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David Tiktinsky - SS623
U.S. Nuclear Regulatory Commission
Division of Waste Management
Washington, D.C. 20555

"NRC Technical Assistance
for Design Reviews"
Contract No. NRC-02-85-002
FIN D1016

ITASCA
Consulting Group, Inc.

Dear David:

Enclosed is the review of "Ground Motion Produced at Yucca Mountain from Pahute Mesa Underground Nuclear Explosions," by Luke J. Vortman (SAND85-1605, February 1986). Please call me if you have any questions.

Sincerely,

Loren

Loren J. Lorig

cc: J. Greeves, Engineering Branch
Office of the Director, NMSS
E. Wiggins, Division of Contracts
DWM Document Control Room

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ITASCA DOCUMENT REVIEW

File No.: 001-02-15

Document: "Ground Motion Produced at Yucca Mountain from Pahute Mesa Underground Nuclear Explosions," by Luke J. Vortman. SAND85-1605, February 1986.

Reviewer: Itasca Consulting Group, Inc. (J. Daemen, L. Lorig)

Date Approved:

Date Review Completed: 6 June 1986

Significance to NRC Waste Management Program

The document provides basic information about the expected ground motions induced at Yucca Mountain as a result of possible future weapons tests at the Nevada Test Site. The author postulates that a multiplication of about 4 might have to be applied because of observed Yucca Mountain amplification, resulting in an approximately fourfold increase in the possible acceleration at the site as compared to the value quoted in the Draft Environmental Assessment (U.S. Department of Energy, 1984, p. 6-38).

The author points out that "Since the data set for Yucca Mountain is relatively small, the possibility exists for even greater enhancements for underground nuclear explosions in locations other than those included in the data set." (Abstract, p. 3, last paragraph; also p. 135, point 2; p. 134, last sentence; and p. 135, last paragraph). The data paucity and resulting uncertainty reinforce NRC Comment 6-7, points 2a and 2b (NRC, 1985, p. 41) with regard to the uncertainty of predicting ground motions induced at Yucca Mountain by underground nuclear explosions at NTS (although, here, for reasons different from those cited in 6-7, 2a).

The Draft EA cites, as a very conservative design criterion, three standard deviations (0.32g, pp. 6-38 and 6-42) and continues with: "A worst-case repository accident scenario resulting from an underground nuclear explosion . . . a surface acceleration of 0.4g at the repository site." The design basis for surface facilities is also listed in the NNWSI Repository Design and Issues Resolu-

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tion Strategy (February 1986, Albuquerque, New Mexico) as 0.4g for an underground nuclear explosion. The revised predictions in this report give a 0.39g acceleration for a single standard deviation and 0.64 g for two standard deviations (p. 135). The predictions are based on an explosion with 700 kt yield and slant range of 22.8 km. The potential for weapon tests in the range of 1 megaton or slightly more does exist (p. 9).

In summary, this document presents a significant increase in expected peak accelerations compared to earlier analyses. The analyses presented here only indirectly address the issue of the impact of underground nuclear detonations on a Yucca Mountain repository. Based on the limited data presented here, and on a conventional but highly simplified empirical estimates, the probability of major damage to conventionally designed and supported underground excavations appears to be small (see Appendix I). However, confidence in the data is small, given their small numbers and the doubts about their representativeness.

Summary of the Document

The Abstract of this document seems fully adequate and is inserted here as summary.

> Prediction equations were developed for peak vector acceleration, velocity, and displacement from underground nuclear explosions at Pahute Mesa. Separate equations were developed using data from stations on rock and alluvium, rock only, and alluvium only. Equations were further subdivided into three groups: all data, deletion of data with known site anomalies, and additional deletion of Yucca Mountain data. Differences in the prediction equations for the three groups using rock and alluvium and rock only were small. Alluvium only data were too sparse for valid equations. Data were normalized to remove the effects of source-energy coupling, and prediction equations recalculated.
>
> Anomalously high accelerations had been observed previously at Engine Test Stand 1 in the Nuclear Rocket Development Station area. These new data show peak vector accelerations 4 to 10 times predictions from events in Area 20 and smaller enhancements from events in Area 19. The area receiving the greater accelerations is concentrated at Engine Test Stand 1 and diminishes within about 4 km east and west of that station. Examination of velocity from event location to the point of

measurement suggests transmission paths with a high velocity layer at a shallower depth on the path from Area 19 than from Area 20.

Measurements made at Yucca Mountain indicate that qualitatively similar large accelerations exist at Yucca Mountain but with the largest observed to date only 4.19 times prediction. Since the data set for Yucca Mountain is relatively small, the possibility exists for even greater enhancements for underground nuclear explosions in locations other than those included in the data set.

Problems, Limitations, and Deficiencies

General Comments

It is exceedingly difficult to review the document by itself, as it relies heavily on a fairly intimate familiarity with NTS geography and earlier documents of this on-going series of study reports, usually without any explicit references. Very typical in this regard is that no general location map is provided. It is assumed that the reader knows the various locations mentioned and their position relative to a potential repository location. Neither explosion locations nor seismic monitoring station locations are identified on a general map— hence, neither position with respect to Yucca Mountain nor local geology are known, except to the extent to which they are briefly identified in the report itself. It is probable that at least some of these limitations are due to classification restrictions (p. 7); however, even stations apparently installed specifically for NNWSI Weapons Test Seismic Investigations (p. 12) are identified only in broad descriptive terms (e.g., Table II: Station W-14, Yucca Mountains; Station W-15, Dome Mountains; Station W-16, Forty-mile Canyon, etc.).

This extensive vagueness, combined with several additional complications [in particular, unavailability of the reviewers of most references and earlier documents in this series which might provide more explicit information, the extremely compacted form in which a vast amount of data is condensed, lack of access to the input data (due to classification restrictions), and the very limited review time] necessitate pointing out that this review can be only a superficial assessment of the document. The review cannot assess the validity of the data nor of the conclusions but can only, at best, hope to provide some indication of the possible implications for a Yucca Mountain repository.

Specific Comments

Page 16 The description of the locations of stations A,B,C and D (6th line from the bottom) illustrates particularly well how vaguely the descriptions of the location of the stations are given.

Page 72 The comment below the middle of the page that "differences in measurement techniques before 1977 and those in 1977 and later cause the velocity measurements of the earlier events to be higher" confirms NRC Comment 6-7,2a (NRC,1985, p. 41).

Recommendations

The document identifies new predictions for ground motions induced at a Yucca Mountain repository site. If anything, it reinforces the uncertainty identified in NRC Comment 6-7,2a and 2b (NRC, 1985, p.41). It does not deal with uncertainties in the source term (NRC Comment 6-7,1) but identifies the potential for additional uncertainties as a result of alternate wave propagation paths and alternate deformation points (p. 135, last paragraph).

A first recommendation is to raise an (obvious) flag for the review of the final EA. The document under review is not listed among the December 85 EA draft reference list, and documents, including prediction equations, explicitly superseded by this one (Preface, p. 5, last line) are referenced (DOE Nevada Operations Office, 1985). This suggests that data used in the Final Environmental Assessment might show the substantially lower accelerations as predicted in the earlier, now superseded, documents.

The December 1985 EA draft reference list includes numerous references related to the influence of dynamic effects on the stability of underground openings. Many of these are already quoted in the Draft EA and, hence, presumably already available to the NRC. It would be highly desirable to ensure the availability of all these documents for the Final EA Review. A list of the relevant references is given below (all taken from the Draft reference list for Chapter 6). New references are identified by XN, where X is the priority assigned for review.

Carpenter and Chung, 1985	(1N)
ERC (Environmental Research Corporation), 1974	(2)
Greensfelder et al, 1980	(3N)
Hamilton et al, 1971	(3N)
Jackson, 1985(a) and 1985(b)	(1N)
Joyner and Boore, 1981	(3N)
Meehan et al, 1973	(3N)
Merritt et al, 1985	(1N)
Owen and Scholl, 1981	(1N)
Owen et al, 1980	(1)
Pratt et al, 1978	(2)
Pratt et al, 1979	(2)
Reiter and Jackson, 1983	(3)
Rogers et al, 1976	(3)
Rogers et al, 1977	(3)
Ryall and Van Wormer, 1980	(2N)
SAIC (Science Application International Corporation), 1982	(2)
SAIC (Science Application International Corporation), 1985(b)	(1N)
Stratta et al, 1977	(3N)
Vortman, 1979; 1980; 1982; 1983	(1)
Vortman and Lang, 1982(a); 1982(b)	(1)
Willis et al, 1974	(1)

Assuming that NRC Comment 6-7 (NRC, 1985, p.41) will be revisited during the Final EA Review, it would be desirable if, as a minimum, the documents classified with Priority 1 could be provided prior to the review in order to allow at least a scanning acquaintance therewith.

Depending on the importance to this topic, several more intense efforts could be considered:

(1) an integrated review of Yucca Mountain ground motion predictions. This would consist of a comprehensive review of all immediately applicable SNL and critical supporting documents. Estimated working time: 5 to 10 days

(2) expansion of (1) to include assessment of source terms (likely to require security clearance) and of effects on underground structures (simplified analytical considerations only). The second part of this, effects on underground structures, is likely to add 5 to 10 days.

(3) comprehensive and independent NRC assessment of dynamic effects at Yucca Mountain—i.e., primarily numerical simulations. Estimated working time: weeks to months

References

U.S. Department of Energy. Draft Environmental Assessment (EA) References. Letter from M. B. Blanchard, Chief, Geologic Investigations Branch, Waste Management Project Office, to P. T. Prestholt, Sr., On-Site Representative, U.S. Nuclear Regulatory Commission. 1985.

U.S. Department of Energy. Draft Environmental Assessment, Yucca Mountain Site, Nevada Research and Development Area, Nevada. DOE/RW-0012. 1984.

U. S. Nuclear Regulatory Commission. Comments on DOE Draft Environmental Assessment for the Yucca Mountain Site. March 20, 1985.

APPENDIX I

ESTIMATE OF DAMAGE TO UNDERGROUND EXCAVATIONS IN ROCK

In order to assess the potential for ground motions at Yucca Mountain to damage underground excavations, it is necessary to know both the nature of the ground motion and its effects. Estimates of ground motion at Yucca Mountain from Pahute Mesa underground nuclear explosions are given by Vortman (1986). Empirical damage criteria may be used to estimate the effect of these motions.

The commonly used levels of damage to be considered are:

No Damage	—	no cracks or rockfall
Minor Damage	—	new cracking and minor rockfalls
Damage	—	severe cracking, major rockfalls

Results of correlation of the peak surface acceleration and peak particle velocity with damage reported by others are shown in Fig. I-1 and I-2. It should be noted that the ground motion parameters (i.e., acceleration and velocity) were not recorded at the excavation sites but were calculated using empirical relations similar to those presented by Vortman (1986). Of these two correlations, the one based on velocity is generally preferred.

The requirement to minimize damage to underground tunnels due to conventional blasting has led to the development of empirical design criteria. For unlined tunnels in rock, Langefors and Kihlstrom (1963) suggest that particle velocities of 30 cm/sec cause rock to fall. These criteria are conservative when compared to results from the Underground Explosion Test Program (UET).

There is one important difference between the ground motion resulting from earthquake and that generated by a nuclear explosion. The former may last for several seconds, subjecting the excavation to several displacement cycles while the later predominantly comprises a single compression pulse lasting milliseconds. More permanent deformation may be expected in a rock mass around a tunnel subject to cyclic loading.

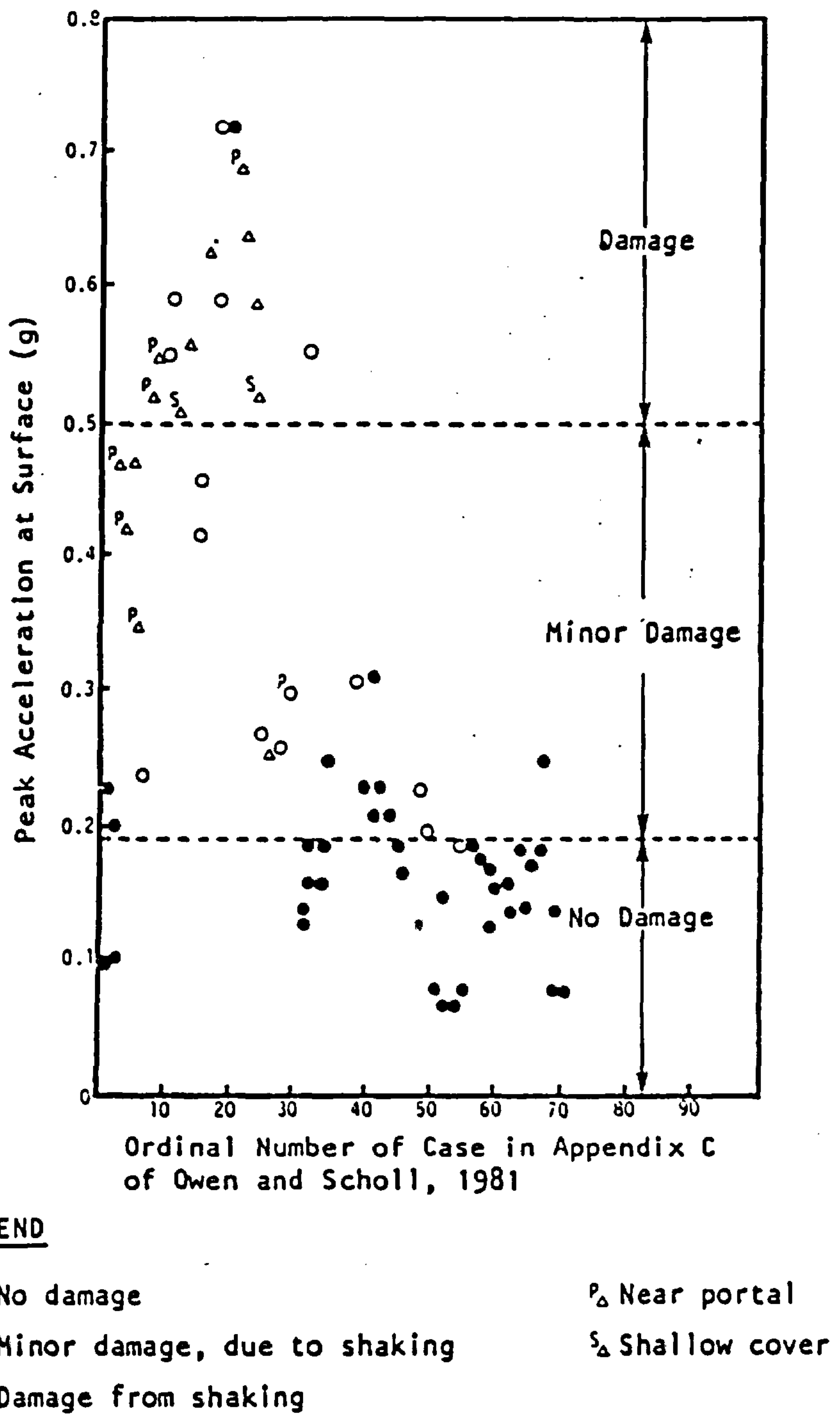

Fig. I-1 Calculated Peak Surface Accelerations and Associated Damage Observations in Underground Excavations in Rock for Earthquakes (Owen and Scholl, 1981)

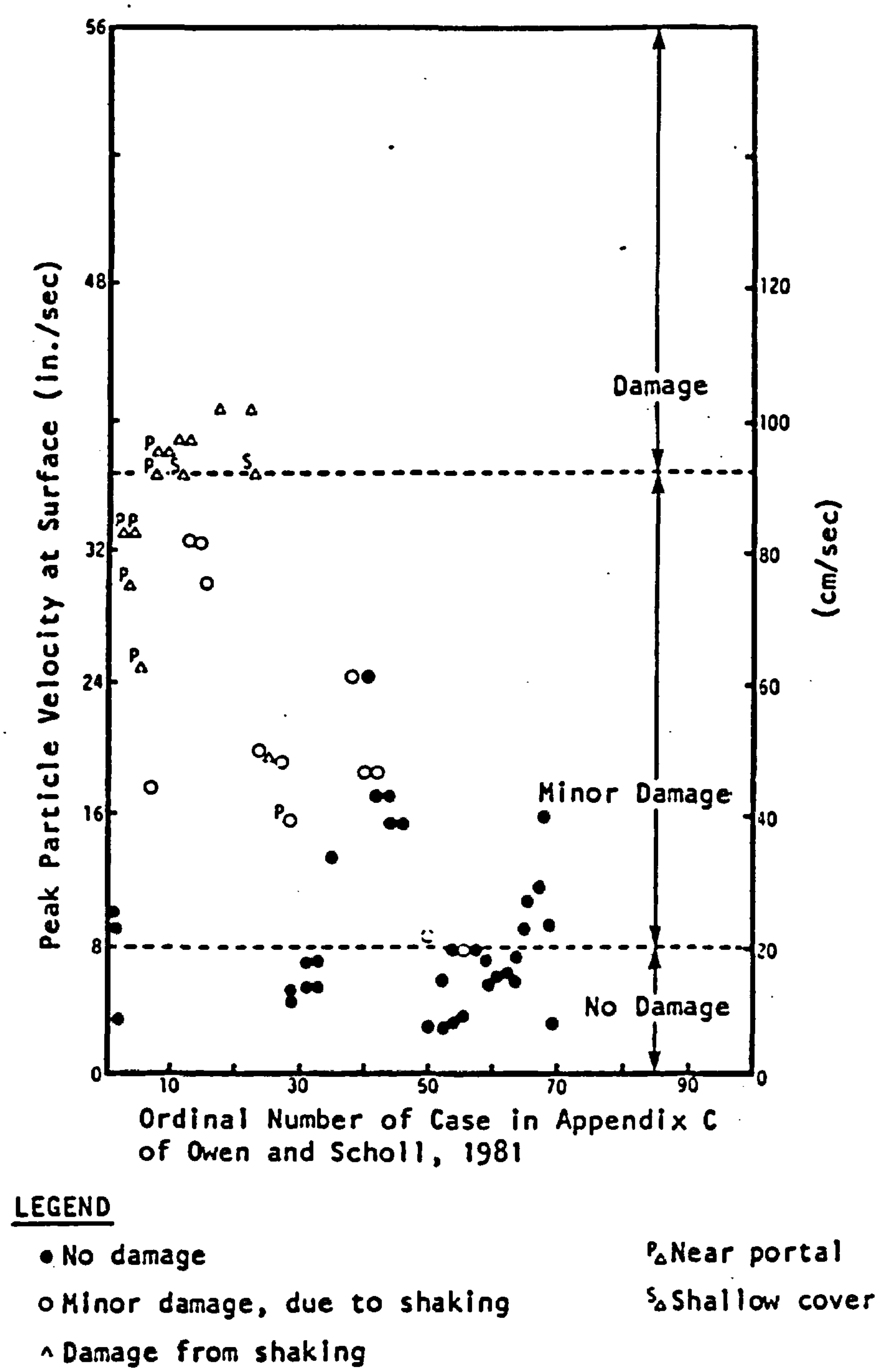

Fig. I-2 Calculated Peak Particle Velocities and Associated Damage Observations in Underground Excavations in Rock for Earthquakes (Owen and Scholl, 1981)

In summary, no damage should be expected if the peak particle velocity is less than approximately 20 cm/sec. If an enhancement of 4 may be applied to estimated velocities at Yucca Mountain, as was applied to accelerations (p. 135), then the estimated mean velocities (Table IV, p. 30) resulting from a 700 kt at 22.8 km would slightly exceed the 20 cm/sec threshold, and some minor damage could result. Many factors have not been included in this very simplistic approach, including considerations of spectral content and the large scatter of the data base (both for damage criteria and estimated velocities).

REFERENCES

Owen, G. N., and R. E. Scholl. "Underground Structures Intersecting Active Faults," Earthquake Engineering of Large Underground Structures, FHWA/RD-80/195. Washington, D.C.: U.S. Dept. of Transportation, 1981.

Langefors, U. and B. Kihlstrom. Rock Blasting. New York: John Wiley and Sons, 1963.