.25	1.78	1.88	1.59	1.83	2.53	2.53	2.08	2.17	1.80	1.86
0.06	2.61	2.48	3.62	3.28	2.49	2.79	2.83	3.14	2.86	2.85	2.37	2.86	2.59	2.78	1.69	1.74	2.13	2.02	2.58	2.87	1.94	2.26	2.19	2.02
0.07	2.83	3.39	3.87	3.23	1.80	1.91	2.99	2.88	3.79	3.25	1.96	2.15	1.96	2.04	1.58	1.78	2.52	2.62	2.52	2.42	1.70	1.87	2.39	2.45
0.08	3.37	3.89	3.53	2.62	1.89	1.80	3.31	3.06	3.71	3.21	1.94	1.80	1.64	1.73	1.97	1.79	2.79	2.85	2.53	2.21	1.98	1.89	2.73	2.67
0.09	5.15	6.32	2.56	2.12	1.50	1.69	3.68	3.37	3.24	2.89	1.68	1.66	1.97	1.70	2.41	2.25	2.89	2.89	2.41	2.14	2.27	2.23	2.94	3.14
0.1	5.46	5.24	2.26	2.10	1.47	1.51	4.33	4.11	2.75	2.73	1.58	1.61	1.86	1.96	2.77	2.97	2.57	2.82	2.22	2.26	2.48	2.74	2.73	3.03
0.11	5.05	3.80	2.19	1.76	1.39	1.26	4.57	4.45	2.50	2.19	1.45	1.40	2.13	2.02	3.42	3.20	2.54	2.28	2.13	2.13	2.99	2.90	2.75	2.39
0.12	3.68	3.48	2.06	1.64	1.41	1.18	5.00	4.30	2.55	2.04	1.49	1.31	2.48	2.43	3.90	3.64	2.47	2.25	2.58	2.23	3.55	3.43	2.76	2.41
0.13	2.93	2.63	1.80	1.32	1.23	1.14	4.08	3.79	2.12	1.72	1.32	1.16	2.69	2.88	3.54	3.76	1.97	1.84	2.73	2.69	3.55	3.64	2.09	2.07
0.14	2.28	2.18	1.39	1.25	1.20	1.23	3.04	3.17	1.60	1.51	1.23	1.19	2.97	3.09	3.21	3.40	1.56	1.53	2.96	2.93	3.27	3.28	1.70	1.65
0.15	1.92	1.89	1.34	1.29	1.18	1.20	2.75	2.81	1.48	1.44	1.22	1.19	3.31	3.50	2.93	3.10	1.53	1.50	3.19	3.29	3.29	3.19	1.66	1.61
0.16	2.02	1.84	1.38	1.32	1.15	1.18	2.75	2.53	1.53	1.38	1.22	1.21	3.98	3.66	3.03	2.77	1.57	1.36	3.61	3.34	3.36	2.96	1.69	1.47
0.17	1.87	1.80	1.30	1.35	1.09	1.17	2.47	2.51	1.42	1.48	1.17	1.21	4.36	4.23	2.72	2.67	1.45	1.43	4.21	3.61	3.13	2.87	1.56	1.53
0.18	1.52	1.86	1.23	1.36	1.12	1.09	1.94	2.48	1.35	1.49	1.17	1.19	4.64	4.63	2.06	2.70	1.34	1.45	4.74	4.28	2.32	2.98	1.40	1.55
0.19	1.56	1.54	1.25	1.08	1.09	1.08	1.78	2.06	1.36	1.23	1.15	1.08	4.93	4.15	1.89	2.29	1.36	1.25	5.16	4.10	2.05	2.50	1.43	1.30
0.2	1.62	1.36	1.24	1.12	1.14	1.10	1.90	1.73	1.38	1.14	1.17	1.11	5.02	3.59	1.95	1.76	1.40	1.15	5.26	3.87	2.06	1.96	1.44	1.24
0.3	1.56	1.43	1.21	1.20	1.10	1.09	1.88	1.57	1.35	1.22	1.14	1.12	4.78	3.24	1.97	1.85	1.35	1.20	4.90	3.80	2.13	1.80	1.42	1.25
0.4	1.30	1.24	1.16	1.13	1.05	1.08	1.33	1.36	1.19	1.15	1.08	1.09	2.41	2.26	1.42	1.41	1.19	1.16	2.66	2.69	1.54	1.49	1.22	1.20
0.5	1.12	1.25	1.08	1.08	1.04	1.06	1.28	1.40	1.11	1.14	1.04	1.06	1.60	1.57	1.32	1.34	1.10	1.15	1.85	1.69	1.36	1.36	1.10	1.18
0.6	1.11	1.17	1.10	1.05	1.03	1.04	1.18	1.33	1.11	1.06	1.04	1.05	1.54	1.55	1.22	1.29	1.11	1.06	1.57	1.51	1.23	1.31	1.10	1.10
0.8	1.10	1.07	1.07	1.04	1.05	1.03	1.12	1.09	1.07	1.05	1.04	1.02	1.27	1.28	1.10	1.08	1.05	1.05	1.30	1.34	1.11	1.09	1.06	1.05
1	1.13	1.09	1.07	1.04	1.03	1.03	1.13	1.07	1.09	1.06	1.03	1.03	1.26	1.17	1.08	1.06	1.08	1.06	1.29	1.19	1.09	1.07	1.08	1.06
2	1.11	1.13	1.06	1.05	1.05	1.03	1.13	1.14	1.07	1.07	1.05	1.04	1.22	1.21	1.10	1.11	1.07	1.07	1.27	1.24	1.12	1.12	1.08	1.09

TABLE 9 Summary of Amplification Ratios (Cont'd.)
Damping = 10%

L = Lower Bound Properties, M = Median Properties, U = Upper Bound Properties

Profile	5						6						7					
Property	L		M		U		L		M		U		L		M		U	
History	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
Period, (sec)	Amplification Ratio at Period, (sec)																	
0.01	2.35	2.14	2.31	1.79	2.10	1.81	2.59	2.01	2.53	2.10	2.00	1.73	1.35	1.34	1.12	1.12	1.04	1.03
0.03	2.12	1.98	2.06	1.76	2.05	1.67	2.29	1.79	2.32	1.97	1.88	1.75	1.50	1.33	1.13	1.11	1.02	1.02
0.04	1.96	1.80	1.85	1.79	2.06	2.09	1.95	1.78	2.46	2.13	2.20	1.94	1.91	1.85	1.34	1.34	1.16	1.17
0.05	1.96	1.87	1.60	1.92	1.60	1.58	2.06	1.91	1.87	2.13	1.77	1.86	1.47	1.55	1.12	1.21	1.02	1.10
0.06	1.66	2.07	2.26	2.44	1.51	1.56	2.37	2.00	2.49	2.22	1.52	1.84	1.23	1.40	1.07	1.18	1.01	1.09
0.07	1.31	1.88	1.76	1.83	1.45	1.66	1.95	2.40	2.12	2.01	1.44	1.70	1.31	1.28	1.16	1.10	1.09	1.05
0.08	1.90	1.64	1.48	1.52	1.74	1.59	2.01	2.03	1.93	1.89	1.67	1.60	1.26	1.24	1.14	1.11	1.08	1.05
0.09	2.36	1.99	1.82	1.53	2.17	1.98	2.53	2.20	1.97	1.66	2.04	1.93	1.13	1.15	1.05	1.06	1.02	1.02
0.1	2.08	2.20	1.74	1.74	2.36	2.57	2.66	2.27	1.89	1.84	2.21	2.47	1.08	1.11	1.03	1.05	1.00	1.02
0.11	1.72	1.46	1.82	1.81	2.86	2.68	2.16	2.11	1.72	1.77	2.64	2.58	1.08	1.10	1.03	1.06	1.01	1.03
0.12	1.70	1.55	2.16	2.13	3.22	3.04	1.89	2.11	2.16	2.01	3.08	2.92	1.16	1.09	1.08	1.05	1.04	1.03
0.13	1.83	1.44	2.27	2.52	2.94	3.14	1.96	1.79	2.25	2.43	2.97	3.14	1.05	1.08	1.02	1.04	1.00	1.03
0.14	1.95	1.55	2.55	2.71	2.68	2.91	2.11	1.56	2.54	2.62	2.77	2.82	1.04	1.04	1.01	1.01	1.00	1.00
0.15	1.88	1.81	2.81	3.04	2.65	2.69	1.96	1.80	2.74	2.86	2.82	2.76	1.06	1.07	1.03	1.04	1.01	1.02
0.16	1.99	1.76	3.38	3.12	2.76	2.46	2.07	1.81	3.13	2.96	2.86	2.55	1.06	1.06	1.03	1.02	1.02	1.01
0.17	2.02	1.74	3.70	3.51	2.49	2.44	2.10	1.75	3.60	3.17	2.63	2.48	1.04	1.05	1.02	1.03	1.00	1.02
0.18	2.00	2.11	3.96	3.84	1.89	2.47	1.89	2.10	4.01	3.67	2.02	2.61	1.04	1.04	1.02	1.02	1.01	1.01
0.19	2.02	2.36	4.23	3.60	1.78	2.07	1.87	2.35	4.33	3.47	1.88	2.17	1.03	1.03	1.02	1.01	1.01	1.01
0.2	2.29	2.43	4.35	3.12	1.88	1.63	2.18	2.45	4.40	3.26	1.93	1.69	1.05	1.04	1.02	1.02	1.01	1.01
0.3	3.79	3.64	4.10	2.99	1.88	1.61	3.99	3.71	4.18	3.24	1.96	1.68	1.04	1.03	1.02	1.02	1.01	1.01
0.4	3.65	3.81	2.30	2.24	1.39	1.38	3.94	3.86	2.44	2.45	1.45	1.43	1.02	1.02	1.01	1.01	1.00	1.00
0.5	2.23	2.68	1.58	1.51	1.29	1.30	2.39	2.73	1.70	1.55	1.31	1.31	1.01	1.02	1.01	1.01	1.00	1.01
0.6	1.88	2.09	1.48	1.49	1.19	1.25	1.96	2.16	1.51	1.46	1.20	1.26	1.01	1.01	1.01	1.01	1.00	1.00
0.8	1.57	1.53	1.26	1.25	1.09	1.08	1.63	1.59	1.28	1.29	1.09	1.08	1.02	1.01	1.01	1.00	1.01	1.00
1	1.33	1.51	1.24	1.16	1.07	1.06	1.36	1.56	1.27	1.16	1.07	1.06	1.01	1.01	1.00	1.00	1.00	1.00
2	1.27	1.32	1.21	1.19	1.09	1.09	1.31	1.32	1.23	1.20	1.10	1.09	1.01	1.01	1.00	1.01	1.00	1.00

TABLE 9 Summary of Amplification Ratios (Cont'd.)
Damping = 10%

L = Lower Bound Properties, M = Median Properties, U = Upper Bound Properties

	Total	Average	Max	85%	Total	Average	Max	85%	Total	Average	Max	85%	Total	Average	Max	85%
Profile																
Property	L	L	L	L	M	M	M	M	U	U	U	U	All	All	All	All
History																
Period, (sec)																
0.01	33.99	2.43	3.26	3.10	31.66	2.26	3.43	3.11	28.39	2.03	2.88	2.49	94.04	2.24	3.43	2.87
0.03	32.28	2.31	3.12	3.04	30.27	2.16	3.37	2.97	29.02	2.07	3.37	3.09	91.58	2.18	3.37	3.02
0.04	31.03	2.22	3.01	2.67	31.40	2.24	3.32	2.89	34.02	2.43	4.76	4.50	96.45	2.30	4.76	2.89
0.05	30.92	2.21	3.08	2.70	28.51	2.04	2.78	2.74	30.04	2.15	4.58	3.87	89.48	2.13	4.58	2.74
0.06	32.63	2.33	3.14	2.87	31.90	2.28	3.62	3.26	27.41	1.96	2.86	2.79	91.94	2.19	3.62	2.86
0.07	31.18	2.23	3.39	2.99	31.07	2.22	3.87	3.79	26.19	1.87	2.62	2.52	88.44	2.11	3.87	2.99
0.08	31.83	2.27	3.89	3.37	29.77	2.13	3.71	3.53	27.21	1.94	2.85	2.79	88.82	2.11	3.89	3.21
0.09	38.10	2.72	6.32	5.15	29.07	2.08	3.24	2.89	28.55	2.04	3.14	2.94	95.72	2.28	6.32	3.14
0.1	38.84	2.77	5.46	5.24	30.08	2.15	2.97	2.77	28.95	2.07	3.03	2.82	97.87	2.33	5.46	2.97
0.11	35.92	2.57	5.05	4.57	30.35	2.17	3.42	3.20	28.27	2.02	2.86	2.75	94.53	2.25	5.05	3.20
0.12	35.69	2.55	5.00	4.30	33.41	2.39	3.90	3.64	29.61	2.12	3.22	3.08	98.72	2.35	5.00	3.55
0.13	33.55	2.40	4.08	3.79	32.97	2.35	3.76	3.64	27.03	1.93	3.14	3.14	93.55	2.23	4.08	3.54
0.14	31.87	2.28	3.17	3.09	31.36	2.24	3.40	3.28	24.47	1.75	2.91	2.82	87.70	2.09	3.40	3.09
0.15	32.24	2.30	3.50	3.31	31.59	2.26	3.29	3.19	24.04	1.72	2.82	2.76	87.88	2.09	3.50	3.19
0.16	33.47	2.39	3.98	3.66	32.37	2.31	3.38	3.36	23.51	1.68	2.86	2.76	89.35	2.13	3.98	3.34
0.17	34.76	2.48	4.36	4.23	32.96	2.35	3.70	3.60	22.66	1.62	2.63	2.49	90.38	2.15	4.36	3.60
0.18	36.26	2.59	4.74	4.64	33.01	2.36	4.01	3.96	21.32	1.52	2.61	2.47	90.59	2.16	4.74	3.96
0.19	35.93	2.57	5.16	4.93	31.32	2.24	4.33	4.23	19.65	1.40	2.17	2.07	86.90	2.07	5.16	4.10
0.2	35.78	2.56	5.26	5.02	29.78	2.13	4.40	4.35	18.90	1.35	1.93	1.88	84.46	2.01	5.26	3.59
0.3	40.36	2.88	4.90	4.78	29.09	2.08	4.18	4.10	18.83	1.35	1.96	1.88	88.28	2.10	4.90	3.80
0.4	32.56	2.33	3.94	3.86	21.93	1.57	2.45	2.44	16.73	1.19	1.45	1.43	71.22	1.70	3.94	2.66
0.5	23.81	1.70	2.73	2.68	18.16	1.30	1.70	1.58	15.97	1.14	1.31	1.31	57.94	1.38	2.73	1.70
0.6	21.08	1.51	2.16	2.09	17.32	1.24	1.51	1.49	15.44	1.10	1.26	1.25	53.84	1.28	2.16	1.55
0.8	17.91	1.28	1.63	1.59	15.69	1.12	1.29	1.28	14.71	1.05	1.09	1.09	48.31	1.15	1.63	1.30
1	17.12	1.22	1.56	1.51	15.41	1.10	1.27	1.24	14.67	1.05	1.08	1.08	47.20	1.12	1.56	1.27
2	16.70	1.19	1.32	1.32	15.53	1.11	1.23	1.21	14.87	1.06	1.10	1.09	47.10	1.12	1.32	1.24

TABLE 10 Summary of Amplification Ratios
Damping = 12%

L = Lower Bound Properties, M = Median Properties, U = Upper Bound Properties

Profile	1						2						3						4					
Property	L		M		U		L		M		U		L		M		U		L		M		U	
History	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
Period, (sec)	Amplification Ratio at Period, (sec)																							
0.01	3.10	2.84	3.10	2.42	2.88	2.50	3.26	2.83	3.43	2.68	2.38	2.04	2.68	2.11	2.50	2.04	2.35	1.98	2.87	2.52	2.38	2.12	2.31	2.24
0.03	3.01	3.13	2.98	2.36	3.34	3.09	3.04	2.71	3.39	2.62	2.64	2.10	2.34	2.09	2.41	1.89	2.20	1.89	2.62	2.38	2.23	2.09	2.22	2.17
0.04	2.58	3.06	2.49	2.58	4.59	4.37	2.67	2.77	3.36	2.91	2.99	2.77	2.11	2.04	2.33	2.27	2.12	2.09	2.38	2.47	2.28	2.31	2.07	2.20
0.05	2.60	2.80	2.72	2.77	4.22	3.77	2.71	3.14	2.52	2.95	2.68	2.76	1.88	2.34	1.85	1.99	1.67	1.96	2.55	2.67	2.14	2.22	1.87	1.99
0.06	2.66	2.71	3.64	3.16	2.51	2.78	2.90	3.26	3.04	2.96	2.37	2.82	2.54	2.72	1.75	1.82	2.29	2.10	2.62	2.84	1.98	2.36	2.29	2.19
0.07	2.85	3.51	3.82	3.04	1.80	1.96	3.05	2.99	3.78	3.30	1.96	2.14	1.96	2.04	1.63	1.83	2.53	2.57	2.50	2.43	1.74	1.96	2.39	2.42
0.08	3.39	3.98	3.41	2.57	1.91	1.80	3.34	3.04	3.43	3.10	1.87	1.83	1.70	1.76	1.96	1.90	2.73	2.76	2.42	2.26	1.91	1.90	2.60	2.63
0.09	4.77	5.90	2.78	2.16	1.59	1.71	3.83	3.36	3.10	2.84	1.73	1.69	2.04	1.76	2.41	2.36	2.80	2.86	2.48	2.29	2.29	2.28	2.79	3.08
0.1	5.37	5.00	2.39	2.03	1.46	1.50	4.29	4.14	2.78	2.59	1.63	1.54	1.97	1.97	2.77	2.96	2.60	2.70	2.31	2.27	2.54	2.71	2.70	2.89
0.11	5.00	3.76	2.24	1.78	1.39	1.25	4.65	4.36	2.56	2.21	1.48	1.41	2.27	2.09	3.42	3.18	2.53	2.32	2.26	2.17	3.06	2.86	2.78	2.42
0.12	3.53	3.51	2.07	1.66	1.42	1.17	4.90	4.30	2.58	2.07	1.47	1.33	2.61	2.53	3.80	3.57	2.46	2.28	2.69	2.33	3.51	3.36	2.72	2.46
0.13	3.02	2.62	1.84	1.38	1.26	1.14	4.08	3.84	2.12	1.81	1.32	1.16	2.75	3.01	3.47	3.76	1.97	1.96	2.80	2.78	3.47	3.63	2.11	2.14
0.14	2.36	2.27	1.45	1.25	1.20	1.22	3.07	3.14	1.71	1.45	1.23	1.19	3.09	3.11	3.18	3.34	1.63	1.54	3.14	2.93	3.26	3.22	1.80	1.73
0.15	2.05	1.98	1.34	1.29	1.19	1.21	2.77	2.82	1.52	1.38	1.21	1.20	3.38	3.48	2.99	3.10	1.53	1.45	3.36	3.26	3.34	3.17	1.66	1.59
0.16	2.11	1.92	1.38	1.34	1.17	1.19	2.76	2.57	1.53	1.39	1.20	1.22	4.01	3.59	3.04	2.74	1.58	1.41	3.82	3.33	3.40	2.98	1.69	1.52
0.17	1.98	1.89	1.27	1.39	1.15	1.17	2.47	2.60	1.44	1.51	1.17	1.24	4.36	4.13	2.63	2.76	1.47	1.45	4.32	3.65	3.06	2.88	1.51	1.55
0.18	1.60	1.86	1.25	1.36	1.12	1.11	1.91	2.48	1.37	1.51	1.18	1.18	4.49	4.43	2.01	2.78	1.37	1.45	4.71	4.18	2.28	3.02	1.42	1.59
0.19	1.59	1.54	1.25	1.08	1.08	1.09	1.79	2.09	1.38	1.24	1.14	1.08	4.77	3.97	1.84	2.26	1.37	1.26	5.01	3.85	2.04	2.45	1.43	1.28
0.2	1.60	1.39	1.22	1.12	1.13	1.11	1.89	1.73	1.37	1.14	1.15	1.10	4.98	3.49	1.94	1.80	1.40	1.18	5.15	3.71	2.11	2.00	1.45	1.24
0.3	1.60	1.44	1.21	1.22	1.11	1.10	1.92	1.58	1.36	1.22	1.16	1.13	4.82	3.22	1.96	1.63	1.35	1.21	4.99	3.69	2.15	1.79	1.43	1.25
0.4	1.34	1.27	1.17	1.14	1.08	1.09	1.34	1.42	1.22	1.17	1.09	1.11	2.51	2.30	1.44	1.42	1.20	1.17	2.77	2.75	1.57	1.50	1.24	1.20
0.5	1.15	1.28	1.09	1.09	1.05	1.07	1.31	1.46	1.12	1.16	1.05	1.07	1.63	1.58	1.34	1.37	1.10	1.17	1.90	1.70	1.37	1.39	1.10	1.21
0.6	1.12	1.17	1.08	1.05	1.04	1.05	1.17	1.33	1.12	1.06	1.04	1.06	1.55	1.46	1.22	1.25	1.12	1.07	1.60	1.44	1.23	1.27	1.12	1.08
0.8	1.10	1.06	1.07	1.04	1.05	1.05	1.12	1.12	1.07	1.05	1.05	1.05	1.30	1.31	1.10	1.08	1.06	1.03	1.32	1.35	1.11	1.11	1.07	1.03
1	1.12	1.11	1.08	1.05	1.04	1.04	1.11	1.10	1.09	1.08	1.04	1.03	1.24	1.20	1.10	1.07	1.07	1.07	1.27	1.18	1.10	1.08	1.08	1.08
2	1.14	1.17	1.07	1.05	1.07	1.05	1.14	1.16	1.09	1.08	1.05	1.05	1.24	1.24	1.11	1.12	1.09	1.08	1.31	1.26	1.13	1.13	1.09	1.10

TABLE 10 Summary of Amplification Ratios (Cont'd.)
Damping = 12%

L = Lower Bound Properties, M = Median Properties, U = Upper Bound Properties

Profile	5						6						7					
Property	L		M		U		L		M		U		L		M		U	
History	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
Period, (sec)	Amplification Ratio at Period, (sec)																	
0.01	2.35	2.14	2.31	1.79	2.10	1.81	2.59	2.01	2.53	2.10	2.00	1.73	1.35	1.34	1.12	1.12	1.04	1.03
0.03	2.13	1.98	2.07	1.76	2.05	1.67	2.30	1.79	2.32	1.98	1.88	1.75	1.50	1.32	1.13	1.11	1.02	1.02
0.04	1.99	1.81	1.82	1.80	2.04	2.05	2.00	1.80	2.45	2.16	2.16	1.85	1.87	1.80	1.33	1.32	1.15	1.15
0.05	1.98	1.91	1.61	2.01	1.65	1.70	2.06	2.02	1.89	2.22	1.80	1.85	1.42	1.57	1.12	1.23	1.02	1.11
0.06	1.71	2.10	2.27	2.40	1.56	1.63	2.41	2.04	2.50	2.27	1.62	1.90	1.27	1.37	1.08	1.15	1.01	1.06
0.07	1.38	1.90	1.76	1.81	1.47	1.71	1.90	2.42	2.09	2.04	1.49	1.76	1.32	1.31	1.16	1.12	1.09	1.05
0.08	1.85	1.70	1.52	1.55	1.73	1.66	1.98	2.09	1.81	1.94	1.61	1.68	1.21	1.26	1.09	1.12	1.04	1.06
0.09	2.31	2.02	1.89	1.58	2.16	2.08	2.57	2.14	2.02	1.74	2.02	1.96	1.14	1.16	1.06	1.06	1.02	1.02
0.1	2.08	2.13	1.79	1.74	2.36	2.56	2.63	2.11	1.97	1.83	2.25	2.45	1.09	1.10	1.03	1.05	1.01	1.02
0.11	1.82	1.59	1.93	1.86	2.86	2.66	2.20	2.14	1.83	1.81	2.70	2.55	1.08	1.10	1.04	1.06	1.01	1.03
0.12	1.85	1.59	2.24	2.21	3.16	3.01	2.06	2.12	2.23	2.07	3.02	2.87	1.15	1.09	1.06	1.05	1.02	1.03
0.13	1.95	1.57	2.36	2.62	2.88	3.14	2.10	1.88	2.31	2.51	2.88	3.11	1.06	1.09	1.02	1.05	1.01	1.03
0.14	2.05	1.60	2.65	2.73	2.71	2.86	2.22	1.59	2.68	2.63	2.83	2.83	1.05	1.05	1.02	1.02	1.00	1.00
0.15	2.01	1.83	2.93	3.02	2.70	2.68	2.12	1.82	2.88	2.83	2.85	2.72	1.05	1.07	1.02	1.03	1.01	1.01
0.16	2.13	1.84	3.41	3.12	2.77	2.42	2.22	1.88	3.32	2.95	2.88	2.55	1.05	1.06	1.02	1.03	1.01	1.01
0.17	2.11	1.95	3.77	3.42	2.39	2.51	2.21	1.97	3.70	3.20	2.57	2.57	1.04	1.05	1.02	1.03	1.01	1.02
0.18	2.06	2.30	3.87	3.75	1.86	2.49	1.97	2.29	3.93	3.57	1.94	2.64	1.04	1.02	1.02	1.00	1.02	1.00
0.19	2.10	2.41	4.09	3.39	1.78	2.05	1.95	2.41	4.21	3.26	1.86	2.12	1.02	1.03	1.01	1.01	1.00	1.01
0.2	2.37	2.52	4.28	3.04	1.86	1.62	2.25	2.54	4.39	3.16	1.92	1.71	1.04	1.03	1.01	1.02	1.00	1.01
0.3	3.61	3.59	4.18	2.98	1.87	1.59	3.79	3.66	4.24	3.16	1.98	1.68	1.04	1.03	1.02	1.01	1.01	1.01
0.4	3.50	3.76	2.39	2.29	1.41	1.38	3.76	3.79	2.53	2.50	1.47	1.44	1.03	1.02	1.01	1.01	1.01	1.01
0.5	2.24	2.64	1.60	1.51	1.30	1.33	2.40	2.67	1.73	1.56	1.32	1.34	1.01	1.02	1.01	1.01	1.00	1.01
0.6	1.93	2.11	1.49	1.40	1.18	1.21	2.02	2.18	1.54	1.37	1.19	1.22	1.01	1.02	1.01	1.01	1.00	1.00
0.8	1.68	1.55	1.28	1.28	1.09	1.07	1.76	1.63	1.30	1.28	1.10	1.08	1.02	1.01	1.01	1.00	1.01	1.00
1	1.36	1.57	1.22	1.16	1.08	1.06	1.36	1.62	1.25	1.15	1.08	1.07	1.01	1.01	1.01	1.00	1.00	1.00
2	1.29	1.31	1.23	1.21	1.10	1.10	1.33	1.31	1.26	1.22	1.11	1.10	1.01	1.02	1.00	1.01	1.00	1.00

TABLE 10 Summary of Amplification Ratios (Cont'd.)
Damping = 12%

L = Lower Bound Properties, M = Median Properties, U = Upper Bound Properties

Profile	Total	Average	Max	85%	Total	Average	Max	85%	Total	Average	Max	85%	Total	Average	Max	85%
Property	L	L	L	L	M	M	M	M	U	U	U	U	All	All	All	All
History																
Period, (sec)																
0.01	33.99	2.43	3.26	3.10	31.66	2.26	3.43	3.10	28.39	2.03	2.88	2.50	94.04	2.24	3.43	2.87
0.03	32.33	2.31	3.13	3.04	30.33	2.17	3.39	2.98	29.03	2.07	3.34	3.09	91.70	2.18	3.39	3.01
0.04	31.36	2.24	3.06	2.77	31.40	2.24	3.36	2.91	33.62	2.40	4.59	4.37	96.37	2.29	4.59	2.91
0.05	31.65	2.26	3.14	2.80	29.23	2.09	2.95	2.77	30.06	2.15	4.22	3.77	90.94	2.17	4.22	2.77
0.06	33.15	2.37	3.26	2.90	32.38	2.31	3.64	3.16	28.13	2.01	2.82	2.78	93.66	2.23	3.64	2.90
0.07	31.57	2.25	3.51	3.05	31.06	2.22	3.82	3.78	26.33	1.88	2.57	2.53	88.96	2.12	3.82	3.04
0.08	31.97	2.28	3.98	3.39	29.22	2.09	3.43	3.41	26.89	1.92	2.76	2.73	88.08	2.10	3.98	3.10
0.09	37.76	2.70	5.90	4.77	29.56	2.11	3.10	2.84	28.51	2.04	3.08	2.86	95.84	2.28	5.90	3.08
0.1	38.46	2.75	5.37	5.00	30.19	2.16	2.96	2.78	28.67	2.05	2.89	2.70	97.32	2.32	5.37	2.89
0.11	36.48	2.61	5.00	4.65	30.83	2.20	3.42	3.18	28.38	2.03	2.86	2.76	95.68	2.28	5.00	3.18
0.12	36.27	2.59	4.90	4.30	33.47	2.39	3.80	3.57	29.40	2.10	3.16	3.02	99.14	2.36	4.90	3.51
0.13	34.55	2.47	4.08	3.84	33.36	2.38	3.76	3.63	27.11	1.94	3.14	3.11	95.02	2.26	4.08	3.47
0.14	32.68	2.33	3.14	3.14	31.59	2.26	3.34	3.26	24.78	1.77	2.86	2.83	89.04	2.12	3.34	3.14
0.15	33.00	2.36	3.48	3.38	31.84	2.27	3.34	3.17	23.99	1.71	2.85	2.72	88.83	2.12	3.48	3.17
0.16	34.31	2.45	4.01	3.82	32.65	2.33	3.41	3.40	23.63	1.69	2.88	2.77	90.59	2.16	4.01	3.33
0.17	35.72	2.55	4.36	4.32	33.07	2.36	3.77	3.70	22.78	1.63	2.57	2.57	91.57	2.18	4.36	3.65
0.18	36.35	2.60	4.71	4.49	32.72	2.34	3.93	3.87	21.36	1.53	2.64	2.49	90.43	2.15	4.71	3.87
0.19	35.53	2.54	5.01	4.77	30.52	2.18	4.21	4.09	19.55	1.40	2.12	2.05	85.61	2.04	5.01	3.85
0.2	35.68	2.55	5.15	4.98	29.59	2.11	4.39	4.28	18.88	1.35	1.92	1.86	84.16	2.00	5.15	3.49
0.3	39.99	2.86	4.99	4.82	29.13	2.08	4.24	4.18	18.88	1.35	1.98	1.87	88.00	2.10	4.99	3.69
0.4	32.55	2.33	3.79	3.76	22.35	1.60	2.53	2.50	16.91	1.21	1.47	1.44	71.81	1.71	3.79	2.75
0.5	24.00	1.71	2.67	2.64	18.35	1.31	1.73	1.60	16.11	1.15	1.34	1.33	58.47	1.39	2.67	1.73
0.6	21.11	1.51	2.18	2.11	17.10	1.22	1.54	1.49	15.38	1.10	1.22	1.21	53.59	1.28	2.18	1.55
0.8	18.34	1.31	1.76	1.68	15.79	1.13	1.30	1.28	14.74	1.05	1.10	1.09	48.88	1.16	1.76	1.32
1	17.27	1.23	1.62	1.57	15.43	1.10	1.25	1.22	14.73	1.05	1.08	1.08	47.43	1.13	1.62	1.25
2	16.93	1.21	1.33	1.31	15.72	1.12	1.26	1.23	15.01	1.07	1.11	1.10	47.65	1.13	1.33	1.26

TABLE 11 Summary of Amplification Ratios (
Damping = 15%

L = Lower Bound Properties, M = Median Properties, U = Upper Bound Properties

Profile	1						2						3						4					
Property	L		M		U		L		M		U		L		M		U		L		M		U	
History	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
Period, (sec)	Amplification Ratio at Period, (sec)																							
0.01	3.10	2.84	3.10	2.42	2.88	2.50	3.26	2.83	3.43	2.68	2.38	2.04	2.68	2.11	2.50	2.04	2.35	1.98	2.87	2.52	2.38	2.12	2.31	2.24
0.03	3.01	3.14	2.99	2.36	3.30	3.09	3.06	2.73	3.42	2.63	2.65	2.10	2.36	2.09	2.41	1.88	2.23	1.91	2.64	2.38	2.23	2.09	2.23	2.18
0.04	2.60	3.09	2.61	2.63	4.22	4.18	2.72	2.91	3.44	2.97	2.97	2.75	2.19	2.09	2.30	2.22	2.20	2.17	2.49	2.57	2.24	2.30	2.13	2.27
0.05	2.65	2.98	2.68	2.81	3.95	3.61	2.78	3.19	2.51	3.13	2.62	2.75	1.90	2.43	1.90	2.09	1.80	2.15	2.57	2.80	2.17	2.26	1.99	2.15
0.06	2.72	3.04	3.64	2.76	2.62	2.74	3.00	3.11	3.25	2.79	2.42	2.51	2.55	2.42	1.81	1.82	2.50	1.99	2.67	2.56	2.03	2.27	2.49	2.19
0.07	2.89	3.62	3.74	2.81	1.82	2.02	3.15	2.98	3.77	3.15	1.95	2.02	1.99	1.99	1.73	1.82	2.56	2.40	2.48	2.40	1.80	1.99	2.39	2.40
0.08	3.28	4.11	3.20	2.50	1.93	1.79	3.35	3.00	3.22	2.98	1.89	1.88	1.75	1.79	1.93	2.01	2.62	2.62	2.36	2.35	1.87	2.01	2.43	2.56
0.09	4.45	5.44	3.01	2.21	1.73	1.77	3.93	3.52	3.08	2.76	1.81	1.74	2.13	1.84	2.45	2.50	2.71	2.84	2.57	2.45	2.34	2.36	2.73	2.99
0.1	5.17	4.73	2.57	2.04	1.48	1.49	4.23	4.19	2.80	2.55	1.69	1.55	2.10	1.99	2.80	2.96	2.66	2.62	2.47	2.30	2.66	2.70	2.68	2.75
0.11	4.80	3.76	2.34	1.81	1.39	1.24	4.76	4.30	2.73	2.24	1.57	1.43	2.48	2.20	3.44	3.15	2.50	2.37	2.44	2.26	3.17	2.83	2.79	2.48
0.12	3.49	3.51	2.03	1.62	1.43	1.16	4.55	4.19	2.49	2.10	1.43	1.30	2.68	2.59	3.62	3.39	2.41	2.19	2.71	2.37	3.29	3.20	2.54	2.45
0.13	3.15	2.69	1.88	1.47	1.28	1.15	4.06	3.84	2.11	1.86	1.34	1.18	2.90	3.14	3.36	3.68	2.00	2.06	2.99	2.87	3.35	3.56	2.18	2.17
0.14	2.46	2.33	1.56	1.24	1.17	1.21	3.33	3.11	1.82	1.54	1.24	1.19	3.26	3.17	3.11	3.24	1.78	1.68	3.41	2.94	3.35	3.24	1.91	1.83
0.15	2.20	2.10	1.39	1.28	1.18	1.23	2.74	2.86	1.55	1.42	1.16	1.21	3.49	3.46	2.97	3.08	1.57	1.52	3.58	3.22	3.29	3.13	1.68	1.68
0.16	2.17	2.02	1.42	1.36	1.18	1.21	2.69	2.66	1.56	1.42	1.19	1.23	4.05	3.61	2.94	2.81	1.61	1.48	4.04	3.33	3.34	3.02	1.67	1.63
0.17	1.96	2.03	1.27	1.40	1.16	1.18	2.33	2.63	1.44	1.50	1.18	1.25	4.20	3.91	2.46	2.80	1.50	1.49	4.23	3.58	2.80	2.96	1.52	1.61
0.18	1.71	1.83	1.27	1.31	1.12	1.11	1.89	2.46	1.40	1.48	1.19	1.15	4.32	4.09	1.92	2.75	1.39	1.41	4.63	3.89	2.21	2.93	1.45	1.56
0.19	1.67	1.53	1.26	1.10	1.11	1.10	1.81	2.13	1.40	1.25	1.14	1.09	4.57	3.75	1.82	2.24	1.40	1.27	4.83	3.63	2.05	2.48	1.43	1.32
0.2	1.71	1.45	1.26	1.11	1.09	1.12	1.86	1.80	1.38	1.16	1.13	1.11	4.76	3.33	1.89	1.85	1.40	1.23	5.00	3.55	2.12	2.02	1.47	1.29
0.3	1.67	1.47	1.21	1.24	1.11	1.11	1.90	1.63	1.35	1.23	1.15	1.13	4.63	3.20	1.95	1.63	1.38	1.21	4.91	3.57	2.10	1.78	1.45	1.29
0.4	1.37	1.31	1.18	1.18	1.10	1.10	1.39	1.43	1.26	1.24	1.11	1.11	2.49	2.31	1.38	1.43	1.25	1.19	2.75	2.76	1.52	1.50	1.28	1.23
0.5	1.21	1.34	1.11	1.11	1.05	1.08	1.35	1.49	1.14	1.20	1.05	1.08	1.76	1.55	1.36	1.37	1.11	1.21	1.97	1.73	1.38	1.38	1.13	1.25
0.6	1.13	1.20	1.10	1.06	1.05	1.06	1.18	1.36	1.15	1.07	1.04	1.06	1.59	1.42	1.22	1.24	1.14	1.08	1.65	1.51	1.25	1.26	1.14	1.11
0.8	1.12	1.09	1.08	1.04	1.06	1.07	1.14	1.15	1.08	1.05	1.07	1.05	1.36	1.36	1.11	1.10	1.06	1.04	1.42	1.41	1.13	1.14	1.07	1.06
1	1.08	1.15	1.06	1.07	1.05	1.05	1.10	1.14	1.07	1.10	1.03	1.04	1.24	1.24	1.10	1.08	1.05	1.09	1.27	1.26	1.10	1.10	1.05	1.10
2	1.13	1.23	1.06	1.07	1.03	1.06	1.12	1.21	1.08	1.10	1.03	1.07	1.25	1.26	1.08	1.16	1.07	1.11	1.31	1.28	1.12	1.17	1.08	1.14

TABLE 11 Summary of Amplification Ratios (Cont'd.)
Damping = 15%

L = Lower Bound Properties, M = Median Properties, U = Upper Bound Properties

Profile	5						6						7					
Property	L		M		U		L		M		U		L		M		U	
History	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
Period, (sec)	Amplification Ratio at Period, (sec)																	
0.01	2.35	2.14	2.32	1.79	2.10	1.81	2.59	2.01	2.53	2.11	2.00	1.73	1.35	1.34	1.12	1.12	1.04	1.03
0.03	2.14	1.98	2.08	1.77	2.05	1.67	2.31	1.80	2.34	2.00	1.87	1.76	1.49	1.30	1.13	1.10	1.02	1.01
0.04	2.03	1.84	1.83	1.83	2.01	2.01	2.07	1.84	2.47	2.20	2.15	1.86	1.84	1.74	1.33	1.29	1.16	1.14
0.05	2.00	1.97	1.65	2.09	1.70	1.83	2.08	2.15	2.01	2.31	1.80	1.86	1.38	1.56	1.13	1.23	1.03	1.12
0.06	1.78	1.95	2.31	2.15	1.61	1.62	2.47	1.92	2.50	2.13	1.75	1.81	1.33	1.20	1.09	1.06	1.02	1.00
0.07	1.48	1.84	1.77	1.72	1.51	1.67	1.89	2.33	2.12	2.00	1.55	1.74	1.32	1.28	1.16	1.09	1.09	1.02
0.08	1.79	1.75	1.56	1.58	1.70	1.76	1.94	2.14	1.81	2.02	1.58	1.77	1.15	1.29	1.03	1.14	0.98	1.07
0.09	2.32	2.07	1.97	1.67	2.17	2.20	2.62	2.25	2.08	1.88	2.03	2.07	1.18	1.17	1.09	1.07	1.05	1.03
0.1	2.08	2.08	1.88	1.76	2.35	2.57	2.62	2.02	2.08	1.84	2.30	2.45	1.10	1.10	1.04	1.05	1.01	1.02
0.11	2.01	1.78	2.09	1.94	2.87	2.65	2.40	2.18	2.08	1.87	2.79	2.55	1.14	1.10	1.07	1.06	1.04	1.04
0.12	1.97	1.65	2.26	2.26	3.02	2.88	2.20	2.07	2.26	2.10	2.80	2.78	1.09	1.05	1.04	1.01	1.01	0.99
0.13	2.09	1.74	2.47	2.72	2.77	3.08	2.28	1.98	2.56	2.57	2.74	3.02	1.07	1.08	1.03	1.04	1.01	1.02
0.14	2.19	1.70	2.84	2.76	2.76	2.78	2.38	1.66	2.90	2.66	2.89	2.83	1.06	1.06	1.03	1.03	1.02	1.01
0.15	2.10	1.89	3.03	3.00	2.67	2.65	2.26	1.87	3.06	2.78	2.79	2.64	1.04	1.05	1.01	1.01	1.00	1.00
0.16	2.25	2.00	3.46	3.11	2.67	2.47	2.34	2.02	3.50	2.95	2.82	2.56	1.06	1.07	1.03	1.03	1.01	1.02
0.17	2.11	2.17	3.63	3.34	2.17	2.54	2.21	2.19	3.58	3.12	2.34	2.63	1.04	1.05	1.02	1.01	1.01	1.00
0.18	2.12	2.45	3.74	3.47	1.78	2.47	2.07	2.43	3.86	3.31	1.90	2.54	1.04	1.02	1.02	1.00	1.01	1.00
0.19	2.18	2.51	3.94	3.19	1.78	2.01	2.05	2.51	4.08	3.11	1.87	2.13	1.03	1.03	1.01	1.02	1.00	1.01
0.2	2.40	2.61	4.13	2.96	1.82	1.66	2.27	2.62	4.24	3.12	1.93	1.71	1.03	1.02	1.01	1.01	1.01	1.00
0.3	3.34	3.55	4.06	2.99	1.83	1.58	3.57	3.60	4.11	3.12	1.92	1.67	1.03	1.04	1.02	1.02	1.01	1.01
0.4	3.24	3.63	2.37	2.31	1.36	1.38	3.36	3.65	2.50	2.52	1.43	1.45	1.03	1.03	1.02	1.01	1.01	1.01
0.5	2.21	2.62	1.71	1.51	1.32	1.33	2.39	2.65	1.79	1.58	1.32	1.33	1.02	1.02	1.01	1.01	1.01	1.01
0.6	2.01	2.18	1.53	1.35	1.18	1.20	2.10	2.26	1.59	1.36	1.20	1.21	1.01	1.02	1.01	1.01	1.00	1.00
0.8	1.83	1.64	1.31	1.32	1.10	1.09	1.91	1.66	1.36	1.33	1.10	1.11	1.02	1.02	1.01	1.01	1.01	1.00
1	1.38	1.71	1.22	1.19	1.08	1.08	1.38	1.76	1.24	1.22	1.08	1.09	1.01	1.01	1.01	1.01	1.00	1.00
2	1.28	1.31	1.22	1.22	1.07	1.14	1.32	1.33	1.25	1.23	1.09	1.14	1.01	1.02	1.01	1.01	1.00	1.01

TABLE 11 Summary of Amplification Ratios (Cont'd.)
Damping = 15%

L = Lower Bound Properties, M = Median Properties, U = Upper Bound Properties

	Total	Average	Max	85%	Total	Average	Max	85%	Total	Average	Max	85%	Total	Average	Max	85%
Profile																
Property	L	L	L	L	M	M	M	M	U	U	U	U	All	All	All	All
History																
Period, (sec)																
0.01	33.99	2.43	3.26	3.10	31.66	2.26	3.43	3.10	28.39	2.03	2.88	2.50	94.03	2.24	3.43	2.87
0.03	32.43	2.32	3.14	3.06	30.43	2.17	3.42	2.99	29.07	2.08	3.30	3.09	91.92	2.19	3.42	3.01
0.04	32.01	2.29	3.09	2.91	31.65	2.26	3.44	2.97	33.22	2.37	4.22	4.18	96.88	2.31	4.22	2.97
0.05	32.42	2.32	3.19	2.98	29.97	2.14	3.13	2.81	30.33	2.17	3.95	3.61	92.72	2.21	3.95	2.81
0.06	32.72	2.34	3.11	3.04	31.60	2.26	3.64	3.25	28.28	2.02	2.74	2.62	92.60	2.20	3.64	2.79
0.07	31.64	2.26	3.62	3.15	30.66	2.19	3.77	3.74	26.14	1.87	2.56	2.40	88.43	2.11	3.77	2.98
0.08	32.04	2.29	4.11	3.35	28.86	2.06	3.22	3.20	26.59	1.90	2.62	2.62	87.49	2.08	4.11	3.00
0.09	37.95	2.71	5.44	4.45	30.46	2.18	3.08	3.01	28.86	2.06	2.99	2.84	97.28	2.32	5.44	3.01
0.1	38.18	2.73	5.17	4.73	30.72	2.19	2.96	2.80	28.62	2.04	2.75	2.68	97.52	2.32	5.17	2.80
0.11	37.61	2.69	4.80	4.76	31.84	2.27	3.44	3.17	28.71	2.05	2.87	2.79	98.16	2.34	4.80	3.17
0.12	36.13	2.58	4.55	4.19	32.65	2.33	3.62	3.39	28.40	2.03	3.02	2.88	97.18	2.31	4.55	3.39
0.13	35.86	2.56	4.06	3.84	33.65	2.40	3.68	3.56	26.99	1.93	3.08	3.02	96.50	2.30	4.06	3.35
0.14	34.06	2.43	3.41	3.33	32.33	2.31	3.35	3.24	25.29	1.81	2.89	2.83	91.67	2.18	3.41	3.24
0.15	33.87	2.42	3.58	3.49	32.00	2.29	3.29	3.13	23.98	1.71	2.79	2.67	89.85	2.14	3.58	3.13
0.16	35.31	2.52	4.05	4.04	32.95	2.35	3.50	3.46	23.75	1.70	2.82	2.67	92.01	2.19	4.05	3.34
0.17	35.63	2.55	4.23	4.20	32.34	2.31	3.63	3.58	22.58	1.61	2.63	2.54	90.55	2.16	4.23	3.58
0.18	35.95	2.57	4.63	4.32	31.67	2.26	3.86	3.74	21.09	1.51	2.54	2.47	88.70	2.11	4.63	3.74
0.19	35.23	2.52	4.83	4.57	29.95	2.14	4.08	3.94	19.66	1.40	2.13	2.01	84.83	2.02	4.83	3.63
0.2	35.42	2.53	5.00	4.76	29.27	2.09	4.24	4.13	18.96	1.35	1.93	1.82	83.64	1.99	5.00	3.33
0.3	39.11	2.79	4.91	4.63	28.79	2.06	4.11	4.06	18.86	1.35	1.92	1.83	86.76	2.07	4.91	3.57
0.4	31.75	2.27	3.65	3.63	22.41	1.60	2.52	2.50	17.00	1.21	1.45	1.43	71.16	1.69	3.65	2.75
0.5	24.30	1.74	2.65	2.62	18.64	1.33	1.79	1.71	16.27	1.16	1.33	1.33	59.21	1.41	2.65	1.79
0.6	21.65	1.55	2.26	2.18	17.20	1.23	1.59	1.53	15.48	1.11	1.21	1.20	54.33	1.29	2.26	1.59
0.8	19.13	1.37	1.91	1.83	16.06	1.15	1.36	1.33	14.88	1.06	1.11	1.10	50.08	1.19	1.91	1.41
1	17.74	1.27	1.76	1.71	15.57	1.11	1.24	1.22	14.80	1.06	1.10	1.09	48.10	1.15	1.76	1.26
2	17.06	1.22	1.33	1.32	15.78	1.13	1.25	1.23	15.04	1.07	1.14	1.14	47.88	1.14	1.33	1.28

8.0 DESIGN RESPONSE SPECTRA CURVES

Calculations were performed to develop smooth top of ground (soil/weathered shale) design response spectra curves using the results of the foregoing SHAKE analysis. These design curves are to be used for the seismic evaluation of the structures founded on soil/weathered shale. The top of ground smooth response spectra was determined by multiplying the rock response spectra by the soil and weathered shale amplification ratios. This approach is represented by the schematic shown on Fig. 15.

A summary of amplification ratios for the seven soil columns considered is presented in Tables 6 through 11. The average, maximum and the 85 percent peak acceleration values were plotted to envelop the spectral acceleration values. This envelope was used to finalize the smooth top of ground design response spectra curve.

The Newmark and Hall data (Ref. 34) are used to define the differences in response spectra for different damping ratios. These differences are used to scale the 5 percent damped ground spectra to other damping ratios. These scaling factors are also validated by site studies for one soil profile.

It was decided to develop separate design response spectra curves for the following three groups of foundations.

- (1) Soil columns 1 through 7 with lower bound, mean and upper bound shear wave velocities:
This case is applicable to the seismic evaluation of structures founded on soil deposits thicker than 10 ft. (10 to 30 ft. of soil overlying 10 to 20 ft. weathered shale).
- (2) Soil columns 1 and 7 with lower bound, mean and upper bound shear wave velocities:
Response curve for this condition is applicable to structures founded on soil deposits equal to or less than 10 ft.
- (3) Soil column 7 with lower bound, mean and upper bound shear wave velocities:
This case is applicable to structures supported on weathered shale.

8.1 PC-3 FACILITIES

Smooth top of ground response curves were determined for the PC-3 SSCs 5 percent damping for the three cases discussed in Section 8.0. SHAKE analysis was performed at 2, 7, 10, 12, and 15 percent damping, also. Formulations presented in Ref. (34) for the Newmark and Hall Spectra were used to develop the smooth response spectra curves for 2, 7, 10, 12 and 15 percent dampings from the 5% damped spectra. Design spectra for 5% damping developed from independent SHAKE run results was compared with the Newmark and Hall formulations which checked very closely with the independent SHAKE analysis results. Therefore, it should be justified to use Newmark and Hall method which resulted in time saving without any sacrifice in quality.

Smooth top of ground design response spectra curves for PC-3 facilities are presented in Tables 12 through 15 and Figures 16 through 19.

8.2 PC-2 FACILITIES

For PC-2 facilities it was not considered necessary to perform the response analysis using SHAKE 91. Instead, the 1000-year seismic hazard level was linearly scaled of the PGA's from the 2000-year event. Smooth top of ground design response curves for the PC-2 facilities are depicted in Figures 20 through 23.

8.3 PC-1 FACILITIES

Similar to PC-2 facilities, the 500-year seismic hazard level was scaled from the 2000-year event. Figures 24 through 27 present the smooth top of ground design response curves for PC-1 facilities.

Table 12 Design Response Spectra for PC-3 Facilities
Supported on Fresh Rock

Period (Sec)	Frequency (Hz)	Peak Ground Acceleration (g) at Damping					
		2%	5%	7%	10%	12%	15%
.0125	80.0	.12	.12	.12	.12	.12	.12
.04	25.0	.34	.26	.23	.20	.18	.16
.18	5.55	.34					
.19	5.26		.26				
.20	5.0			.23	.20	.18	
.22	4.55						.16
2.0	0.5	.030	.024	.023	.02	.019	.018

Note: For PC-1 and PC-2 Facilities, the Peak Ground Acceleration can be scaled from the Acceleration Values Given in this Table.

Table 13 Design Response Spectra for PC-3 Facilities
Supported on Weathered Rock (Shale)

Period (Sec)	Frequency (Hz)	Peak Ground Acceleration (g) at Damping					
		2%	5%	7%	10%	12%	15%
.0125	80.0	.16	.16	.16	.16	.16	.16
.04	25.0	.45	.35	.31	.27	.25	.23
.17	5.88	0.45					
.175	5.71		0.35				
.18	5.55			0.31			
.19	5.26				0.27		
.20	5.0					.25	.23
.40	2.5	.20	.15	.14	.13	.12	.11
2.0	0.5	.03	.024	.023	.020	.019	.018

Note: For PC-1 and PC-2 Facilities, the Peak Ground Acceleration
can be scaled from the Acceleration Values Given in this Table.

Table 14 Design Response Spectra for PC-3 Facilities
Supported on Thin Overburden Soil ≤ 10 Ft.

Period (Sec)	Frequency (Hz)	Peak Ground Acceleration (g) at Damping					
		2%	5%	7%	10%	12%	15%
.0125	80.0	0.28	0.28	0.28	0.28	0.28	0.28
.04	25.0	0.90	0.70	0.62	0.54	0.50	0.46
.09	11.11	0.90					
.10	10.0		0.70	0.62	0.54	0.50	
.11	9.09						0.46
.40	2.5	0.20	0.17	0.16	0.14	0.13	0.12
2.0	0.5	0.03	0.024	0.023	0.020	0.019	0.018

Note: For PC-1 and PC-2 Facilities, the Peak Ground Acceleration
Can Be Scaled from the Acceleration Values Given in this Table.

Table 15 Design Response Spectra for PC-3 Facilities
Supported on Overburden Soil > 10 Ft.

Period (Sec)	Frequency (Hz)	Peak Ground Acceleration (g) at Damping					
		2%	5%	7%	10%	12%	15%
.0125	80.0	0.30	0.30	0.30	0.30	0.30	0.30
.04	25.0	1.03	0.80	0.71	0.62	0.58	0.52
.20	5.0	1.03	0.80				
.21	4.76			0.71	0.62	0.58	
.23	4.35						0.52
.40	2.5	0.52	0.40	0.38	0.34	0.30	0.28
2.0	0.5	0.03	0.024	0.023	0.02	0.019	0.018

Note: For PC-1 and PC-2 Facilities, the Peak Ground Acceleration
can be scaled from the Acceleration Values Given in this Table.

FIG. 16 Y-12 SITE SPECIFIC EARTHQUAKE DESIGN RESPONSE SPECTRA FOR HORIZONTAL ROCK MOTION 2000 - YEAR RETURN PERIOD

PC-3 FACILITIES SUPPORTED ON FRESH ROCK

FIG. 17 Y-12 SITE SPECIFIC EARTHQUAKE DESIGN RESPONSE SPECTRA FOR HORIZONTAL WEATHERED ROCK (SHALE) MOTION 2000 - YEAR RETURN PERIOD

PC-3 FACILITIES SUPPORTED ON WEATHERED ROCK (SHALE).

**FIG. 18 Y-12 SITE SPECIFIC EARTHQUAKE DESIGN RESPONSE
SPECTRA FOR HORIZONTAL SOIL MOTION
SOIL OVERBURDEN ≤ 10 ft.
2000 - YEAR RETURN PERIOD
PC-3 FACILITIES SUPPORTED ON SOIL
OVERBURDEN ≤ 10 FT**

**FIG. 19 Y-12 SITE SPECIFIC EARTHQUAKE DESIGN RESPONSE
SPECTRA FOR HORIZONTAL SOIL MOTION
SOIL OVERBURDEN > 10 ft.
2000 - YEAR RETURN PERIOD**

**PG-3 FACILITIES SUPPORTED ON SOIL
OVERBURDEN > 10FT**

FIG. 20 Y-12 SITE SPECIFIC EARTHQUAKE DESIGN RESPONSE SPECTRA FOR HORIZONTAL ROCK MOTION 1000 - YEAR RETURN PERIOD

PC-2 FACILITIES SUPPORTED ON FRESH ROCK

FIG. 21 Y-12 SITE SPECIFIC EARTHQUAKE DESIGN RESPONSE SPECTRA FOR HORIZONTAL WEATHERED ROCK (SHALE) MOTION 1000 - YEAR RETURN PERIOD

PC-2 FACILITIES SUPPORTED ON WEATHERED ROCK (SHALE)

FIG. 22 Y-12 SITE SPECIFIC EARTHQUAKE DESIGN RESPONSE SPECTRA FOR HORIZONTAL SOIL MOTION
SOIL OVERBURDEN ≤ 10 ft.
1000 - YEAR RETURN PERIOD

PC-2 FACILITIES SUPPORTED ON SOIL OVERBURDEN ≤ 10 FT.

**FIG. 23 Y-12 SITE SPECIFIC EARTHQUAKE DESIGN RESPONSE
SPECTRA FOR HORIZONTAL SOIL MOTION
SOIL OVERBURDEN > 10 ft.
1000 - YEAR RETURN PERIOD**

**PC-2 FACILITIES SUPPORTED ON SOIL
OVERBURDEN > 10FT.**

FIG. 24 Y-12 SITE SPECIFIC EARTHQUAKE DESIGN RESPONSE SPECTRA FOR HORIZONTAL ROCK MOTION 500 - YEAR RETURN PERIOD

PC-1 FACILITIES SUPPORTED ON FRESH ROCK

FIG. 25 Y-12 SITE SPECIFIC EARTHQUAKE DESIGN RESPONSE SPECTRA FOR HORIZONTAL WEATHERED ROCK (SHALE) MOTION 500 - YEAR RETURN PERIOD

PC-1 FACILITIES SUPPORTED ON WEATHERED ROCK (SHALE)

**FIG. 26 Y-12 SITE SPECIFIC EARTHQUAKE DESIGN RESPONSE
SPECTRA FOR HORIZONTAL SOIL MOTION
SOIL OVERBURDEN ≤ 10 ft.
500 - YEAR RETURN PERIOD**

**PC-1 FACILITIES SUPPORTED ON SOIL
OVERBURDEN ≤ 10 FT.**

**FIG. 27 Y-12 SITE SPECIFIC EARTHQUAKE DESIGN RESPONSE SPECTRA FOR HORIZONTAL SOIL MOTION
SOIL OVERBURDEN > 10 ft.
500 - YEAR RETURN PERIOD**

**PC-1 FACILITIES SUPPORTED ON SOIL
OVERBURDEN > 10FT.**

9.0 SOIL LIQUEFACTION ASSESSMENT

Liquefaction, or the loss of shear strength due to an increase in pore water pressure, is a phenomenon associated with saturated cohesionless soils. The increase in pore pressure is a result of the densification of loose soil, which may occur due to ground shaking. The increase in the pore pressure results in a decrease in the intergranular or effective stress, with a corresponding decrease in strength and stiffness. This densification can be a problem with coarse-grained cohesionless soils such as sands.

The cohesion and plasticity exhibited by fine-grained soils (silts and clays) restrict the tendency for volume decrease and pore pressure increase during ground shaking. Although recent research suggests that fine-grained soils may liquefy, liquefaction generally occurs only if the fines are totally non-plastic. Non-plastic fines occur in materials that are produced by the crushing of rock, such as, rock flour or man-made materials such as mine tailings. Even low plasticity silts formed by the weathering of rock have sufficient plasticity to restrict the densification upon shaking. Thus, it is the presence of plastic fines that prohibit the rearrangement of particles leading to densification and liquefaction.

Geotechnical data from the investigation of the Y-12 site (Ref. 18 through 28) indicate that the subsurface materials are classified as silts and clays. This means that the overburden soil is primarily fine-grained. All samples for which Atterberg limits were determined were found to have plastic limits. Based on the reported plasticity, these materials should not be susceptible to liquefaction.

9.1 LIQUEFACTION ANALYSIS OF SILTS AND CLAYS

The visual examination of all SPT samples, and the results of the Atterberg limits and natural water content determinations (Ref. 18, 20, 24, 27, and 28) suggest that the Y-12 foundation soils consist of silts and clays with substantial percentages of fine-grained materials.

To further demonstrate that the Y-12 SSCs foundation materials are not susceptible to liquefaction, a detailed evaluation of the potential for liquefaction has been performed. The evaluation is based upon methodologies reported by Seed, et al., for clayey soils and cohesionless soils with varying percentages of fines (Ref. 11 and 12). The liquefaction analysis is performed using the geotechnical information available in Ref. 18, 20, 24, 27, and 28.

1. According to Ref. 11, clayey soils may be vulnerable to liquefaction as a result of earth shaking if they have the following characteristics:
 - a) Percent finer than .005 mm < 15 %
 - b) Liquid Limit < 35
 - c) Water Content > .9 X Liquid Limit

The data on liquid limit, plasticity index, natural water content and grain size distribution reported in Ref. 18, 20, 24, 27, and 28 are presented in Table 5. The liquid limit and natural water content values are plotted on Fig. 28. It is clear from this plot that out of a total 94 samples, 93 are outside the zone of potential liquefaction and only one sample is on the border line.

Fig. 29 shows the plot of the liquid limit and plasticity index on the Plasticity Chart. The plot indicates that a majority of soils are silty clays (CL). Also a significant number of silty soils (ML) have liquid limit higher than 35 and therefore, they are not liquefiable. The remaining few samples have liquid limit below 35 but their natural water contents are less than 90 percent of the corresponding liquid limits (see Fig. 28). Consequently, the silty soils (ML) are not susceptible to liquefaction.

Grain size distribution data are available in Ref. 28 and this data is included in Table 5. Test results indicate that the percentages of particles finer than .005 mm are 34, 26, 24, 21 and 12. Thus, there is only one sample that contains fines below 15 percent but for all practical purposes 12 percent is fairly close to the required 15 percent fines. Furthermore, it can be argued that this ML sample has significantly lower water content (12.8 %) than the 0.9 times liquid limit (26.1 %) and therefore, this soil should be qualified as a nonliquefiable soil.

9.2 LIQUEFACTION ANALYSIS OF SANDY SOILS

Seed et. al., have developed the boundaries of liquefaction zones for sandy soils containing varying percentages of fines (Ref. 11 and 12). These boundaries are established on the basis of the N values and the CSRs of the soil deposit.

Review of the available geotechnical information (Ref. 17 through 28) indicates that sands or silty sands are generally not encountered at the Y-12 site. Out of several borings, only one boring V-1 (Ref. 27) drilled in the vicinity of Building 9206 revealed the presence of a small, thin and confined pocket of silty sand at 13.5 to 15 ft. depth just above the refusal. This pocket of silty sand will be evaluated for liquefaction potential.

Additionally, a cohesionless soil (sand or silty sand) must be fully saturated in order to liquefy. Geotechnical and hydrological investigations at the site indicate that groundwater is generally encountered in the weathered rock or fresh rock below the soil overburden. In general, the soils at the site are not completely saturated and consequently should not liquefy. Although there are indications of presence of groundwater (most probably perched water) within soil overburden at the north vault of building 9212 and in the vicinity areas of buildings 9215, 9204-2, 9204-2E and 9720-5 but sandy soils are not present at these locations. Therefore, the overburden soils at the site are in general not susceptible to liquefaction.

9.2.1 COMPUTER PROGRAM "SLIQ"

Computer Program "SLIQ" (Ref. 10) evaluates liquefaction potential for sandy soils using the methodology presented by Seed, et. al., in Ref. 11 and 12. This methodology is based upon the relationship between the N values and the CSRs of the soil layer. The N values are corrected for overburden, hammer energy ratio, and very short drill rod lengths. Overburden correction is applied using the method recommended by Liao and Whitman (Ref. 33). For hammer energy ratio, a correction factor of 1.0 is generally used assuming a standard energy ratio of 60 percent of the free fall energy of the hammer (Ref. 12).

x Data Points

FIG. 28 LIQUID LIMIT VS NATURAL WATER CONTENT

FIG. 29 SOIL CLASSIFICATION ASTM D 2487
(Plasticity Chart)

The corrected N values are designated by the symbol $(N_1)_{60}$. The CSR is calculated from the following equation:

$$\frac{\tau_{ave}}{\sigma^1} \approx 0.65 \left(\frac{a_{max}}{g} \right) \left(\frac{\sigma}{\sigma^1} \right) (r_d)$$

τ_{ave} = Average Cyclic Shear Stress

σ = Vertical total Stress

σ^1 = Vertical Effective Stress

a_{max} = Maximum ground Acceleration

g = Acceleration Due to Gravity

r_d = Stress reduction factor

Stress reduction factors are taken from Ref. (12).

Liquefaction analysis was performed using SLIQ program. Soil profiles from three borings V-1, V-3 and V-6 were used. The main objective of the SLIQ analysis was to determine if the thin pocket of silty sand is vulnerable to liquefaction. The input for this analysis is based upon the following assumptions which are very conservative.

- (1) Groundwater was not encountered in borings V-1, V-3 and V-6. In this analysis water level was assumed to be at 5 ft. below the ground for borings V-1 and V-3, and at the ground surface and 2 ft. below the ground surface for boring V-6 which makes the analysis extremely conservative.
- (2) Grain size distribution curves indicate the percentage of -200 fines varying from 38 to 100 but the analysis was performed using 5, 10 and 35 percent fines for borings V-1, V-3 and V-6.
- (3) A 2000-year peak ground acceleration equal to .12 g for fresh rock and .30 g for soil were used in the analysis.

9.2.2 SLIQ ANALYSIS RESULTS

The SLIQ output is presented in Appendix B of this report. The results of the analysis indicate that the materials encountered in the three borings should not liquefy. The factors of safety for liquefaction of the silty sand encountered in boring V-1 using PGA = .12 g and water table at 5 ft. below ground, are 1.34, 1.61 and 2.25 for 5, 10 and 35 percent fines contents, respectively.

For the same water level but a $PGA = .30$ g, the safety factor for silty sand containing 35% of fines is .9 indicating initial liquefaction. Using $PGA = .30$ g and waterlevel at 10 ft. depth, the safety factor is 1.04 indicating no liquefaction. However, assumptions for groundwater at 5 ft. below ground, and using .30 g are extremely conservative and unrealistic. The application of .12 g is more realistic since the thin layer of silty sand is very close to the refusal or top of rock. The assumption of groundwater at 10 ft. is still conservative. Therefore, the silty sand pocket is not vulnerable to liquefaction.

9.3 CONCLUSION OF LIQUEFACTION ANALYSIS

The results of the foregoing liquefaction analysis of clays, silts and silty sand lead to the conclusion that the soils encountered at the Y-12 site are generally not vulnerable to liquefaction. This conclusion is applicable to PC-3, -2, and -1 facilities located at Y-12 plant. The evaluation was performed for the PC-3 earthquake level and indicated no liquefaction concerns. Since the PC-2 and -1 earthquake levels are lower, the results are applicable. Therefore, the design basis earthquakes for the 500, 1000, and 2000 years return periods should not cause any adverse effect on the structural integrity of the soil supported facilities at the Y-12 site.

10.0 REFERENCES

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11.0 APPENDIX

- A1 Spectral Acceleration Plots
- A2 Amplification Ratio Plots
- B Soil Liquefaction 'SLIQ' Computer Output
- C Drawings

A1 Spectral Acceleration Plots

Absolute Response Acceleration Spectra for 2000-Year Event

Absolute Response Acceleration Spectra for 2000-Year Event

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A2 Amplification Ratio Plots

Ratio of Absolute Response Acceleration Spectra for 2000-Year Event

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B Soil Liquefaction 'SLIQ' Computer Output

LIQUEFACTION POTENTIAL OF SILTY SAND

TITLE: Y-12 SARUP, REF. 27, BORING V-1

TRIAL NO. 1

Magnitude of Earthquake (M) = 5.80
 Ground Acceleration (Ah)max = .12 g
 Percentage of silt particles = 35.00
 Unsaturated Unit Weight = 120.00 pcf
 Submerged Unit Weight = 58.00 pcf
 Depth of ground water table = 5.00 ft
 Correction factor for Rod Energy = 1.00

Depth (ft.)	Total Pres (psf)	rd	EQ Shear Stress (psf)
2.50	300.00	.996	23.29
5.00	600.00	.991	46.38
7.50	901.00	.987	69.33
10.00	1202.00	.982	92.07
15.00	1804.00	.973	136.91

Depth (ft.)	Effective Pressure (psf)	Cn	N	(N1)60	CSR Stress (psf)	Liq. Shear
2.50	300.00	2.58	12.0	30.98	*****	*****
5.00	600.00	1.83	36.0	65.73	*****	*****
7.50	745.00	1.64	30.0	49.15	*****	*****
10.00	890.00	1.50	62.0	92.94	*****	*****
15.00	1180.00	1.30	8.0	10.42	.2609	307.86

Depth (ft.)	SDE (psf)	SLQ (psf)	FOS (SLQ/SDE)	
2.5	23.3	*****	*****	No liquefaction.
5.0	46.4	*****	*****	No liquefaction.
7.5	69.3	*****	*****	No liquefaction.
10.0	92.1	*****	*****	No liquefaction.
15.0	136.9	307.9	2.25	

TRIAL NO. 2

Magnitude of Earthquake (M) = 5.80
 Ground Acceleration (Ah)max = .12 g
 Percentage of silt particles = 10.00
 Unsaturated Unit Weight = 120.00 pcf
 Submerged Unit Weight = 58.00 pcf
 Depth of ground water table = 5.00 ft
 Correction factor for Rod Energy = 1.00

Depth (ft.)	Total Pres (psf)	rd	EQ Shear Stress (psf)
2.50	300.00	.996	23.29
5.00	600.00	.991	46.38
7.50	901.00	.987	69.33
10.00	1202.00	.982	92.07
15.00	1804.00	.973	136.91

Depth (ft.)	Effective Pressure (psf)	Cn	N	(N1)60	CSR Stress (psf)	Liq. Shear
2.50	300.00	2.58	12.0	30.98	*****	*****
5.00	600.00	1.83	36.0	65.73	*****	*****
7.50	745.00	1.64	30.0	49.15	*****	*****
10.00	890.00	1.50	62.0	92.94	*****	*****
15.00	1180.00	1.30	8.0	10.42	.1869	220.53

Depth (ft.)	SDE (psf)	SLQ (psf)	FOS (SLQ/SDE)	
2.5	23.3	*****	*****	No liquefaction.
5.0	46.4	*****	*****	No liquefaction.
7.5	69.3	*****	*****	No liquefaction.
10.0	92.1	*****	*****	No liquefaction.
15.0	136.9	220.5	1.61	

TRIAL NO. 3

Magnitude of Earthquake (M) = 5.80
 Ground Acceleration (Ah)max = .12 g
 Percentage of silt particles = 5.00
 Unsaturated Unit Weight = 120.00 pcf
 Submerged Unit Weight = 58.00 pcf

Depth of ground water table = 5.00 ft
 Correction factor for Rod Energy = 1.00

Depth (ft.)	Total Pres (psf)	rd	EQ Shear Stress (psf)
2.50	300.00	.996	23.29
5.00	600.00	.991	46.38
7.50	901.00	.987	69.33
10.00	1202.00	.982	92.07
15.00	1804.00	.973	136.91

Depth (ft.)	Effective Pressure (psf)	Cn	N	(N1)60	CSR Stress (psf)	Liq. Shear
2.50	300.00	2.58	12.0	30.98	*****	*****
5.00	600.00	1.83	36.0	65.73	*****	*****
7.50	745.00	1.64	30.0	49.15	*****	*****
10.00	890.00	1.50	62.0	92.94	*****	*****
15.00	1180.00	1.30	8.0	10.42	.1557	183.77

Depth (ft.)	SDE (psf)	SLQ (psf)	FOS (SLQ/SDE)	
2.5	23.3	*****	*****	No liquefaction.
5.0	46.4	*****	*****	No liquefaction.
7.5	69.3	*****	*****	No liquefaction.
10.0	92.1	*****	*****	No liquefaction.
15.0	136.9	183.8	1.34	

TRIAL NO. 4

Magnitude of Earthquake (M) = 5.80
 Ground Acceleration (Ah)max = .12 g
 Unsaturated Unit Weight = 120.00 pcf
 Submerged Unit Weight = 58.00 pcf
 Depth of ground water table = 5.00 ft
 Correction factor for Rod Energy = 1.00

Depth (ft.)	Total Pres (psf)	rd	EQ Shear Stress (psf)
2.50	300.00	.996	23.29

5.00	600.00	.991	46.38
7.50	901.00	.987	69.33
10.00	1202.00	.982	92.07
15.00	1804.00	.973	136.91

Depth (ft.)	Effective Pressure (psf)	Cn	N	(N1)60	CSR Stress (psf)	Liq. Shear
2.50	300.00	2.58	12.0	30.98	*****	*****
5.00	600.00	1.83	36.0	65.73	*****	*****
7.50	745.00	1.64	30.0	49.15	*****	*****
10.00	890.00	1.50	62.0	92.94	*****	*****
15.00	1180.00	1.30	8.0	10.42	.1557	183.77

Depth (ft.)	SDE (psf)	SLQ (psf)	FOS (SLQ/SDE)	
2.5	23.3	*****	*****	No liquefaction.
5.0	46.4	*****	*****	No liquefaction.
7.5	69.3	*****	*****	No liquefaction.
10.0	92.1	*****	*****	No liquefaction.
15.0	136.9	183.8	1.34	

LIQUEFACTION POTENTIAL OF SILTY SAND

TITLE: Y-12 SARUP, REF.27, BORING V-1

TRIAL NO. 1

Magnitude of Earthquake (M) = 5.80
 Ground Acceleration (Ah)max = .30 g
 Percentage of silt particles = 35.00
 Unsaturated Unit Weight = 120.00 pcf
 Submerged Unit Weight = 58.00 pcf
 Depth of ground water table = 5.00 ft
 Correction factor for Rod Energy = 1.00

Depth (ft.)	Total Pres (psf)	rd	EQ Shear Stress (psf)
2.50	300.00	.996	58.24
5.00	600.00	.991	115.95
7.50	901.00	.987	173.32
10.00	1202.00	.982	230.17
15.00	1804.00	.973	342.28

Depth (ft.)	Effective Pressure (psf)	Cn	N	(N1)60	CSR Stress (psf)	Liq. Shear
2.50	300.00	2.58	12.0	30.98	*****	*****
5.00	600.00	1.83	36.0	65.73	*****	*****
7.50	745.00	1.64	30.0	49.15	*****	*****
10.00	890.00	1.50	62.0	92.94	*****	*****
15.00	1180.00	1.30	8.0	10.42	.2609	307.86

Depth (ft.)	SDE (psf)	SLQ (psf)	FOS (SLQ/SDE)	
2.5	58.2	*****	*****	No liquefaction.
5.0	115.9	*****	*****	No liquefaction.
7.5	173.3	*****	*****	No liquefaction.
10.0	230.2	*****	*****	No liquefaction.
15.0	342.3	307.9	.90	Initial Liquefaction

TRIAL NO. 2

Magnitude of Earthquake (M) = 5.80
 Ground Acceleration (Ah)max = .30 g
 Percentage of silt particles = 35.00
 Unsaturated Unit Weight = 120.00 pcf
 Submerged Unit Weight = 58.00 pcf
 Depth of ground water table = 10.00 ft
 Correction factor for Rod Energy = 1.00

Depth (ft.)	Total Pres (psf)	rd	EQ Shear Stress (psf)
2.50	300.00	.996	58.24
5.00	600.00	.991	115.95
7.50	900.00	.987	173.13
10.00	1200.00	.982	229.79
15.00	1802.00	.973	341.90

Depth (ft.)	Effective Pressure (psf)	Cn	N	(N1)60	CSR Stress (psf)	Liq. Shear
2.50	300.00	2.58	12.0	30.98	*****	*****
5.00	600.00	1.83	36.0	65.73	*****	*****
7.50	900.00	1.49	30.0	44.72	*****	*****
10.00	1200.00	1.29	62.0	80.04	*****	*****
15.00	1490.00	1.16	8.0	9.27	.2394	356.75

Depth (ft.)	SDE (psf)	SLQ (psf)	FOS (SLQ/SDE)	
2.5	58.2	*****	*****	No liquefaction.
5.0	115.9	*****	*****	No liquefaction.
7.5	173.1	*****	*****	No liquefaction.
10.0	229.8	*****	*****	No liquefaction.
15.0	341.9	356.7	1.04	

LIQUEFACTION POTENTIAL OF SILTY SAND

TITLE: Y-12 SARUP, REF. 27, BORING V-3

TRIAL NO. 1

Magnitude of Earthquake (M) = 5.80
 Ground Acceleration (Ah)max = .12 g
 Percentage of silt particles = 35.00
 Unsaturated Unit Weight = 120.00 pcf
 Submerged Unit Weight = 58.00 pcf
 Depth of ground water table = 5.00 ft
 Correction factor for Rod Energy = 1.00

Depth (ft.)	Total Pres (psf)	rd	EQ Shear Stress (psf)
2.50	300.00	.996	23.29
5.00	600.00	.991	46.38
7.30	876.92	.987	67.50
10.00	1202.00	.982	92.07
15.00	1804.00	.973	136.91
20.00	2406.00	.964	180.91
25.00	3008.00	.939	220.32

Depth (ft.)	Effective Pressure (psf)	Cn	N	(N1)60	CSR Stress (psf)	Liq. Shear
2.50	300.00	2.58	14.0	36.15	*****	*****
5.00	600.00	1.83	27.0	49.30	*****	*****
7.30	733.40	1.65	89.0	146.97	*****	*****
10.00	890.00	1.50	45.0	67.46	*****	*****
15.00	1180.00	1.30	36.0	46.87	*****	*****
20.00	1470.00	1.17	74.0	86.32	*****	*****
25.00	1760.00	1.07	85.0	90.61	*****	*****

Depth (ft.)	SDE (psf)	SLQ (psf)	FOS (SLQ/SDE)	
2.5	23.3	*****	*****	No liquefaction.
5.0	46.4	*****	*****	No liquefaction.

7.3	67.5	*****	*****	No liquefaction.
10.0	92.1	*****	*****	No liquefaction.
15.0	136.9	*****	*****	No liquefaction.
20.0	180.9	*****	*****	No liquefaction.
25.0	220.3	*****	*****	No liquefaction.

TRIAL NO. 2

Magnitude of Earthquake (M) = 5.80
 Ground Acceleration (Ah)max = .12 g
 Percentage of silt particles = 10.00
 Unsaturated Unit Weight = 120.00 pcf
 Submerged Unit Weight = 58.00 pcf
 Depth of ground water table = 5.00 ft
 Correction factor for Rod Energy = 1.00

Depth (ft.)	Total Pres (psf)	rd	EQ Shear Stress (psf)
2.50	300.00	.996	23.29
5.00	600.00	.991	46.38
7.30	876.92	.987	67.50
10.00	1202.00	.982	92.07
15.00	1804.00	.973	136.91
20.00	2406.00	.964	180.91
25.00	3008.00	.939	220.32

Depth (ft.)	Effective Pressure (psf)	Cn	N	(N1)60	CSR Stress (psf)	Liq. Shear
2.50	300.00	2.58	14.0	36.15	*****	*****
5.00	600.00	1.83	27.0	49.30	*****	*****
7.30	733.40	1.65	89.0	146.97	*****	*****
10.00	890.00	1.50	45.0	67.46	*****	*****
15.00	1180.00	1.30	36.0	46.87	*****	*****
20.00	1470.00	1.17	74.0	86.32	*****	*****
25.00	1760.00	1.07	85.0	90.61	*****	*****

Depth (ft.)	SDE (psf)	SLQ (psf)	FOS (SLQ/SDE)	
2.5	23.3	*****	*****	No liquefaction.
5.0	46.4	*****	*****	No liquefaction.
7.3	67.5	*****	*****	No liquefaction.

10.0	92.1	*****	*****	No liquefaction.
15.0	136.9	*****	*****	No liquefaction.
20.0	180.9	*****	*****	No liquefaction.
25.0	220.3	*****	*****	No liquefaction.

TRIAL NO. 3

Magnitude of Earthquake (M) = 5.80
 Ground Acceleration (Ah)max = .12 g
 Percentage of silt particles = 5.00
 Unsaturated Unit Weight = 120.00 pcf
 Submerged Unit Weight = 58.00 pcf
 Depth of ground water table = 5.00 ft
 Correction factor for Rod Energy = 1.00

Depth (ft.)	Total Pres (psf)	rd	EQ Shear Stress (psf)
2.50	300.00	.996	23.29
5.00	600.00	.991	46.38
7.30	876.92	.987	67.50
10.00	1202.00	.982	92.07
15.00	1804.00	.973	136.91
20.00	2406.00	.964	180.91
25.00	3008.00	.939	220.32

Depth (ft.)	Effective Pressure (psf)	Cn	N	(N1)60	CSR Stress (psf)	Liq. Shear
2.50	300.00	2.58	14.0	36.15	*****	*****
5.00	600.00	1.83	27.0	49.30	*****	*****
7.30	733.40	1.65	89.0	146.97	*****	*****
10.00	890.00	1.50	45.0	67.46	*****	*****
15.00	1180.00	1.30	36.0	46.87	*****	*****
20.00	1470.00	1.17	74.0	86.32	*****	*****
25.00	1760.00	1.07	85.0	90.61	*****	*****

Depth (ft.)	SDE (psf)	SLQ (psf)	FOS (SLQ/SDE)	
2.5	23.3	*****	*****	No liquefaction.
5.0	46.4	*****	*****	No liquefaction.
7.3	67.5	*****	*****	No liquefaction.
10.0	92.1	*****	*****	No liquefaction.

15.0	136.9	*****	*****	No liquefaction.
20.0	180.9	*****	*****	No liquefaction.
25.0	220.3	*****	*****	No liquefaction.

TRIAL NO. 4

Magnitude of Earthquake (M) = 5.80
 Ground Acceleration (Ah)max = .12 g
 Unsaturated Unit Weight = 120.00 pcf
 Submerged Unit Weight = 58.00 pcf
 Depth of ground water table = 5.00 ft
 Correction factor for Rod Energy = 1.00

Depth (ft.)	Total Pres (psf)	rd	EQ Shear Stress (psf)
2.50	300.00	.996	23.29
5.00	600.00	.991	46.38
7.30	876.92	.987	67.50
10.00	1202.00	.982	92.07
15.00	1804.00	.973	136.91
20.00	2406.00	.964	180.91
25.00	3008.00	.939	220.32

Depth (ft.)	Effective Pressure (psf)	Cn	N	(N1)60	CSR Stress (psf)	Liq. Shear
2.50	300.00	2.58	14.0	36.15	*****	*****
5.00	600.00	1.83	27.0	49.30	*****	*****
7.30	733.40	1.65	89.0	146.97	*****	*****
10.00	890.00	1.50	45.0	67.46	*****	*****
15.00	1180.00	1.30	36.0	46.87	*****	*****
20.00	1470.00	1.17	74.0	86.32	*****	*****
25.00	1760.00	1.07	85.0	90.61	*****	*****

Depth (ft.)	SDE (psf)	SLQ (psf)	FOS (SLQ/SDE)	
2.5	23.3	*****	*****	No liquefaction.
5.0	46.4	*****	*****	No liquefaction.
7.3	67.5	*****	*****	No liquefaction.
10.0	92.1	*****	*****	No liquefaction.
15.0	136.9	*****	*****	No liquefaction.
20.0	180.9	*****	*****	No liquefaction.

25.0 220.3 ***** No liquefaction.

LIQUEFACTION POTENTIAL OF SILTY SAND

TITLE: Y-12 SARUP, REF. 27, BORING V-3

TRIAL NO. 1

Magnitude of Earthquake (M) = 5.80
 Ground Acceleration (Ah)max = .30 g
 Percentage of silt particles = 35.00
 Unsaturated Unit Weight = 120.00 pcf
 Submerged Unit Weight = 58.00 pcf
 Depth of ground water table = 5.00 ft
 Correction factor for Rod Energy = 1.00

Depth (ft.)	Total Pres (psf)	rd	EQ Shear Stress (psf)
2.50	300.00	.996	58.24
5.00	600.00	.991	115.95
7.30	876.92	.987	168.75
10.00	1202.00	.982	230.17
15.00	1804.00	.973	342.28
20.00	2406.00	.964	452.28
25.00	3008.00	.939	550.80

Depth (ft.)	Effective Pressure (psf)	Cn	N	(N1)60	CSR Stress (psf)	Liq. Shear
2.50	300.00	2.58	14.0	36.15	*****	*****
5.00	600.00	1.83	27.0	49.30	*****	*****
7.30	733.40	1.65	89.0	146.97	*****	*****
10.00	890.00	1.50	45.0	67.46	*****	*****
15.00	1180.00	1.30	36.0	46.87	*****	*****
20.00	1470.00	1.17	74.0	86.32	*****	*****
25.00	1760.00	1.07	85.0	90.61	*****	*****

Depth (ft.)	SDE (psf)	SLQ (psf)	FOS (SLQ/SDE)	
2.5	58.2	*****	*****	No liquefaction.
5.0	115.9	*****	*****	No liquefaction.

7.3	168.8	*****	*****	No liquefaction.
10.0	230.2	*****	*****	No liquefaction.
15.0	342.3	*****	*****	No liquefaction.
20.0	452.3	*****	*****	No liquefaction.
25.0	550.8	*****	*****	No liquefaction.

LIQUEFACTION POTENTIAL OF SILTY SAND

TITLE: Y-12 SARUP, REF. 27, BORING V-6

TRIAL NO. 1

Magnitude of Earthquake (M) = 5.80
 Ground Acceleration (Ah)max = .12 g
 Percentage of silt particles = 35.00
 Saturated Unit Weight = 120.40 pcf
 Submerged Unit Weight = 58.00 pcf
 Depth of ground water table = .00 ft
 Correction factor for Rod Energy = 1.00

Depth (ft.)	Total Pres (psf)	rd	EQ Shear Stress (psf)
2.50	301.00	.996	23.37
5.00	602.00	.991	46.53

Depth (ft.)	Effective Pressure (psf)	Cn	N	(N1)60	CSR Stress (psf)	Liq. Shear
2.50	145.00	3.71	53.0	196.84	*****	*****
5.00	290.00	2.63	28.0	73.53	*****	*****

Depth (ft.)	SDE (psf)	SLQ (psf)	FOS (SLQ/SDE)	
2.5	23.4	*****	*****	No liquefaction.
5.0	46.5	*****	*****	No liquefaction.

TRIAL NO. 2

Magnitude of Earthquake (M) = 5.80
 Ground Acceleration (Ah)max = .12 g
 Percentage of silt particles = 10.00
 Saturated Unit Weight = 120.40 pcf
 Submerged Unit Weight = 58.00 pcf
 Depth of ground water table = .00 ft
 Correction factor for Rod Energy = 1.00

Depth (ft.)	Total Pres (psf)	rd	EQ Shear Stress (psf)
2.50	301.00	.996	23.37
5.00	602.00	.991	46.53

Depth (ft.)	Effective Pressure (psf)	Cn	N	(N1)60	CSR Stress (psf)	Liq. Shear
2.50	145.00	3.71	53.0	196.84	*****	*****
5.00	290.00	2.63	28.0	73.53	*****	*****

Depth (ft.)	SDE (psf)	SLQ (psf)	FOS (SLQ/SDE)	
2.5	23.4	*****	*****	No liquefaction.
5.0	46.5	*****	*****	No liquefaction.

TRIAL NO. 3

Magnitude of Earthquake (M) = 5.80
 Ground Acceleration (Ah)max = .12 g
 Percentage of silt particles = 5.00
 Saturated Unit Weight = 120.40 pcf
 Submerged Unit Weight = 58.00 pcf
 Depth of ground water table = .00 ft
 Correction factor for Rod Energy = 1.00

Depth (ft.)	Total Pres (psf)	rd	EQ Shear Stress (psf)
2.50	301.00	.996	23.37
5.00	602.00	.991	46.53

Depth (ft.)	Effective Pressure (psf)	Cn	N	(N1)60	CSR Stress (psf)	Liq. Shear
2.50	145.00	3.71	53.0	196.84	*****	*****
5.00	290.00	2.63	28.0	73.53	*****	*****

Depth (ft.)	SDE (psf)	SLQ (psf)	FOS (SLQ/SDE)	
2.5	23.4	*****	*****	No liquefaction.
5.0	46.5	*****	*****	No liquefaction.

TRIAL NO. 4

Magnitude of Earthquake (M) = 5.80
 Ground Acceleration (Ah)max = .12 g
 Saturated Unit Weight = 120.40 pcf
 Submerged Unit Weight = 58.00 pcf
 Depth of ground water table = .00 ft
 Correction factor for Rod Energy = 1.00

Depth (ft.)	Total Pres (psf)	rd	EQ Shear Stress (psf)
2.50	301.00	.996	23.37
5.00	602.00	.991	46.53

Depth (ft.)	Effective Pressure (psf)	Cn	N	(N1)60	CSR Stress (psf)	Liq. Shear
2.50	145.00	3.71	53.0	196.84	*****	*****
5.00	290.00	2.63	28.0	73.53	*****	*****

Depth (ft.)	SDE (psf)	SLQ (psf)	FOS (SLQ/SDE)	
2.5	23.4	*****	*****	No liquefaction.
5.0	46.5	*****	*****	No liquefaction.

LIQUEFACTION POTENTIAL OF SILTY SAND

TITLE: Y-12 SARUP, REF.27, BORING V-6

TRIAL NO. 1

Magnitude of Earthquake (M) = 5.80
 Ground Acceleration (Ah)max = .30 g
 Percentage of silt particles = 35.00
 Unsaturated Unit Weight = 120.00 pcf
 Submerged Unit Weight = 58.00 pcf
 Depth of ground water table = 2.00 ft
 Correction factor for Rod Energy = 1.00

Depth (ft.)	Total Pres (psf)	rd	EQ Shear Stress (psf)
2.50	300.20	.996	58.28
5.00	601.20	.991	116.18

Depth (ft.)	Effective Pressure (psf)	Cn	N	(N1)60	CSR Stress (psf)	Liq. Shear
2.50	269.00	2.73	53.0	144.52	*****	*****
5.00	414.00	2.20	28.0	61.54	*****	*****

Depth (ft.)	SDE (psf)	SLQ (psf)	FOS (SLQ/SDE)	
2.5	58.3	*****	*****	No liquefaction.
5.0	116.2	*****	*****	No liquefaction.

TRIAL NO. 2

Magnitude of Earthquake (M) = 5.80
 Ground Acceleration (Ah)max = .30 g
 Percentage of silt particles = 35.00
 Saturated Unit Weight = 120.00 pcf
 Submerged Unit Weight = 58.00 pcf
 Depth of ground water table = .00 ft
 Correction factor for Rod Energy = 1.00

Depth (ft.)	Total Pres (psf)	rd	EQ Shear Stress (psf)
2.50	301.00	.996	58.43
5.00	602.00	.991	116.33

Depth (ft.)	Effective Pressure (psf)	Cn	N	(N1)60	CSR Stress (psf)	Liq. Shear
2.50	145.00	3.71	53.0	196.84	*****	*****
5.00	290.00	2.63	28.0	73.53	*****	*****

Depth (ft.)	SDE (psf)	SLQ (psf)	FOS (SLQ/SDE)	
2.5	58.4	*****	*****	No liquefaction.
5.0	116.3	*****	*****	No liquefaction.

C Drawings

H

G

F

E

1020
1016
1012
1008
1004
1000
996
992
988
984
980
976
972

40
9995

41
9995

1
995

42
9995

[illegible]

[illegible]

D

C

C2E900000A959

E

A

RPE		DSGN SB AHMED	03-15-95	MARTIN MARIETTA		MARTIN MARIETTA ENERGY SYSTEMS, INC. managed for the DEPARTMENT OF ENERGY under U.S. GOVERNMENT contracts DE-AC-85-84OR21488 and DE-AC-85-76OR00001 Oak Ridge, Tennessee • Paducah, Kentucky • Portsmouth, Ohio					
		DRW DOUG LEGG	03-15-95	PROJECT NAME: Y-12 SARUP SUPPORT							
		CHKR VG OLDHAM	4-20-95								
		SECT		SOIL PROFILES (COLUMNS)							
		DEPT									
		PE		BUILDING 9995							
		PJ									
		REQ		1 48 49 50 PLANT BLDG FL SH. OF TYPE CLASS 3 C G N Y-12 YAREA ARE 1 1 S U							
				51 52 53 NC NA IN C2E900000A959 REV O							
REV. DATE		MMES									
DRAWING APPROVALS											

H

G

F

E

22
9998

23
9998

BOTT
BLDG
EL. 1

GRADE EL. 1011.0

GRADE EL. 1005.0

TOP OF
WEATHERED
ROCK EL. 990.0

TOP OF
WEATHERED
ROCK EL. 989.0

BOTTOM OF
BLDG. FDN.
EL. 980.0

GROUND
WATER
EL. 982.0

GR
WAT
EL.

TOP OF FRESH
ROCK EL. 978.0

TOP OF FRESH
ROCK EL. 976.0

23
9998

24
9998

GRADE EL. 985.0

TOP OF
WEATHERED
ROCK EL. 974.0

GROUND
WATER
EL. 972.0

GRADE EL. 974.0

GR
WAT
EL.

TOP OF FRESH
ROCK EL. 960.0

BOTTOM OF
BLDG. FDN.
EL. 960.0

TOP OF
WEATHERED
ROCK EL. 964.0

BOT
BLD
EL.

25
9996

26
9996

GRADE EL.1011.0

BOTTOM OF
BLDG. FDN.
EL.1009.5

GRADE EL.1011.0

1012

1008

1004

1002

998

994

990

986

982

978

974

970

968

TOP OF
WEATHERED
ROCK EL.988.0TOP OF
WEATHERED
ROCK EL.987.0GROUND
WATER
EL.980.0TOP OF FRESH
ROCK EL.970.0TOP OF FRESH
ROCK EL.972.0

26

9996

27

9996

GRADE EL.971.0

GROUND
WATER
EL.966.0TOP OF
WEATHERED
ROCK EL.960.0GROUND
WATER
EL.961.0BOTTOM OF
BLDG. FDN.
EL.953.0

GRADE EL.967.0

TOP OF
WEATHERED
ROCK EL.962.0

990

986

982

978

974

970

966

962

958

954

D

C

B

SECTION

950

946

942

28

9215

29

9215

972

968

964

960

TOP OF
WEATHERED
ROCK EL.956.0

GRADE EL.958.0

GRADE EL.958.0

TOP OF
WEATHERED
ROCK EL.95

956

BOTTOM OF
BLDG. FDN.
EL.950.0

GROUND
WATER
EL.957.5

GROUND
WATER
EL.952.0

952

948

944

TOP OF FRESH
ROCK EL.940.0

BOTTOM OF
BLDG. FDN.
EL.941.0

940

TOP OF FRE
ROCK EL.93

936

932

928

924

34

9204-2

35

9204-2
TUNNEL

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EG-C-37 Review By: _____
Guideline Documents: _____
UCN-19586 (12356 4-93)

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DRAWING ON
WHICH SECTION
OR DETAIL IS
SHOWN

SECTION AND DETAIL KEY

THIS DOCUMENT
CONTROLLED BY

CHANGE CONTROL
SYSTEM _____

ENGINEERING
PROCEDURE _____

REV _____

TOP OF FRESH
ROCK EL.950.0

30
9215

TOP OF
WEATHERED
ROCK EL.958.0

GROUND
WATER
EL.952.0

BOTTOM OF
BLDG. FDN.
EL.950.0

GRADE EL.960.0

BOTTOM OF
BLDG. FDN.
EL.960.0

GROUND
WATER
EL.950.0

TOP OF
WEATHERED
ROCK EL.946.0

TOP OF FRESH
ROCK EL.938.0

TOP OF FRESH
ROCK EL.927.0

36
9204-2

REV	CHANGE TYPE	DATE ENTERED	CHANGE BY	DESCRIPTION	BY	CHK	SECT	DEPT	DATE	PE	REQ	DATE	MMES	DATE	RPE	RPE N
REVISION OR ISSUE PURPOSE					REVISION APPROVALS											

6

5

32
9204-2E

TOP OF FRESH
ROCK EL. 940.0

BOTTOM OF
BLDG. FDN.
EL. 960.0

GRADE EL. 966.0

TOP OF
WEATHERED
ROCK EL. 959.0

TOP OF FRESH
ROCK EL. 948.0

BOTTOM OF
BLDG. FDN.
EL. 960.0

GRADE EL. 966.0

GF
W
EL

TOP OF
WEATHERED
ROCK EL.958.0

TOP OF FRESH
ROCK EL. 944.0

37
9720-5

38
9720-5

[illegible]

38
9720-5

39
9720-5

SE	RPE	OSGN SB AHMED	03-15-95											
		DRW DOUG LEGG	03-15-95	MARTIN MARIETTA ENERGY SYSTEMS, INC. managed for the DEPARTMENT OF ENERGY under U.S. GOVERNMENT contracts DE-AC-85-B40R21488 and DE-AC-85-760R98801 Oak Ridge, Tennessee • Paducah, Kentucky • Portsmouth, Ohio										
		CHKR VG OLDHAM	4-20-95	PROJECT NAME:										
		SECT		Y-12 SARUP SUPPORT										
		DEPT		SOIL PROFILES (COLUMNS)										
	PE			BLDG. 9998, 9996,										
	PJ			9215, 9204-2&2E, 9720-5										
	REQ			1	48	49	50	PLANT	BLDG	FL	SH.	OF	TYPE	CLASS
				3	C	G	N	Y-12	YAREA	ARE	1	1	S	U
				51	52	53								REV
				NC	NA	IN								O
	REV.	DATE	MMES	C2E900000A958										
DRAWING APPROVALS

01
NORTH VAULT

02
NORTH VAULT

GRADE EL. 1014.0

GROUND
WATER
EL. 1011.0BOTTOM OF
BLDG. FDN.
EL. 1005.0TOP OF
WEATHERED
ROCK EL. 998.0BOTTOM OF
BLDG. FDN.
EL. 997.0TOP OF FRESH
ROCK EL. 974.0

GRADE EL. 1011.0

GROUND
WATER
EL. 1008.0TOP OF
WEATHERED
ROCK EL. 1002.0TOP OF FRESH
ROCK EL. 993.0BOTTOM OF
BLDG. FDN.
EL. 1005.0BOTTOM OF
BLDG. FDN.
EL. 997.0

GRADE EL.

TOP OF
WEATHERED
ROCK EL.TOP OF F
ROCK EL.

03

"E" WING

04

"E" WING

GRADE EL. 1011.0

BOTTOM
BSMT. SLAB
EL. 1007.0TOP OF
WEATHERED
ROCK EL. 1001.0TOP OF FRESH
ROCK EL. 995.0BOTTOM OF
BLDG. FDN.
EL. 1005.0GROUND
WATER
EL. 998.0

GRADE EL. 1011.0

BOTTOM
BSMT. SLAB
EL. 1007.0TOP OF
WEATHERED
ROCK EL. 1001.0TOP OF FRESH
ROCK EL. 992.0BOTTOM OF
BLDG. FDN.
EL. 1005.0

GRADE EL.

BOTTOM
BSMT. S
EL. 1007TOP OF
WEATHERED
ROCK EL.TOP OF
ROCK EL.

GRADE EL.1011.0

GRADE EL.1011.0

GROUND
WATER
EL.1008.0

BOTTOM OF
BLDG. FDN.
EL.1005.0

GROUND
WATER
EL.1008.0

BOTTOM OF
BLDG. FDN.
EL.1005.0

TOP OF
WEATHERED
ROCK EL.1003.0

TOP OF
WEATHERED
ROCK EL.1003.0

GROUND
WATER
EL.1003.0

TOP OF FRESH
ROCK EL.996.0

TOP OF FRESH
ROCK EL.1000.0

BOTTOM OF
BLDG. FDN.
EL.997.0

04

WING

05

"E" WING

06

"D" WING
HEADHOUSE

GRADE EL.1011.0

GRADE EL.1011.0

BOTTOM
BSMT. SLAB
EL.1007.0

BOTTOM OF
BLDG. FDN.
EL.1005.0

BOTTOM
BSMT. SLAB
EL.1007.0

BOTTOM OF
BLDG. FDN.
EL.1005.0

TOP OF
WEATHERED
ROCK EL.999.0

TOP OF
WEATHERED
ROCK EL.998.0

GROUND
WATER
EL.998.0

GROUND
WATER
EL.994.0

TOP OF FRESH
ROCK EL.988.0

TOP OF FRESH
ROCK EL.993.0

06
"D" WING
HEADHOUSE

07
"D" WING

H

G

F

E

←

"D" WING

"C" WING

"A" WING

"A" WING

Document Rev. No.: _____ Date: _____
EG-C-37 Review By: _____
Guideline Documents: _____
UCN-19586 (12356 4-93)

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WHICH SECTION
OR DETAIL IS
TAKEN

-DRAWING ON WHICH SECTION OR DETAIL IS SHOWN

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CHANGE CONTROL
SYSTEM _____

ENGINEERING PROCEDURE

REV	CHANGE TYPE	CHANGE CONTROL SYSTEM	CHANGE REQUEST NUMBER
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10
"C" WING

11.
"C" WING

~~GRADE EL.1011.0~~

BOTTOM
BSMT. SLAB
EL. 1007.0

BOTTOM OF
 BLDG. FDN.
 EL. 1005.0

TOP OF
WEATHERED
ROCK EL. 994.0

GROUND
WATER
EL. 989.0

TOP OF FRESH
ROCK EL. 981.0

~~GRADE EL. 1011.0~~

BOTTOM
BSMT. SLAB
EL. 1007.0

TOP OF
WEATHERED
ROCK EL. 994.0

GROUND
WATER
EL. 989.0

TOP OF FRESH
ROCK EL. 980.0

BOTTOM OF
 BLDG. FDN.
 EL. 1005.0

GROUND
WATER
EL. 988.0

~~GRADE EL.~~

BOTTOM
BSMT. SLAB
EL. 1007.0

TOP OF
WEATHERED
ROCK EL. 99

TOP OF FRE
ROCK EL. 98

17
"A" WING

18
HEADHOUSE
9998

[illegible]

"C" WING

"B" WING

"B"

"A2" WING

"A2"

[illegible]

13
"B" WING

14
"B" WING

20
"A2" WING

21
"A2" WING

C2E900000A957

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		CHANGE CONTROL SYSTEM _____ ENGINEERING PROCEDURE _____	
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REVISION OR ISSUE PURPOSE		BY		CHK	SECT	DEPT	DATE	PE	REQ	DATE	MNES	DATE	RP
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SOIL BORING REFERENCES

- 1 USR-III RUN 47810 BLDG. ADDN. 9206. GEOTEK 1986
- 3 FOUNDATION INVESTIGATION AND ANALYSIS 9215 BUILDING. U.S. ARMY C.O.E. 1956
- 4 FOUNDATION INVESTIGATION AND ANALYSIS BUILDING 9998. U.S. ARMY C.O.E. 1954
- 5 FOUNDATION INVESTIGATION FOR BUILDING 9204-5. U.S. ARMY C.O.E. 1967
- 6 SUBSURFACE INVESTIGATION FOR BUILDING 9215 BUILDING ADDITION. GEOTEK 1978
- 10 PILE DATA BLDG. 9212 NORTH EXTENSION. THE AUSTON CO. 1951
- 11 BUILDING 9212 FOUNDATION INFORMATION ANALYSIS & BORING. U.S. ARMY C.O.E. CORE DRILLING REPORT 1943-44
- 12 GEOTECHNICAL INVESTIGATION FOR THE PROPOSED ADDITION TO BLDG. 9212 NORTH. GEOTEK 1986
- 23 FOUNDATION INVESTIGATION FOR BUILDING 9201-6. GEOTEK 1967
- 24 GEOTECHNICAL INVESTIGATION FOR THE PROPOSED VAULT ADDITION TO THE 9212 BLDG. GEOTEK 1984
- 25 CROSS BORE HOLE SHEAR WAVE STUDY OF SUBSURFACE CONDITIONS IN THE VICINITY OF BUILDING 9206. 1989
- 26 VIBROSEISMIC SURVEY (PRA 9206) EDGE. 1989 (SAME BORING LOCATIONS AS 25)
- 13 GEOTECHNICAL INVESTIGATION FOR PROPOSED VAULT ADDITION TO 9220-5. GEOTEK 1984

MONITORING WELL REFERENCES

UPDATED SUBSURFACE DATA BASE FOR BEAR CREEK VALLEY. CHESTNUT RIDGE AND PARTS OF BETHEL VALLEY REVISION 2. OCTOBER 1993

CALANDER YEAR 1993 GROUNDWATER QUALITY REPORT FOR THE UPPER EAST FORK POPLAR CREEK HYDROLOGIC REGIME. Y-12 PLANT FEBRUARY 1994

SOUNDING REFERENCES

ADDITION TO BUILDING 9212 SOUNDING LOCATIONS A-1 AND B-1 WINGS DRAWING E2F12902. 1950

LEGEND

- SOUNDING
- SOIL BORING
- MONITORING WELL
- SELECTED DRIVEN PILE LOCATIONS
- TOP OF WEATHERED ROCK CONTOURS

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SOIL COLUMN LOCATIONS

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SOIL BORING REFERENCES

- 1 USR-III RUN 47810 BLDG. ADDN. 9206. GEOTEK 1986
- 3 FOUNDATION INVESTIGATION AND ANALYSIS 9215 BUILDING. U.S. ARMY C.O.E. 1956
- 4 FOUNDATION INVESTIGATION AND ANALYSIS BUILDING 9998. U.S. ARMY C.O.E. 1954
- 5 FOUNDATION INVESTIGATION FOR BUILDING 9204-5. U.S. ARMY C.O.E. 1967
- 6 SUBSURFACE INVESTIGATION FOR BUILDING 9215 BUILDING ADDITION. GEOTEK 1978
- 10 PILE DATA BLDG. 9212 NORTH EXTENSION, THE AUSTON CO. 1951
- 11 BUILDING 9212 FOUNDATION INFORMATION ANALYSIS & BORING. U.S. ARMY C.O.E. CORE DRILLING REPORT 1943-44
- 12 GEOTECHNICAL INVESTIGATION FOR THE PROPOSED ADDITION TO BLDG. 9212 NORTH. GEOTEK 1986
- 23 FOUNDATION INVESTIGATION FOR BUILDING 9201-6. GEOTEK 1967
- 24 GEOTECHNICAL INVESTIGATION FOR THE PROPOSED VAULT ADDITION TO THE 9212 BLDG. GEOTEK 1984
- 25 CROSS BORE HOLE SHEAR WAVE STUDY OF SUBSURFACE CONDITIONS IN THE VICINITY OF BUILDING 9206. 1989
- 26 VIBROSEISMIC SURVEY (PRA 9206) EDGE. 1989 (SAME BORING LOCATIONS AS 25)
- 13 GEOTECHNICAL INVESTIGATION FOR PROPOSED VAULT ADDITION TO 9204-5. GEOTEK 1984

MONITORING WELL REFERENCES

UPDATED SUBSURFACE DATA BASE FOR BEAR CREEK VALLEY, CHESTNUT RIDGE AND PARTS OF BETHEL VALLEY REVISION 2. OCTOBER 1993

CALANDER YEAR 1993 GROUNDWATER QUALITY REPORT FOR THE UPPER EAST FORK POPLAR CREEK HYDROLOGIC REGIME, Y-12 PLANT FEBRUARY 1994

SOUNDING REFERENCES

ADDITION TO BUILDING 9212 SOUNDING LOCATIONS A-1 AND B-1 WINGS DRAWING E2F12902, 1950

LEGEND

- SOUNDING
- SOIL BORING
- MONITORING WELL
- SELECTED DRIVEN PILE LOCATIONS
- GROUND WATER CONTOURS

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		DRW DOUG LEGG	2-14-95											
		CHKR VG OLDHAM	4-20-95											
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SOIL BORING REFERENCES

- 1 USR-III RUN 47810 BLDG. ADDN. 9206. GEOTEK 1986
- 3 FOUNDATION INVESTIGATION AND ANALYSIS 9215 BUILDING. U.S. ARMY C.O.E. 1956
- 4 FOUNDATION INVESTIGATION AND ANALYSIS BUILDING 9998. U.S. ARMY C.O.E. 1954
- 5 FOUNDATION INVESTIGATION FOR BUILDING 9204-5. U.S. ARMY C.O.E. 1967
- 6 SUBSURFACE INVESTIGATION FOR BUILDING 9215 BUILDING ADDITION. GEOTEK 1978
- 10 PILE DATA BLDG. 9212 NORTH EXTENSION. THE AUSTON CO. 1951
- 11 BUILDING 9212 FOUNDATION INFORMATION ANALYSIS & BORING. U.S. ARMY C.O.E. CORE DRILLING REPORT 1943-44
- 12 GEOTECHNICAL INVESTIGATION FOR THE PROPOSED ADDITION TO BLDG. 9212 NORTH. GEOTEK 1986
- 23 FOUNDATION INVESTIGATION FOR BUILDING 9201-6. GEOTEK 1967
- 24 GEOTECHNICAL INVESTIGATION FOR THE PROPOSED VAULT ADDITION TO THE 9212 BLDG. GEOTEK 1984
- 25 CROSS BORE HOLE SHEAR WAVE STUDY OF SUBSURFACE CONDITIONS IN THE VICINITY OF BUILDING 9206. 1989 (SAME BORING LOCATIONS AS 25)
- 26 VIBROSEISMIC SURVEY (PRA 9206) EDGE. 1989 (SAME BORING LOCATIONS AS 25)
- 13 GEOTECHNICAL INVESTIGATION FOR PROPOSED VAULT ADDITION TO 9220-6. GEOTEK 1984

MONITORING WELL REFERENCES

UPDATED SUBSURFACE DATA BASE FOR BEAR CREEK VALLEY, CHESTNUT RIDGE AND PARTS OF BETHEL VALLEY REVISION 2, OCTOBER 1993

CALANDER YEAR 1993 GROUNDWATER QUALITY REPORT FOR THE UPPER EAST FORK POPLAR CREEK HYDROLOGIC REGIME. Y-12 PLANT FEBRUARY 1994

SOUNDING REFERENCES

ADDITION TO BUILDING 9212 SOUNDING LOCATIONS A-1 AND B-1 WINGS DRAWING E2F12902, 1950

LEGEND

- SOUNDING
- ▲ SOIL BORING
- ⊕ MONITORING WELL
- SELECTED DRIVEN PILE LOCATIONS
- TOP OF FRESH ROCK CONTOURS

RPE	DSGN SB AHMED	2/14/95
	DRW DOUG LEGG	2/14/95
	CHKR VG OLDHAM	4-20-95
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MARTIN MARIETTA

MARTIN MARIETTA ENERGY SYSTEMS, INC.
managed for the DEPARTMENT OF ENERGY under
U.S. GOVERNMENT contracts DE-AC-85-84OR21488 and DE-AC-85-76OR00001
Oak Ridge, Tennessee • Paducah, Kentucky • Portsmouth, Ohio

PROJECT NAME:

Y-12 SARUP SUPPORT
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SOIL BORING REFERENCE

- 1 USR-III RUN 47810 BLDG. ADDN. 9206.
- 3 FOUNDATION INVESTIGATION AND ANALYSIS
- 4 FOUNDATION INVESTIGATION AND ANALYSIS
- 5 FOUNDATION INVESTIGATION FOR BUILDING
- 6 SUBSURFACE INVESTIGATION FOR BUILDING
- 10 PILE DATA BLDG. 9212 NORTH EXTENSION
- 11 BUILDING 9212 FOUNDATION INFORMATION
- 12 CORE DRILLING REPORT 1943-44
- 12 GEOTECHNICAL INVESTIGATION FOR THE
- 23 FOUNDATION INVESTIGATION FOR BUILDING
- 24 GEOTECHNICAL INVESTIGATION FOR THE
- 25 TO THE 9212 BLDG. GEOTEK 1984
- 25 CROSS BORE HOLE SHEAR WAVE STUDY OF
- 26 VICINITY OF BUILDING 9206. 1989
- 13 VIBROSEISMIC SURVEY (PRA 9206) EDG
- 13 GEOTECHNICAL INVESTIGATION FOR PROPOSED

MONITORING WELL REFERENCE

UPDATED SUBSURFACE DATA BASE FOR BETHEL
CHESTNUT RIDGE AND PARTS OF BETHEL
OCTOBER 1993

CALANDER YEAR 1993 GROUNDWATER QUALITY
UPPER EAST FORK POPLAR CREEK HYDROLOGICAL
PLANT FEBRUARY 1994

SOUNDING REFERENCES

ADDITION TO BUILDING 9212 SOUNDING
DRAWING E2F12902, 1950

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- 1 USR-III RUN 47810 BLDG. ADDN. 9206, GEOTEK 1986
3 FOUNDATION INVESTIGATION AND ANALYSIS 9215 BUILDING. U.S. ARMY C.O.E. 1956
4 FOUNDATION INVESTIGATION AND ANALYSIS BUILDING 9998, U.S. ARMY C.O.E. 1954
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6 SUBSURFACE INVESTIGATION FOR BUILDING 9215 BUILDING ADDITION, GEOTEK 1978
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12 GEOTECHNICAL INVESTIGATION FOR THE PROPOSED ADDITION TO BLDG. 9212 NORTH, GEOTEK 1986
23 FOUNDATION INVESTIGATION FOR BUILDING 9201-6, GEOTEK 1967
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 TO THE 9212 BLDG. GEOTEK 1984
25 CROSS BORE HOLE SHEAR WAVE STUDY OF SUBSURFACE CONDITIONS IN THE
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26 VIBROSEISMIC SURVEY (PRA 9206) EDGE, 1989 (SAME BORING LOCATIONS AS 25)
13 GEOTECHNICAL INVESTIGATION FOR PROPOSED VAULT ADDITION TO 9720-5, GEOTEK 1984

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PLANT FEBRUARY 1994

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DRAWING E2F12902. 1950

LEGEND

- SOIL COLUMN LOCATION
SOUNDING
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MONITORING WELL
SELECTED DRIVEN PILE LOCATIONS
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