SHERWOOD PROJECT
REVEGETATION RECLAMATION
SYSTEM EVALUATION

APPENDIX 3

SEISMIC EVALUATION REPORT

EARTHQUAKE-INDUCED SETTLEMENT SHERWOOD TAILINGS IMPOUNDMENT

Stevens County, Washington

Prepared for:

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May 5, 1994

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May 5, 1994
SMI-100-2

Mr. Lou Miller, P.E.
Shepherd Miller, Inc.
1600 Specht Point Drive, Suite F
Fort Collins, CO 80525

Subject: Transmittal of Final Report
Sherwood Tailing Impoundment

Dear Lou:

The enclosed report presents the results of a detailed engineering analyses related to the potential for earthquake-induced settlement at the Sherwood Tailing Impoundment. A brief summary of the principal report findings and conclusions is presented below:

- The uranium tailing material within the impoundment has a wide range in gradation. The tailing ranges from clean sand (SP and SP-SM) to dirty sand (SM) to sand silt (ML). Since the impoundment was formed by perimeter spigotting of slurried tailing, this range in gradation distribution is considered typical. It appears that the cleanest sand may be located within the first 200-300 feet from the crest, due to natural sedimentation principals.

- Standard Penetration Tests (SPT) were obtained in 10 borings within the tailing impoundment. The vast majority of these tests were obtained in the dirtier sand (SM) and sandy silt (ML) materials.

- A review of the seismicity in the Pacific Northwest indicates that eastern Washington is relatively quiescent. A 1990 USGS report indicates that the peak ground acceleration to be expected at the project site during the next 250 years, with a 90% confidence limit, will be about 0.075g. Such an acceleration <u>would not</u> be adequate to induce liquefaction of the tailing material. For purposes of the current study, a design basis "floating" earthquake of Magnitude 5 was assigned about 10 km from the site. Such an earthquake would produce a peak ground acceleration, a_{max}, at the site equal to about 0.15g.

- An assessment of the liquefaction potential at the Sherwood Tailing Impoundment was performed using the "Simplified Seed Method" of analysis. This approach is based on comparing the SPT values of soils deposits which did or did not liquefy during previous earthquakes. The results indicate that some portions of the tailing are susceptible to liquefaction in the event that an a_{max} of 0.15g occurred at the site. The thickness of potentially liquefiable materials, based on the 10 drill holes studied in detail, varied from a minimum of 0 feet to a maximum of about 10 feet.

- An assessment of the post-liquefaction settlement potential at the site was made by assuming that different thicknesses of tailing could liquefy. Based on a very conservative set of earthquake ground motions and material properties assumptions, the results of this assessment indicate that a maximum earthquake-induced settlement of up to 14 inches appears possible at any location. A more realistic, but less conservative set of assumptions, indicates that the total settlement would be limited to less than 6 inches.

- Based on my 20-year experience with tailing dam construction in general, and the variability of engineering properties from spigotting in particular, I estimate that the magnitude of differential settlement could be as high as 6 inches within any 50-ft segment anywhere in the tailing pond. I further recommend that this value be used to design for the required flexibility of the clay cover.

We trust the report is adequate for your purpose of completing the reclamation plan currently being completed for the Sherwood Tailing Facility. If you have any questions, or we can provide additional information, please do not hesitate to contact us.

REGISTERED PROFESSIONAL ENGINEER
RICHARD L. VOLPE
No. 866
Exp. 9-30-97
GEOTECHNICAL
STATE OF CALIFORNIA

Very truly yours,

R. L. VOLPE & ASSOCIATES, Inc.

Richard L. Volpe

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Principal

Enclosure

EARTHQUAKE-INDUCED SETTLEMENT
SHERWOOD TAILING IMPOUNDMENT

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EARTHQUAKE-INDUCED SETTLEMENT
SHERWOOD TAILING IMPOUNDMENT

Stevens County, Washington

I. INTRODUCTION

This report has been prepared by R. L. Volpe & Associates, Inc. (RLVA) of Los Gatos, California, for Shepherd Miller, Inc. (SMI) of Fort Collins, Colorado. It presents the results of a special earthquake-induced settlement assessment of the tailing impoundment located at the Sherwood uranium tailing facility in eastern Washington. SMI is providing consulting engineering services related to the Sherwood Tailing Reclamation Plan which is currently being prepared for submittal to the Washington Department of Health. The completion of the reclamation plan includes the design of a protective earthen cover over the tailing pond, and other activities related to mine reclamation. This report focuses on the potential for earthquake-induced differential settlement of the tailing material and its impact on the protective cover.

The Sherwood mill complex is located in Stevens County, Washington, on the Spokane Indian reservation, about 6 miles southwest of Wellpinit. The site lies immediately east of FDR Lake on the Spokane River (see Fig. 1). The facility was opened in 1977. Ore was processed in the mill using conventional acid leach and solvent extraction technology to produce uranium oxide. Tailing leaving the mill was slurried and flowed by gravity to the adjacent Sherwood tailing pond where it was neutralized with lime prior to deposition. The Sherwood tailing impoundment was constructed in 1977 and subsequently enlarged in stages until 1982 when the mill operations ceased. During its six years of operation (1977 to 1982), the Sherwood impoundment received an estimated total of 3 million cubic yards of tailing. Based on a review of original and current topography, and the results of a recently (1993) completed field investigation, the maximum thickness of the tailing is about 70 feet. A typical cross section through the tailing impoundment and surrounding dikes is presented in Fig. 2.

The containment dikes which support the tailing impoundment were compacted in place using site soils and a synthetic liner was used to cover the impoundment area prior to initiation of tailing deposition. A more complete description of the site facilities and local geology, along with a presentation of detailed results of a field and laboratory investigation, locations of exploratory borings, and other engineering analyses, can be found in a report detailing the Sherwood Tailing Reclamation Plan currently being prepared by SMI. Much of the previously collected data have been submitted to the Washington Department of Health in the form of appendices. The current study, which evaluates the potential for earthquake-induced settlement, has used field and laboratory data developed for the site soils and supplied to RLVA by SMI.

II. SEISMICITY

The seismicity of eastern Washington is relatively quiescent when compared to other areas of the northwest, especially the area adjacent to the coastal subduction zone where the Pacific Plate is being forced under the North America Plate. This relatively low level of seismicity is confirmed by the results of a recent study performed by the U.S. Geological Survey (Algermissen and others, 1990). Based on a probabilistic earthquake method of analysis with a 90% confidence limit, the USGS studies indicate that the estimated peak horizontal rock acceleration at the Sherwood site should not exceed a value of between 0.06g and 0.075g in the next 250 years. These results are shown in Fig. 3 which presents contours of equal acceleration for the Pacific Northwest based on the USGS study.

A. Earthquake History

The most complete description of earthquake history in the Pacific Northwest (Ludwin and others, 1991) indicates that high-quality earthquake locations (epicentral precision ± 2 km) for Washington and northern Oregon are only available beginning in 1970, when installation of the modern seismic network began. Prior to 1970, only a few earthquakes had even moderately well-constrained epicentral locations (± 10 km). It should be noted that all known earthquakes greater than a magnitude 6 in Oregon and Washington occurred prior to 1970. Locations of eight (8) Pacific Northwest earthquakes believed to have been larger than magnitude 6 are shown in Fig. 4, and these events are largely restricted to northwestern Washington. The two events closest to the project site are discussed below.

The 1872 North Cascades earthquake is generally considered the largest earthquake known in Washington and Oregon (Milne, 1956), with an estimated magnitude of 7.4 (Malone and Bor, 1979). Although the inferred location and estimated magnitude of this earthquake remain controversial, the location as shown in Fig. 4 indicates that the epicenter was located about 250 km northwest of the Sherwood site, near the US/Canada border. Based on this epicentral distance, and using recently published earthquake attenuation relationships (Sadigh and others, 1989), we estimate that this event would have produced a peak rock acceleration at the site of about 0.01g. The other large magnitude earthquake shown in Fig. 4 is referred to as the Milton-Freeman earthquake of 1936. It is the only large event known to have occurred in the eastern Washington region. Its estimated magnitude based on felt area has been calculated to be 6.4 (Noson and others, 1988). As shown in Fig. 4, the location of this earthquake is estimated to have been about 180 km due south of the site on the Oregon-Washington border. We estimate that the 1936 Milton-Freeman earthquake would have produced a peak rock acceleration at the site of 0.007g.

B. Design Basis Earthquake

As discussed above, the estimated mean peak rock accelerations from the two largest historical earthquakes are estimated to have been between 0.007g and 0.01g. As mentioned previously, based on probabilistic studies, it is estimated with 90% confidence that within the next 250 years the peak rock acceleration at the Sherwood site will not exceed a value between 0.06g and 0.075g. Based on the inferred strength and composition of the tailing materials at the Sherwood impoundment site, this range in acceleration value is probably insufficient (too low) to cause liquefaction to develop within the tailing.

For design purposes, it is recommended that SMI adopt a more conservative approach with regard to potential future seismicity. One such approach that has been used in other relatively quiescent seismic areas is to assume that a magnitude 5 earthquake could occur within a distance of about 10 km from the site. Such an earthquake would produce a mean peak rock acceleration at ground surface of 0.15g. It should be noted that this recommended design value is twice the value estimated by the probabilistic analysis. We believe that the adoption of these earthquake design criteria are appropriate for the intended design life of the reclamation plan, and adds a significant degree of conservatism to the analysis associated with earthquake-induced settlement analysis. A historical summary of the design basis earthquake data is presented on Table 1.

Table 1

Summary of Historical Seismicity and Estimated Maximum Peak Ground Accelerations

A. Historical Earthquakes

Earthquake	Estimated Magnitude	Estimated Distance (km)	Estimated Peak Rock Acceleration
1872 North Cascades	7.4	250	0.010g
1936 Milton-Freewater	6.4	180	0.007g

B. Design Basis Earthquake

Earthquake	Estimated Magnitude	Estimated Distance (km)	Estimated Peak Rock Acceleration
Floating	5.0	10	0.15g

Notes:

1. The approximate locations of the 1872 and 1936 earthquakes are shown on Fig. 4.

2. The design basis earthquake used for the liquefaction analyses is a conservative assessment of the historical seismicity to impact the site area and an estimate of the maximum acceleration to impact the cover design for the Sherwood site.

3. The mean peak horizontal rock acceleration for each earthquake was computed using the attenuation relationships published by Sadigh et al., 1989.

III. MATERIALS DISTRIBUTION

A. Construction Procedures

The exterior dam, which acts as the containment for the tailing impoundment, is a zoned earth embankment. The initial starter dam was expanded as necessary in a downstream direction. The tailing were discharged into the impoundment by perimeter spigotting. As such, the grain size distribution within the tailing pond was controlled during construction primarily by the principles of natural sedimentation. This natural material distribution occurs in any type of slurry discharge due to the sedimentation of the coarser grains closest to the point of discharge and the finer grains further away from the point of discharge. The grain size distribution, however, is not uniform because points of discharge vary during construction, the pond size increases as the perimeter dikes are raised, and distribution methods do not remain constant during construction. The potential for earthquake-induced settlement within the impoundment is directly tied to the variability of sands and silts within the impoundment. In order to assess this settlement potential, we must evaluate how these two materials will act during earthquake motions.

B. Exploration Results

SMI drilled a number of exploratory borings within the tailing pond area to assess the nature and distribution of the tailing materials. One series of borings, which we understand was located somewhat closer to the crest than the other exploratory holes, was specifically drilled to assess whether it would be practical to consider dewatering the tailing during reclamation. Samples for this series of borings were obtained at relatively close intervals (6-7 inches) as compared to the other exploratory holes. A description of the methods used, hole locations, and field results is presented in previous (1992 and 1993) SMI data submittals to the Washington Department of Health. In general, laboratory test results indicate that the tailing material varies from a relatively clean, poorly graded, sand (SP) to a highly elastic silt (MH), although the majority of results show the tailing to vary from a silty sand (SM) to a silt of low plasticity (ML). The following discussion of field and laboratory test results focusses only on those results that have an impact in assessing the liquefaction potential of the tailing material.

1. Gradation Test Results

As mentioned above, the samples for the drill holes were taken at close vertical intervals to assess the variation in the percentage of fines within the tailing material. The test results for one of these holes (Hole 1A) are presented in Fig. 5, in the form of percentage of fines vs. depth. As shown in Fig. 5, within the upper 10 feet the results indicate that the percentage of fines varies between a low of 2% fines to a maximum of 32% fines. Between a depth of 10 and 20 feet the results indicate the percentage of fines varies dramatically over relatively short thickness intervals. For example, at a depth of about 15 feet the percentage of fines is about 80%, whereas at a depth of 17 feet the percentage of fines has dropped to about 15%. Between a depth of about 20 feet to a depth of 48 feet, the percentage of fines ranges between 5% and 20% (average of 13%) with three relatively thin lenses of siltier horizons where the percentage of fines increases to between 37% and 42%. Below a depth of 48 feet, and down to 70 feet which represents the approximate maximum depth of tailing, the gradation results indicate interlayered silty sand and silt materials. Based on the gradation results from this hole, the pure silt horizons (i.e. more than 50% fines) do not appear to be more than about 1-2 feet in thickness, although this observation may be influenced by the sampling/testing interval. Other holes from this series of exploration showed similar variations in the percentage of fines, but not necessarily at the same depth intervals. This apparent lack of horizontal continuity in material type was confirmed when pumping tests performed on two relatively close holes (one of which was Hole 1A) showed a wide range in well capacity (less than 1 gal/min to about 5 gal/min). These field results suggest that, at least over the distance of the two test pump holes (less than 100 feet), the tailing material does not appear to contain similar or contiguous thicknesses of more permeable sands.

The sandier portion of the tailing material is defined as fine to very fine grained sand. The cleaner portion of the sands classify as an SP-SM (poorly graded clean to silty sands with between 5% and 12% fines) and have a median grain size (D_{50}) of between 0.25mm and 0.35mm (between the No. 40 and No. 50 U.S. Standard Sieve). The dirtier sands classify as an SM (between 12% and 50% fines) and have a D_{50} size of about 0.15mm (No. 100 U.S. Standard Sieve).

The gradation results from 7 of the 10 other exploratory borings (T-1 through T-10) are presented in Appendix A. Although these borings were performed to gather general engineering data for the tailing pond area, and were not sampled specifically for gradation results at the same relatively close frequency discussed above for Hole 1A, the gradation results for the seven holes tested show a similar, but perhaps finer, trend of interlayers of more pervious silty sands and less pervious sandy silts to silts. The specific trend from Hole 1A that was not confirmed by the other exploratory holes was a similar range in the percentage of fines between a depth interval from about 20 and 48 feet. Six of the seven holes penetrated at least to 20 feet, and two of the Holes (T-4 and T-7) were taken to depths greater than 60 feet. Within these six holes, 33 gradation tests were performed between a depth interval of 20 and 48 feet. Only 7 of these 33 gradation tests had a percentage of fines less than 20%. More likely than not, the above results tend to confirm that major areas of the pond, at points greater than about 200 to 300 feet from the point of tailing discharge, tend to be finer grained (siltier) than those portions on the pond closer to the point of tailing discharge. This increase in fines content toward the interior of the pond is entirely consistent with other sites where perimeter discharge was used.

2. <u>In-Place Water Content and Dry Density</u>

Relatively undisturbed samples were obtained using thin-wall tube samples from 5 of the 10 borings referenced above for the purpose of determining the variation of in-place water content and dry density and other engineering properties. These laboratory results are also summarized on Sheet 1 in Appendix A. As shown on this summary sheet, 26 samples were tested; 14 samples are classified as a silty sand (SM), and 12 samples were classified as sandy silt (ML). The average results are summarized below on Table 2:

Table 2

Summary of Water Content and Density Test Results

Mat. Type	No. of Samples	Total Unit Wt. (pcf) High	Total Unit Wt. (pcf) Low	Total Unit Wt. (pcf) Mean	Dry Unit Wt. (pcf) High	Dry Unit Wt. (pcf) Low	Dry Unit Wt. (pcf) Mean	Water Content (%) High	Water Content (%) Low	Water Content (%) Mean
SM	14	122.4	101.2	111.9	100.5	67.5	84.2	55.1	21.7	33.6
ML	12	113.5	92.6	102.8	76.1	44.3	60.1	107.9	46.7	72.7

Based on the field data, it appears that the current water table within the pond is at a depth of about 10 feet below ground surface. After the reclamation cover has been constructed, however, it has been assumed by SMI that the water table could migrate upward to the interface of the new cover and the current tailing surface. An estimate of the current and future overburden stresses within the tailings pond were computed using the data presented on Table 2 and the water table assumptions presented above. As shown in graphical form in Fig. 6, if it is assumed that the water table migrates upward to the interface of the new cover and the tailing surface, the increase in effective overburden over the current conditions is relatively small.

3. Standard Penetration Test Results

The variation of Standard Penetration Test Results (SPT or N Value) is a measure of in-place relative density of the material and was performed in accordance with ASTM D-2056. The SPT test result represents the number of blows of a 140 pound hammer required to drive a sampler of a specified size 18 inches in the soil. The number of blows to drive the sampler is recorded for each 6-inch interval and the N Value is reported as the total number of blows to drive the sample the last 12 inches, hence the units are blows/ft. For this project, the SPT tests were performed in a hollow-stem auger drill stem. Once the free standing water surface was encountered, the hollow stem was filled with water in order to maintain essentially the same water pressure at the drill bit and prevent excessively high seepage gradients from developing at the tip of the drill bit. Plots of the measured N Value as a function of depth for Borings T-1 through T-10 are presented in Appendix B. More discussion regarding how the N values were used to assess the liquefaction potential of the tailing is presented in the following section.

IV. ASSESSMENT OF LIQUEFACTION POTENTIAL

A. Introduction

The studies carried out to assess the liquefaction potential of the tailing material at the Sherwood Tailing Impoundment are described in this section of the report. Before commencing with a discussion of these analyses, however, it should be noted that the foundation glacial deposits are not considered herein for the following reasons: 1) they are considerably more dense than the tailing materials; 2) they are unsaturated and, therefore; 3) not considered susceptible to liquefaction.

B. Gradation Characteristics of Tailing

A comparison was made of the gradation characteristics of the tailing materials with a compilation of typical gradations for soils which are known to have liquefied during past earthquakes. Published results of case histories where liquefaction of sandy and silty soils either has, or has not, occurred during past earthquakes are readily available in the technical literature. Based on these case histories, it appears that the gradational characteristics of soils which may be subject to liquefaction can range from clean gravel to silts and some low plastic clays, depending on the severity of earthquake shaking. The manner in which the gradation of the tailing material was factored into the liquefaction assessment is discussed later in this section.

C. Simplified Liquefaction Analyses

1. Introduction

The year 1966 marked the birth of geotechnical earthquake engineering as currently practiced with the publication by H.B. Seed and K.L. Lee from the University of California at Berkeley on the "Liquefaction of Saturated Sands During Cyclic Loading". Since that time, various procedures have been developed by a number of investigators for evaluating liquefaction potential of saturated cohesionless soil deposits. The liquefaction potential of a soil deposit is dependent on many factors other than gradation. Among these are such values as peak ground acceleration, duration of strong shaking, relative density or degree of compaction of the soil, boundary conditions, and permeability/drainage characteristics of the soil deposit. Although much of the earlier liquefaction research dealt with the development of proper laboratory testing procedures, it is now standard practice in geotechnical earthquake engineering to use carefully developed empirical methods which rely heavily on field data. These empirical methods have been developed by reviewing the results of saturated cohesionless soil deposits where liquefaction has either occurred, or not occurred, during earthquake shaking.

Standard Penetration Test (SPT) blow count measurements have been shown to provide an excellent correlation with the degree of compaction (and liquefaction potential) of cohesionless soils in-situ. As part of the current study for the Sherwood Impoundment, the number of blows required to drive an SPT sampler in the soil deposit a distance of up to 18 inches was recorded. The samplers were driven into the soil deposit using a doughnut-shaped 140-pound hammer (hammer energy ratio of 45%) falling freely through a distance of 30 inches, and a rope-and-pulley system. These field procedures adopted by SMI are in compliance with the procedures recommended by Seed, et al. (1985) when they evaluated the influence of SPT procedures in evaluating soil liquefaction resistance (i.e., the current ASTM Test method D-1586).

An evaluation of the liquefaction potential at the Sherwood Impoundment was completed using blow-count data obtained from the SPT's performed at the site, and the "Simplified Seed Method" for a horizontal soil deposit (Seed et al., 1967). This method was originally developed for evaluating the liquefaction potential of saturated clean sand and silty deposits, and subsequently has been modified as discussed below.

A plot of SPT-corrected blow counts, defined herein as $(N_1)_{60}$, versus cyclic stress ratio (CSR) (τ_{avg}/σ_0') required to cause liquefaction is presented for a Magnitude 7.5 earthquake and fines content of 5% on Fig. 7 (Seed et al., 1983, 1984). The data points shown on this figure represent a comprehensive collection and assessment of site conditions where evidence of liquefaction, or no liquefaction, is known to have occurred during past earthquakes. Relationships of this type have been developed for different magnitude earthquakes and for sands with different fines contents. It should be noted that the majority of liquefaction case histories shown on Fig. 7 have occurred at shallow depths on the order of 30 feet or less. The relationship shown in Fig. 7, together with similar relationships developed for other values of fines contents, have been used in the liquefaction analysis discussed herein. Finally, it should be noted that the $(N_1)_{60}$ value is derived directly from the field measured (uncorrected) N value as discussed below.

2. Review and Interpretation of Blow-Count Data

In order to evaluate the liquefaction potential of the tailing material using the "Simplified Seed Method," the uncorrected field-measured blow count (N) data were first reviewed, interpreted and analyzed in various ways. In order to use the field-measured N value data with the "Simplified Seed Method," it is first necessary to apply various correction factors to the data to account for the overburden stress and the percentage of fines for the sample where the N value is determined. The field-measured N values were corrected to account for the following:

a. Drill Rod Stiffness - This correction is appropriate when the drill rod length is less than 10 feet; N_c = 0.75 (Seed et al., 1985).

b. Hammer Efficiency - When using a doughnut-type hammer with rope and pulley, the energy ratio is only 45% of that for a safety hammer. It has been recommended that the uncorrected N value be multiplied by N_c = 0.75 to account for this difference (Seed et al., 1985).

c. SPT Sampler Without Liner - Blow counts measured without liners are lower than those obtained when liners are used inside the SPT sampler, N_c = 1.2 (Seed et al., 1985).

d. Silty Materials - Blow counts were increased by 7.0 when fines content was greater than 35% (Seed et al., 1985). Since gradation tests were not performed for every SPT, it was necessary to assume a gradation based on the description of materials presented on drill hole logs.

e. Overburden Effects - The relationships provided by Seed et al. (1984) based on data and analyses from Marcuson and Bieganousky (1977) were used to correct the measured blow counts. This relationship is referred to as C_n and its relationship with effective overburden is presented in Fig. 8.

The $(N_1)_{60}$ corrected blow counts were determined for all field- determined SPT values using the five correction factors referenced above, in the order presented. Spread sheets showing the detailed calculations are presented on Sheets 1 through 6 in Appendix B and the computed $(N_1)_{60}$ values are plotted as a function of depth for Borings T-1 through T-10 on Fig. B-11 through Fig. B-20 in Appendix B. Based on the relationship developed for sands by Tokimatsu and Seed (1987), these corrected blow counts generally indicated loose to medium dense materials.

3. Correlations For Different Magnitude Earthquakes

The results presented in Fig. 7 provide a realistic basis for developing correlations between SPT values and the liquefaction characteristics of sands and silty sands for a Magnitude 7½ earthquake. These results can be extended to other magnitude events by noting that from a liquefaction point of view, the main difference between different magnitude events is in the number of cycles of stress which they produce. Statistical studies show that the number of cycles representative of different magnitude earthquakes is typically as shown in Table 3, below.

Table 3

Number of Cycles Representative of Different Magnitude Earthquakes

Magnitude	Number of Representative Cycles at 0.65 τ_{max}
8½	26
7½	15
6¾	10
6	5-6
5¼	2-3

Using this concept of a lower number of representative cycles for a lower magnitude earthquake, the data presented in Fig. 7 for a magnitude 7½ event have been modified for other earthquakes of lower magnitude. These data are presented in Fig. 9 in the form of modified penetration resistance $(N_1)_{60}$ vs. cyclic stress ratio causing liquefaction in clean sands for earthquakes ranging from M 5¼ to M 7½. The same curves are also used for silty sands and sandy silts, provided the SPT values are normalized, using the correction factors previously discussed, before entering the chart shown in Fig. 9. It should be noted that another degree of conservatism is necessary for the Sherwood Impoundment analyses since the original modifications for different magnitude earthquakes was performed for M 5¼. This is a slightly higher magnitude than our design earthquake of M 5. The liquefaction resistance for any potentially liquefiable soil is slightly greater for a M 5 earthquake than for a M 5¼ earthquake. The steps used in the liquefaction assessment for the Sherwood Tailing Impoundment are discussed below.

4. Liquefaction Assessment

The liquefaction potential of the tailing material was evaluated using the "Simplified Seed Method" previously described, and relationships based on historical earthquakes where liquefaction or no liquefaction was observed similar to that shown on Fig. 7. The cyclic stress ratios (τ_{avg}/σ_0') induced by the design basis earthquake ground motions in the tailing deposit were computed using a simplified procedure outlined by Seed and Idriss (1967). In this method, the cyclic stress ratio within a horizontal soil deposit may be estimated using the relationship:

$$\left(\frac{\tau_{avg}}{\sigma_o'}\right)=0.65*a_{max}\left(\frac{\sigma_o}{\sigma_o'}\right)*r_d$$

where a_{max} = peak ground acceleration; σ_o = total overburden pressure at a given depth; σ_o' = effective overburden pressure; and r_d = a stress reduction factor varying from a value of 1.0 at the ground surface to an average value of about 0.9 at a depth of 30 feet. For these analyses, the value of r_d was fixed at 0.9 for depths greater than 30 feet.

A peak ground acceleration (a_{max}) of 0.15 g at the site was assigned to the Magnitude 5 design basis earthquake used for these analyses. Values of cyclic stress ratios were computed as a function of depth through the tailing deposit using appropriate average values of unit weight for the tailing and the assumed ground-water table at 10 feet below ground surface. Detailed calculations for Borings T-1 through T-10 are presented in Appendix C. As shown on Sheets 1 through 6 in Appendix C, the range of cyclic stress ratios (τ_{avg}/σ_0') induced by the design basis earthquake (M5) at the project site are shown to vary from about 0.10 at a depth of 10 feet to about 0.175 at a depth of 70 feet. In order to assess the liquefaction potential at a specified depth, it is necessary to compare the earthquake-induced cyclic stress ratio at that depth with the resisting cyclic stress ratio based on the specific $(N_1)_{60}$ value computed at the specified depth. These detailed analyses were performed for Borings T-1 through T-10 and are presented on Sheets 1 through 6 in

Appendix C. As shown by the detailed calculations in Appendix C, a simplified factor of safety (FS) against liquefaction is defined by comparing the ratio of resisting cyclic strength to earthquake-induced cyclic stress ratio.

Results of the detailed liquefaction assessments for the six borings extending to depths greater than 20 feet are shown in graphical form in Figs. 10 through 15 for Borings T-2, T-3, T-4, T-5, T-7, and T-8, respectively. In all of these figures, the solid squares represent the earthquake-induced cyclic stress ratio for the design basis M 5 earthquake while the shaded circles represent the resisting cyclic stress ratio as inferred from Fig. 9 and the calculated $(N_1)_{60}$ value computed at the specified depth for a M 5¼ earthquake. Plots of the FS against liquefaction vs. depth for borings T-4 and T-7, the two deep borings which extend to the near maximum thickness of the tailing impoundment, are presented in Figs. 16 and 17, respectively. The results inferred from these figures are briefly discussed below.

Boring T-4 - As shown in Fig. 16, the FS results against liquefaction are less than 1.4 for the depth interval between about 14 feet and 33 feet. The minimum FS was computed to be 0.95 at a depth of 21 feet. Between a depth of 33 and 51 feet, the FS is greater than 1.6. Between 51 and 53 feet, the FS drops to a value of 1.1, then increases to 2.1 at a depth of 61 feet, and then decreases to about 1.1 at a depth of 64 feet, the maximum depth explored.

Boring T-7 - As shown in Fig. 17, the results for Boring T-7 are generally lower than that for Boring T-4. The FS results within the upper 20 feet are similar to those discussed above for Boring T-4. In Boring T-7, however, a greater section of the tailing would appear to be susceptible to liquefaction with marginal FS values. Between a depth interval of 21 to 54 feet, the FS ranges between 0.85 and 1.4 with an average value of about 1.1. Between a depth interval of 56 to 65 feet, the FS is generally above 1.7.

5. Conclusions

Based on the results presented above, it appears that portions of the tailing material within the impoundment would be susceptible to liquefaction if a Magnitude 5 earthquake occurred within about 10 km of the site. The liquefaction potential is not pervasive throughout the impoundment. The results of the liquefaction assessment also showed a significantly higher vulnerability to liquefaction for the clean sand portions (SP and SP-SM) of the pond over that of the pure silts (ML). As noted in Section 3.0, it appears that the major portion of the impoundment either contains significant thicknesses of silt, or relatively frequent silt lenses. Although it is not possible with current analytical techniques to critically assess the impact of impeding drainage layers on both the onset and propagation of liquefaction, it is clear that the drainage conditions for major sections of the

Sherwood Impoundment are such that liquefaction could not develop. Finally, it should be clearly understood that the embankment and foundation materials are not susceptible to liquefaction. Since the exterior slope of the embankment will be substantially flattened in association with the reclamation plan, there also is essentially no potential for a release of tailing material.

It is clear, however, that limited portions of the impoundment do possess cleaner materials. As noted in Section 3.0, and based on detailed gradation results, one of the drill holes (Hole 1A) located closer to the point of spigotting indicates a significantly cleaner material exists closer to the point of spigotting, although, in a gross sense the soil column is still significantly interlayered with much finer silts (ML). This suggests that locations closer to the points of spigotting, would, most likely, have a higher susceptibility to liquefaction over the much larger area defined by the remaining portion of the pond. Although this conclusion is valid, it is general in nature and is not quantifiable due to the random distribution of materials in the impoundment.

As mentioned above, the liquefaction analyses were performed for a Magnitude 5 earthquake producing a peak ground acceleration of 0.15g at the site. As discussed in Section II of the report, the USGS has performed a probabilistic analysis for the Pacific Northwest and these results show, with a 90% confidence limit, that the peak ground acceleration at the site within the next 250 years will be about 1/2 (0.06g to 0.075g) of the value used in the detailed analyses. Such a value, if it were to occur, would indicate that all sections of the impoundment with SM or ML classifications would be safe against liquefaction. There may still be a potential for liquefaction in the cleaner sands (SP or SP-SM) which may be focused closer to the original points of spigotting.

V. ASSESSMENT OF DIFFERENTIAL SETTLEMENT POTENTIAL

A. General

It has long been recognized that sands tend to settle and densify when they are subjected to earthquake shaking. If the sand is dry, the settlement will occur virtually instantaneously and the sand will densify during the earthquake shaking. Unlike static loading, however, the settlement during earthquake loading is due to the vibrational energy imparted by the shaking. The larger the intensity and duration of shaking, the larger will be the settlement. If the sand is saturated, however, and there is no possibility for drainage, so that constant volume conditions are maintained, the primary effect of the shaking is the generation of excess pore water pressures within the saturated interstitial pores of the sand. Settlement then occurs as a time-dependent process as the earthquake-induced excess pore pressures dissipate. Depending on the permeability characteristics of the soil and the length of the drainage path, the time required for all settlement to occur can vary considerably, from almost immediately to a day or two. During the 1989 Loma Prieta Earthquake in California, sand boils (the migration of excess pore water to the surface) were noted to occur up to 40 hours after the event.

Notice that the above discussion of earthquake-induced settlement did not introduce the concept of liquefaction. It is not necessary for materials to liquefy in order for earthquake-induced settlement to occur. Liquefaction merely represents an upper bound to the amount of excess pore pressure that can develop during earthquake shaking, and therefore also represents an upper bound to the magnitude of earthquake-induced settlement.

B. Estimated Range of Relative Density Within Impoundment

The settlement of the ground surface resulting from liquefaction of sand deposits during an earthquake can be estimated if the factor of safety against liquefaction and the relative density are known as a function of depth. For this purpose, it is convenient to estimate the relative density using the formula originally proposed by Meyerhoff (1957), and modified based on the data by Gibbs and Holtz (1957). Using this approach, the relative density (D_r) is expressed as follows;

$$D_r = 21 * \sqrt{\frac{N}{\sigma'_v + 0.7}}$$

where N is the uncorrected SPT value and σ_v' is the effective overburden pressure in metric tons per square meters (1.1 ton/ft^2). A figure showing values of SPT vs. relative density for a range of effective vertical stress between 0.2 and 3.0 tsf is presented in Fig. 16. The data presented in Fig. 16 are valid <u>only</u> for relatively clean sands (i.e., SP or SP-SM with fines content of less than 12%). When sands contain more than about 12% fines, we refer their in-place density to a relative compaction rather than relative density.

The range in gradation characteristics for the tailing material throughout the impoundment was discussed in Section III, Materials Distribution. Due to the fine-grained nature of the tailing, and the fact that they were deposited by perimeter spigotting, it appears that the majority of the impoundment is comprised of SM and ML material. Based on the gradation test results from Hole 1A, it would also appear that the tailing material within a distance of less than about 300 feet from the point of discharge are inter-layered with variable thicknesses of silty material within cleaner sandy deposits (see Fig. 5). In order to assess the likely range of relative density for the sandier portions of the impoundment, it has been assumed that the SPT results obtained in borings T-1 through T-10 are appropriate. Table 4 presents a range of SPT values versus depth for the 11 borings in which SPT values were obtained.

Table 4

Range of SPT Values vs. Depth

Boring	0-10	10-15	15-20	20-30	30-40	40-50
T-1	NA	2-3	-	-	-	-
T-2	NA	2-3	2-3	-	-	-
T-3	NA	1	1	1-4	-	-
T-4	NA	1-2	0-2	0-9	6-17	12-18
T-5	NA	2-4	0-1	0-6	-	-
T-6	NA	-	-	-	-	-
T-7	NA	1-4	1-5	1-4	2-8	4-10
T-8	NA	1-4	1-2	1-3	-	-
T-9	NA	-	-	-	-	-
T-10	NA	1-8	-	-	-	-

Notes:

1. The range in depths (e.g. 10-15) are in feet.

2. SPT values are uncorrected. No data shown between 0-10 feet since this zone is unsaturated.

3. A blank entry indicates that no data were collected for that depth interval.

Using the SPT data presented on Table 4, an estimate of the relative density was determined using the Gibbs and Holtz equation presented above and shown graphically in Fig. 18. The impoundment was divided into two broad depth ranges of between 10-30 feet and 30-50 feet. Using the results presented in Fig. 6, the range of effective overburden pressure for the two depth intervals was determined. Using the average overburden pressure, relative density values (reported in percent) were determined for representative SPT values using the relationship presented in Fig. 18 and are presented on Table 5.

Table 5

SPT vs. Relative Density for Various Depth Ranges

Depth (ft)	Effective Stress (tsf)	2	4	6	8	10	12	14	16	18	20
10-30	0.6-1.0	25	35	43	49	55	-	-	-	-	-
30-50	1.0-1.5	20	30	37	43	48	52	56	60	64	67

Notes:

1. The value of SPT is shown to range between 2 and 20.

2. The value of relative density shown is the average for the range in effective overburden as shown in Figure 18.

3. No data are shown for SPT values greater than 12 for the 10-30 feet depth range since no field data greater than this value were recorded.

The data presented on Table 5 indicate that the relative density of the cleaner sand portion of the impoundment could have outside limits between 20% and 67%, with a likely range of between 30-50%. A similar range in the relative density for clean sands deposited by spigotting has been published by Vick (1983), based on original data provided by Mittal and Morgenstern (1977), and Volpe (1979). The estimated range in relative density presented on Table 5 was then used as input to estimate the likely range of post-earthquake settlement within the impoundment.

C. Estimate of Post-Earthquake Settlement Within Impoundment

Ishihara and Yoshimine (1992) have developed a method of estimating the settlement of clean sand deposits assuming that a portion of it liquefies. Basically, their method correlates the factor of safety against liquefaction with that of post-liquefaction volumetric strain, as a function of relative density. The method of development is soundly based on having reviewed many laboratory tests and the method correlates well with actual measured settlements at several locations following earthquakes.

Values of estimated post-liquefaction volumetric strain vs. the factor of safety against liquefaction are presented on Table 6 as a function of relative density. It will be noted that maximum volumetric strain shown is about 10%, independent of relative density. According to the authors, this is the maximum volumetric strain noted in laboratory tests. It will also be noted that the data presented on Table 6 are highly non-linear, especially for factors of safety against liquefaction less than 1.0. The reason for this is apparently related to the high degree of non-linearity that occurs once liquefaction occurs.

Table 6

Post-Liquefaction Volumetric Strain vs. Relative Density

Factor of Safety Against Liquefaction	Post-Liquefaction Volumetric Strain, % — Relative Density, % 70	60	50	40	30
1.4	0.2	0.2	0.3	0.3	0.3
1.2	0.4	0.4	0.5	0.5	0.6
1.0	0.9	1.1	1.5	1.7	2.6
0.9	1.3	2.1	10	10	10
0.8	2.8	10	10	10	10
0.6	10	10	10	10	10

Ishihara and Yoshimine specifically caution against the use of their data for dirty sands (i.e., fines contents greater than 12%) since complete drainage may not be accomplished in these materials. This suggests that such an approach may only be applicable for the cleaner sands within about 200-300 feet from the point of spigotting, and even here the interlayers of silt would likely impede vertical drainage from occurring. Nevertheless, lacking any other reasonable approach, Ishihara and Yoshimine data were used in an attempt to estimate a range in magnitude of post-liquefaction settlement that could be expected for the Sherwood Tailing Impoundment. This further adds to the level of conservatism associated with these analyses.

Using the range in relative density of between 30-50% discussed in the previous section, and the data presented on Table 6, it is estimated that a post-liquefaction volumetric strain of between 1.5-2.6% may be appropriate for a major thickness of potentially liquefiable material within the impoundment. For thinner layers or zones of weaker sandy soils, a volumetric strain of perhaps as high as 10% may be appropriate.

In order to assess a likely thickness of potentially liquefiable material, the detailed liquefaction results for the two holes (Borings T-4 and T-7) which nearly penetrated the total thickness of tailings were reviewed. Looking at the results from Boring T-7 in Fig. 17, it has been assumed that a worst case scenario would be for the entire thickness of tailing between 20 and 55 feet to undergo liquefaction. If this entire 35-ft thick zone were to liquefy, we would estimate a total post-earthquake settlement of between 0.5 ft and 0.9 ft using vertical strain values of between 1.5-2.6%. A review of Figure 5 suggests that the maximum thickness of clean sands (i.e., between intervening silt layers) is about 12 feet between depths of 34 and 46 feet. An upper bound post-earthquake settlement of 1.2 ft (14.4 in.) would be achieved if one were to assume that a 12-ft thick zone could undergo a vertical strain of 10%.

It is interesting to note that the maximum post-liquefaction settlement measured during the 1964 Niigata earthquake (Richter Magnitude 7.3), for sands that were thought to have liquefied to a depth of about 55 feet, was about 52 cm (20.4 inches or 1.7 feet).

D. <u>Conclusions Regarding Post-Earthquake Settlement Potential</u>

The analysis of post-earthquake settlement potential presented in this report is very conservative. This conservatism is associated not only with the magnitude of expected ground motions and probability of earthquake occurrence at the Sherwood Tailing Impoundment, but also the likelihood that liquefaction would, indeed, occur within the impoundment. Numerous assumptions were necessary in order to complete the post-earthquake settlement potential analysis. We used engineering judgment in developing material properties and conservatively assumed a combination of events for what we believe truly represents a worst case scenario.

Based on the engineering analyses presented herein, we conclude that the maximum post-earthquake differential settlement for the Sherwood Impoundment could be on the order of 15 inches, but more likely than not would be limited to less than 6 inches. Furthermore, the maximum earthquake-induced settlement would probably occur within a distance of about 200-300 feet of the existing crest since this is the area where the cleaner sands are located, and they appear to be the material most vulnerable to liquefaction potential and, hence, post-earthquake settlement.

The magnitude of earthquake-induced settlement of between 6 to 14 inches specifically refers to total settlement. The performance of the soil cover, however, is more a function of differential settlement. Based on the writers experience with spigotting of tailing material, and the resulting variability of fines distribution within the pond area, we estimate that the magnitude of the differential settlement could be as high as 6 inches within any 50-foot segment anywhere in the tailing pond.

VI. LIMITATIONS

The recommendations and opinions stated in this report reflect RLVA's current understanding of the project requirements. Our understanding is based on the investigation and evaluation methods performed by others and described in this report, and on the assumptions implicit in those methods. In the performance of our professional services, RLVA, its employees, and its agents comply with the standard of care and skill ordinarily exercised by members of our profession practicing in the same or similar localities. No warranty, either express or implied, is made or intended in connection with the work performed by us, or by the proposal for consulting or other services or by the furnishing of oral or written reports or findings. We are responsible for the conclusions and recommendations contained in this report, which are based on data relating only to the specific project and location discussed herein. Changes in the state-of-the-art of geotechnical engineering and engineering geology may eventually affect the validity of this report. Consequently, this report should not be relied upon after an elapsed period of three years without a review by RLVA for verification of validity.

VII. REFERENCES

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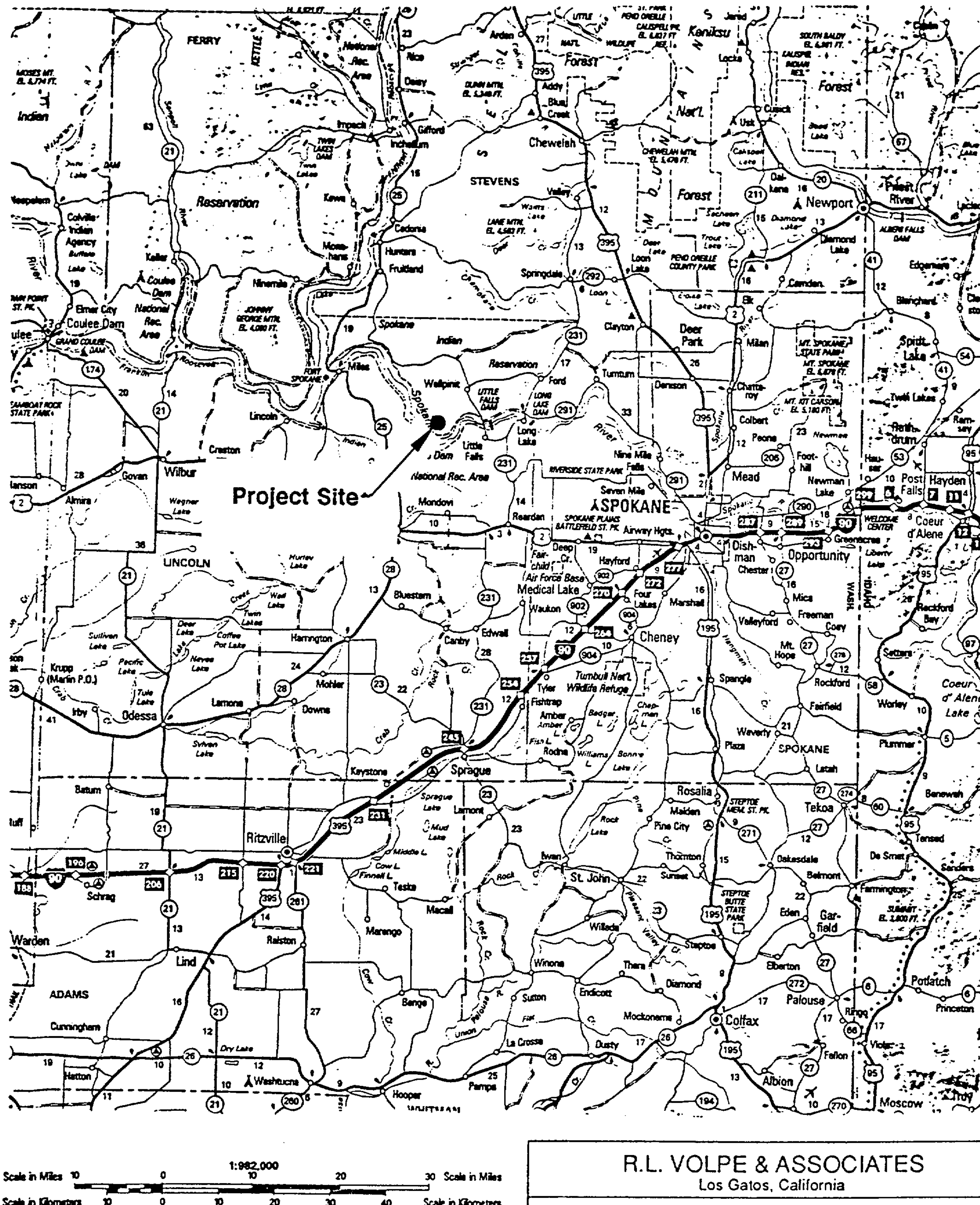

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SHERWOOD TAILING IMPOUNDMENT			
LOCATION MAP			
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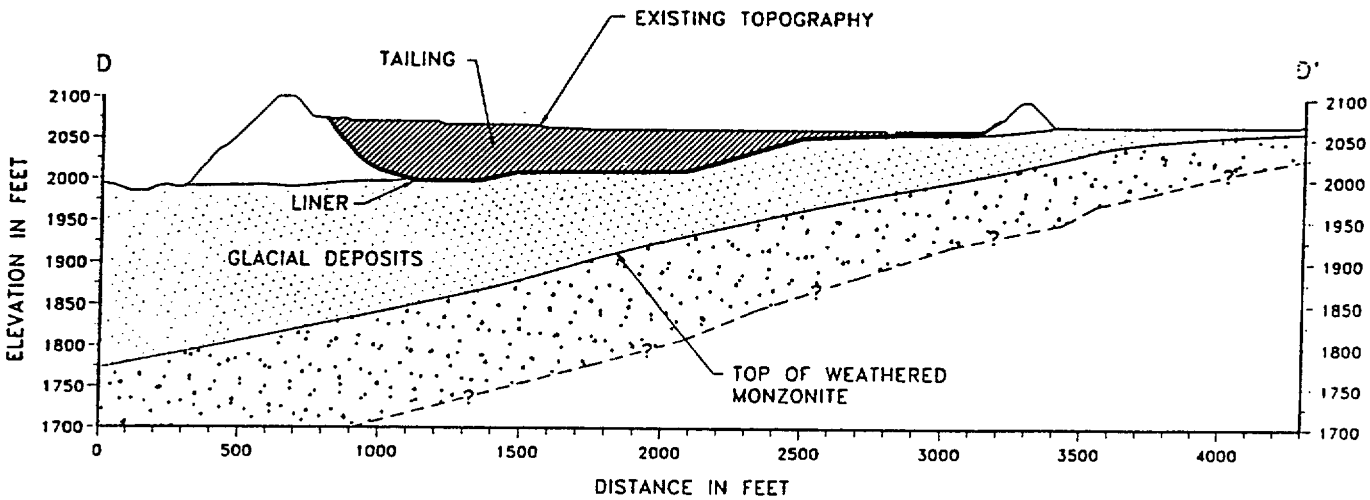
Approved by RLV	Date 5-5-94	SMI-100	1



SCALE: V:H = 3:1

Cross section D-D' showing typical geologic cross section of tailing impoundment and foundation conditions. Note that the ratio of the vertical and horizontal scale is 3:1.

(From Shepherd Miller, Inc., Jan. 1993)

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SHERWOOD TAILING IMPOUNDMENT

TYPICAL CROSS SECTION

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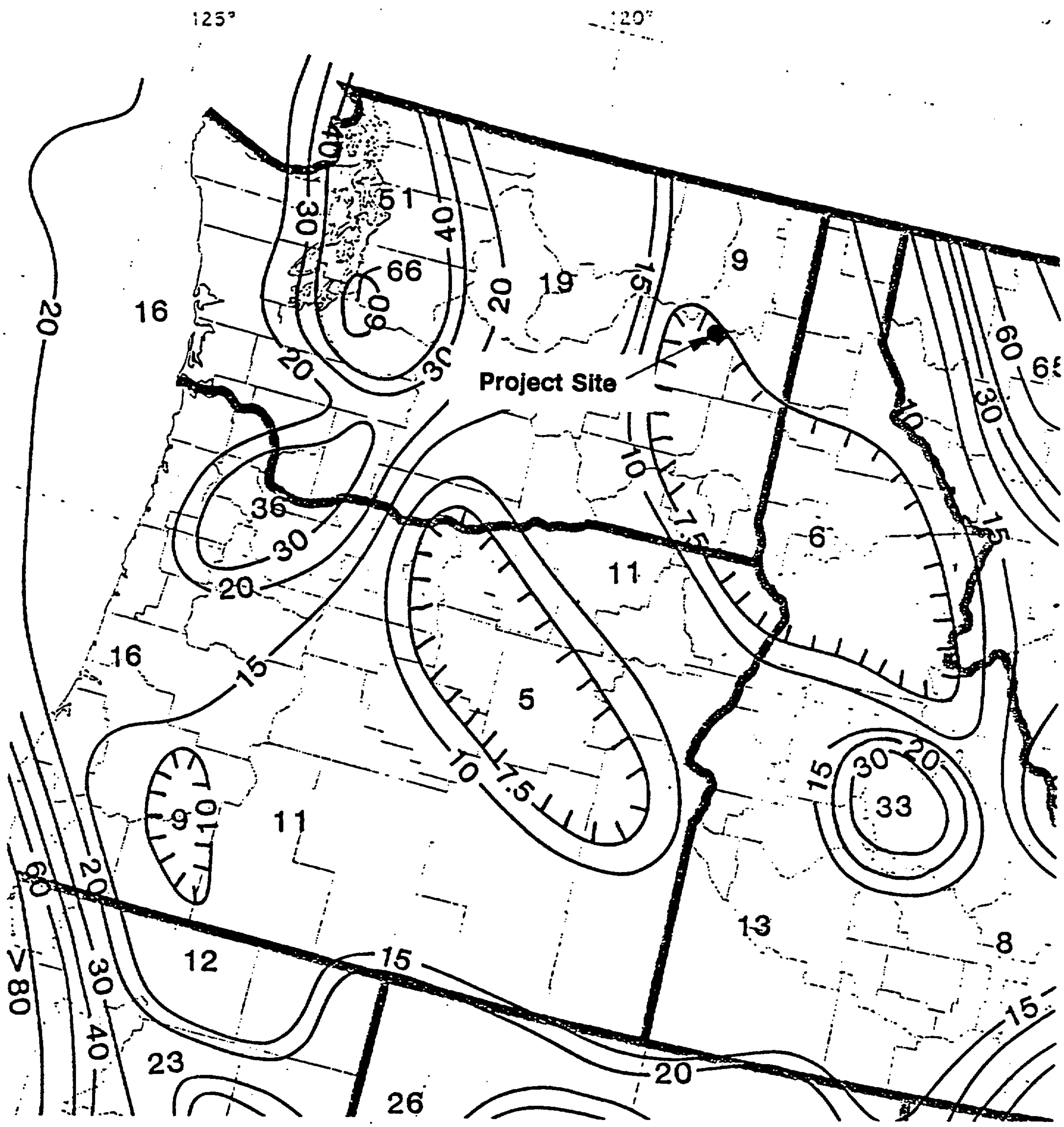

Map showing contours of equal ground acceleration in percent of gravity based on probabilistic analysis. The probability of the acceleration shown occurring in the next 250 years is 90%.

(From Algermissen et al., 1990)

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SHERWOOD TAILING IMPOUNDMENT **CONTOURS OF EQUAL ACCELERATION**			
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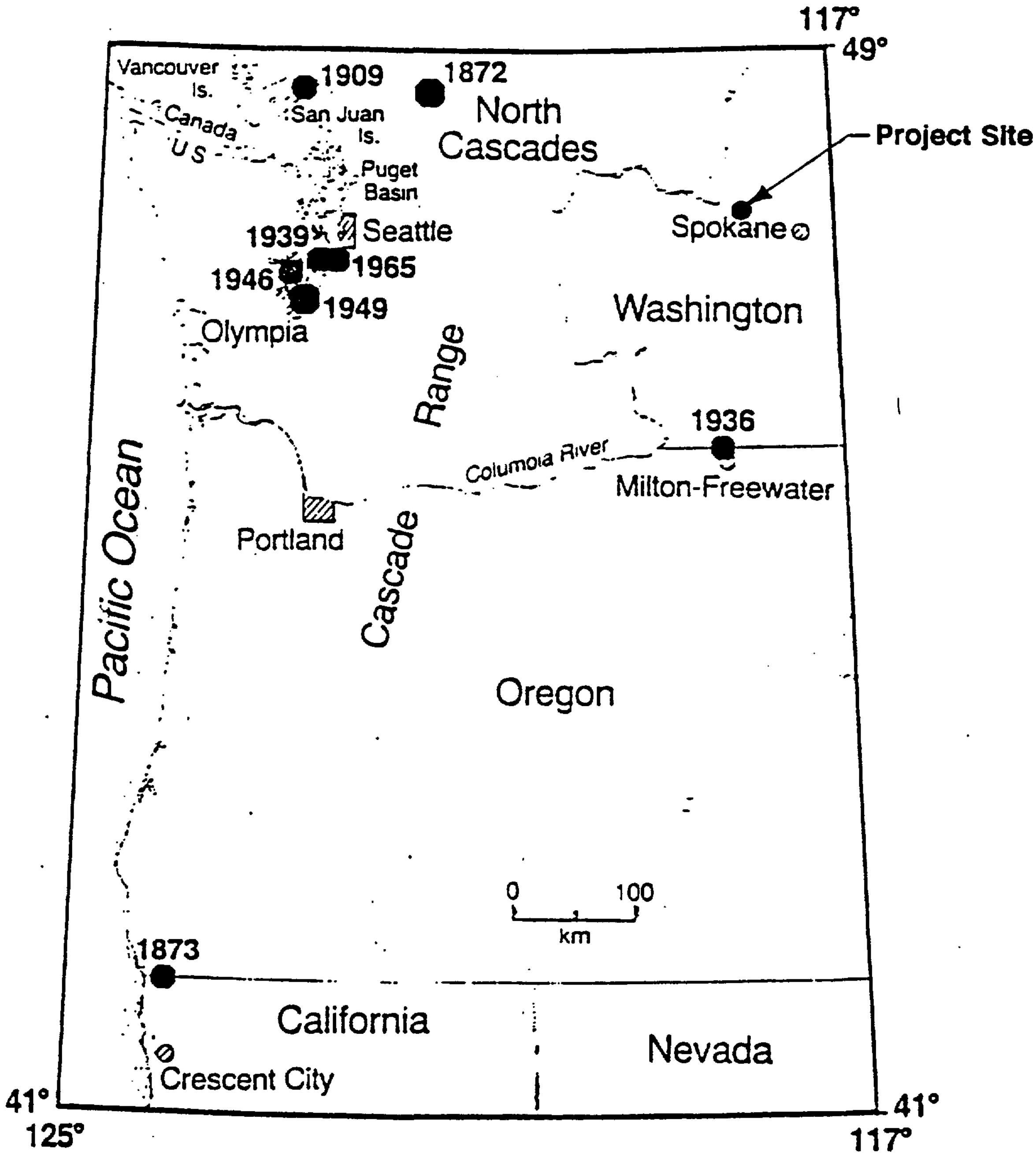
Approved by RLV	Date 5-5-94	SMI-100	3



Map Showing epicenters of largest known earthquakes in the Pacific Northwest; magnitudes were estimated from felt areas to be larger than 6.

(From Ludwin et al., 1991)

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SHERWOOD TAILING IMPOUNDMENT

LOCATION OF MAJOR EARTHQUAKES

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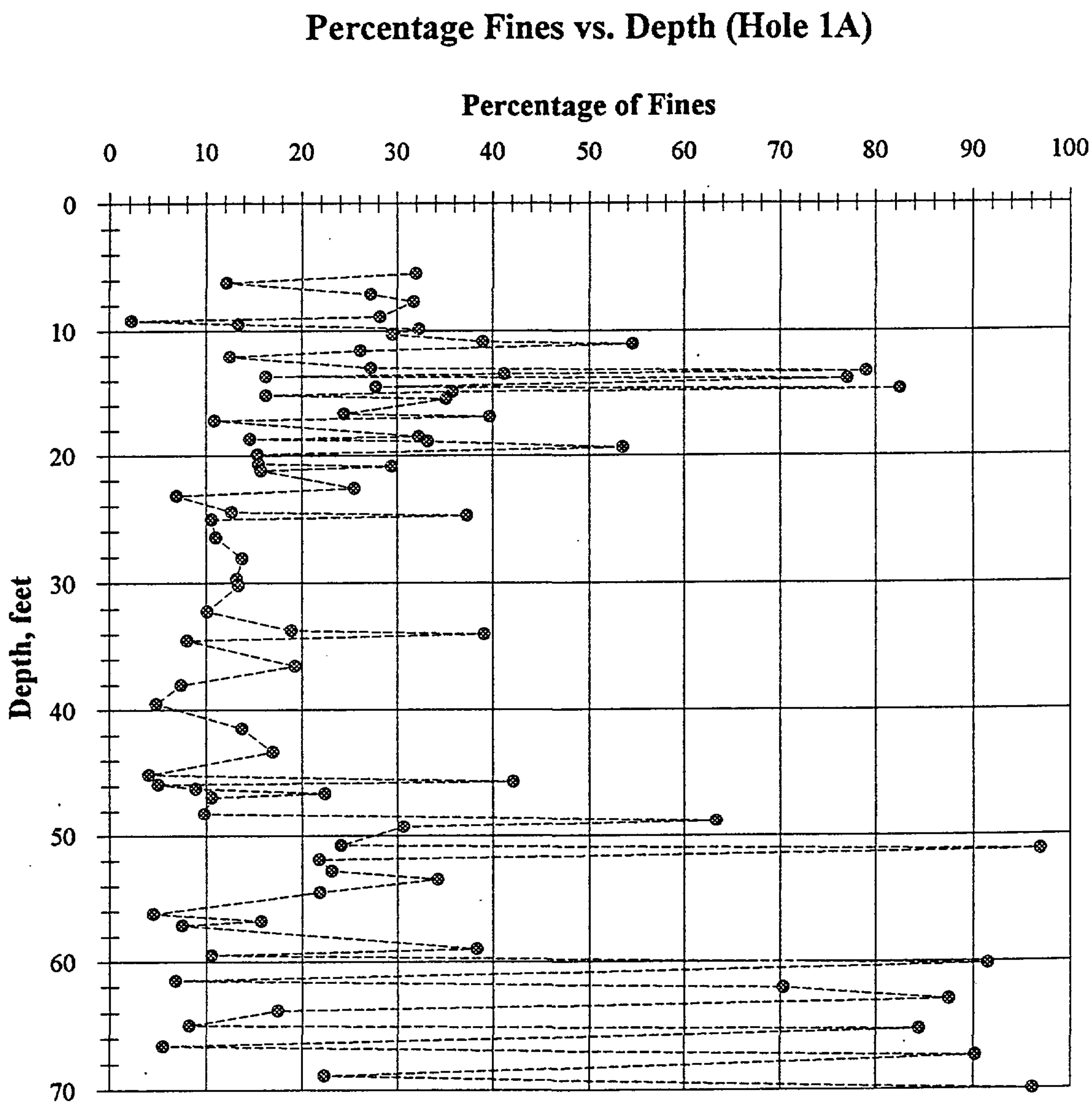
Approved by RLV	Date 5-5-94	SMI-100	4



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SHERWOOD TAILING IMPOUNDMENT

PERCENTAGE OF FINES vs. DEPTH (HOLE 1A)

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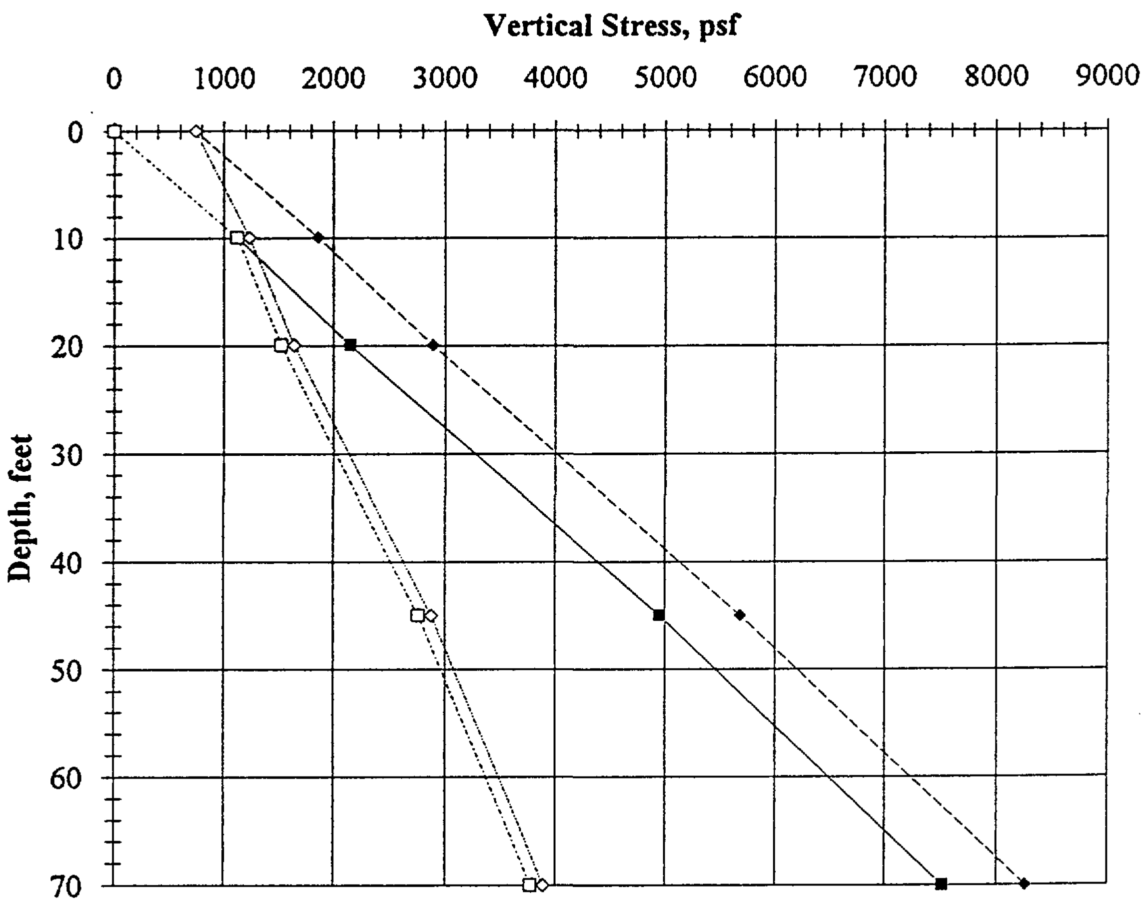
Approved by RLV	Date 5-5-94	SMI-100	5

Total and Effective Overburden Pressure



Notes:

1. The overburden pressure for the existing condition was computed assuming that the water table is at a depth of 10 feet, and with the following assumed typical zonation within the tailing pond:

Depth (ft)	Material	Total Unit Weight (pcf)
0-10	SM	111.9
10-20	ML	102.8
20-45	SM	111.9
45-70	ML	102.8

2. The ultimate condition assumes that the cover is in place ($\Delta\sigma$ = 740 psf) and that the water table is at the interface of the cover and the top of tailing.

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SHERWOOD TAILING IMPOUNDMENT **OVERBURDEN STRESSES IN POND**		
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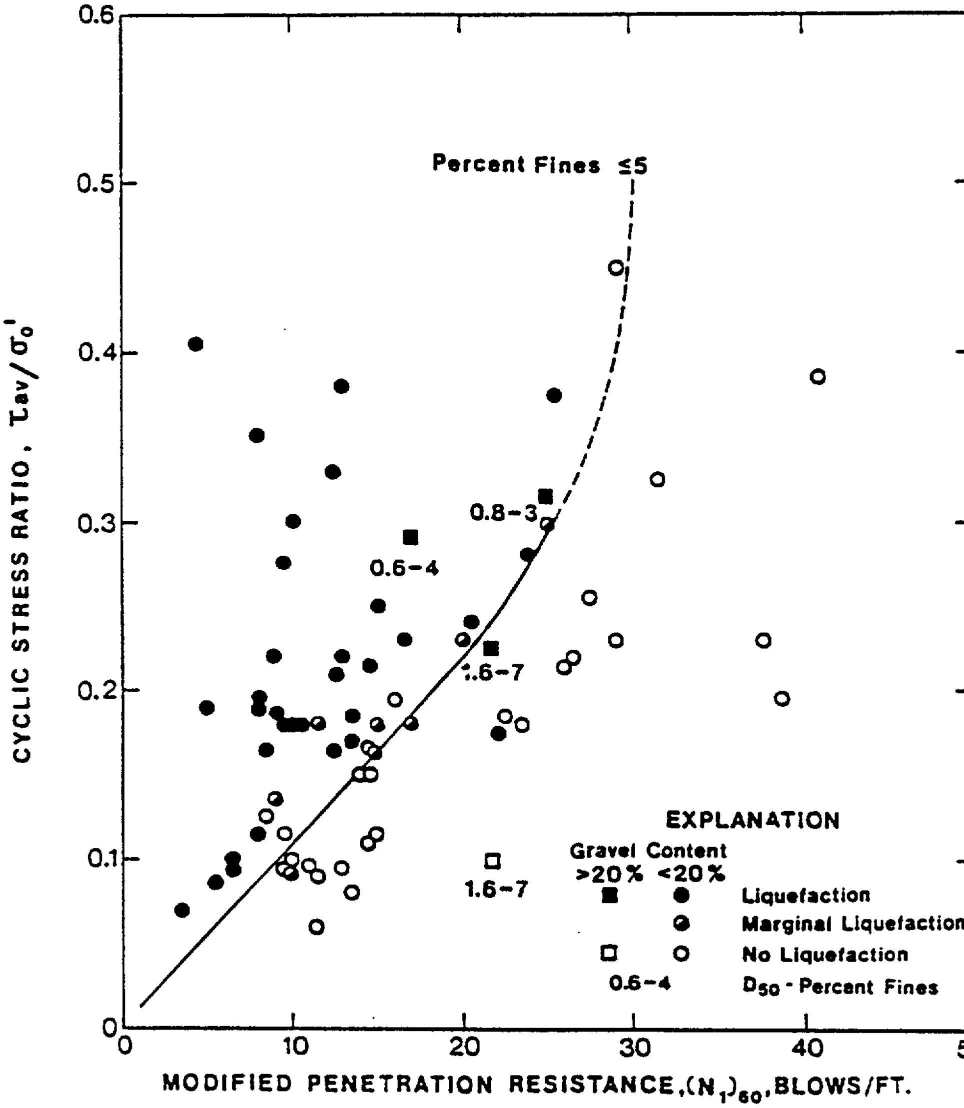

Liquefaction susceptibility chart with data prepared by Seed and others (1984; 1985) for clean sands (percentage of fines ≤ 5%) and a 7.5 magnitude earthquake.

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SHERWOOD TAILING IMPOUNDMENT			
LIQUEFACTION SUSCEPTIBILITY CHART 7.5 MAGNITUDE EARTHQUAKE			
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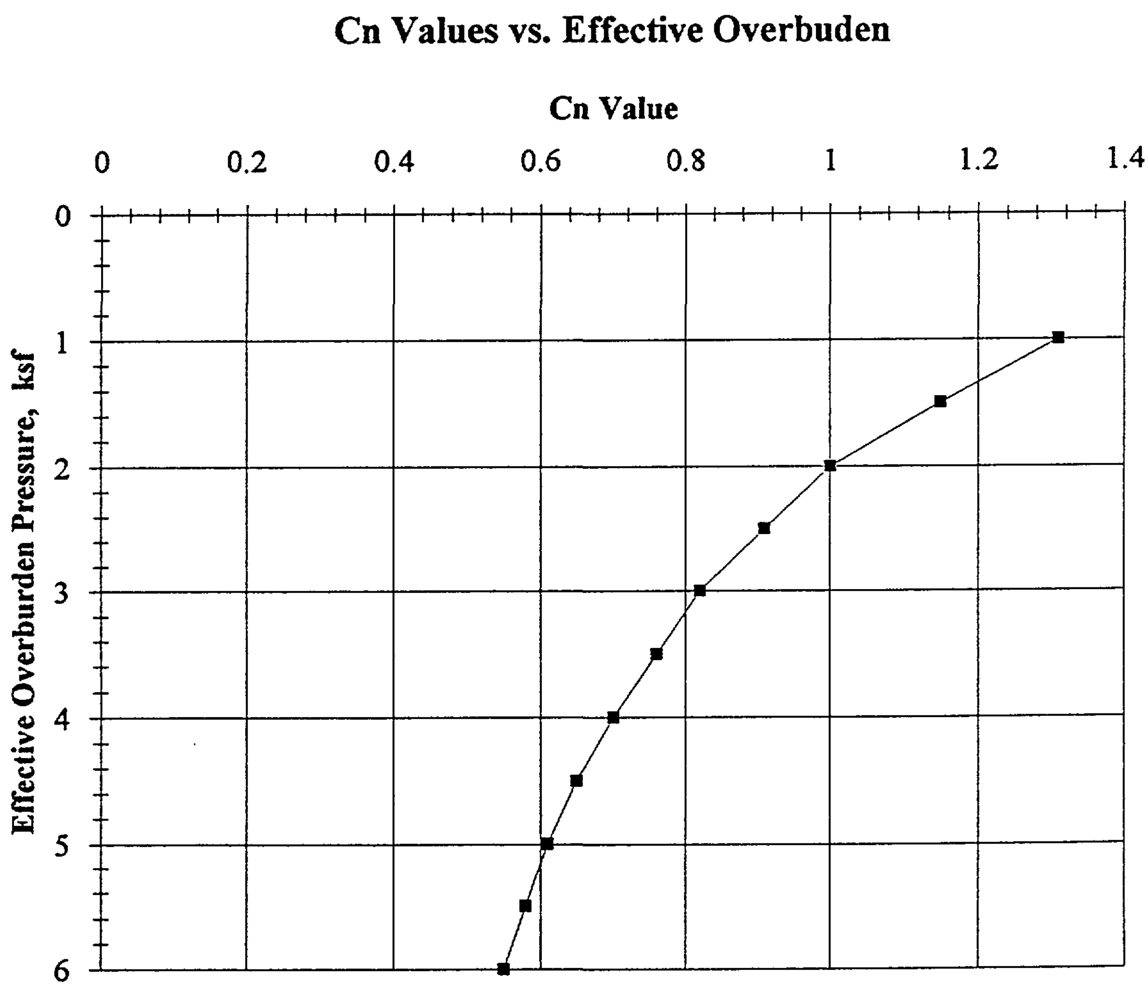
Approved by RLV	Date 5-5-94	SMI-100	7



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SHERWOOD TAILING IMPOUNDMENT

C_n VALUES vs. EFFECTIVE OVERBURDEN PRESSURE

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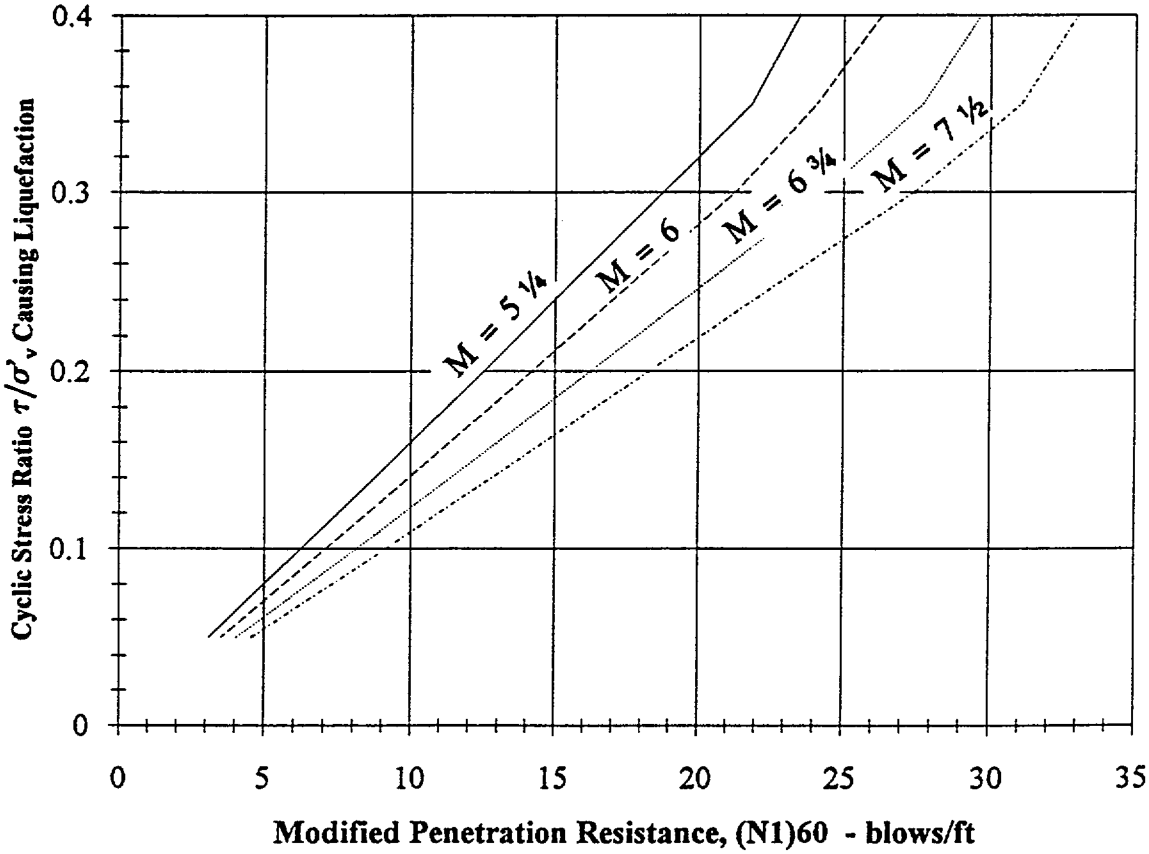
Approved by RLV	Date 5-5-94	SMI-100	8

Chart for Evaluation of Liquefaction Potential for Different Magnitude Earthquakes



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SHERWOOD TAILING IMPOUNDMENT

LIQUEFACTION SUSCEPTIBILITY CHART
DIFFERENT MAGNITUDE EARTHQUAKES

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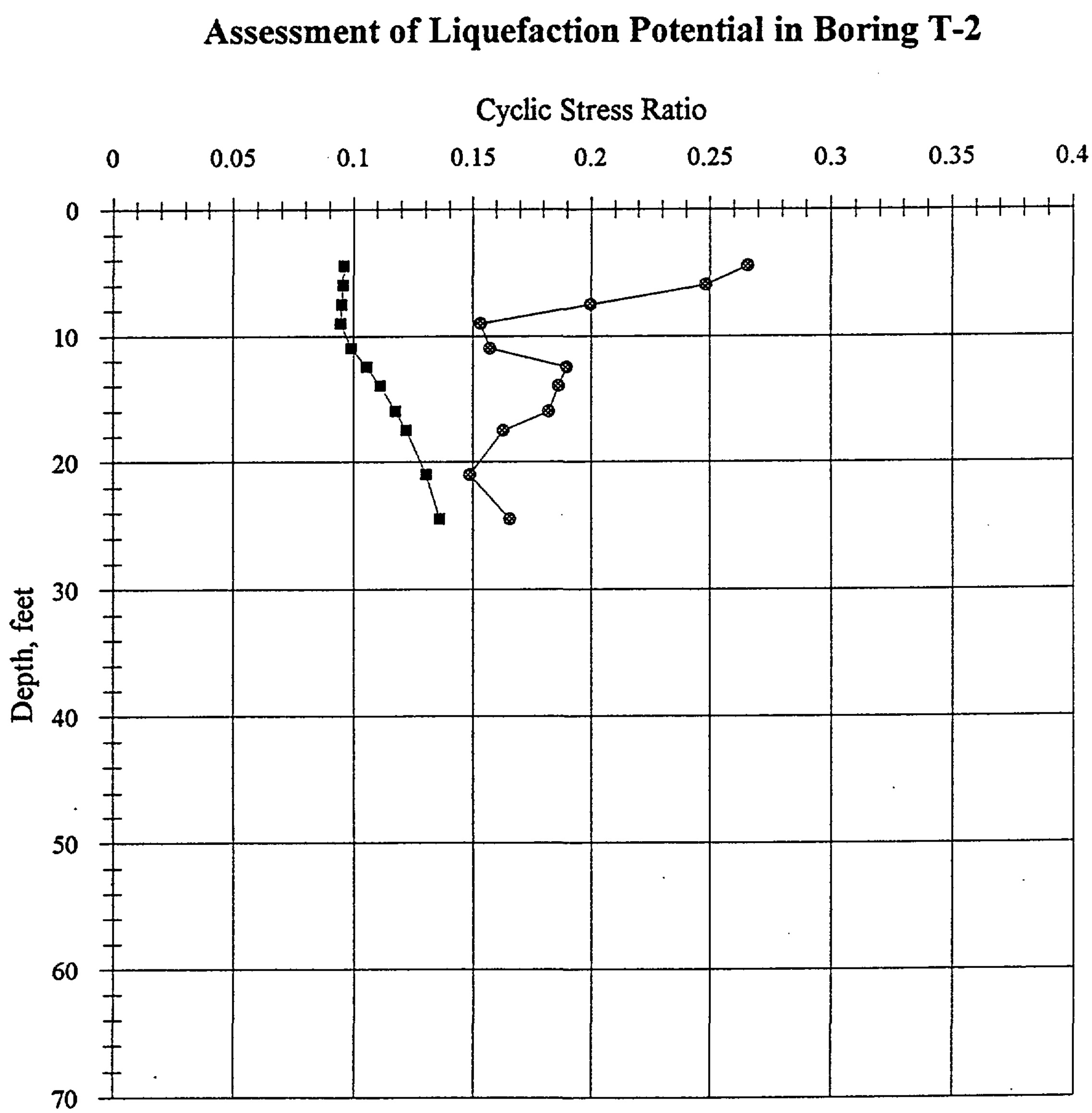

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SHERWOOD TAILING IMPOUNDMENT

LIQUEFACTION POTENTIAL BORING T-2

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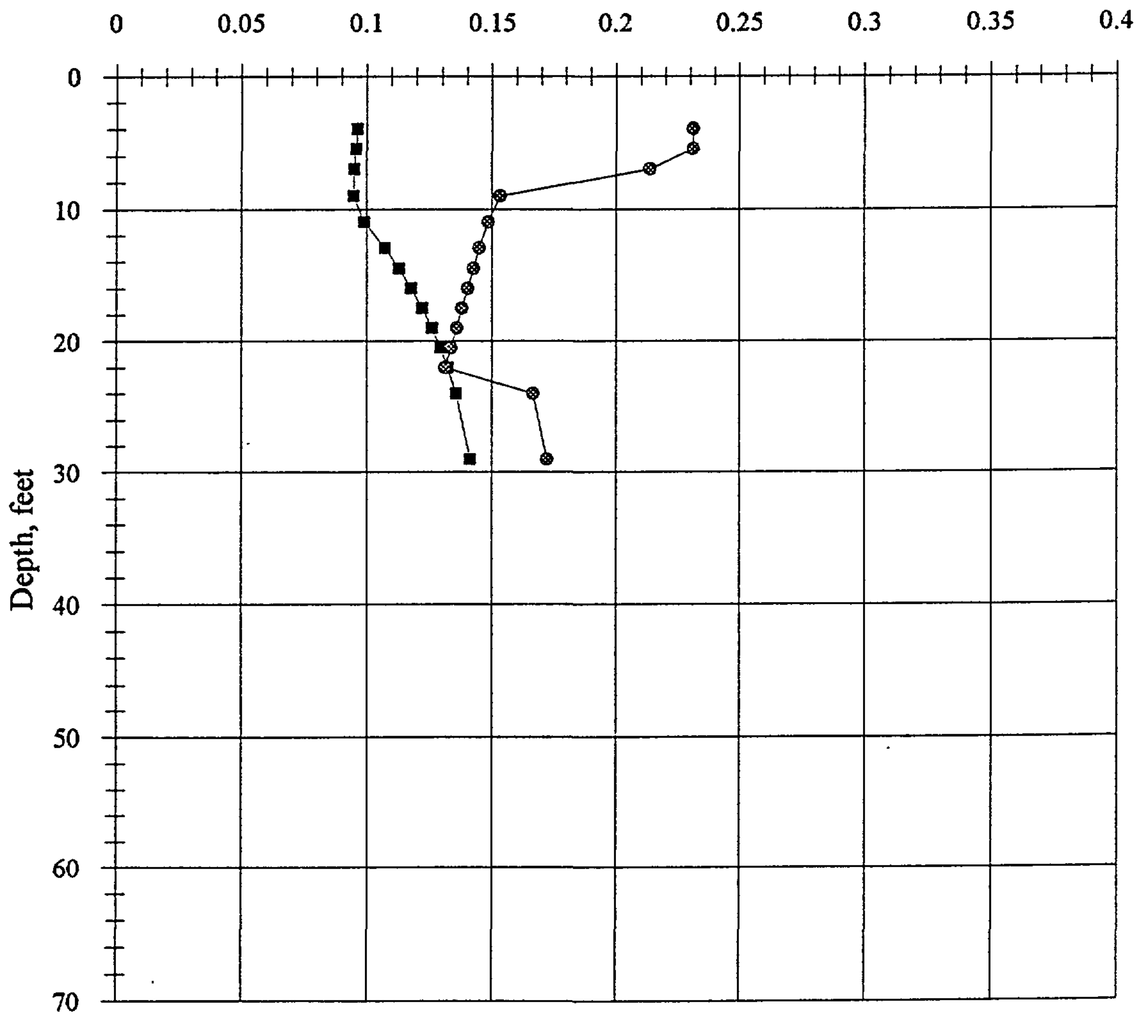
Assessment of Liquefaction Potential in Boring T-3



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LIQUEFACTION POTENTIAL
BORING T-3

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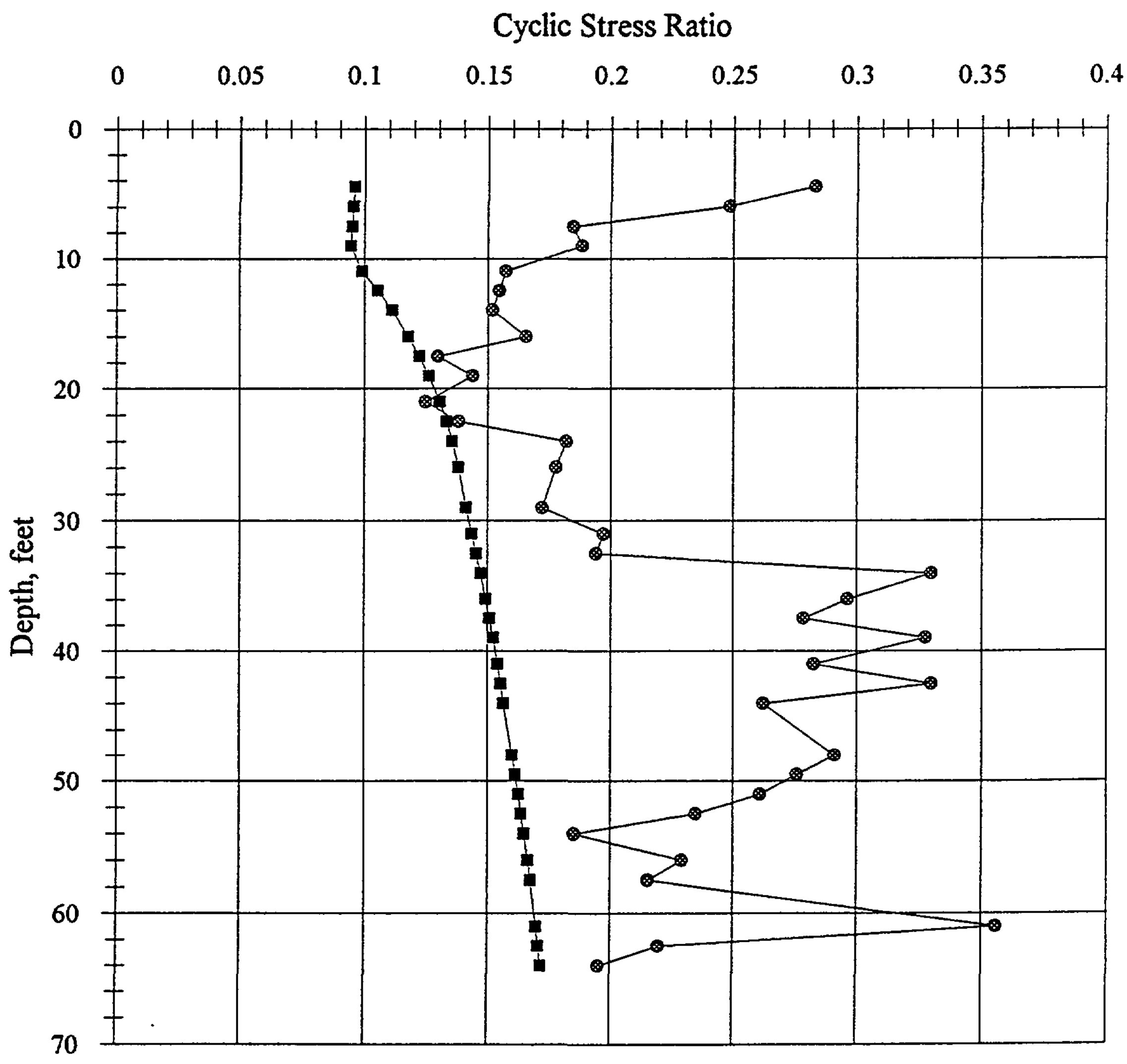
Assessment of Liquefaction Potential in Boring T-4



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SHERWOOD TAILING IMPOUNDMENT

LIQUEFACTION POTENTIAL
BORING T-4

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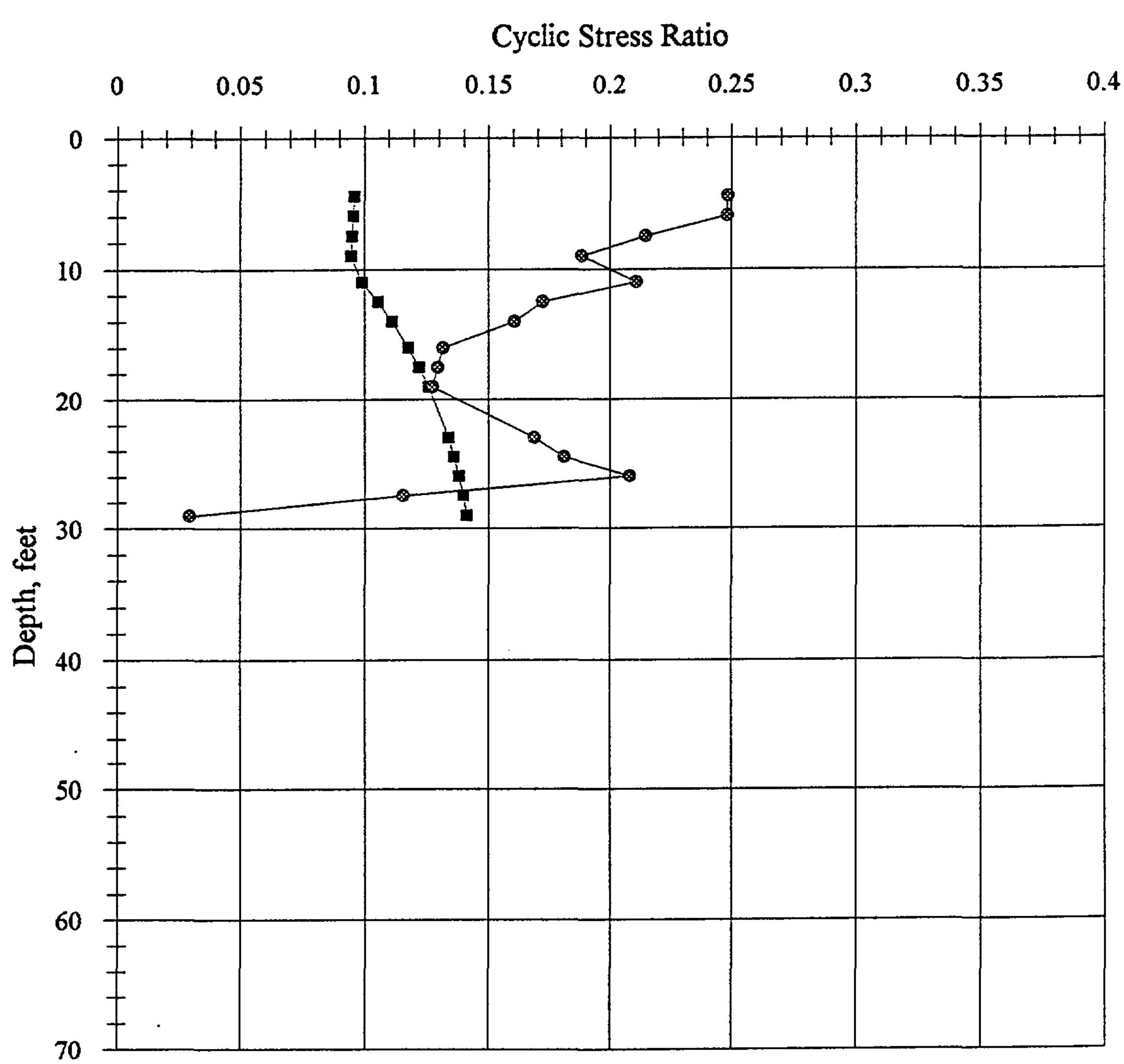
Approved by RLV	Date 5-5-94	SMI-100	12

Assessment of Liquefaction Potential in Boring T-5



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SHERWOOD TAILING IMPOUNDMENT

LIQUEFACTION POTENTIAL BORING T-5

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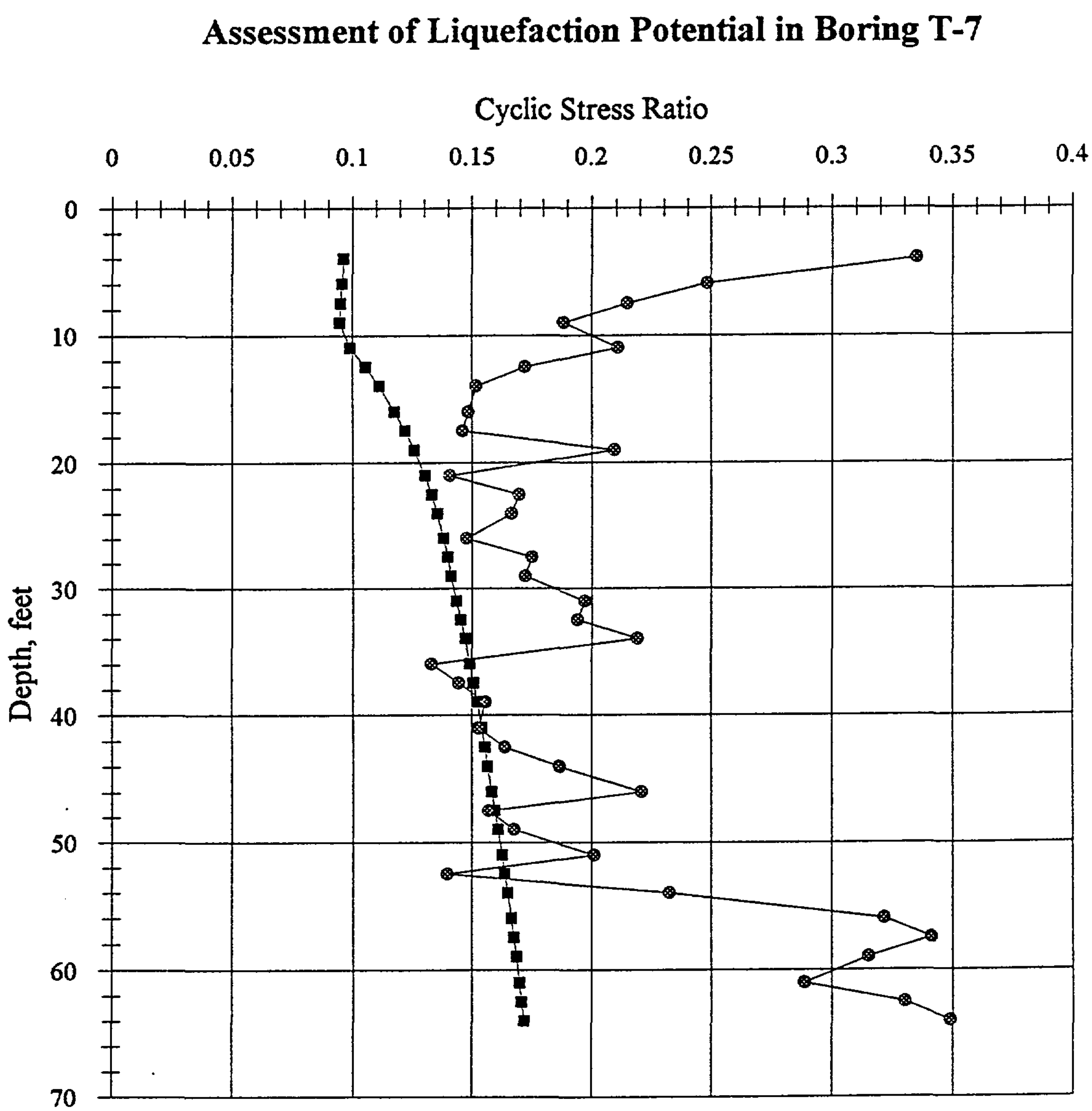

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SHERWOOD TAILING IMPOUNDMENT

LIQUEFACTION POTENTIAL
BORING T-7

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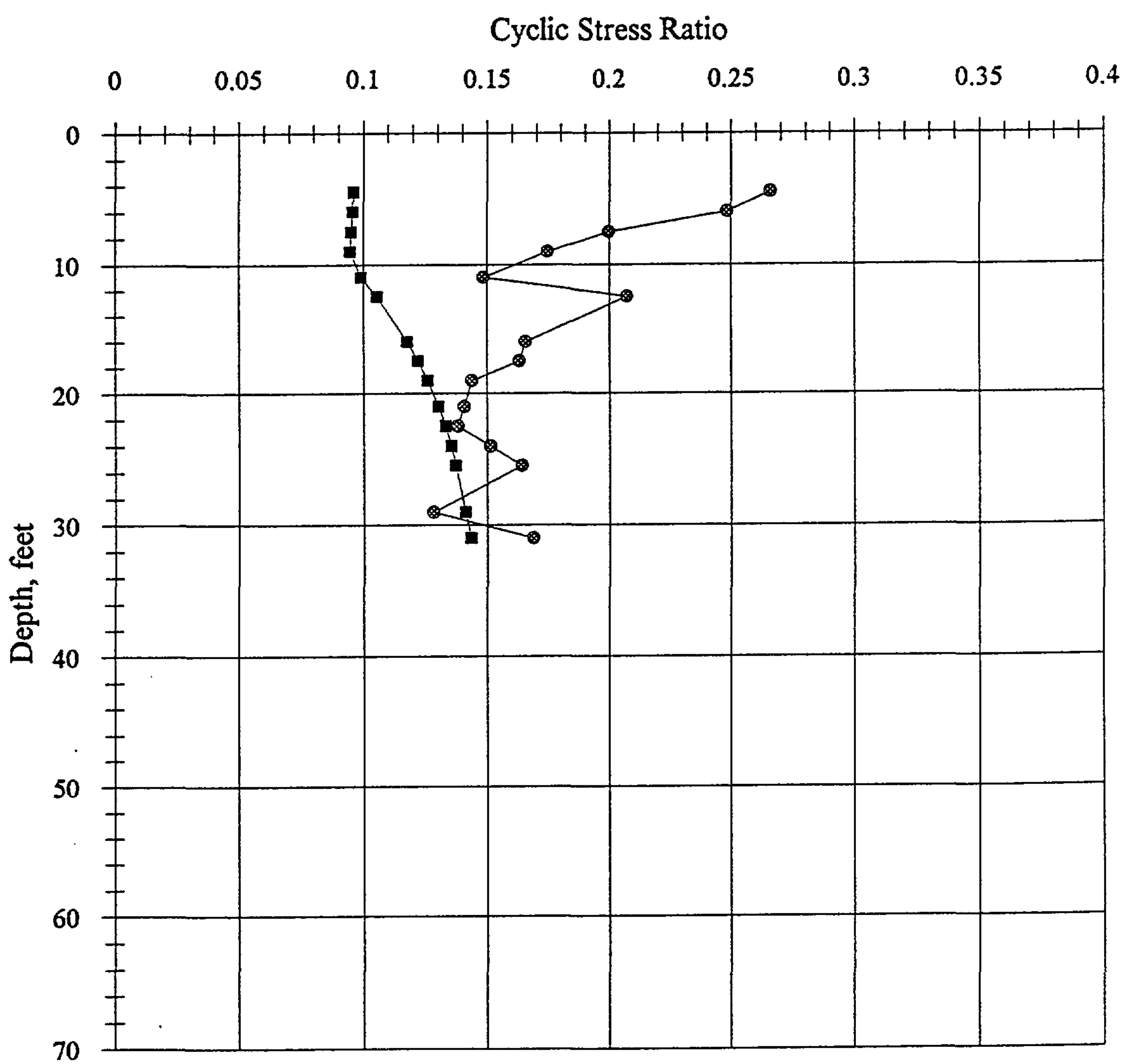
Assessment of Liquefaction Potential in Boring T-8



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SHERWOOD TAILING IMPOUNDMENT

LIQUEFACTION POTENTIAL
BORING T-8

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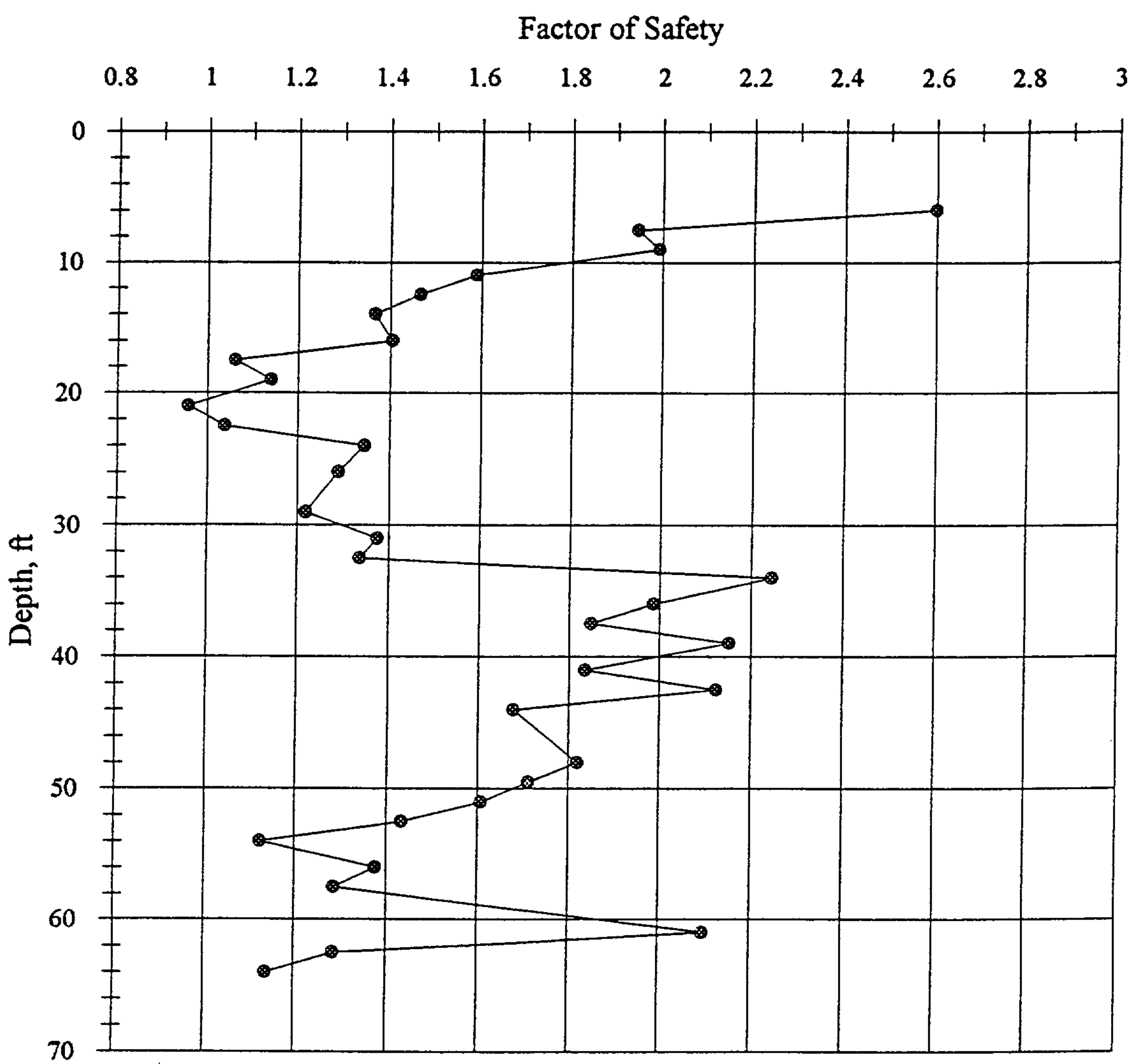
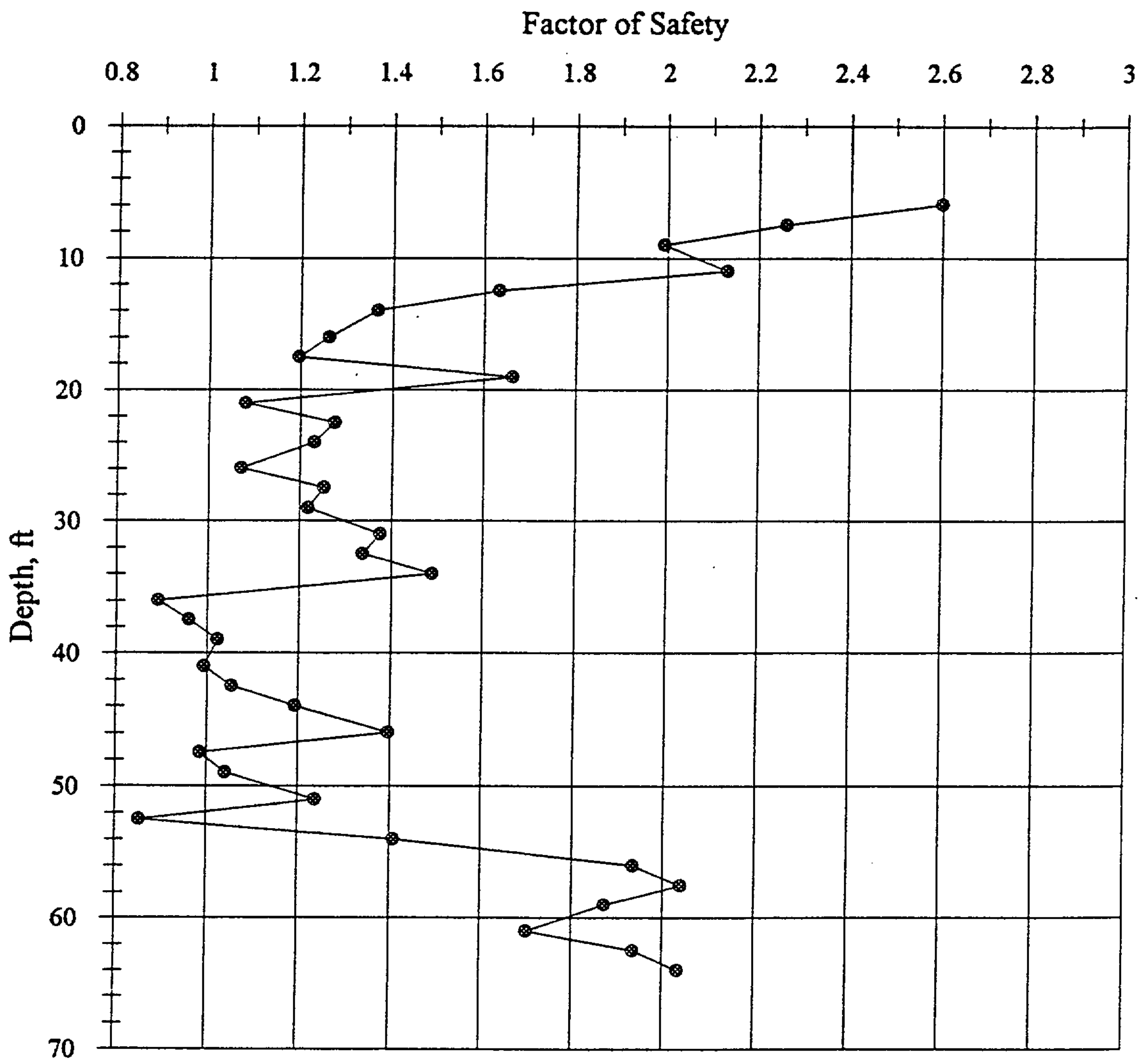
Approved by RLV	Date 5-5-94	SMI-100	15

Factor of Safety Against Liquefaction for Boring T-4



R.L. VOLPE & ASSOCIATES Los Gatos, California		
SHERWOOD TAILING IMPOUNDMENT		
FS AGAINST LIQUEFACTION BORING T-4		
Checked by ~~ Date 5-4-94 Approved by RLV Date 5-5-94	Project No. SMI-100	Figure No. 16

Factor of Safety Against Liquefaction for Boring T-7



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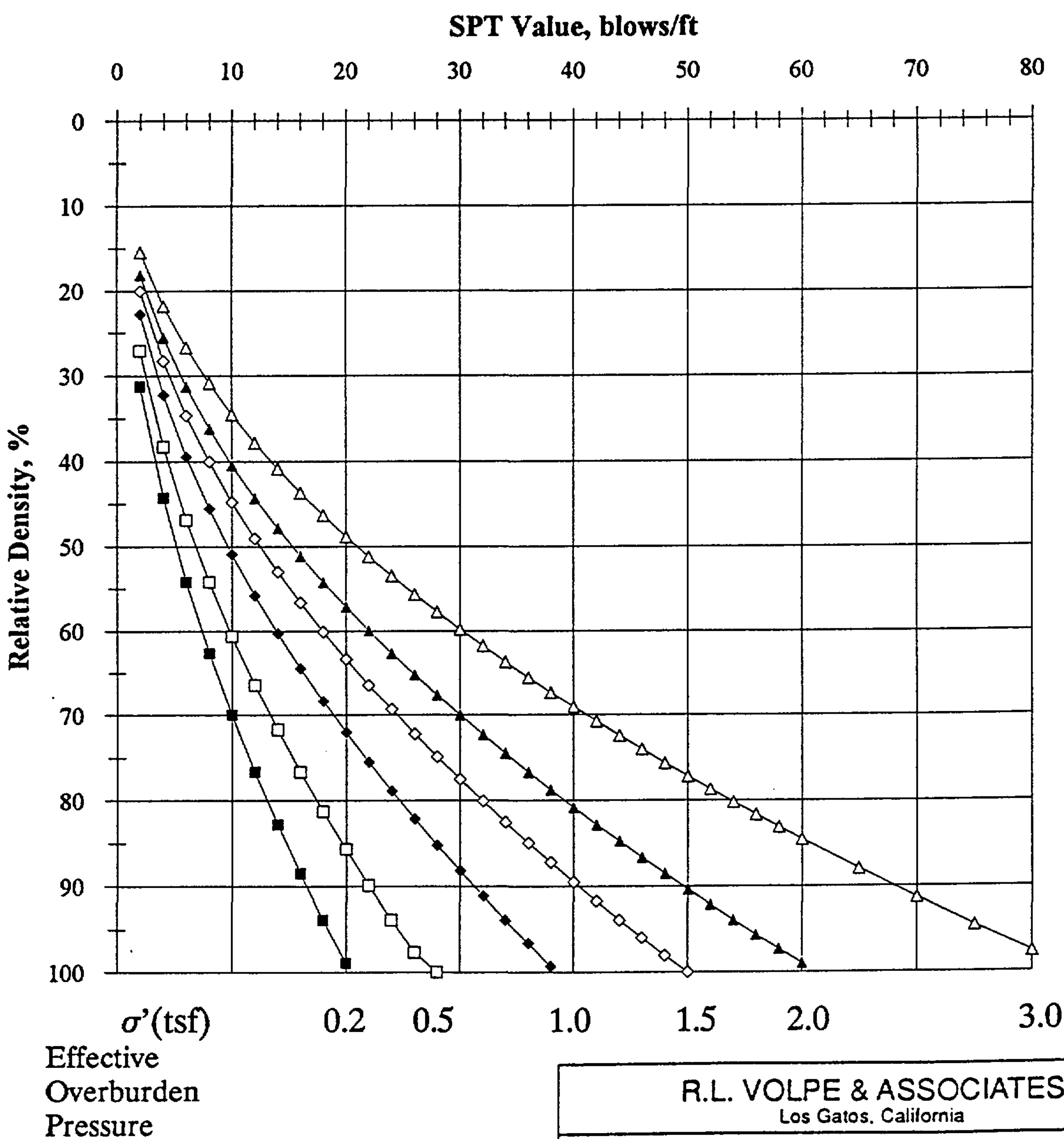
SHERWOOD TAILING IMPOUNDMENT		
FS AGAINST LIQUEFACTION BORING T-7		
Checked by [signature] Date 5-4-94	Project No.	Figure No.
Approved by RLV Date 5-5-94	SMI-100	17

SPT vs. Relative Density for Clean Sands



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SHERWOOD TAILING IMPOUNDMENT

SPT vs. RELATIVE DENSITY

Checked by [signature]	Date 5-4-94	Project No.	Figure No.
Approved by RLV	Date 5-5-94	SMI-100	18

APPENDIX A

SUMMARY OF LABORATORY TEST RESULTS USED FOR LIQUEFACTION ASSESSMENT

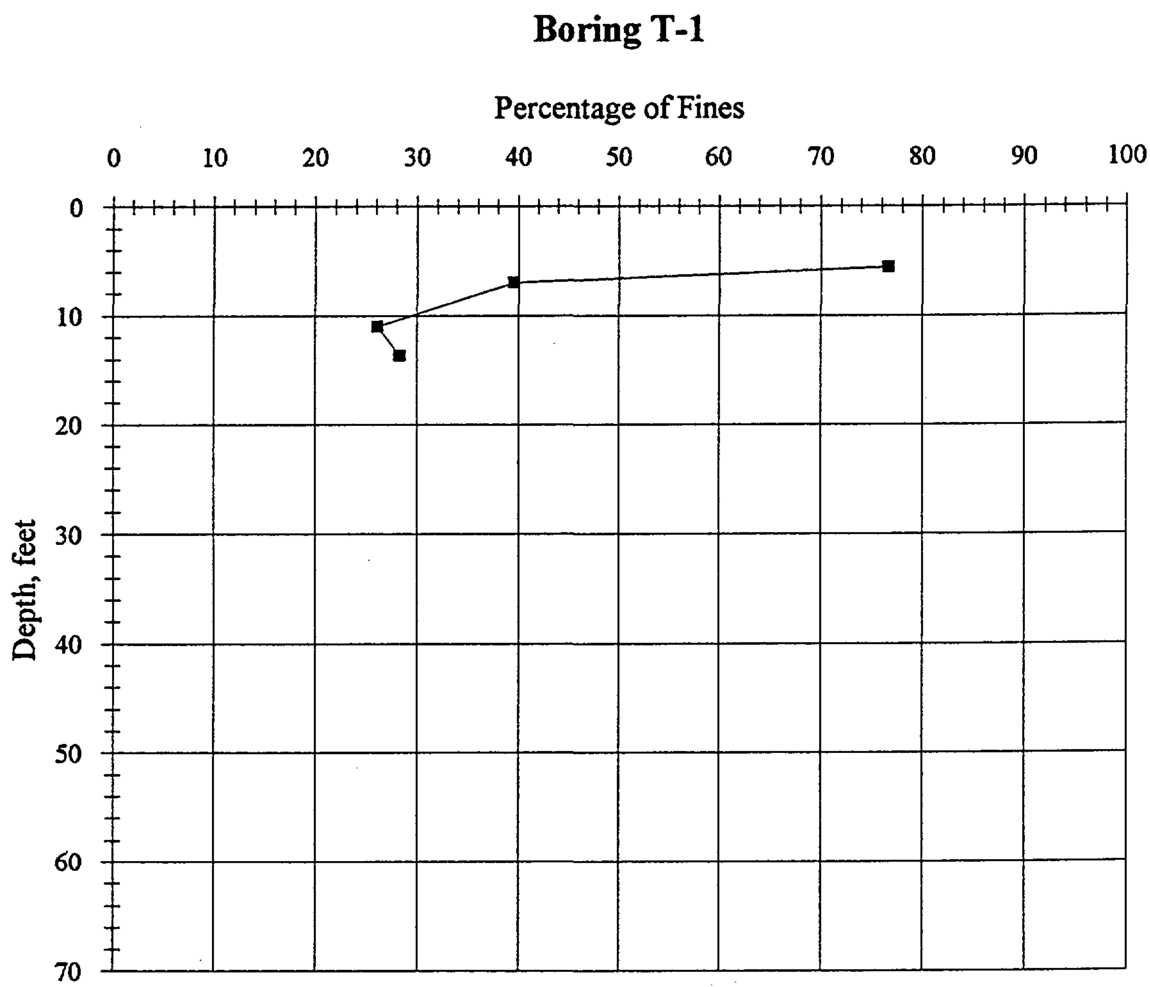
APPENDIX A

SUMMARY OF LABORATORY TEST RESULTS USED FOR LIQUEFACTION ASSESSMENT

This appendix presents the results of laboratory test performed on thin wall tube samples from borings at the Sherwood Tailing Impoundment. The laboratory tests were performed by SMI during their original field investigation of September 1991. The first sheet is a convenient summary of laboratory tests and other computed engineering parameters computed from the basic data. Following the first sheet are plots (Figs. A-1 thru A-7) of percentage of fines vs. depth for those holes in which tests were performed. Percentage of fines vs. depth relationships are presented since this value controls the classification of the sample. Full gradation test results are presented in previous submittals by SMI to the Washington Department of Health. Two items should be noted about the referenced figures: 1) most of the gradation results are not summarized on the first data summary sheet since the samples tested for gradation were obtained from SPT samples and no other engineering tests were performed due to sample disturbance; 2) although the figures show a solid line connecting consecutive individual data points, this is not meant to infer that we assume the percentage of fines, at any depth not sampled, would be equal to that value shown by the solid line.

Summary of Laboratory Test Results From Thin-Wall Tube Samples

Boring	Depth, ft	Total Unit Weight, Pcf	Dry Unit Weight, pcf	Natural Moisture, %	Percent Pass No. 200	Void Ratio	Saturation, %	Soil Classification
T-2	18.0-18.5	116.1	88.9	30.6	34.9	0.86	0.94	SM
	18.5-19.0	122.4	100.5	21.7	14.8	0.65	0.89	SM
	21.5-22.0	104.7	67.5	55.1	45.6	1.45	1.00	SM
	22.0-22.5	112.7	85.6	31.6	31.9	0.93	0.90	SM
	22.5-23.0	109.2	76.6	42.6	40.5	1.16	0.97	SM
	23.0-23.5	112.3	77.5	44.9	42.8	1.13	1.00	SM
T-4	45.0-45.5	94.6	59.7	58.4	74.8	1.77	0.87	ML
	45.5-46.0	100.5	57	76.2		1.90	1.00	ML
	46.0-46.5	105	67.7	55.1	70.2	1.44	1.00	ML
	46.5-47.0	107.3	72.8	47.4	61.2	1.27	0.99	ML
	58.0-58.5	113.5	74.5	52.4	73.4	1.22	1.00	ML
	58.5-59.0	111.6	76.1	46.7	70	1.17	1.00	ML
	59.0-59.5	110.6	82.9	33.4	23.9	0.99	0.89	SM
	59.5-60.0	113.8	85.7	32.8	13	0.93	0.94	SM
T-5	20.0-20.5	106.7	85.8	24.3	15.7	0.93	0.69	SM
	20.5-21.0	109.6	86.3	27	19.6	0.92	0.78	SM
	21.0-21.5	116.3	85.9	35.4	39	0.93	1.00	SM
	21.5-22.0	114.1	83.6	36.5	22.5	0.98	0.99	SM
T-7A	40.0-40.5	97.4	49.5	96.8	55.6	2.34	1.00	ML
	40.5-41.0	101.2	79.1	27.9	17.3	1.09	0.68	SM
	41.0-41.5	97.3	50.9	91.3	99.2	2.25	1.00	ML
	41.5-42.0	103.7	57	81.8		1.90	1.00	ML
T-8	26.0-26.5	99.9	56.3	77.6	98.1	1.94	1.00	ML
	26.5-27.0	99.6	55	81.2	69.6	2.01	1.00	ML
	27.0-27.5	92.2	44.3	107.9	91.4	2.73	1.00	ML
	27.5-28.0	117.1	92.3	117.1	13	0.79	1.00	SM



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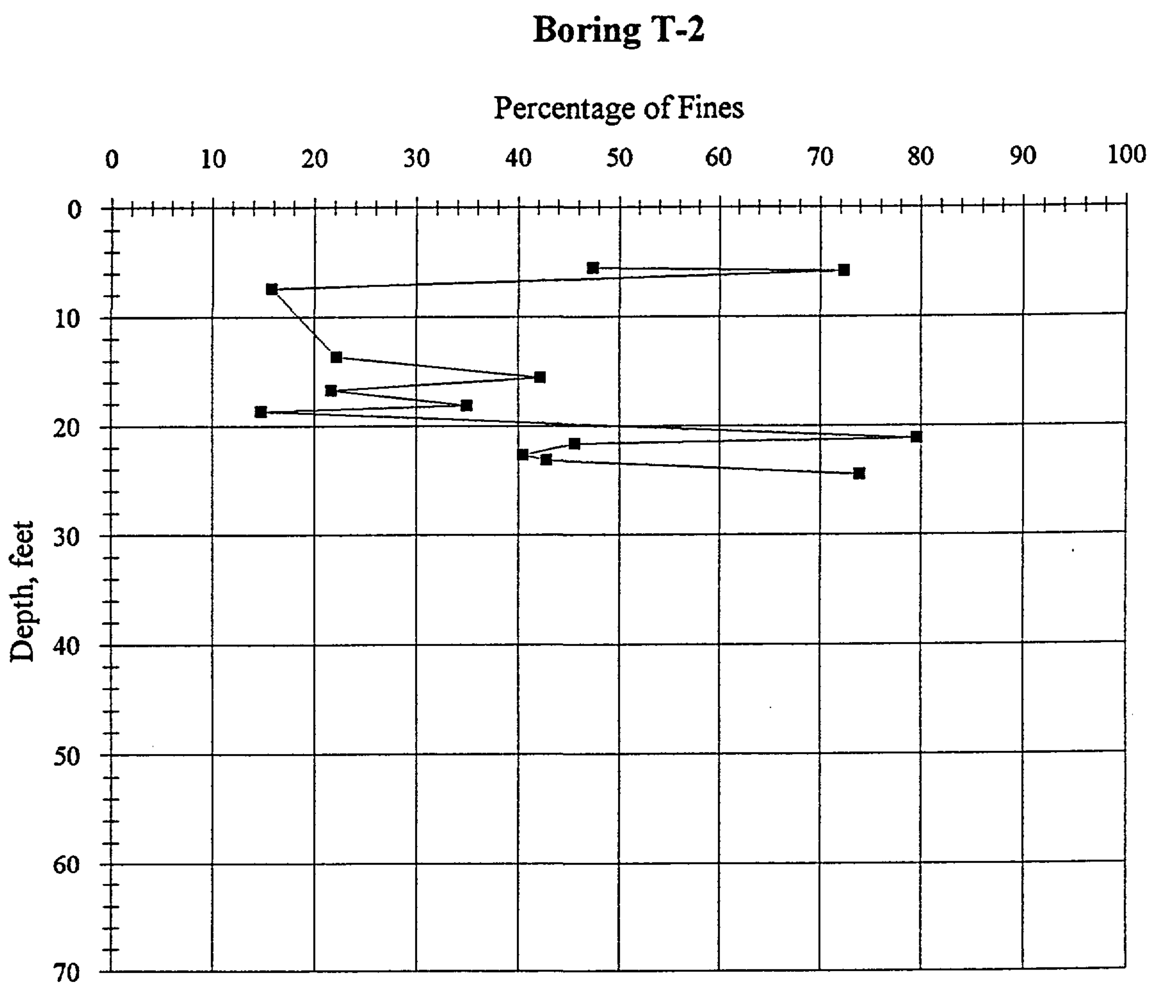
SHERWOOD TAILING IMPOUNDMENT

FINES CONTENT BORING T-1

Checked by	Date 5-4-94	Project No.	Figure No.
Approved by RLV	Date 5-5-94	SMI-100	A-1



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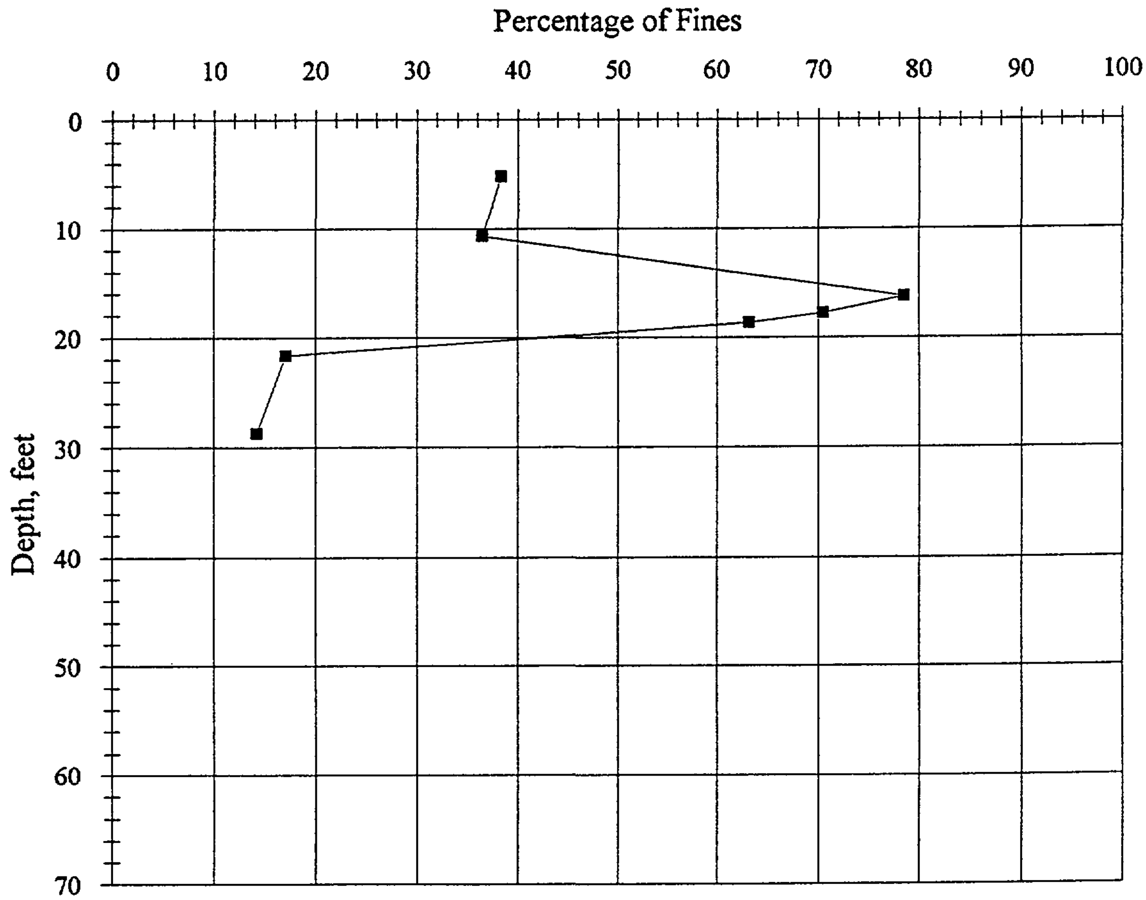
SHERWOOD TAILING IMPOUNDMENT

FINES CONTENT BORING T-2

Checked by ______	Date 5-4-94	Project No.	Figure No.
Approved by RLV	Date 5-5-94	SMI-100	A-2

Boring T-3



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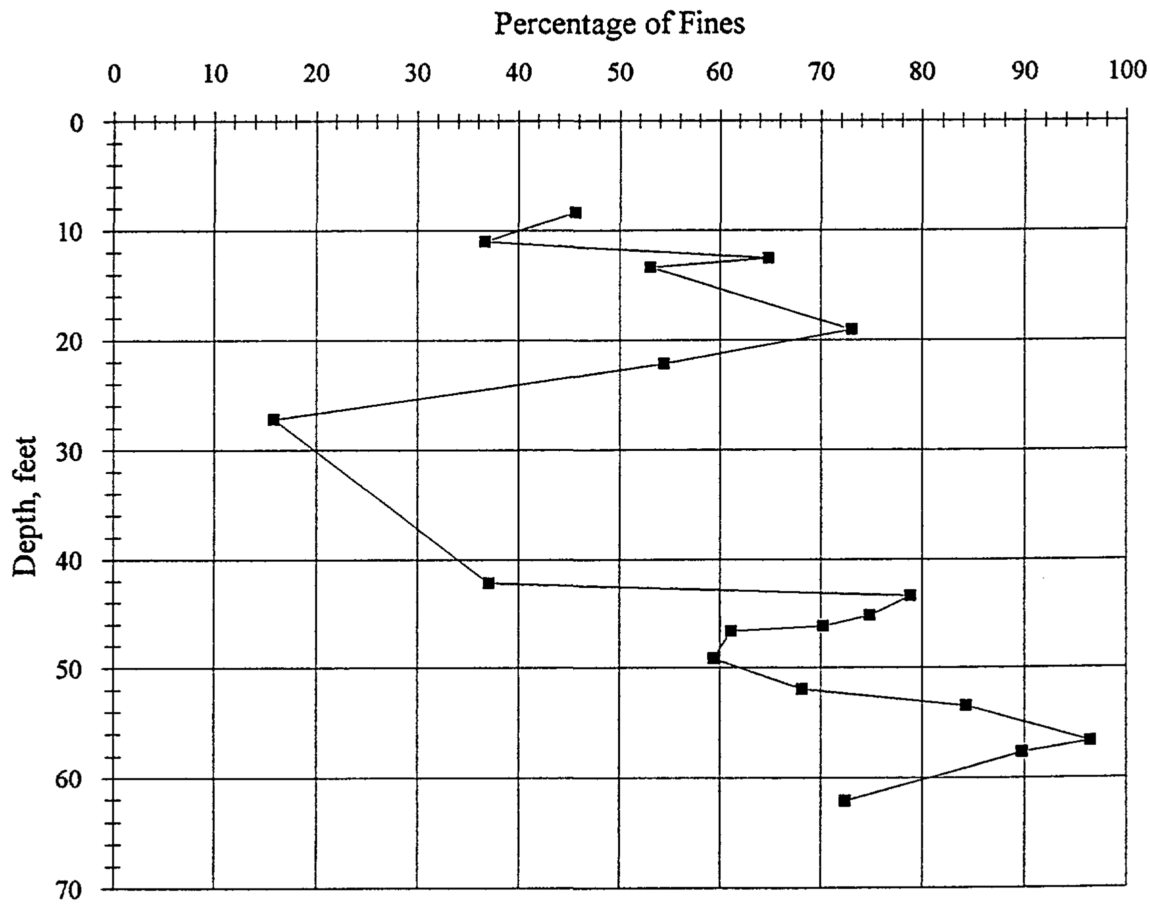
SHERWOOD TAILING IMPOUNDMENT			
FINES CONTENT BORING T-3			
Checked by [signature]	Date 5-4-94	Project No.	Figure No.
Approved by RLV	Date 5-5-94	SMI-100	A-3

Boring T-4



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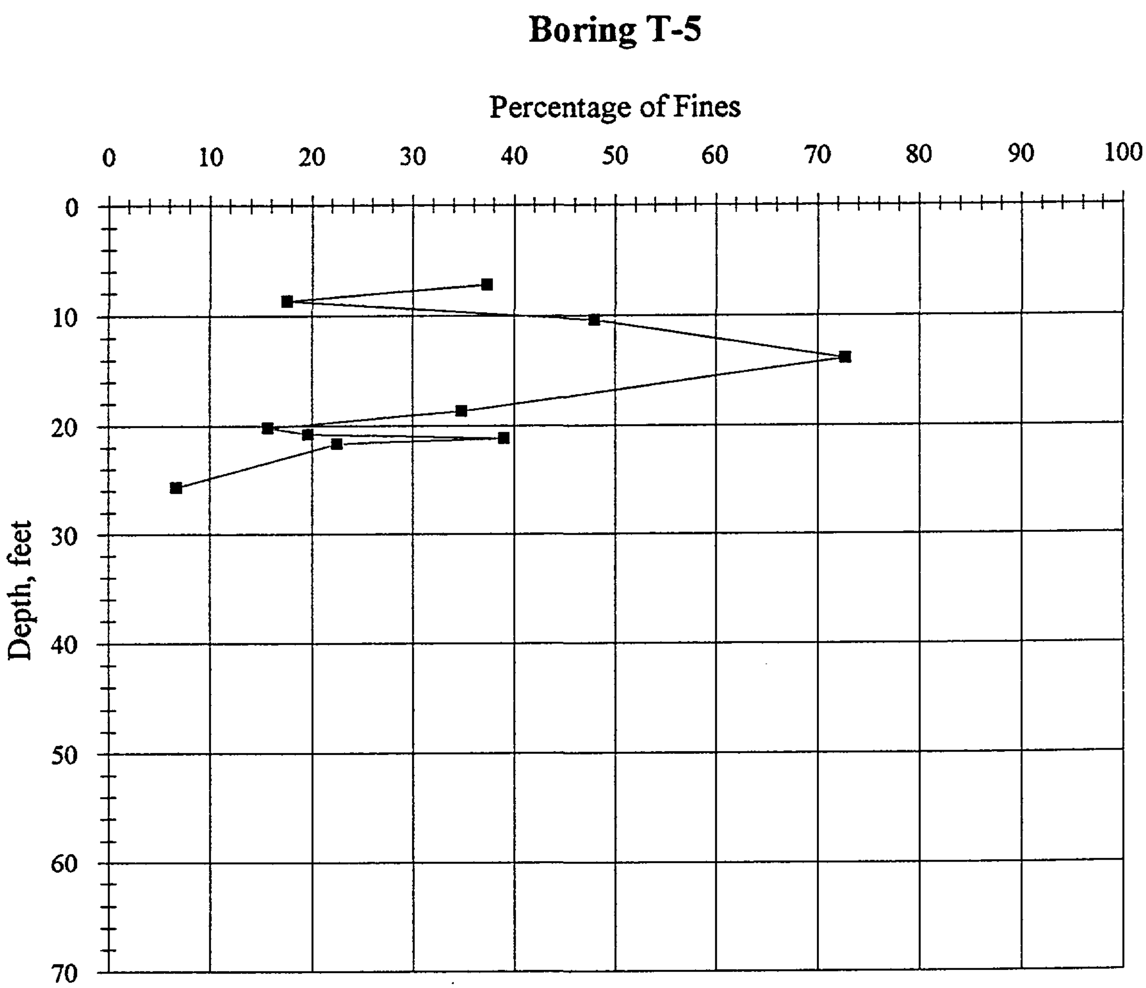
SHERWOOD TAILING IMPOUNDMENT

FINES CONTENT BORING T-4

Checked by [signature]	Date 5-4-94	Project No.	Figure No.
Approved by RLV	Date 5-5-94	SMI-100	A-4



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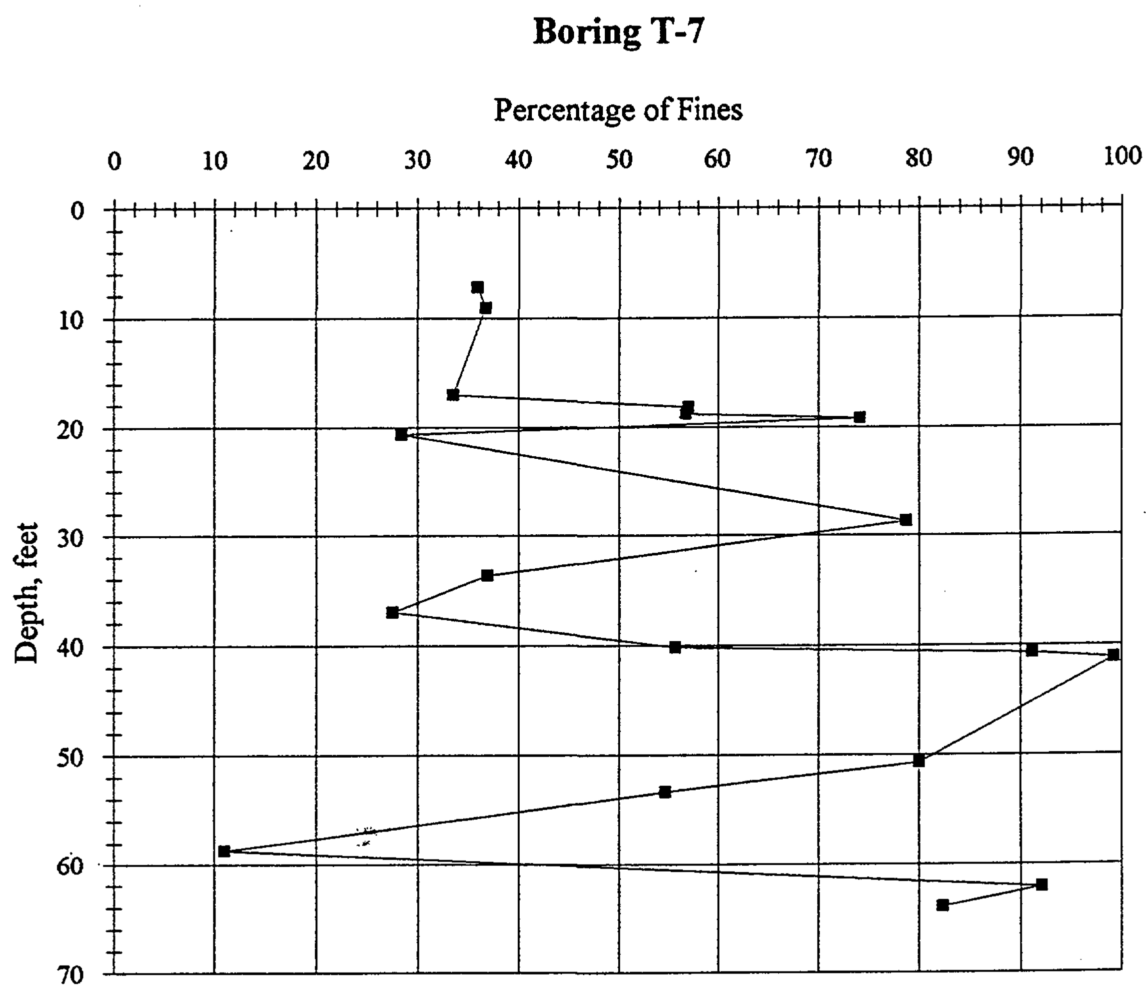
SHERWOOD TAILING IMPOUNDMENT

FINES CONTENT BORING T-5

Checked by lv	Date 5-4-94	Project No.	Figure No.
Approved by RW	Date 5-5-94	SMI-100	A-5



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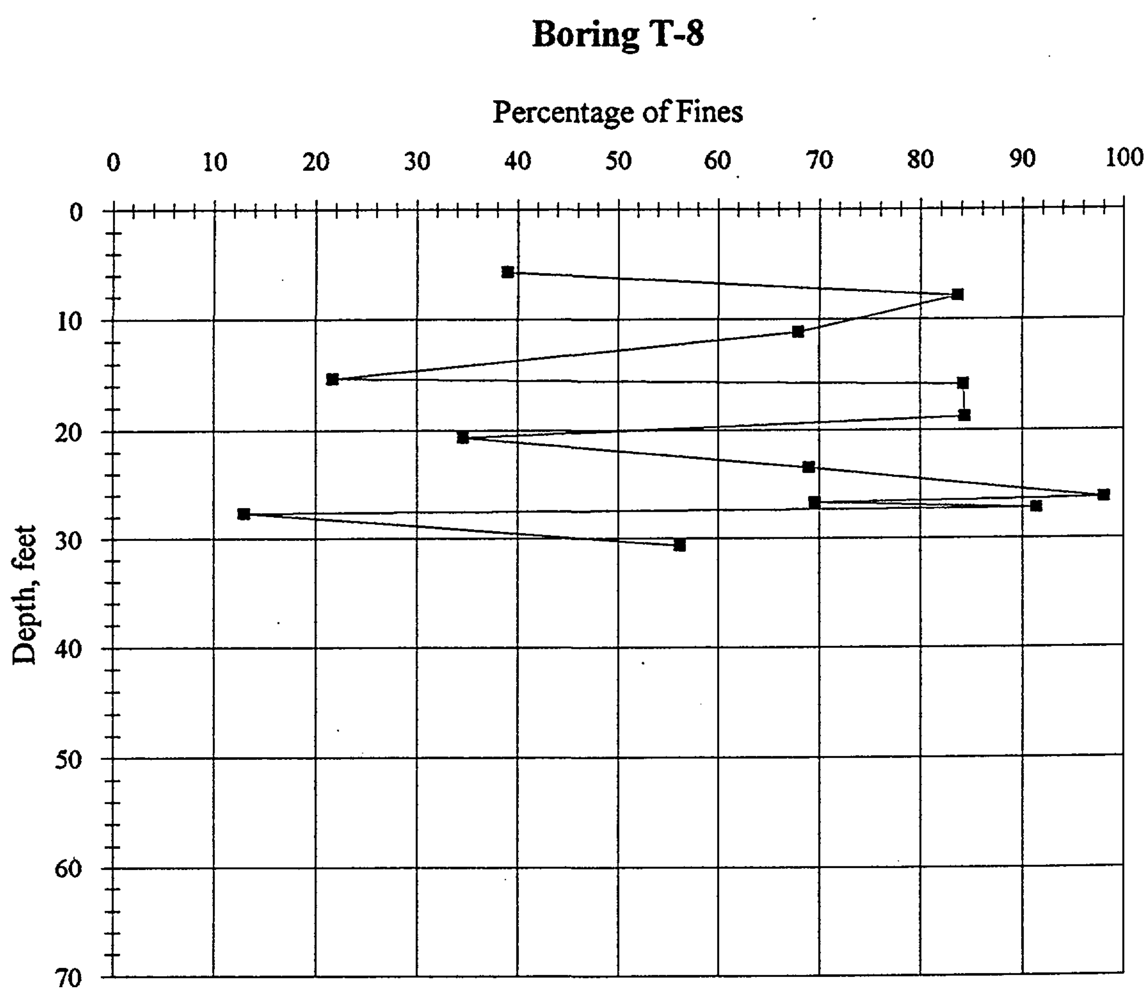
SHERWOOD TAILING IMPOUNDMENT

FINES CONTENT BORING T-7

Checked by lw	Date 5-4-94	Project No.	Figure No.
Approved by RLV	Date 5-5-94	SMI-100	A-6



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SHERWOOD TAILING IMPOUNDMENT

FINES CONTENT BORING T-8

Checked by [signature]	Date 5-4-94	Project No.	Figure No.
Approved by RLV	Date 5-5-94	SMI-100	A-7

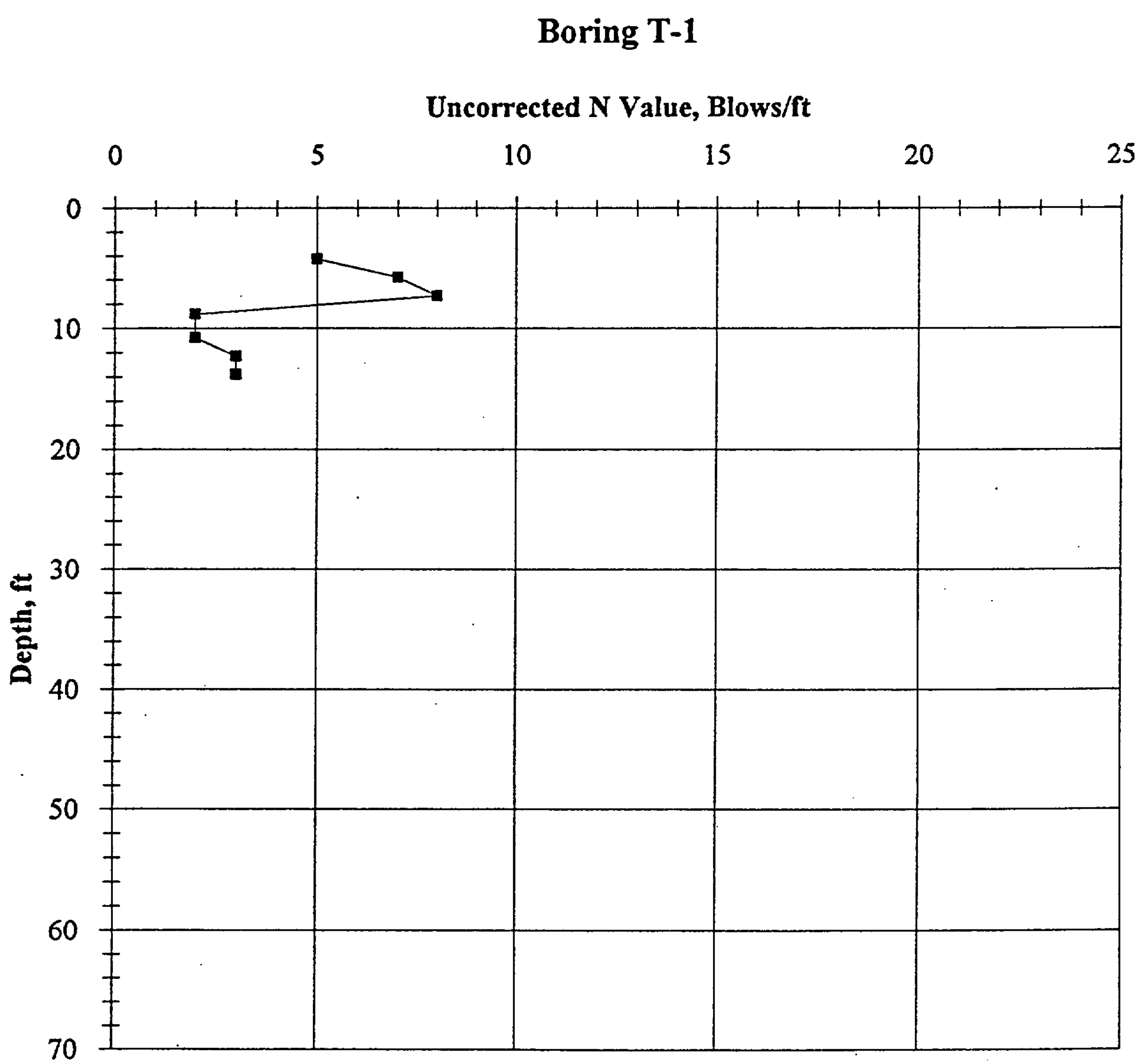
APPENDIX B

STANDARD PENETRATION TEST RESULTS AND $(N_1)_{60}$ VALUES vs. DEPTH

APPENDIX B

STANDARD PENETRATION TEST RESULTS AND $(N_1)_{60}$ VALUES vs. DEPTH

This appendix presents the results of SPT results and $(N_1)_{60}$ values vs. depth for borings performed at the Sherwood Tailing Impoundment. The SPT results were obtained by SMI during their original field investigation of September 1991. These logs are not reproduced herein but can be found in previous transmittals by SMI to the Washington Department of Health. The SPT results for Borings T-1 thru T-10 are presented in Figs. B-1 thru B-10, respectively. Following Figure B10, there are six sheets which present the engineering analyses to compute the $(N_1)_{60}$ values as a function of depth. The analyses are in the form of computer spread sheets showing the correction factors applied to the original SPT values as discussed in Section IV of the text. Several of the sheets contain results from more than one boring. The computed $(N_1)_{60}$ values vs. depth for Borings T-1 thru T-10 are presented in Figs. B-11 thru B-20, respectively. These values were then used to assess the liquefaction potential of the tailing impoundment. It should be noted that the plot of a particular $(N_1)_{60}$ value may be fractional (e.g. 12.4 blows/ft) since it is the result of a calculation. Although the data on the data for $(N_1)_{60}$ shown on the spread sheets has been rounded to the nearest whole number for presentation, the fractional data were used for plotting purposes. Detailed results of this assessment are presented in Appendix C.



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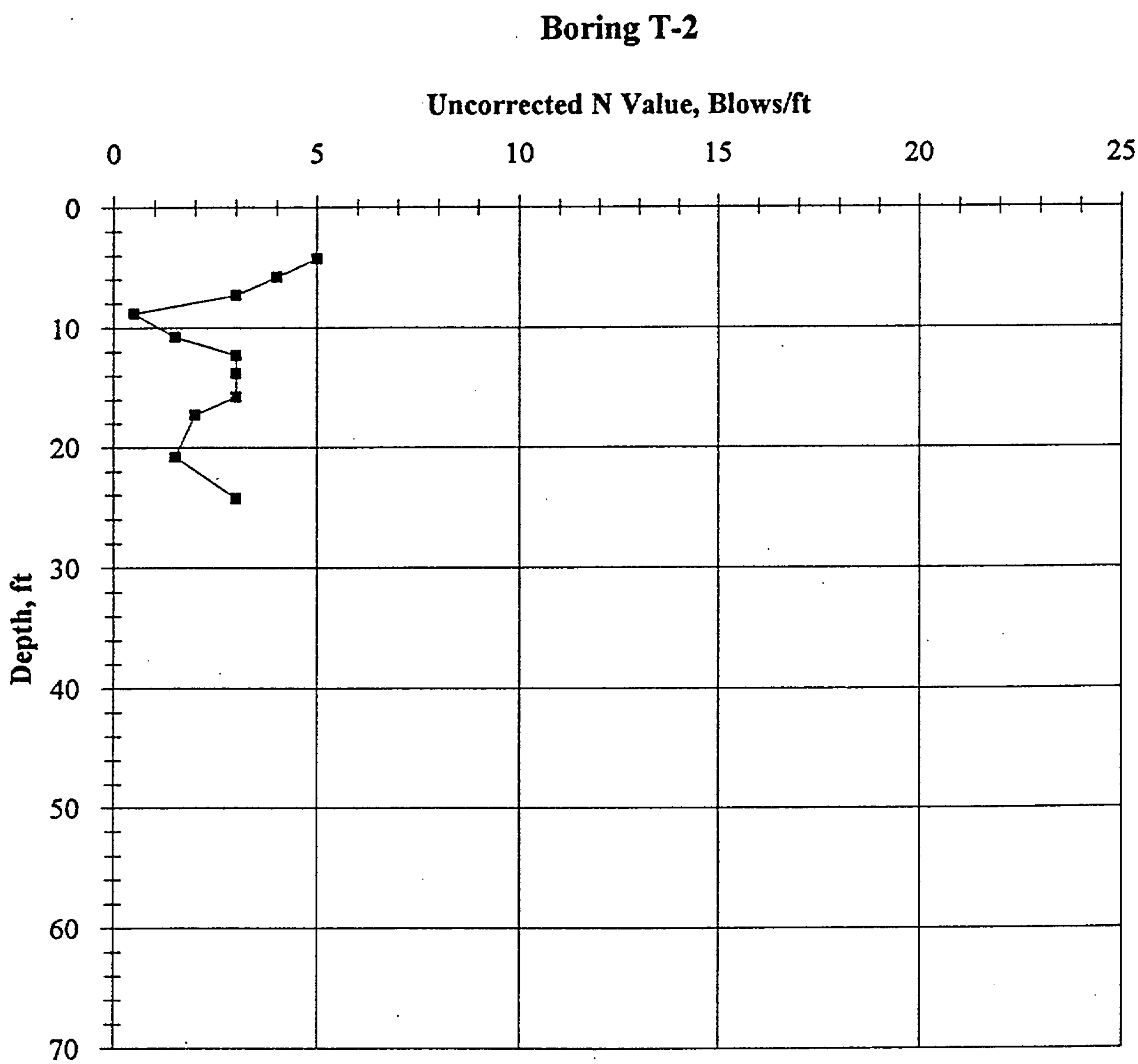
SHERWOOD TAILING IMPOUNDMENT

SPT RESULTS BORING T-1

Checked by [signature]	Date 5-4-94	Project No.	Figure No.
Approved by RLV	Date 5-5-94	SMI-100	B-1



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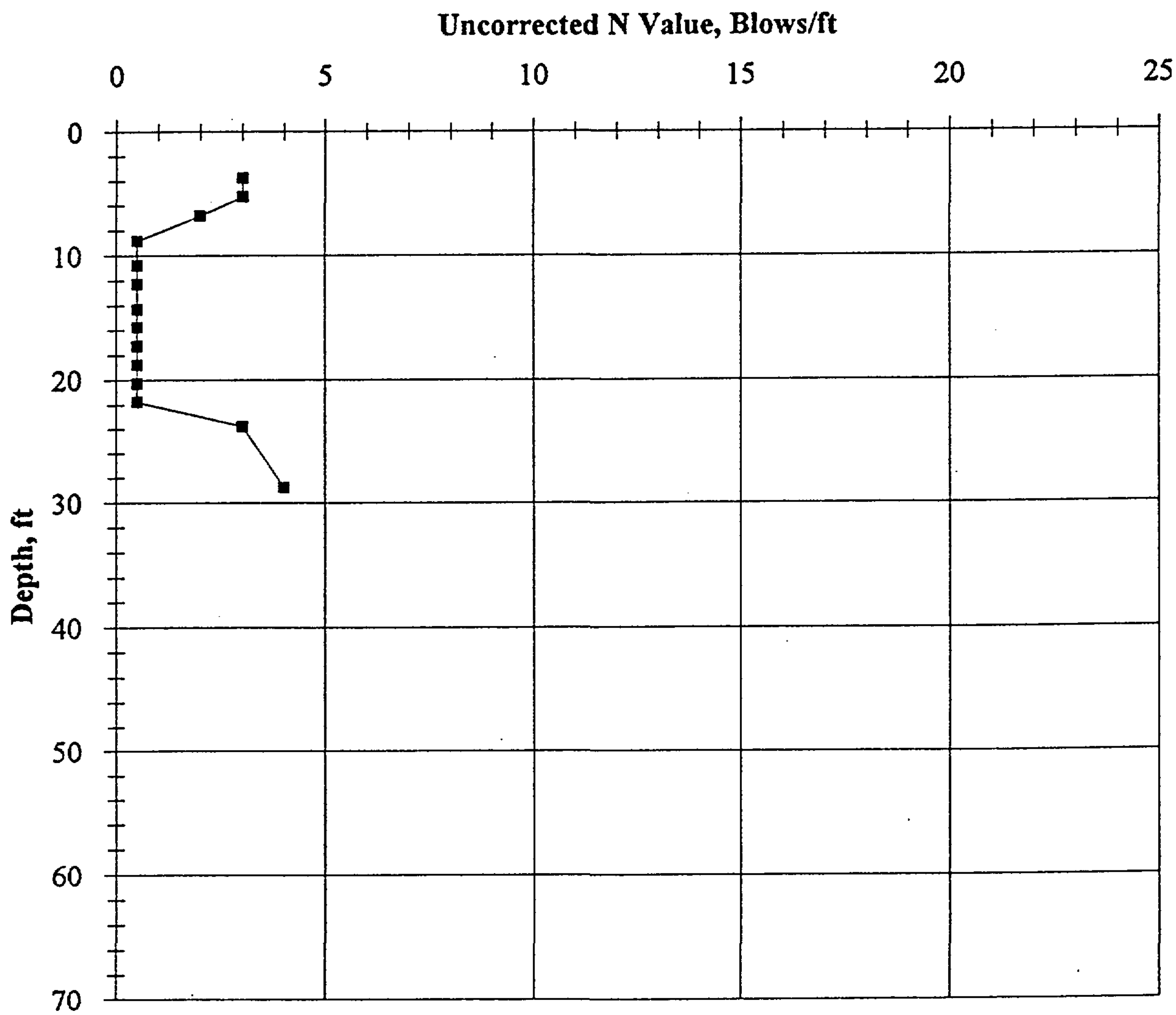
SHERWOOD TAILING IMPOUNDMENT

SPT RESULTS BORING T-2

Checked by *[signature]*	Date 5-4-94	Project No.	Figure No.
Approved by RLV	Date 5-5-94	SMI-100	B-2

Boring T-3



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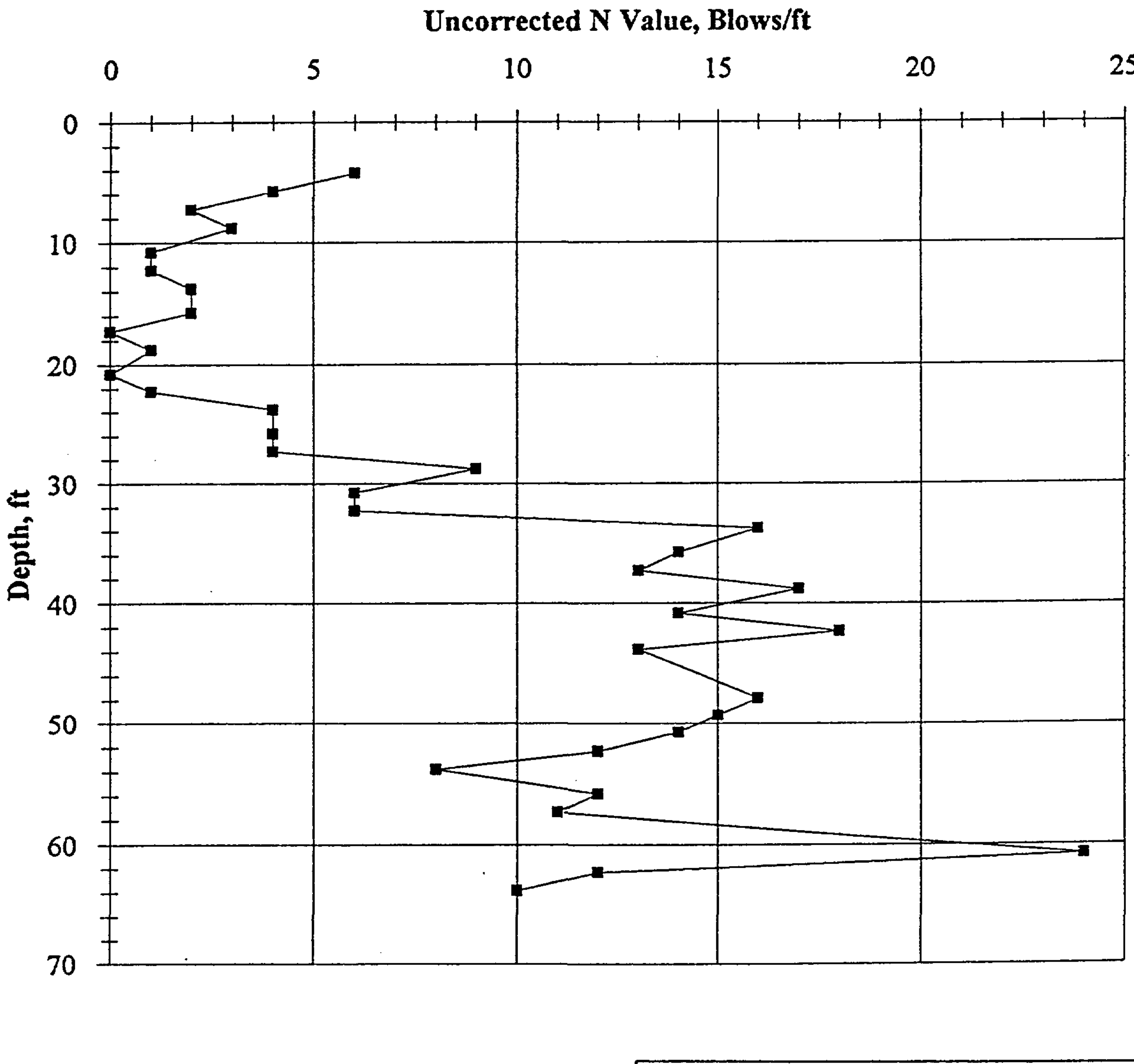
SHERWOOD TAILING IMPOUNDMENT

SPT RESULTS BORING T-3

Checked by [signature]	Date 5-4-94	Project No.	Figure No.
Approved by RLV	Date 5-5-94	SMI-100	B-3

Boring T-4



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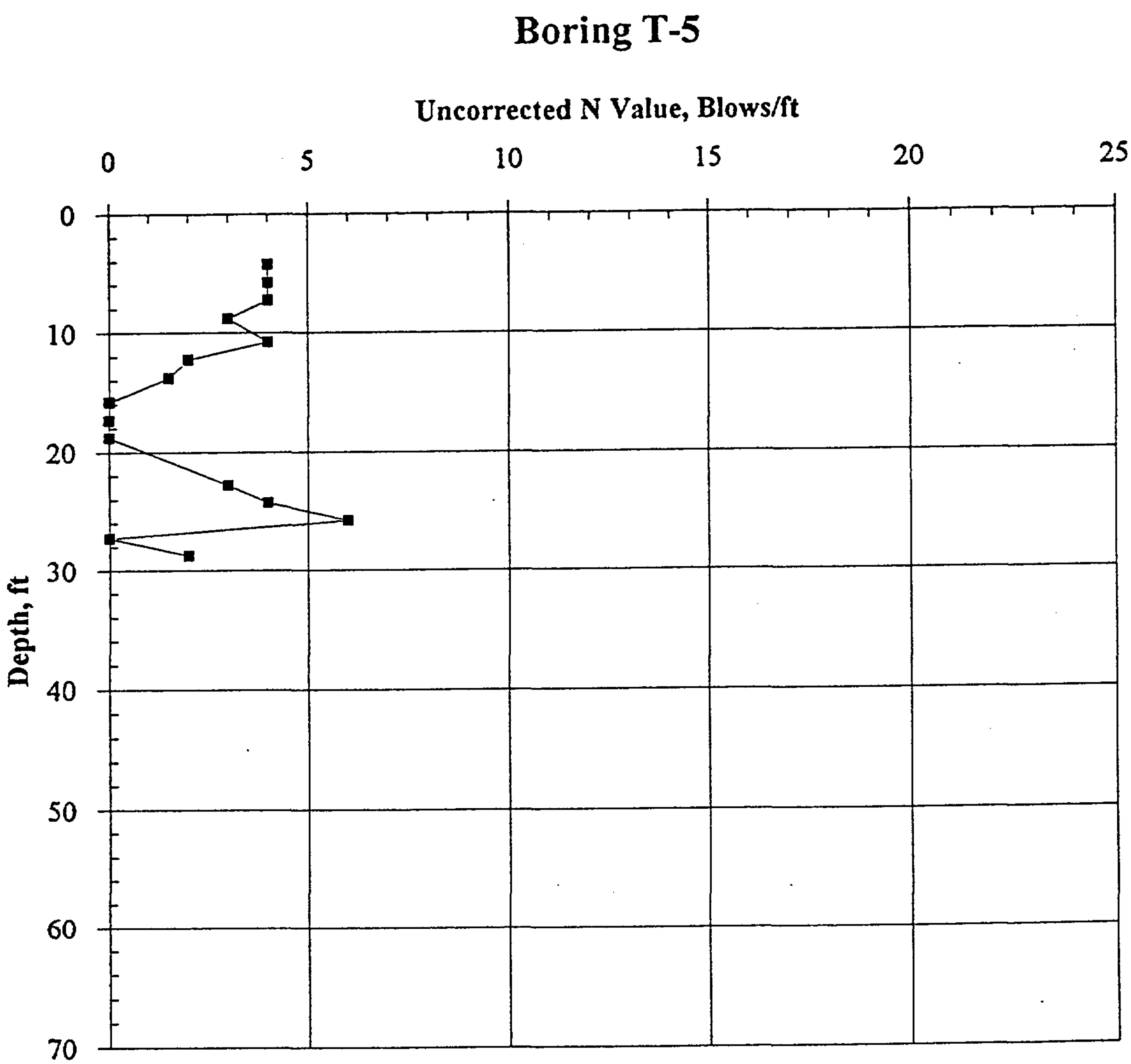
SHERWOOD TAILING IMPOUNDMENT

SPT RESULTS BORING T-4

Checked by [signature]	Date 5-4-94	Project No.	Figure No.
Approved by RLV	Date 5-5-94	SMI-100	B-4



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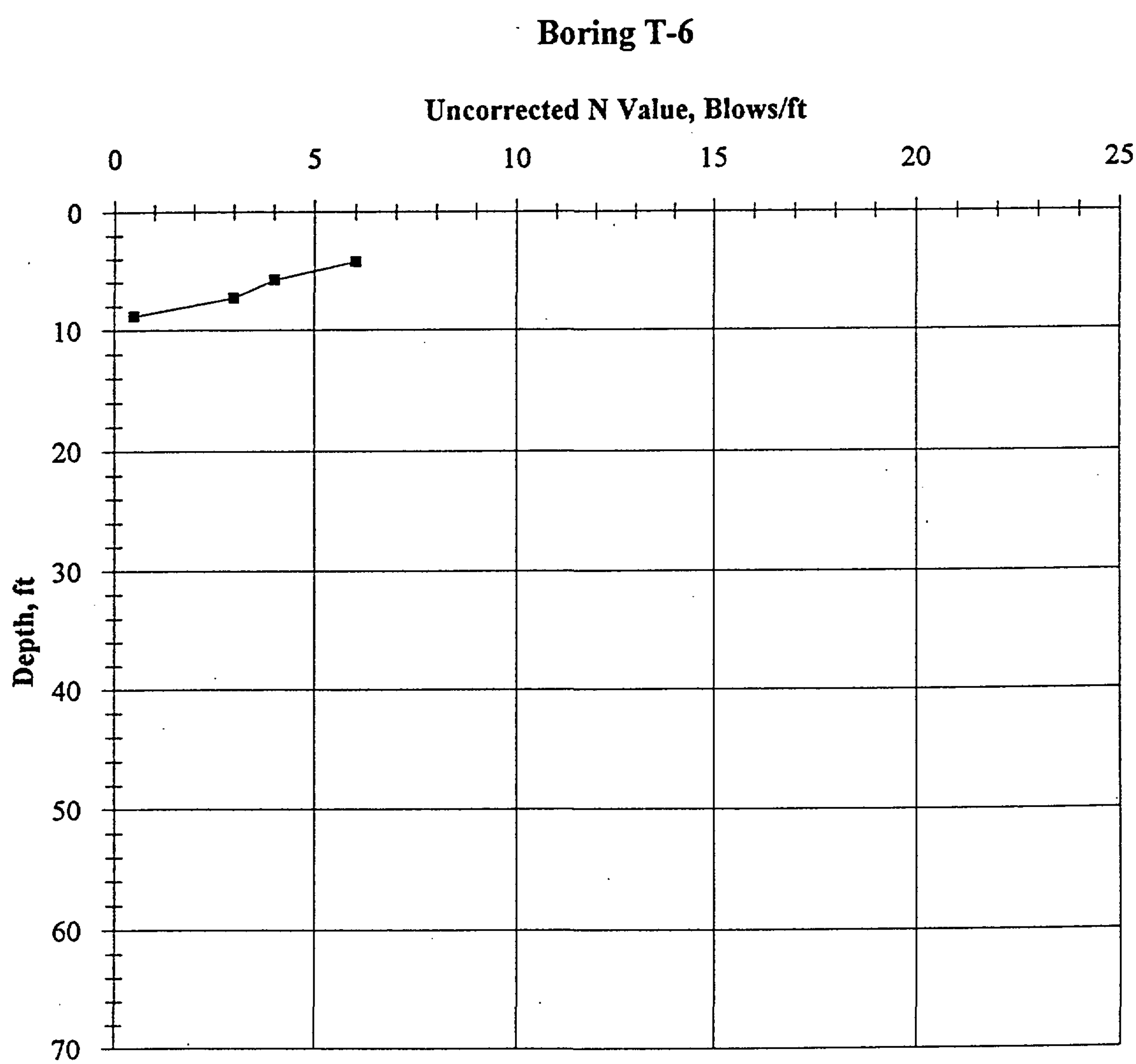
SPT RESULTS BORING T-5

Checked by	Date 5-4-94	Project No.	Figure No.
Approved by RLV	Date 5-5-94	SMI-100	B-5



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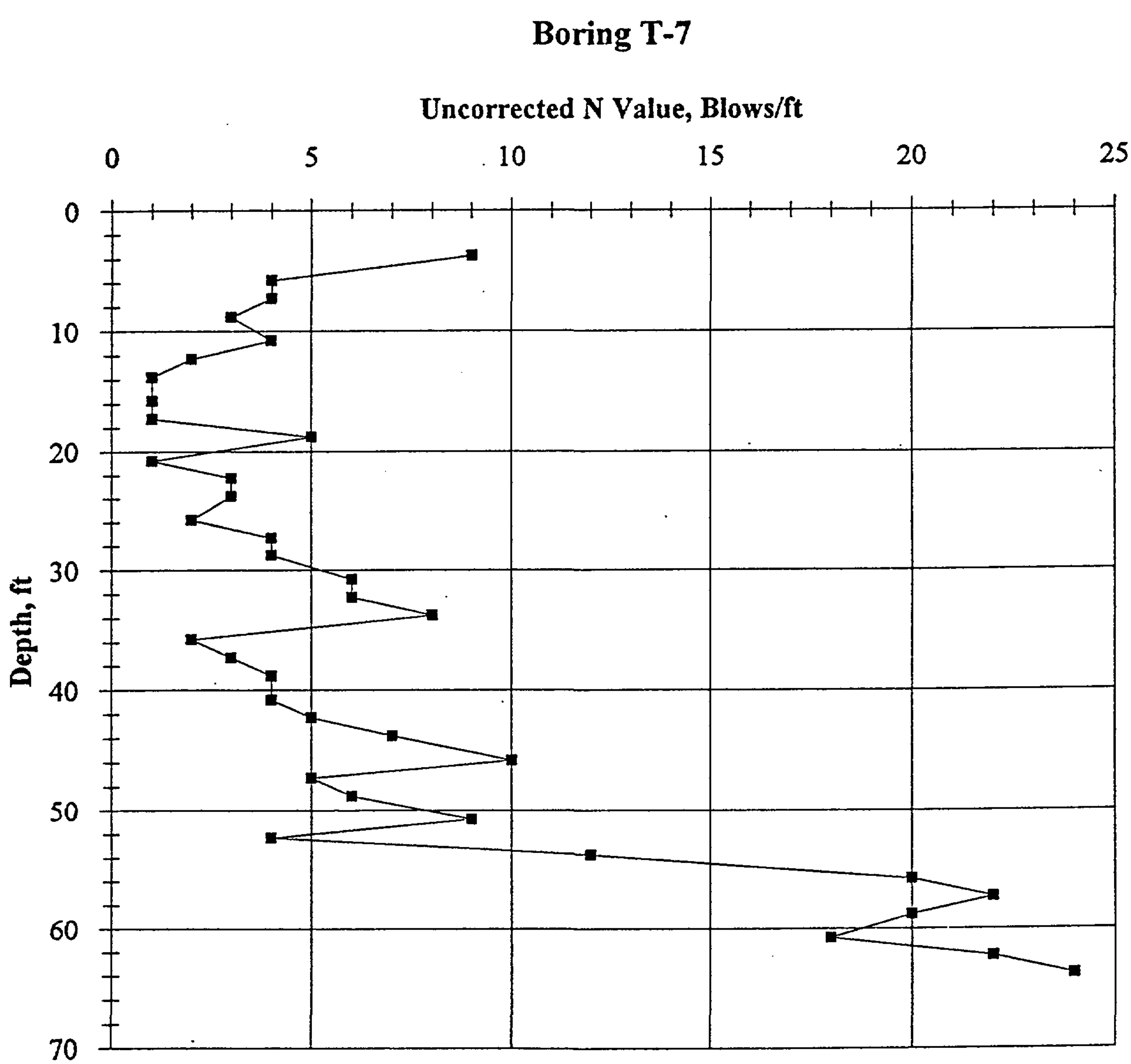
SHERWOOD TAILING IMPOUNDMENT

SPT RESULTS BORING T-6

Checked by [signature]	Date 5-4-94	Project No.	Figure No.
Approved by RLV	Date 5-5-94	SMI-100	B-6



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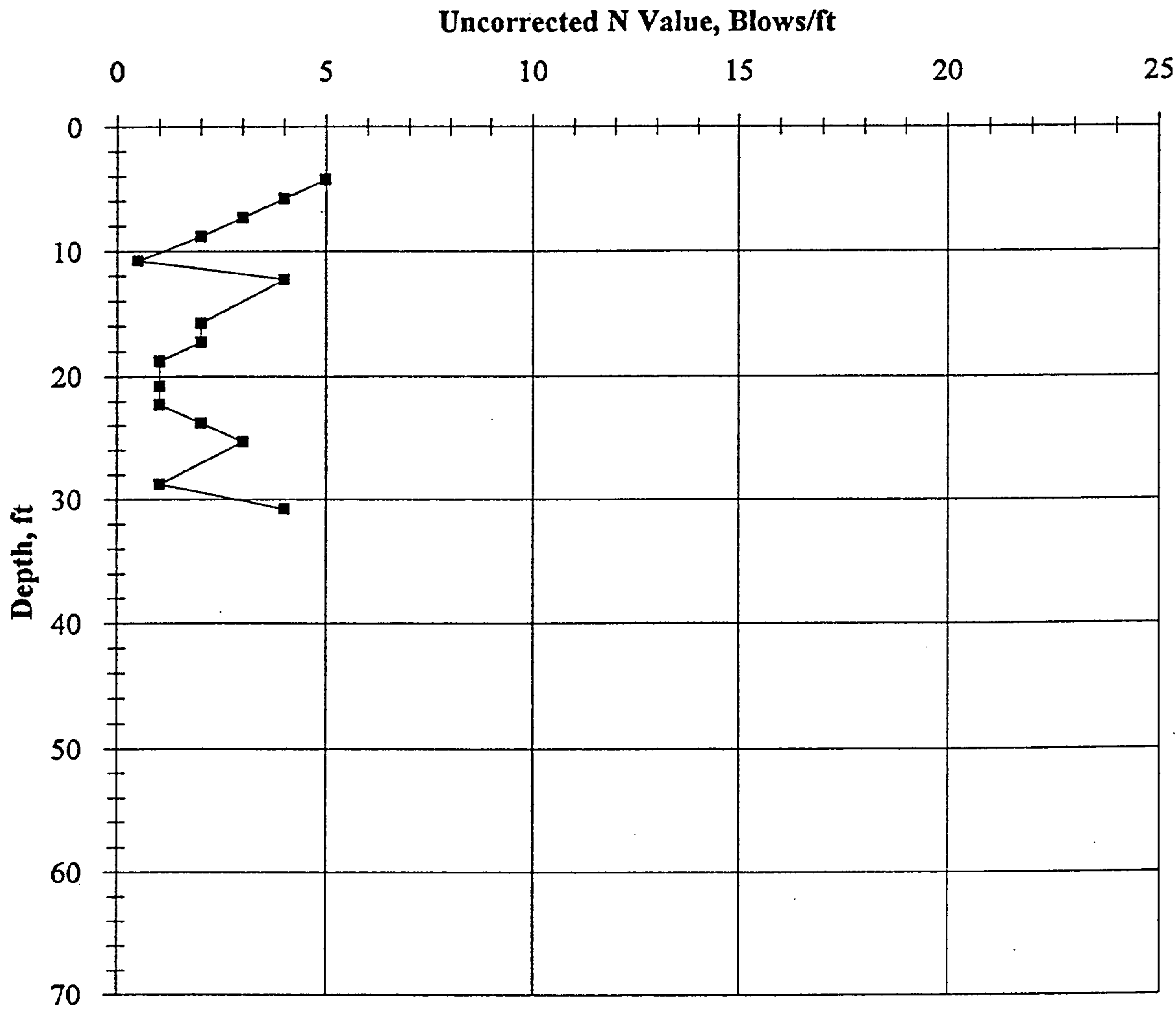
SHERWOOD TAILING IMPOUNDMENT

SPT RESULTS BORING T-7

Checked by ___ Date 5-4-94	Project No.	Figure No.
Approved by RLV Date 5-5-94	SMI-100	B-7

Boring T-8



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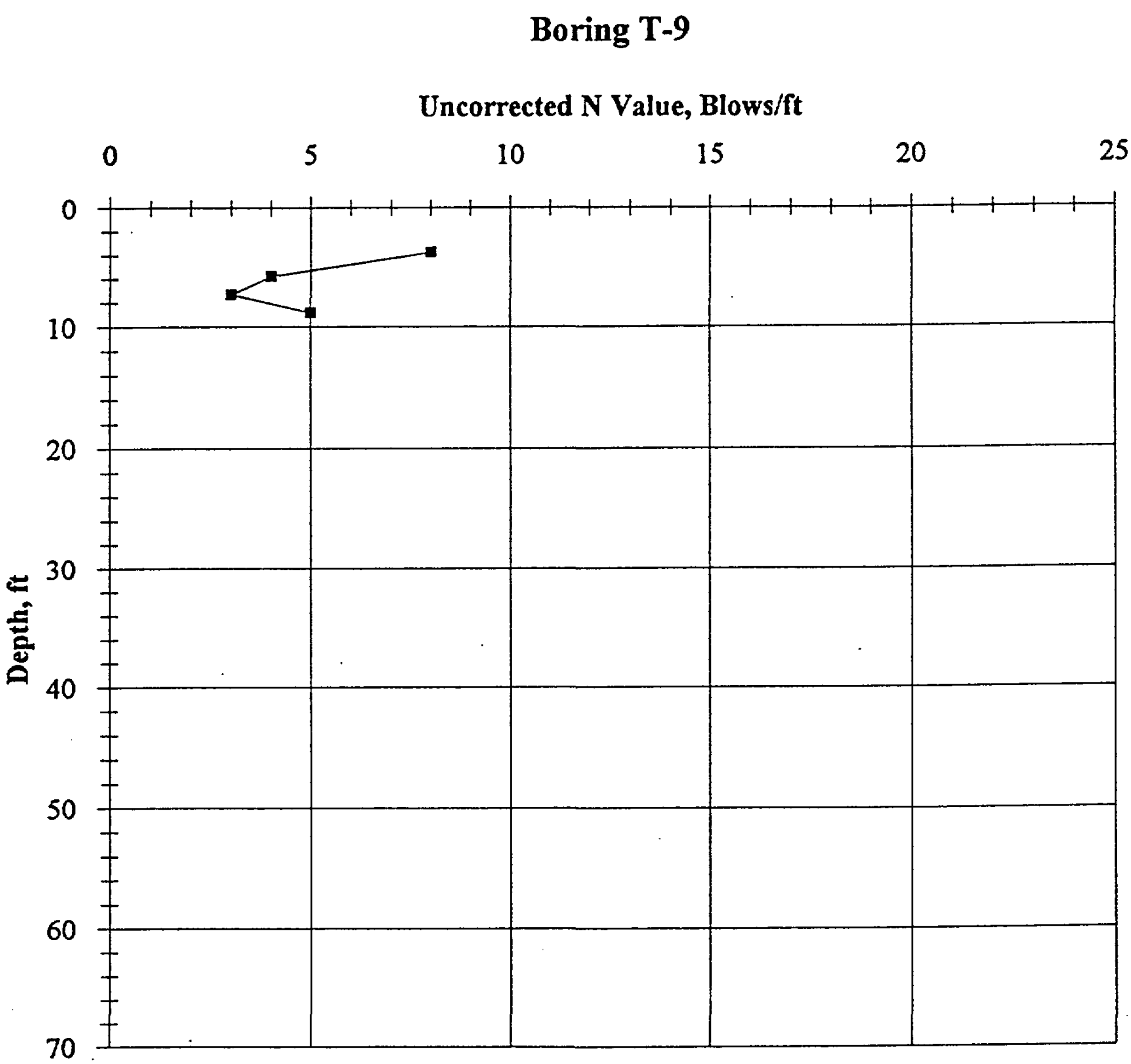
SHERWOOD TAILING IMPOUNDMENT

SPT RESULTS BORING T-8

Checked by Jw	Date 5-4-94	Project No.	Figure No.
Approved by RLV	Date 5-5-94	SMI-100	B-8



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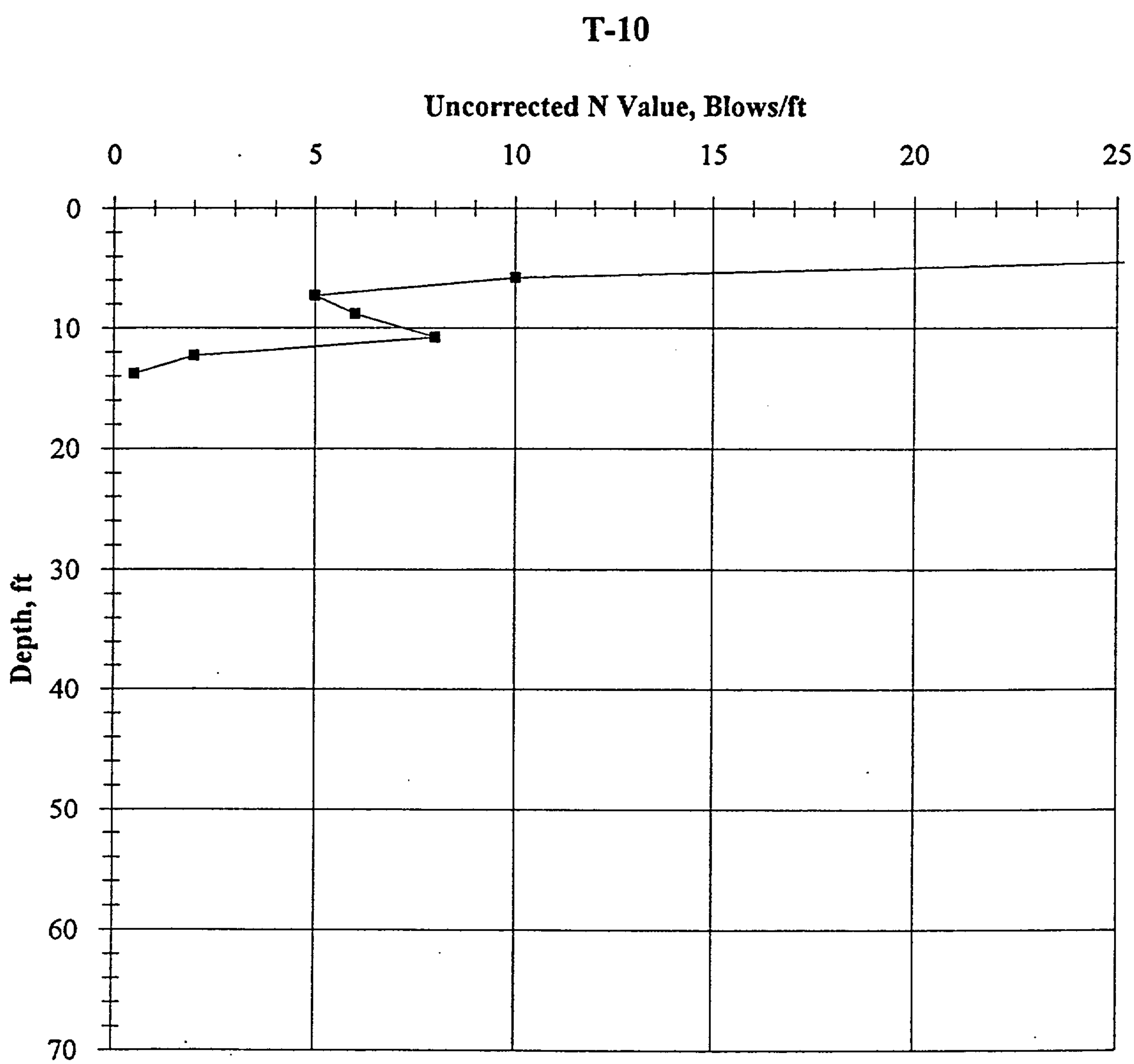
SPT RESULTS BORING T-9

Checked by	Date 5-4-94	Project No.	Figure No.
Approved by RLV	Date 5-5-94	SMI-100	B-9



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SHERWOOD TAILING IMPOUNDMENT

SPT RESULTS BORING T-10

Checked by *[signature]*	Date 5-4-94	Project No.	Figure No.
Approved by RLV	Date 5-5-94	SMI-100	B-10

Corrections to Obtain SPT-Equivalent Blow Counts

JOB NAME: SMI - Sherwood Tailings Impoundments
JOB NO.: SMI-1
BY: RLV 10/27/93

BOREHOLE	DEPTH (ft)	SPT or MOD. CAL.	UNCORRECTED BLOW COUNT N	SOIL TYPE	GRAVEL? Y=yes N=no	CORRECTION FACTORS MOD. CAL. (*.55)	DRILL ROD (*.75@<10')	HAMMER EFF. (*.75)	SPT w/o Liner (*1.2)	SILTS (add 7)	FINAL CORRECTED N	Effective Overburden (psf)	Cn	(N1)60
T-1	4.5	SPT	5	SM	N	5	4	3	3	10	10	504	1.60	17
	6	SPT	7	SM	N	7	5	4	5	12	12	671	1.60	19
	7.5	SPT	8	ML	N	8	6	5	5	12	12	839	1.38	17
	9	SPT	2	SM	N	2	2	1	1	8	8	1007	1.31	11
	11	SPT	3	SM	N	3	3	2	3	10	10	1159	1.24	12
	12.5	SPT	2	SM	N	2	2	2	2	9	9	1220	1.22	11
	14	SPT	1	ML	N	1	1	1	1	8	8	1281	1.20	9
T-2	4.5	SPT	5	SM	N	5	4	3	3	10	10	504	1.60	17
	6	SPT	4	SM	N	4	3	2	3	10	10	671	1.60	16
	7.5	SPT	3	SM	N	3	2	2	2	9	9	839	1.38	12
	9	SPT	0.5	SM	N	1	0	0	0	7	7	1007	1.31	10
	11	SPT	1	SM	N	1	1	1	1	8	8	1159	1.24	10
	12.5	SPT	3	SM	N	3	3	2	3	10	10	1220	1.22	12
	14	SPT	3	SM	N	3	3	2	3	10	10	1281	1.20	12
	16	SPT	3	SM	N	3	3	2	3	10	10	1361	1.17	11
	17.5	SPT	2	SM	N	2	2	2	2	9	9	1422	1.16	10
	21	SPT	1.5	ML	N	2	2	1	1	8	8	1573	1.11	9
	24.5	SPT	3	ML	N	3	3	2	3	10	10	1746	1.07	10

Corrections to Obtain SPT-Equivalent Blow Counts

JOB NAME: SMI - Sherwood Tailings Impoundments
JOB NO.: SMI-1
BY: RLV 10/27/93

BOREHOLE	DEPTH (ft)	SPT or MOD. CAL.	UNCORRECTED BLOW COUNT N	SOIL TYPE	GRAVEL? Y=yes N=no	CORRECTION FACTORS MOD. CAL. (*.55)	DRILL ROD (*.75@<10')	HAMMER EFF. (*.75)	SPT w/o Liner (*1.2)	SILTS (add 7)	FINAL CORRECTED N	Effective Overburden (psf)	Cn	(N1)60
T-3	4	SPT	3	SM	N	3	2	2	2	9	9	448	1.60	14
	5.5	SPT	3	SM	N	3	2	2	2	9	9	615	1.60	14
	7	SPT	2	SM	N	2	2	1	1	8	8	783	1.60	13
	9	SPT	0.5	SM	N	1	0	0	0	7	7	1007	1.31	10
	11	SPT	0.5	SM	N	1	1	0	0	7	7	1159	1.24	9
	13	SPT	0.5	SM	N	1	1	0	0	7	7	1240	1.21	9
	14.5	SPT	0.5	ML	N	1	1	0	0	7	7	1301	1.19	9
	16	SPT	0.5	ML	N	1	1	0	0	7	7	1361	1.17	9
	17.5	SPT	0.5	ML	N	1	1	0	0	7	7	1422	1.16	9
	19	SPT	0.5	ML	N	1	1	0	0	7	7	1483	1.14	8
	20.5	SPT	0.5	SM	N	1	1	0	0	7	7	1548	1.12	8
	22	SPT	0.5	SM	N	1	1	0	0	7	7	1622	1.10	8
	24	SPT	3	SM	N	3	3	2	3	10	10	1721	1.07	10
	29	SPT	4	SM	N	4	4	3	4	11	11	1969	1.02	11

Corrections to Obtain SPT-Equivalent Blow Counts

JOB NAME: SMI - Sherwood Tailings Impoundments
JOB NO.: SMI-1
BY: RLV 10/27/93

BOREHOLE	DEPTH (ft)	SPT or MOD. CAL.	UNCORRECTED BLOW COUNT N	SOIL TYPE	GRAVEL? Y=yes N=no	CORRECTION FACTORS MOD. CAL. (*.55)	DRILL ROD (*.75@<10')	HAMMER EFF. (*.75)	SPT w/o Liner (*1.2)	SILTS (add 7)	FINAL CORRECTED N	Effective Overburden (psf)	Cn	(N1)60
T-4	4.5	SPT	6	SM	N	6	5	3	4	11	11	504	1.60	18
	6	SPT	4	SM	N	4	3	2	3	10	10	671	1.60	16
	7.5	SPT	2	SM	N	2	2	1	1	8	8	839	1.38	12
	9	SPT	3	SM	N	3	2	2	2	9	9	1007	1.31	12
	11	SPT	1	ML	N	1	1	1	1	8	8	1159	1.24	10
	12.5	SPT	1	ML	N	1	1	1	1	8	8	1220	1.22	10
	14	SPT	1	ML	N	1	1	1	1	8	8	1281	1.20	9
	16	SPT	2	SM	N	2	2	2	2	9	9	1361	1.17	10
	17.5	SPT	0	SM	N	0	0	0	0	7	7	1422	1.16	8
	19	SPT	1	ML	N	1	1	1	1	8	8	1483	1.14	9
	21	SPT	0	SM	N	0	0	0	0	7	7	1573	1.11	8
	22.5	SPT	1	SM	N	1	1	1	1	8	8	1647	1.09	9
	24	SPT	4	SM	N	4	4	3	4	11	11	1721	1.07	11
	26	SPT	4	SM	N	4	4	3	4	11	11	1820	1.05	11
	29	SPT	4	SM	N	4	4	3	4	11	11	1969	1.02	11
	31	SPT	6	SM	N	6	6	5	5	12	12	2068	0.99	12
	32.5	SPT	6	SM	N	6	6	5	5	12	12	2142	0.98	12
	34	SPT	16	SM	N	16	16	12	14	21	21	2216	0.96	21
	36	SPT	14	SM	N	14	14	11	13	20	20	2315	0.94	19
	37.5	SPT	13	SM	N	13	13	10	12	19	19	2389	0.93	17
	39	SPT	17	SM	N	17	17	13	15	22	22	2464	0.92	20
	41	SPT	14	SM	N	14	14	11	13	20	20	2563	0.90	18
	42.5	SPT	18	SM	N	18	18	14	16	23	23	2637	0.89	21
	44	SPT	13	ML	N	13	13	10	12	19	19	2711	0.88	16
	48	SPT	16	ML	N	16	16	12	14	21	21	2882	0.85	18
	49.5	SPT	15	ML	N	15	15	11	14	21	21	2943	0.84	17
	51	SPT	14	ML	N	14	14	11	13	20	20	3003	0.83	16
	52.5	SPT	12	ML	N	12	12	9	11	18	18	3064	0.82	15
	54	SPT	8	ML	N	8	8	6	7	14	14	3125	0.82	12
	56	SPT	12	ML	N	12	12	9	11	18	18	3205	0.80	14
	57.5	SPT	11	ML	N	11	11	8	10	17	17	3266	0.80	13
	61	SPT	24	ML	N	24	24	18	22	29	29	3407	0.78	22
	62.5	SPT	12	ML	N	12	12	9	11	18	18	3468	0.77	14
	64	SPT	10	SM	N	10	10	8	9	16	16	3529	0.76	12

$(N_1)_{60}$ Calculations
Sheet 3 of 6

Corrections to Obtain SPT-Equivalent Blow Counts

JOB NAME: SMI - Sherwood Tailings Impoundments
JOB NO.: SMI-1
BY: RLV 10/27/93

BOREHOLE	DEPTH (ft)	SPT or MOD. CAL.	UNCORRECTED BLOW COUNT N	SOIL TYPE	GRAVEL? Y=yes N=no	CORRECTION FACTORS MOD. CAL. (*.55)	DRILL ROD (*.75@<10')	HAMMER EFF. (*.75)	SPT w/o Liner (*1.2)	SILTS (add 7)	FINAL CORRECTED N	Effective Overburden (psf)	Cn	(N1)60
T-5	4.5	SPT	4	SM	N	4	3	2	3	10	10	504	1.60	16
	6	SPT	4	ML	N	4	3	2	3	10	10	671	1.60	16
	7.5	SPT	4	ML	N	4	3	2	3	10	10	839	1.38	13
	9	SPT	3	SM	N	3	2	2	2	9	9	1007	1.31	12
	11	SPT	4	SM	N	4	4	3	4	11	11	1159	1.24	13
	12.5	SPT	2	ML	N	2	2	2	2	9	9	1220	1.22	11
	14	SPT	1.5	ML	N	2	2	1	1	8	8	1281	1.20	10
	16	SPT	0	ML	N	0	0	0	0	7	7	1361	1.17	8
	17.5	SPT	0	ML	N	0	0	0	0	7	7	1422	1.16	8
	19	SPT	0	ML	N	0	0	0	0	7	7	1483	1.14	8
	23	SPT	3	SM	N	3	3	2	3	10	10	1672	1.09	11
	24.5	SPT	4	SM	N	4	4	3	4	11	11	1746	1.07	11
	26	SPT	6	SM	N	6	6	5	5	12	12	1820	1.05	13
	27.5	SPT	0	SM	N	0	0	0	0	7	7	1894	1.03	7
	29	SPT	2	SP-SM	N	2	2	2	2	2	2	1969	1.02	2
T-6	4.5	SPT	6	SM	N	6	5	3	4	11	11	504	1.60	18
	6	SPT	4	SM	N	4	3	2	3	10	10	671	1.60	16
	7.5	SPT	3	SM	N	3	2	2	2	9	9	839	1.38	12
	9	SPT	0.5	ML	N	1	0	0	0	7	7	1007	1.31	10

Corrections to Obtain SPT-Equivalent Blow Counts

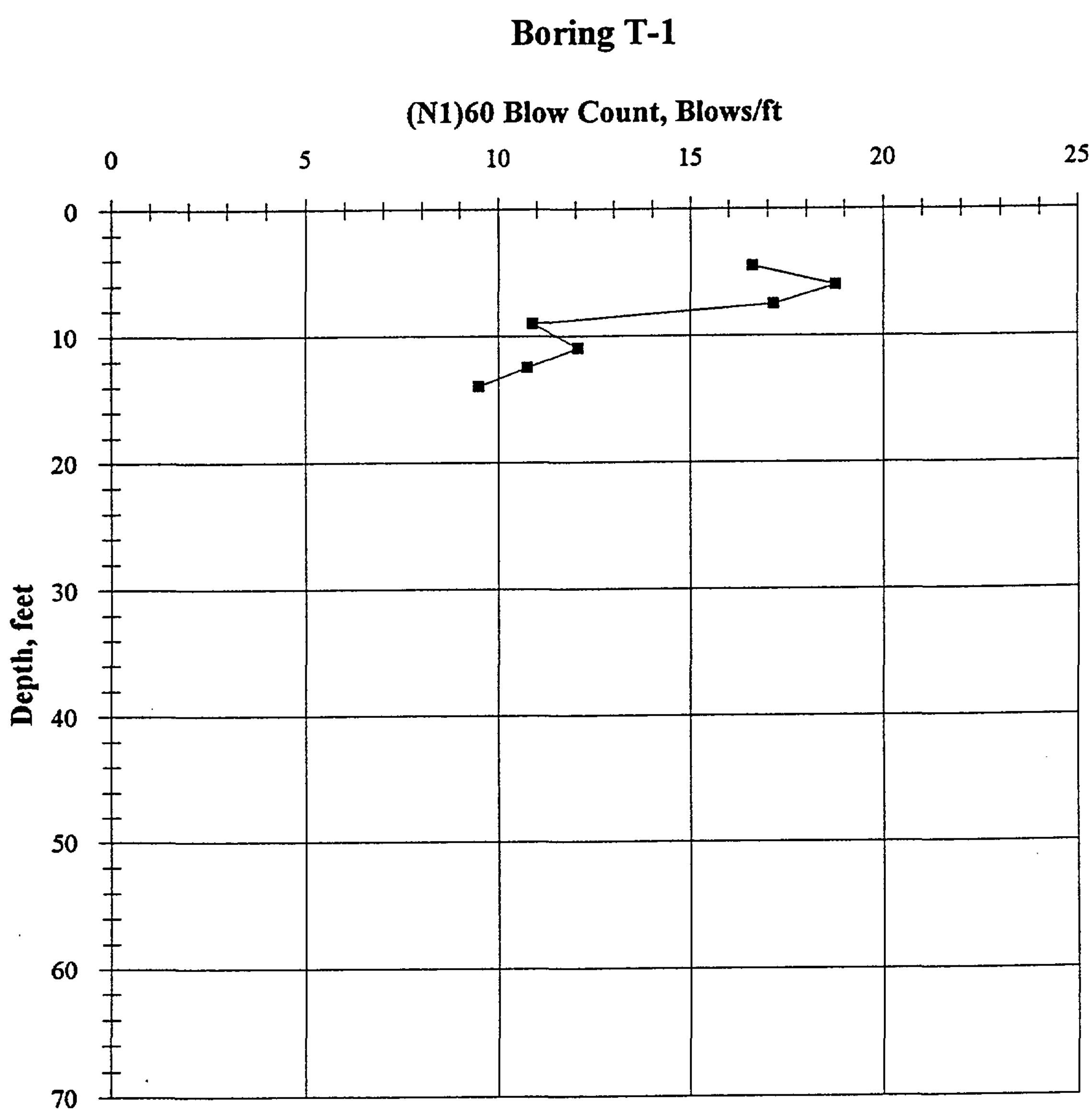
JOB NAME: SMI - Sherwood Tailings Impoundments
JOB NO.: SMI-1
BY: RLV 10/27/93

BOREHOLE	DEPTH (ft)	SPT or MOD. CAL.	UNCORRECTED BLOW COUNT N	SOIL TYPE	GRAVEL? Y=yes N=no	CORRECTION FACTORS MOD. CAL. (*.55)	DRILL ROD (*.75@<10')	HAMMER EFF. (*.75)	SPT w/o Liner (*1.2)	SILTS (add 7)	FINAL CORRECTED N	Effective Overburden (psf)	Cn	(N1)60
T-7	4	SPT	9	SM	N	9	7	5	6	13	13	448	1.60	21
	6	SPT	4	SM	N	4	3	2	3	10	10	671	1.60	16
	7.5	SPT	4	SM	N	4	3	2	3	10	10	839	1.38	13
	9	SPT	3	ML	N	3	2	2	2	9	9	1007	1.31	12
	11	SPT	4	ML	N	4	4	3	4	11	11	1159	1.24	13
	12.5	SPT	2	ML	N	2	2	2	2	9	9	1220	1.22	11
	14	SPT	1	ML	N	1	1	1	1	8	8	1281	1.20	9
	16	SPT	1	SM	N	1	1	1	1	8	8	1361	1.17	9
	17.5	SPT	1	ML	N	1	1	1	1	8	8	1422	1.16	9
	19	SPT	5	ML	N	5	5	4	5	12	12	1483	1.14	13
	21	SPT	1	SM	N	1	1	1	1	8	8	1573	1.11	9
	22.5	SPT	3	SM	N	3	3	2	3	10	10	1647	1.09	11
	24	SPT	3	SM	N	3	3	2	3	10	10	1721	1.07	10
	26	SPT	2	ML	N	2	2	2	2	9	9	1820	1.05	9
	27.5	SPT	4	SM	N	4	4	3	4	11	11	1894	1.03	11
	29	SPT	4	ML	N	4	4	3	4	11	11	1969	1.02	11
	31	SPT	6	ML	N	6	6	5	5	12	12	2068	0.99	12
	32.5	SPT	6	SM	N	6	6	5	5	12	12	2142	0.98	12
	34	SPT	8	SM	N	8	8	6	7	14	14	2216	0.96	14
	36	SPT	2	SM	N	2	2	2	2	9	9	2315	0.94	8
	37.5	SPT	3	SM	N	3	3	2	3	10	10	2389	0.93	9
	39	SPT	4	ML	N	4	4	3	4	11	11	2464	0.92	10
	41	SPT	4	ML	N	4	4	3	4	11	11	2563	0.90	10
	42.5	SPT	5	ML	N	5	5	4	5	12	12	2637	0.89	10
	44	SPT	7	ML	N	7	7	5	6	13	13	2711	0.88	12
	46	SPT	10	ML	N	10	10	8	9	16	16	2801	0.86	14
	47.5	SPT	5	ML	N	5	5	4	5	12	12	2862	0.85	10
	49	SPT	6	ML	N	6	6	5	5	12	12	2923	0.84	10
	51	SPT	9	ML	N	9	9	7	8	15	15	3003	0.83	13
	52.5	SPT	4	ML	N	4	4	3	4	11	11	3064	0.82	9
	54	SPT	12	ML	N	12	12	9	11	18	18	3125	0.82	15
	56	SPT	20	SM	N	20	20	15	18	25	25	3205	0.80	20
	57.5	SPT	22	SM	N	22	22	17	20	27	27	3266	0.80	21
	59	SPT	20	SM	N	20	20	15	18	25	25	3327	0.79	20
	61	SPT	18	ML	N	18	18	14	16	23	23	3407	0.78	18
	62.5	SPT	22	ML	N	22	22	17	20	27	27	3468	0.77	21
	64	SPT	24	ML	N	24	24	18	22	29	29	3529	0.76	22

Corrections to Obtain SPT-Equivalent Blow Counts

JOB NAME: SMI - Sherwood Tailings Impoundments
JOB NO.: SMI-1
BY: RLV 10/27/93

BOREHOLE	DEPTH (ft)	SPT or MOD. CAL.	UNCORRECTED BLOW COUNT N	SOIL TYPE	GRAVEL? Y=yes N=no	CORRECTION FACTORS MOD. CAL. (*.55)	DRILL ROD (*.75@<10')	HAMMER EFF. (*.75)	SPT w/o Liner (*1.2)	SILTS (add 7)	FINAL CORRECTED N	Effective Overburden (psf)	Cn	(N1)60
T-8	4.5	SPT	5	SM	N	5	4	3	3	10	10	504	1.60	17
	6	SPT	4	SM	N	4	3	2	3	10	10	671	1.60	16
	7.5	SPT	3	ML	N	3	2	2	2	9	9	839	1.38	12
	9	SPT	2	SM	N	2	2	1	1	8	8	1007	1.31	11
	11	SPT	0.5	ML	N	1	1	0	0	7	7	1159	1.24	9
	12.5	SPT	4	ML	N	4	4	3	4	11	11	1220	1.22	13
	16	SPT	2	SM	N	2	2	2	2	9	9	1361	1.17	10
	17.5	SPT	2	SM	N	2	2	2	2	9	9	1422	1.16	10
	19	SPT	1	ML	N	1	1	1	1	8	8	1483	1.14	9
	21	SPT	1	ML	N	1	1	1	1	8	8	1573	1.11	9
	22.5	SPT	1	SM	N	1	1	1	1	8	8	1647	1.09	9
	24	SPT	2	ML	N	2	2	2	2	9	9	1721	1.07	9
	25.5	SPT	3	ML	N	3	3	2	3	10	10	1795	1.05	10
	29	SPT	1	ML	N	1	1	1	1	8	8	1969	1.02	8
	31	SPT	4	ML	N	4	4	3	4	11	11	2068	0.99	11
T-9	4	SPT	8	SM	N	8	6	5	5	12	12	448	1.60	20
	6	SPT	4	SM	N	4	3	2	3	10	10	671	1.60	16
	7.5	SPT	3	SM	N	3	2	2	2	9	9	839	1.38	12
	9	SPT	5	SM	N	5	4	3	3	10	10	1007	1.31	14
T-10	4.5	SPT	28	SM	N	28	21	16	19	26	26	504	1.60	41
	6	SPT	10	SM	N	10	8	6	7	14	14	671	1.60	22
	7.5	SPT	5	SM	N	5	4	3	3	10	10	839	1.38	14
	9	SPT	6	ML	N	6	5	3	4	11	11	1007	1.31	14
	11	SPT	8	ML	N	8	8	6	7	14	14	1159	1.24	18
	12.5	SPT	2	SM	N	2	2	2	2	9	9	1220	1.22	11
	14	SPT	1	SM	N	1	1	1	1	8	8	1281	1.20	9



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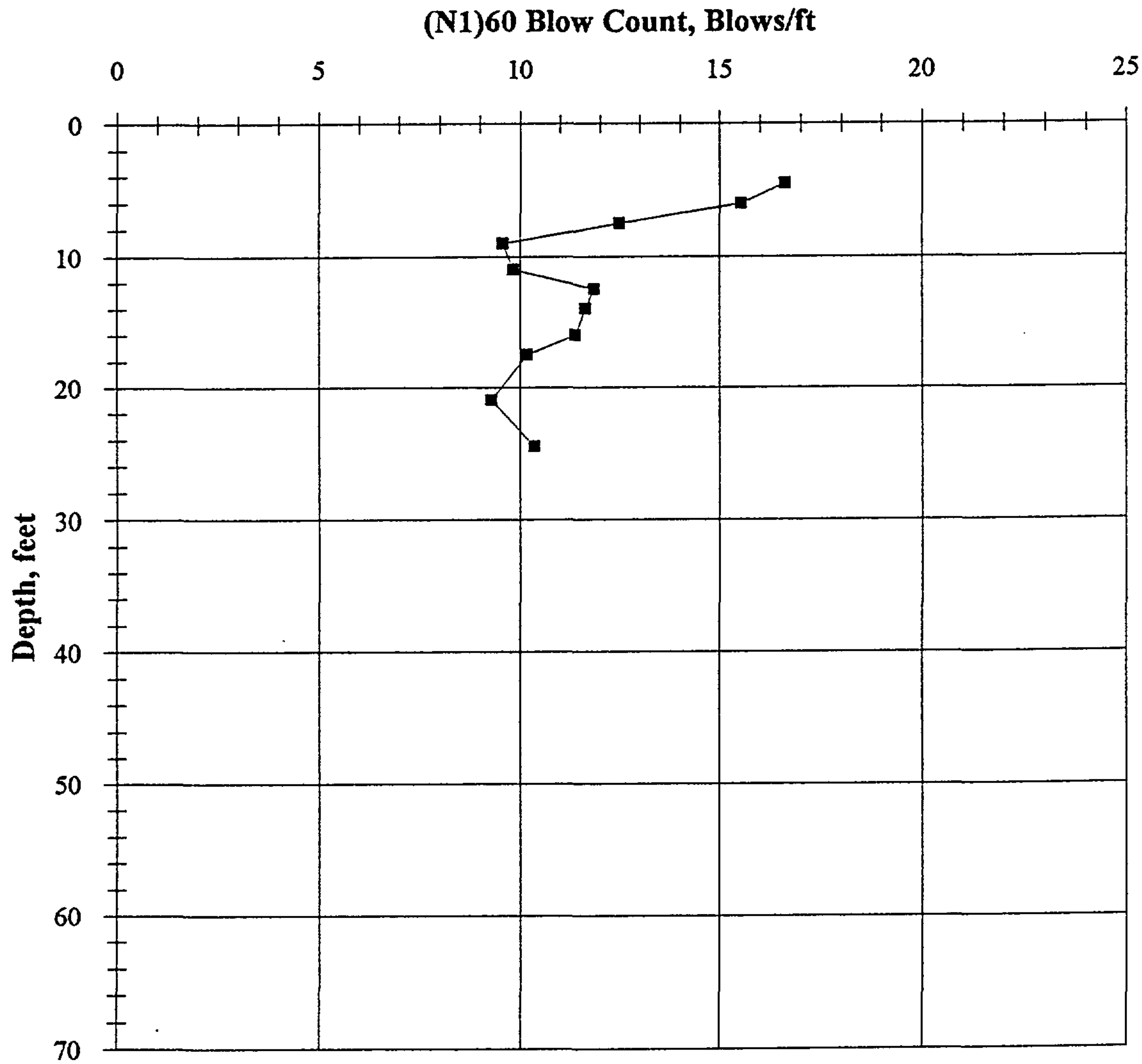
SHERWOOD TAILING IMPOUNDMENT

$(N_1)_{60}$ RESULTS BORING T-1

Checked by	Date 5-4-94	Project No.	Figure No.
Approved by RLV	Date 5-5-94	SMI-100	B-11

Boring T-2



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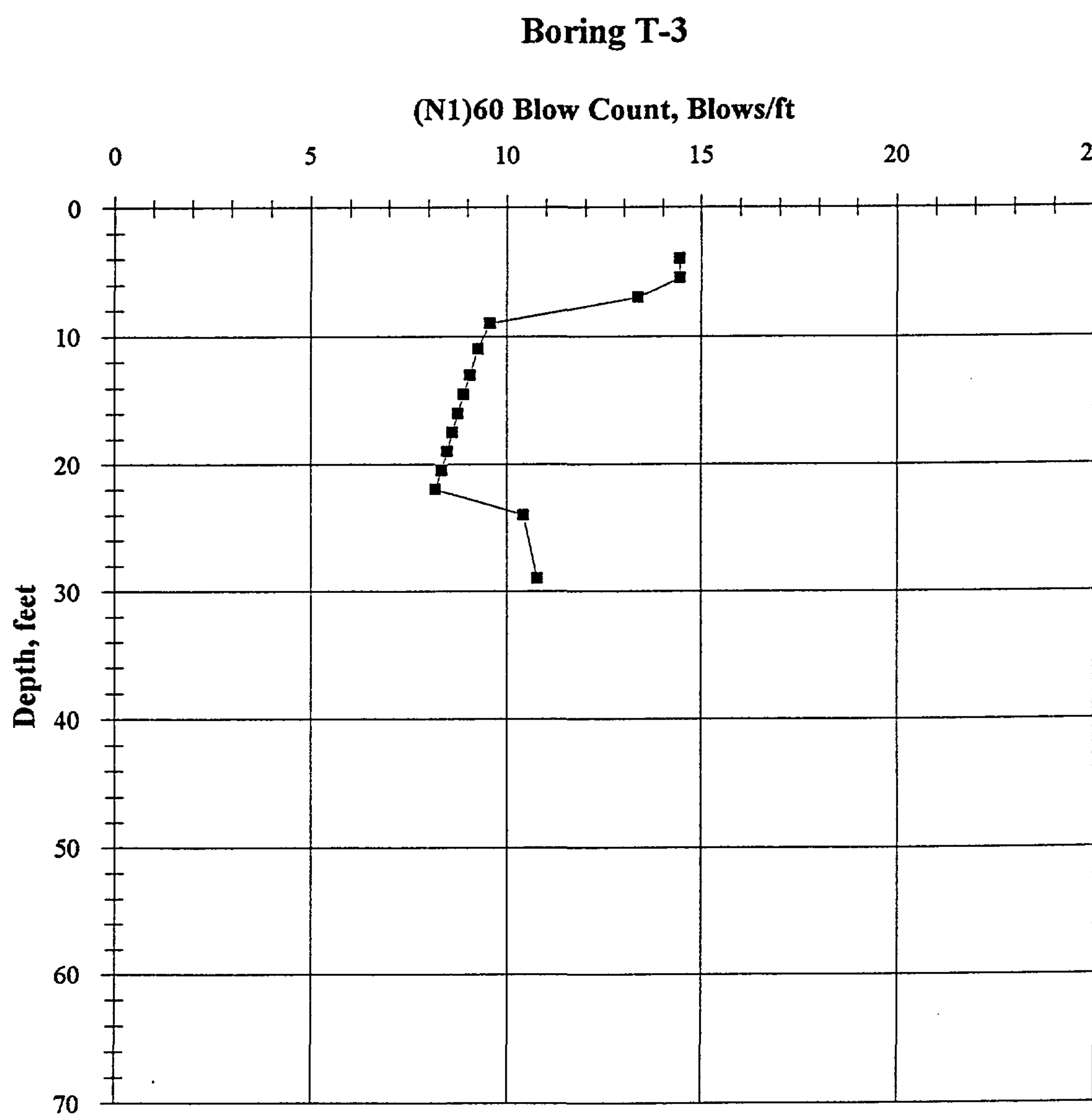
SHERWOOD TAILING IMPOUNDMENT

$(N_1)_{60}$ RESULTS BORING T-2

Checked by	Date 5-4-94	Project No.	Figure No.
Approved by RLV	Date 5-5-94	SMI-100	



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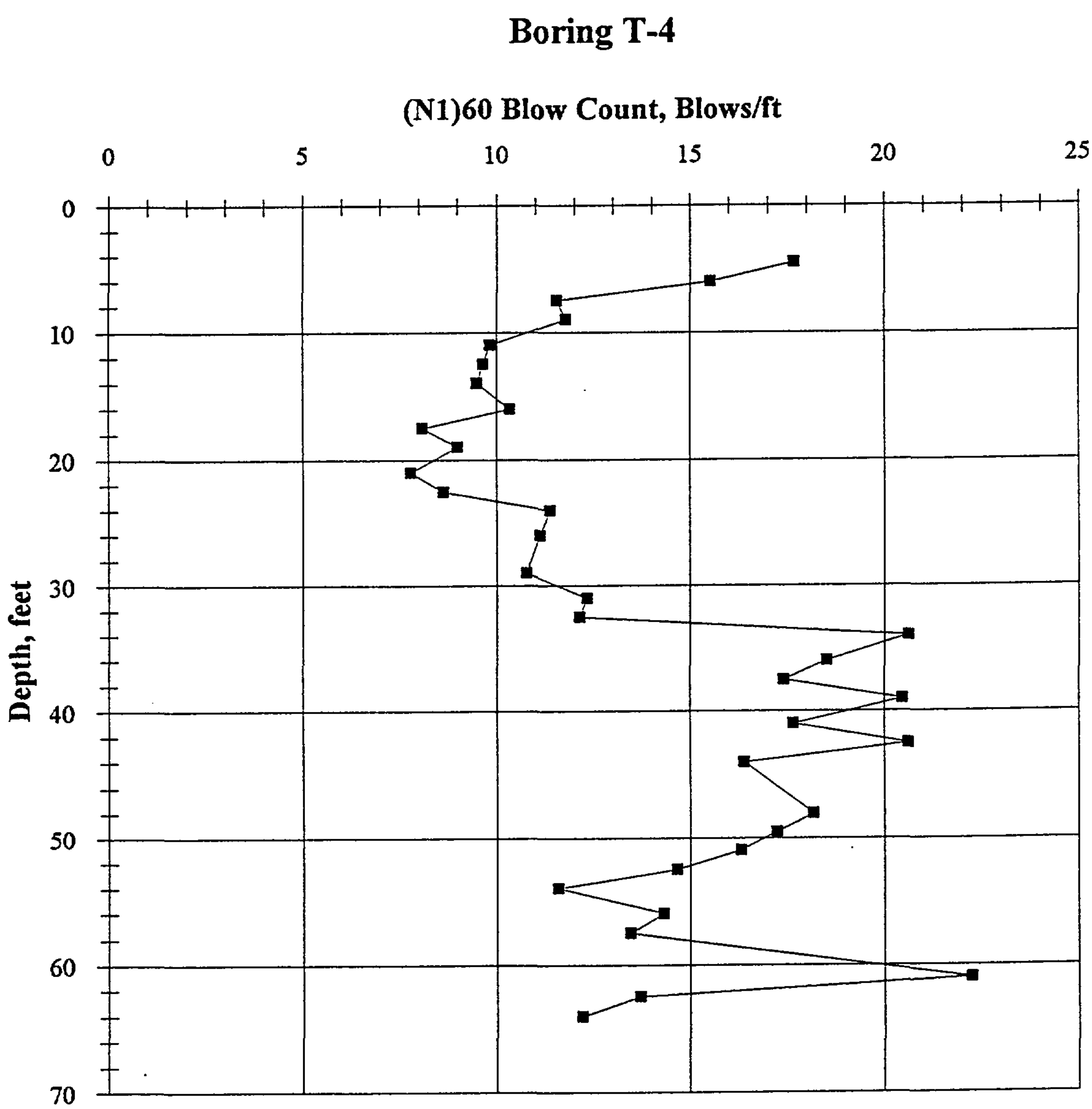
SHERWOOD TAILING IMPOUNDMENT

$(N_1)_{60}$ RESULTS BORING T-3

Checked by [signature]	Date 5-4-94	Project No.	Figure No. B-13
Approved by RLV	Date 5-5-94	SMI-100	



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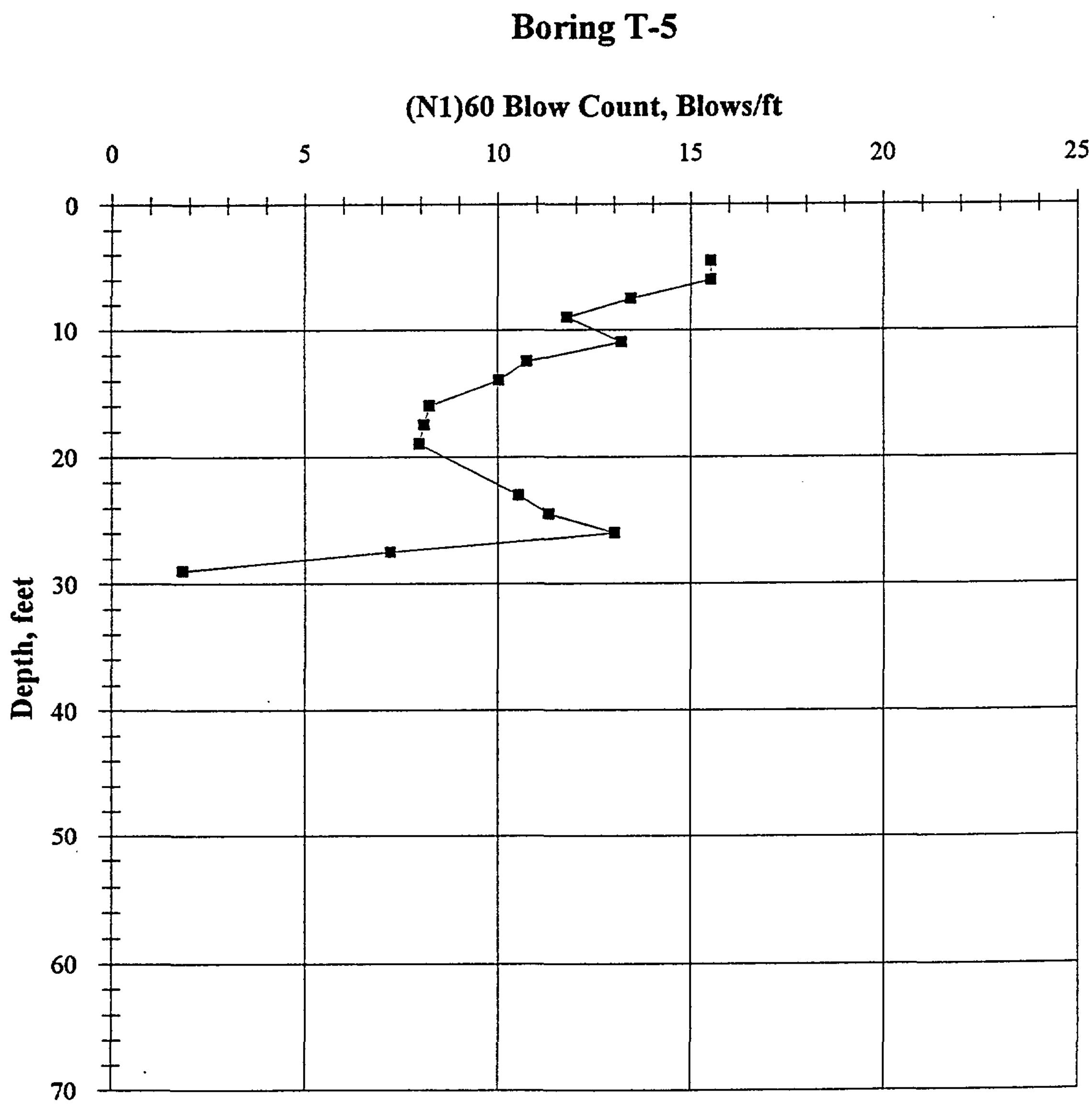
SHERWOOD TAILING IMPOUNDMENT $(N_1)_{60}$ RESULTS BORING T-4		
Checked by Jw Date 5-4-94 Approved by RLV Date 5-5-94	Project No. SMI-100	Figure No. B-14



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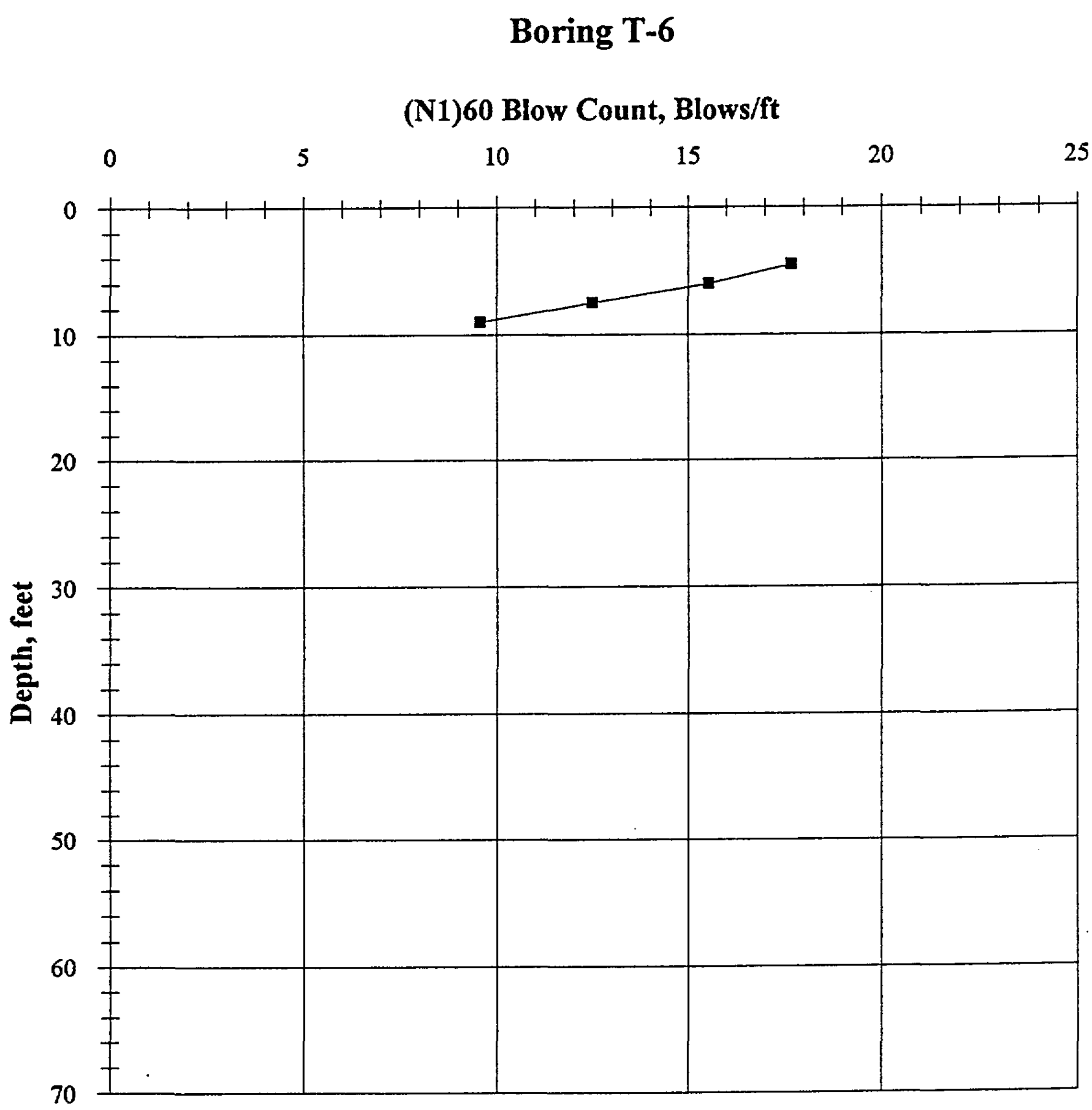
SHERWOOD TAILING IMPOUNDMENT

$(N_1)_{60}$ RESULTS BORING T-5

Checked by	Date 5-4-94	Project No.	Figure No.
Approved by RLV	Date 5-5-94	SMI-100	B-15



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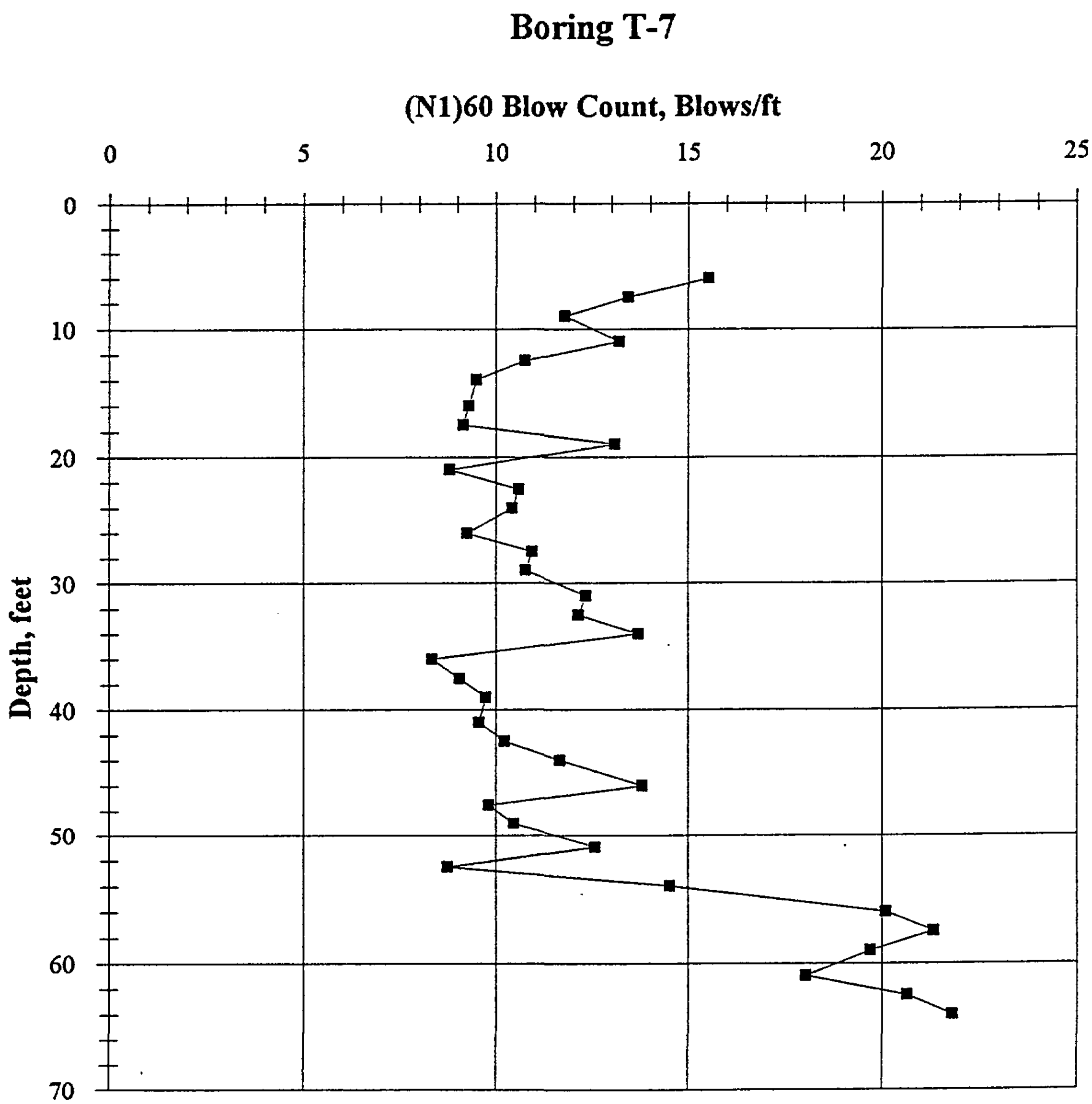
SHERWOOD TAILING IMPOUNDMENT $(N_1)_{60}$ RESULTS BORING T-6			
Checked by [signature]	Date 5-4-94	Project No.	Figure No.
Approved by RLV	Date 5-5-94	SMI-100	B-16



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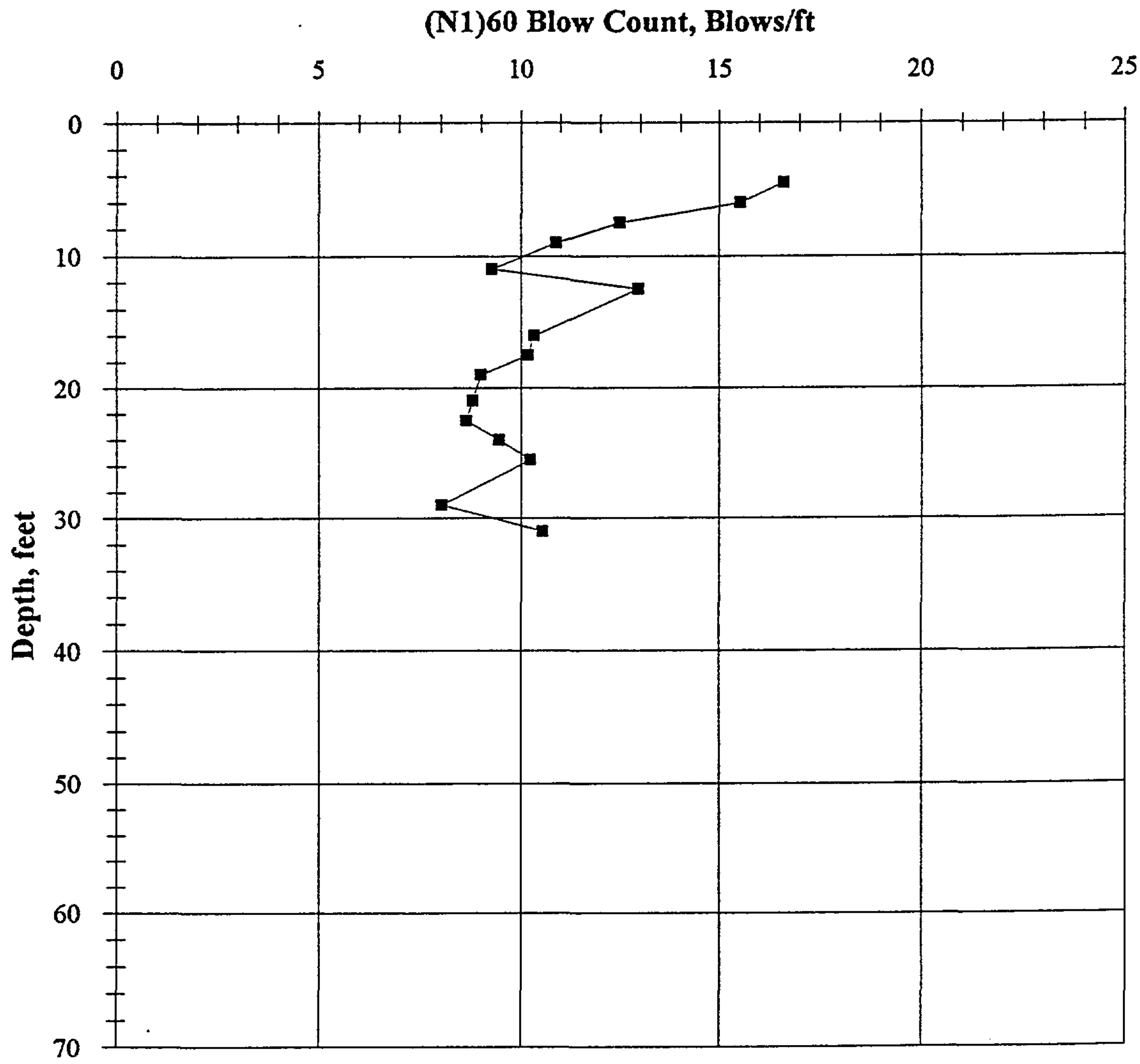
SHERWOOD TAILING IMPOUNDMENT

$(N_1)_{60}$ RESULTS BORING T-7

		Project No.	Figure No.
Checked by [signature]	Date 5-4-94		
Approved by RLV	Date 5-5-94	SMI-100	B-17

Boring T-8



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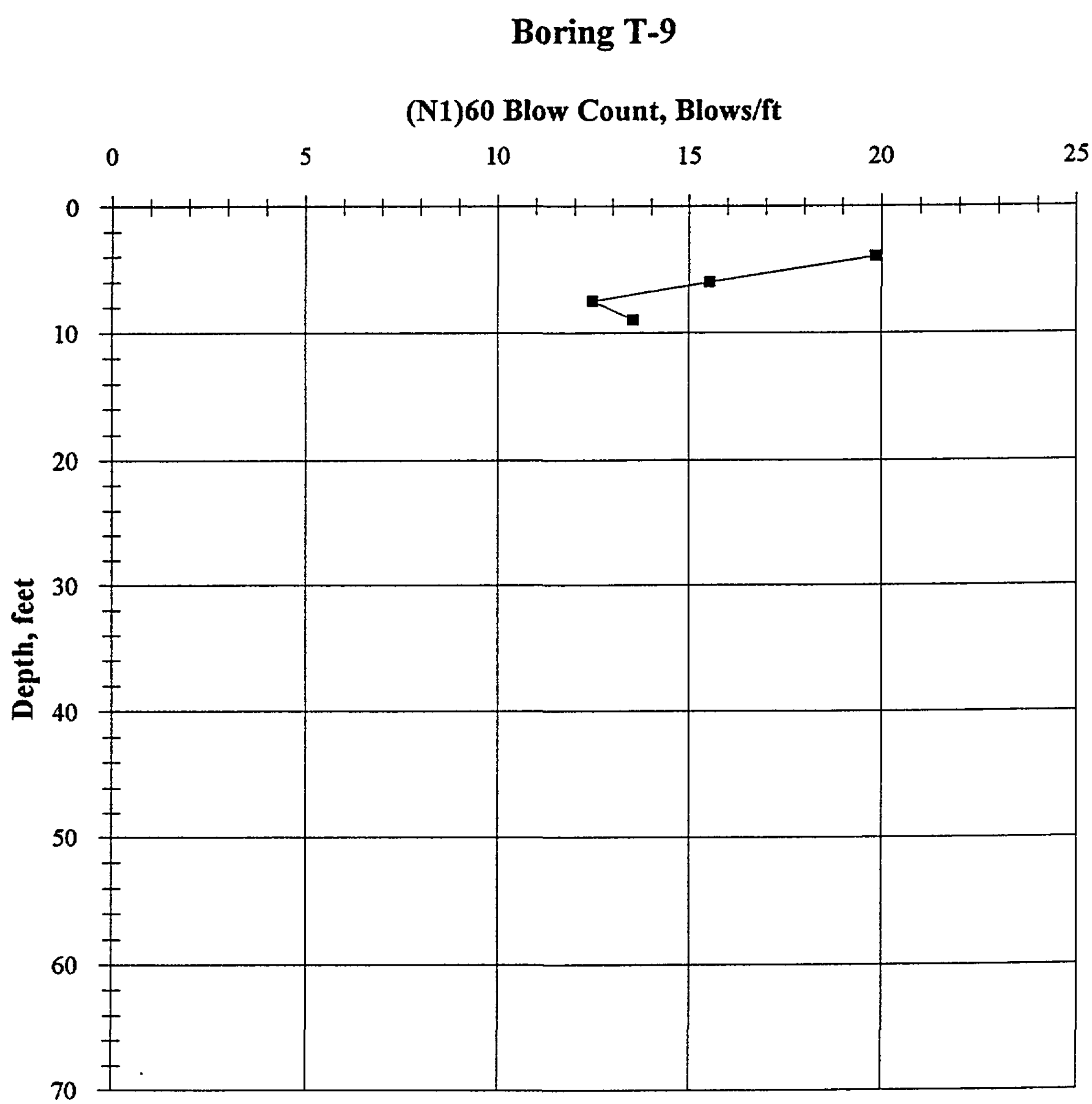
SHERWOOD TAILING IMPOUNDMENT

$(N_1)_{60}$ RESULTS BORING T-8

Checked by	Date 5-4-94	Project No.	Figure No.
Approved by RLV	Date 5-5-94	SMI-100	B-18



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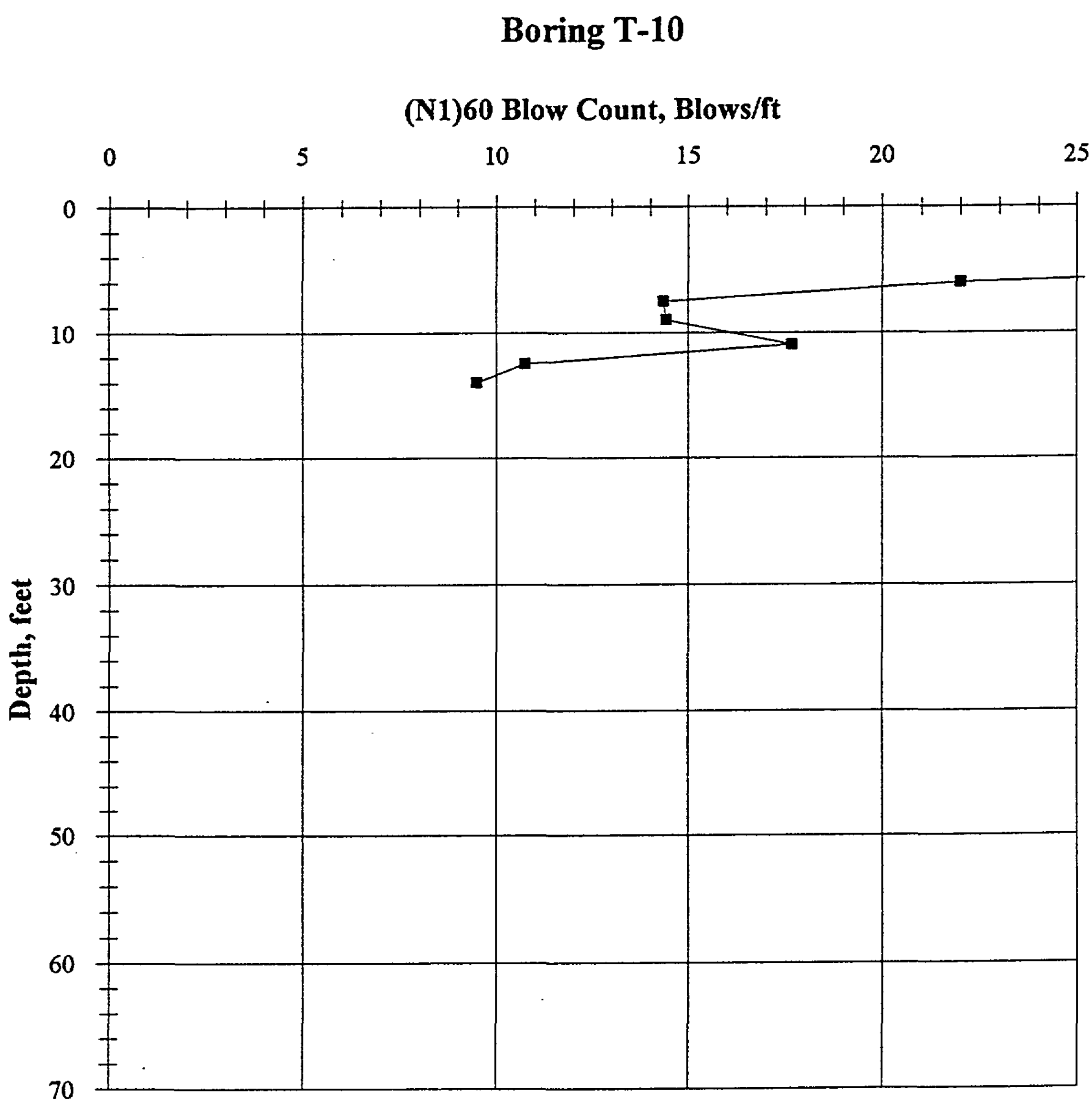
SHERWOOD TAILING IMPOUNDMENT

$(N_1)_{60}$ RESULTS BORING T-9

Checked by ___	Date 5-4-94	Project No.	Figure No.
Approved by RLV	Date 5-5-94	SMI-100	B-19



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SHERWOOD TAILING IMPOUNDMENT

$(N_1)_{60}$ RESULTS BORING T-10

Checked by [signature]	Date 5-4-94	Project No. SMI-100	Figure No. B-20
Approved by RLV	Date 5-5-94		

APPENDIX C

CALCULATIONS TO DETERMINE LIQUEFACTION POTENTIAL

APPENDIX C

CALCULATIONS TO DETERMINE LIQUEFACTION POTENTIAL

This appendix presents the results of calculations to determine the liquefaction potential based on the SPT results and $(N_1)_{60}$ values vs. depth for borings performed at the Sherwood Tailing Impoundment. The calculations are summarized on 6 spread sheets which form an extension of the data presented in Appendix B which presented the $(N_1)_{60}$ values vs. depth for the 9 borings for which data were available. As indicated on the calculation sheets, the liquefaction assessment was determined for a Magnitude 5¼ earthquake producing a peak acceleration at the site equal to 0.15g and using the Simplified Seed Method discussed in Section IV of the report.

Assessment of Liq… …action Potential

JOB NAME: SMI - Sherwood Tailings Impoundments

JOB NO.: SMI-1

BY: RLV 10/27/93

						Corrections to Obtain SPT-Equivalent Blow Counts					Calculations to Determine Liquefaction Potential									
						CORRECTION FACTORS												Mag. 5.25	Available	Factor of
BOREHOLE	DEPTH (ft)	SPT or MOD. CAL.	UNCORRECTED BLOW COUNT N	SOIL TYPE	GRAVEL? Y=yes N=no	MOD. CAL. (*.55)	DRILL ROD (*.75@<10')	HAMMER EFF. (*.75)	SPT w/o Liner (*1.2)	SILTS (add 7)	FINAL CORRECTED N	Effective Overburden (psf)	Cn	(N1)60	Total Overburden (psf)	Overburden Stress Ratio	Stress Reduction Factor r sub d	Induced Stress Ratio	Stress Ratio Based on (N1)60	Safety Against Liquefaction
T-1	4.5	SPT	5	SM	N	5	4	3	3	10	10	504	1.60	17	504	1.00	0.99	0.09605213	0.2656	2.77
	6	SPT	7	SM	N	7	5	4	5	12	12	671	1.60	19	671	1.00	0.98	0.0955695	0.30016	3.14
	7.5	SPT	8	ML	N	8	6	5	5	12	12	839	1.38	17	839	1.00	0.98	0.09508688	0.27457156	2.89
	9	SPT	2	SM	N	2	2	1	1	8	8	1007	1.31	11	1007	1.00	0.97	0.09460425	0.17435317	1.84
	11	SPT	3	SM	N	3	3	2	3	10	10	1159	1.24	12	1222	1.05	0.96	0.09901781	0.19308471	1.95
	12.5	SPT	2	SM	N	2	2	2	2	9	9	1220	1.22	11	1376	1.13	0.96	0.10543107	0.17206566	1.63
	14	SPT	1	ML	N	1	1	1	1	8	8	1281	1.20	9	1530	1.19	0.95	0.11112113	0.15181662	1.37
T-2	4.5	SPT	5	SM	N	5	4	3	3	10	10	504	1.60	17	504	1.00	0.99	0.09605213	0.2656	2.77
	6	SPT	4	SM	N	4	3	2	3	10	10	671	1.60	16	671	1.00	0.98	0.0955695	0.24832	2.60
	7.5	SPT	3	SM	N	3	2	2	2	9	9	839	1.38	12	839	1.00	0.98	0.09508688	0.19983938	2.10
	9	SPT	0.5	SM	N	1	0	0	0	7	7	1007	1.31	10	1007	1.00	0.97	0.09460425	0.15321154	1.62
	11	SPT	1	SM	N	1	1	1	1	8	8	1159	1.24	10	1222	1.05	0.96	0.09901781	0.15725456	1.59
	12.5	SPT	3	SM	N	3	3	2	3	10	10	1220	1.22	12	1376	1.13	0.96	0.10543107	0.18966328	1.80
	14	SPT	3	SM	N	3	3	2	3	10	10	1281	1.20	12	1530	1.19	0.95	0.11112113	0.18640775	1.68
	16	SPT	3	SM	N	3	3	2	3	10	10	1361	1.17	11	1736	1.28	0.95	0.11774982	0.18229888	1.55
	17.5	SPT	2	SM	N	2	2	2	2	9	9	1422	1.16	10	1890	1.33	0.94	0.12210487	0.16273126	1.33
	21	SPT	1.5	ML	N	2	2	1	1	8	8	1573	1.11	9	2259	1.44	0.93	0.1303529	0.14859408	1.14
	24.5	SPT	3	ML	N	3	3	2	3	10	10	1746	1.07	10	2651	1.52	0.92	0.13606454	0.16559939	1.22

Assessment of Liquefaction Potential

Corrections to Obtain SPT-Equivalent Blow Counts

JOB NAME: SMI - Sherwood Tailings Impoundments
JOB NO.: SMI-1
BY: RLV 10/27/93

BOREHOLE	DEPTH (ft)	SPT or MOD. CAL.	UNCORRECTED BLOW COUNT N	SOIL TYPE	GRAVEL? Y=yes N=no	CORRECTION FACTORS MOD. CAL. (*.55)	DRILL ROD (*.75@<10')	HAMMER EFF. (*.75)	SPT w/o Liner (*1.2)	SILTS (add 7)	FINAL CORRECTED N	Effective Overburden (psf)	Cn	(N1)60	Total Overburden (psf)	Overburden Stress Ratio	Stress Reduction Factor r sub d	Mag. 5.25 Induced Stress Ratio	Available Stress Ratio Based on (N1)60	Factor of Safety Against Liquefaction
T-3	4	SPT	3	SM	N	3	2	2	2	9	9	448	1.60	14	448	1.00	0.99	0.096213	0.23104	2.40
	5.5	SPT	3	SM	N	3	2	2	2	9	9	615	1.60	14	615	1.00	0.98	0.09573038	0.23104	2.41
	7	SPT	2	SM	N	2	2	1	1	8	8	783	1.60	13	783	1.00	0.98	0.09524775	0.21376	2.24
	9	SPT	0.5	SM	N	1	0	0	0	7	7	1007	1.31	10	1007	1.00	0.97	0.09460425	0.15321154	1.62
	11	SPT	0.5	SM	N	1	1	0	0	7	7	1159	1.24	9	1222	1.05	0.96	0.09901781	0.14829702	1.50
	13	SPT	0.5	SM	N	1	1	0	0	7	7	1240	1.21	9	1427	1.15	0.96	0.10740287	0.14482222	1.35
	14.5	SPT	0.5	ML	N	1	1	0	0	7	7	1301	1.19	9	1582	1.22	0.95	0.11287457	0.14236161	1.26
	16	SPT	0.5	ML	N	1	1	0	0	7	7	1361	1.17	9	1736	1.28	0.95	0.11774982	0.14001306	1.19
	17.5	SPT	0.5	ML	N	1	1	0	0	7	7	1422	1.16	9	1890	1.33	0.94	0.12210487	0.1377668	1.13
	19	SPT	0.5	ML	N	1	1	0	0	7	7	1483	1.14	8	2044	1.38	0.94	0.1260035	0.13561431	1.08
	20.5	SPT	0.5	SM	N	1	1	0	0	7	7	1548	1.12	8	2203	1.42	0.93	0.12938604	0.1333962	1.03
	22	SPT	0.5	SM	N	1	1	0	0	7	7	1622	1.10	8	2371	1.46	0.93	0.13216479	0.13097938	0.99
	24	SPT	3	SM	N	3	3	2	3	10	10	1721	1.07	10	2595	1.51	0.92	0.13535038	0.16655828	1.23
	29	SPT	4	SM	N	4	4	3	4	11	11	1969	1.02	11	3154	1.60	0.90	0.14127236	0.17215154	1.22

Assessment of Liquefaction Potential

Corrections to Obtain SPT-Equivalent Blow Counts

JOB NAME: SMI - Sherwood Tailings Impoundments
JOB NO.: SMI-1
BY: RLV 10/27/93

BOREHOLE	DEPTH (ft)	SPT or MOD. CAL.	UNCORRECTED BLOW COUNT N	SOIL TYPE	GRAVEL? Y=yes N=no	CORRECTION FACTORS: MOD. CAL. (*.55)	DRILL ROD (*.75@<10')	HAMMER EFF. (*.75)	SPT w/o Liner (*1.2)	SILTS (add 7)	FINAL CORRECTED N	Effective Overburden (psf)	Cn	(N1)60	Total Overburden (psf)	Overburden Stress Ratio	Stress Reduction Factor r sub d	Mag. 6.25 Induced Stress Ratio	Available Stress Ratio Based on (N1)60	Factor of Safety Against Liquefaction
T-4	4.5	SPT	6	SM	N	6	5	3	4	11	11	504	1.60	18	504	1.00	0.99	0.09605213	0.28288	2.95
	6	SPT	4	SM	N	4	3	2	3	10	10	671	1.60	16	671	1.00	0.98	0.0955695	0.24832	2.60
	7.5	SPT	2	SM	N	2	2	1	1	8	8	839	1.38	12	839	1.00	0.98	0.09508688	0.18489294	1.94
	9	SPT	3	SM	N	3	2	2	2	9	9	1007	1.31	12	1007	1.00	0.97	0.09460425	0.18844759	1.99
	11	SPT	1	ML	N	1	1	1	1	8	8	1159	1.24	10	1222	1.05	0.96	0.09901781	0.15725456	1.59
	12.5	SPT	1	ML	N	1	1	1	1	8	8	1220	1.22	10	1376	1.13	0.96	0.10543107	0.15446803	1.47
	14	SPT	1	ML	N	1	1	1	1	8	8	1281	1.20	9	1530	1.19	0.95	0.11112113	0.15181662	1.37
	16	SPT	2	SM	N	2	2	2	2	9	9	1361	1.17	10	1736	1.28	0.95	0.11774982	0.16538455	1.40
	17.5	SPT	0	SM	N	0	0	0	0	7	7	1422	1.16	8	1890	1.33	0.94	0.12210487	0.12944532	1.06
	19	SPT	1	ML	N	1	1	1	1	8	8	1483	1.14	9	2044	1.38	0.94	0.1260035	0.14380577	1.14
	21	SPT	0	SM	N	0	0	0	0	7	7	1573	1.11	8	2259	1.44	0.93	0.1303529	0.12456988	0.96
	22.5	SPT	1	SM	N	1	1	1	1	8	8	1647	1.09	9	2427	1.47	0.93	0.13301349	0.13806263	1.04
	24	SPT	4	SM	N	4	4	3	4	11	11	1721	1.07	11	2595	1.51	0.92	0.13535038	0.18201214	1.34
	26	SPT	4	SM	N	4	4	3	4	11	11	1820	1.05	11	2818	1.55	0.91	0.13803114	0.17790759	1.29
	29	SPT	4	SM	N	4	4	3	4	11	11	1969	1.02	11	3154	1.60	0.90	0.14127236	0.17215154	1.22
	31	SPT	6	SM	N	6	6	5	5	12	12	2068	0.99	12	3378	1.63	0.90	0.14336674	0.19717242	1.38
	32.5	SPT	6	SM	N	6	6	5	5	12	12	2142	0.98	12	3546	1.66	0.90	0.14527352	0.19414345	1.34
	34	SPT	16	SM	N	16	16	12	14	21	21	2216	0.96	21	3714	1.68	0.90	0.14705253	0.33000477	2.24
	36	SPT	14	SM	N	14	14	11	13	20	20	2315	0.94	19	3937	1.70	0.90	0.14924702	0.2963167	1.99
	37.5	SPT	13	SM	N	13	13	10	12	19	19	2389	0.93	17	4105	1.72	0.90	0.15077354	0.27862317	1.85
	39	SPT	17	SM	N	17	17	13	15	22	22	2464	0.92	20	4273	1.73	0.90	0.15220805	0.32753704	2.15
	41	SPT	14	SM	N	14	14	11	13	20	20	2563	0.90	18	4497	1.75	0.90	0.1539914	0.28253369	1.83
	42.5	SPT	18	SM	N	18	18	14	16	23	23	2637	0.89	21	4665	1.77	0.90	0.15524104	0.32983977	2.12
	44	SPT	13	ML	N	13	13	10	12	19	19	2711	0.88	16	4833	1.78	0.90	0.15642222	0.26226696	1.68
	48	SPT	16	ML	N	16	16	12	14	21	21	2882	0.85	18	5253	1.82	0.90	0.15994235	0.29106182	1.82
	49.5	SPT	15	ML	N	15	15	11	14	21	21	2943	0.84	17	5408	1.84	0.90	0.16124674	0.27586777	1.71
	51	SPT	14	ML	N	14	14	11	13	20	20	3003	0.83	16	5562	1.85	0.90	0.16249849	0.26099057	1.61
	52.5	SPT	12	ML	N	12	12	9	11	18	18	3064	0.82	15	5716	1.87	0.90	0.16370072	0.23456032	1.43
	54	SPT	8	ML	N	8	8	6	7	14	14	3125	0.82	12	5870	1.88	0.90	0.16485632	0.18519576	1.12
	56	SPT	12	ML	N	12	12	9	11	18	18	3205	0.80	14	6076	1.90	0.90	0.16632915	0.22900058	1.38
	57.5	SPT	11	ML	N	11	11	8	10	17	17	3266	0.80	13	6230	1.91	0.90	0.16738595	0.21523056	1.29
	61	SPT	24	ML	N	24	24	18	22	29	29	3407	0.78	22	6590	1.93	0.90	0.16970563	0.35584424	2.10
	62.5	SPT	12	ML	N	12	12	9	11	18	18	3468	0.77	14	6744	1.94	0.90	0.17064187	0.21929707	1.29
	64	SPT	10	SM	N	10	10	8	9	16	16	3529	0.76	12	6898	1.95	0.90	0.17154595	0.19520206	1.14

Assessment of Liquefaction Potential

Corrections to Obtain SPT-Equivalent Blow Counts

JOB NAME: SMI - Sherwood Tailings Impoundments
JOB NO.: SMI-1
BY: RLV 10/27/93

BOREHOLE	DEPTH (ft)	SPT or MOD. CAL.	UNCORRECTED BLOW COUNT N	SOIL TYPE	GRAVEL? Y=yes N=no	CORRECTION FACTORS: MOD. CAL. (*.55)	DRILL ROD (*.75@<10')	HAMMER EFF. (*.75)	SPT w/o Liner (*1.2)	SILTS (add 7)	FINAL CORRECTED N	Effective Overburden (psf)	Cn	(N1)60	Total Overburden (psf)	Overburden Stress Ratio	Stress Reduction Factor	Mag 5.25 Induced Stress Ratio	Available Stress Ratio Based on (N1)60	Factor of Safety Against Liquefaction
T-5	4.5	SPT	4	SM	N	4	3	2	3	10	10	504	1.60	16	504	1.00	0.99	0.09605213	0.24832	2.59
	6	SPT	4	ML	N	4	3	2	3	10	10	671	1.60	16	671	1.00	0.98	0.0955695	0.24832	2.60
	7.5	SPT	4	ML	N	4	3	2	3	10	10	839	1.38	13	839	1.00	0.98	0.09508688	0.21478582	2.26
	9	SPT	3	SM	N	3	2	2	2	9	9	1007	1.31	12	1007	1.00	0.97	0.09460425	0.18844759	1.99
	11	SPT	4	SM	N	4	4	3	4	11	11	1159	1.24	13	1222	1.05	0.96	0.09901781	0.21099979	2.13
	12.5	SPT	2	ML	N	2	2	2	2	9	9	1220	1.22	11	1376	1.13	0.96	0.10543107	0.17206566	1.63
	14	SPT	1.5	ML	N	2	2	1	1	8	8	1281	1.20	10	1530	1.19	0.95	0.11112113	0.1604644	1.44
	16	SPT	0	ML	N	0	0	0	0	7	7	1361	1.17	8	1736	1.28	0.95	0.11774982	0.13155589	1.12
	17.5	SPT	0	ML	N	0	0	0	0	7	7	1422	1.16	8	1890	1.33	0.94	0.12210487	0.12944532	1.06
	19	SPT	0	ML	N	0	0	0	0	7	7	1483	1.14	8	2044	1.38	0.94	0.1260035	0.12742284	1.01
	23	SPT	3	SM	N	3	3	2	3	10	10	1672	1.09	11	2483	1.49	0.92	0.13382629	0.16851814	1.26
	24.5	SPT	4	SM	N	4	4	3	4	11	11	1746	1.07	11	2651	1.52	0.92	0.13606454	0.18096428	1.33
	26	SPT	6	SM	N	6	6	5	5	12	12	1820	1.05	13	2818	1.55	0.91	0.13803114	0.20811832	1.51
	27.5	SPT	0	SM	N	0	0	0	0	7	7	1894	1.03	7	2986	1.58	0.91	0.13975804	0.11554831	0.83
	29	SPT	2	SP-SM	N	2	2	2	2	2	2	1969	1.02	2	3154	1.60	0.90	0.14127236	0.02923328	0.21
T-6	4.5	SPT	6	SM	N	6	5	3	4	11	11	504	1.60	18	504	1.00	0.99	0.09605213	0.28288	2.95
	6	SPT	4	SM	N	4	3	2	3	10	10	671	1.60	16	671	1.00	0.98	0.0955695	0.24832	2.60
	7.5	SPT	3	SM	N	3	2	2	2	9	9	839	1.38	12	839	1.00	0.98	0.09508688	0.19983938	2.10
	9	SPT	0.5	ML	N	1	0	0	0	7	7	1007	1.31	10	1007	1.00	0.97	0.09460425	0.15321154	1.62

Assessment of Liquefaction Potential

JOB NAME: SMI - Sherwood Tailings Impoundments
JOB NO.: SMI-1
BY: RLV 10/27/93

BOREHOLE	DEPTH (ft)	SPT or MOD. CAL.	UNCORRECTED BLOW COUNT N	SOIL TYPE	GRAVEL? Y=yes N=no	Corrections to Obtain SPT-Equivalent Blow Counts — CORRECTION FACTORS: MOD. CAL. (*.55)	DRILL ROD (*.75@<10')	HAMMER EFF. (*.75)	SPT w/o Liner (*1.2)	SILTS (add 7)	FINAL CORRECTED N	Effective Overburden (psf)	Cn	(N1)60	Total Overburden (psf)	Overburden Stress Ratio	Stress Reduction Factor r sub d	Mag. 6.25 Induced Stress Ratio	Available Stress Ratio Based on (N1)60	Factor of Safety Against Liquefaction
T-7	4	SPT	9	SM	N	9	7	5	6	13	13	448	1.60	21	448	1.00	0.9868	0.096213	0.33472	3.48
	6	SPT	4	SM	N	4	3	2	3	10	10	671	1.60	16	671	1.00	0.9802	0.0955695	0.24832	2.60
	7.5	SPT	4	SM	N	4	3	2	3	10	10	839	1.38	13	839	1.00	0.97525	0.09508688	0.21478582	2.26
	9	SPT	3	ML	N	3	2	2	2	9	9	1007	1.31	12	1007	1.00	0.9703	0.09460425	0.18844759	1.99
	11	SPT	4	ML	N	4	4	3	4	11	11	1159	1.24	13	1222	1.05	0.9637	0.09901781	0.21099979	2.13
	12.5	SPT	2	ML	N	2	2	2	2	9	9	1220	1.22	11	1376	1.13	0.95875	0.10543107	0.17206566	1.63
	14	SPT	1	ML	N	1	1	1	1	8	8	1281	1.20	9	1530	1.19	0.9538	0.11112113	0.15181662	1.37
	16	SPT	1	SM	N	1	1	1	1	8	8	1361	1.17	9	1736	1.28	0.9472	0.11774982	0.14847022	1.26
	17.5	SPT	1	ML	N	1	1	1	1	8	8	1422	1.16	9	1890	1.33	0.94225	0.12210487	0.14608829	1.20
	19	SPT	5	ML	N	5	5	4	5	12	12	1483	1.14	13	2044	1.38	0.9373	0.1260035	0.20933752	1.66
	21	SPT	1	SM	N	1	1	1	1	8	8	1573	1.11	9	2259	1.44	0.9307	0.1303529	0.14058601	1.08
	22.5	SPT	3	SM	N	3	3	2	3	10	10	1647	1.09	11	2427	1.47	0.92575	0.13301349	0.16951994	1.27
	24	SPT	3	SM	N	3	3	2	3	10	10	1721	1.07	10	2595	1.51	0.9208	0.13535038	0.16655828	1.23
	26	SPT	2	ML	N	2	2	2	2	9	9	1820	1.05	9	2818	1.55	0.9142	0.13803114	0.14769687	1.07
	27.5	SPT	4	SM	N	4	4	3	4	11	11	1894	1.03	11	2986	1.58	0.90925	0.13975804	0.17497315	1.25
	29	SPT	4	ML	N	4	4	3	4	11	11	1969	1.02	11	3154	1.60	0.9043	0.14127236	0.17215154	1.22
	31	SPT	6	ML	N	6	6	5	5	12	12	2068	0.99	12	3378	1.63	0.9	0.14336674	0.19717242	1.38
	32.5	SPT	6	SM	N	6	6	5	5	12	12	2142	0.98	12	3546	1.66	0.9	0.14527352	0.19414345	1.34
	34	SPT	8	SM	N	8	8	6	7	14	14	2216	0.96	14	3714	1.68	0.9	0.14705253	0.21897513	1.49
	36	SPT	2	SM	N	2	2	2	2	9	9	2315	0.94	8	3937	1.70	0.9	0.14924702	0.13304015	0.89
	37.5	SPT	3	SM	N	3	3	2	3	10	10	2389	0.93	9	4105	1.72	0.9	0.15077354	0.14452646	0.96
	39	SPT	4	ML	N	4	4	3	4	11	11	2464	0.92	10	4273	1.73	0.9	0.15220805	0.15569025	1.02
	41	SPT	4	ML	N	4	4	3	4	11	11	2563	0.90	10	4497	1.75	0.9	0.1539914	0.15279883	0.99
	42.5	SPT	5	ML	N	5	5	4	5	12	12	2637	0.89	10	4665	1.77	0.9	0.15524104	0.16349816	1.05
	44	SPT	7	ML	N	7	7	5	6	13	13	2711	0.88	12	4833	1.78	0.9	0.15642222	0.18653211	1.19
	46	SPT	10	ML	N	10	10	8	9	16	16	2801	0.86	14	5048	1.80	0.9	0.15811539	0.22076605	1.40
	47.5	SPT	5	ML	N	5	5	4	5	12	12	2862	0.85	10	5202	1.82	0.9	0.15949528	0.15697169	0.98
	49	SPT	6	ML	N	6	6	5	5	12	12	2923	0.84	10	5356	1.83	0.9	0.16081795	0.16745767	1.04
	51	SPT	9	ML	N	9	9	7	8	15	15	3003	0.83	13	5562	1.85	0.9	0.16249849	0.20106927	1.24
	52.5	SPT	4	ML	N	4	4	3	4	11	11	3064	0.82	9	5716	1.87	0.9	0.16370072	0.13968199	0.85
	54	SPT	12	ML	N	12	12	9	11	18	18	3125	0.82	15	5870	1.88	0.9	0.16485632	0.2321468	1.41
	56	SPT	20	SM	N	20	20	15	18	25	25	3205	0.80	20	6076	1.90	0.9	0.16632915	0.32163003	1.93
	57.5	SPT	22	SM	N	22	22	17	20	27	27	3266	0.80	21	6230	1.91	0.9	0.16738595	0.34131236	2.04
	59	SPT	20	SM	N	20	20	15	18	25	25	3327	0.79	20	6384	1.92	0.9	0.16840424	0.31520636	1.87
	61	SPT	18	ML	N	18	18	14	16	23	23	3407	0.78	18	6590	1.93	0.9	0.16970563	0.28865686	1.70
	62.5	SPT	22	ML	N	22	22	17	20	27	27	3468	0.77	21	6744	1.94	0.9	0.17064187	0.33017762	1.93
	64	SPT	24	ML	N	24	24	18	22	29	29	3529	0.76	22	6898	1.95	0.9	0.17154595	0.34892369	2.03

Assessment of Liq...action Potential

Corrections to Obtain SPT-Equivalent Blow Counts

JOB NAME: SMI - Sherwood Tailings Impoundments
JOB NO.: SMI-1
BY: RLV 10/27/93

BOREHOLE	DEPTH (ft)	SPT or MOD. CAL.	UNCORRECTED BLOW COUNT N	SOIL TYPE	GRAVEL? Y=yes . N=no	CORRECTION FACTORS: MOD. CAL. (*.55)	DRILL ROD (*.75@<10')	HAMMER EFF. (*.75)	SPT w/o Liner (*1.2)	SILTS (add 7)	FINAL CORRECTED N	Effective Overburden (psf)	Cn	(N1)60	Total Overburden (psf)	Overburden Stress Ratio	Stress Reduction Factor r sub u	Mag 5 25 Induced Stress Ratio	Available Stress Ratio Based on (N1)60	Factor of Safety Against Liquefaction
T-8	4 5	SPT	5	SM	N	5	4	3	3	10	10	504	1.60	17	504	1.00	0 99	0 09605213	0 2656	2.77
	6	SPT	4	SM	N	4	3	2	3	10	10	671	1.60	16	671	1.00	0.98	0.0955695	0 24832	2 60
	7.5	SPT	3	ML	N	3	2	2	2	9	9	839	1.38	12	839	1.00	0 98	0 09508688	0.19983938	2.10
	9	SPT	2	SM	N	2	2	1	1	8	8	1007	1.31	11	1007	1.00	0.97	0 09460425	0.17435317	1.84
	11	SPT	0.5	ML	N	1	1	0	0	7	7	1159	1.24	9	1222	1.05	0.96	0 09901781	0 14829702	1.50
	12.5	SPT	4	ML	N	4	4	3	4	11	11	1220	1.22	13	1376	1.13	0.96	0.10543107	0 20726091	1.97
	16	SPT	2	SM	N	2	2	2	2	9	9	1361	1.17	10	1738	1.28	0.95	0.11774982	0.16538455	1.40
	17.5	SPT	2	SM	N	2	2	2	2	9	9	1422	1.16	10	1890	1.33	0.94	0.12210487	0.16273126	1 33
	19	SPT	1	ML	N	1	1	1	1	8	8	1483	1.14	9	2044	1.38	0 94	0 1260035	0.14380577	1. 14
	21	SPT	1	ML	N	1	1	1	1	8	8	1573	1.11	9	2259	1.44	0 93	0.1303529	0.14058601	1.08
	22.5	SPT	1	SM	N	1	1	1	1	8	8	1647	1.09	9	2427	1.47	0.93	0.13301349	0.13806263	1 04
	24	SPT	2	ML	N	2	2	2	2	9	9	1721	1.07	9	2595	1.51	0.92	0 13535038	0.15110442	1.12
	25.5	SPT	3	ML	N	3	3	2	3	10	10	1795	1.05	10	2762	1.54	0 92	0.13740371	0.16372173	1.19
	29	SPT	1	ML	N	1	1	1	1	8	8	1969	1.02	8	3154	1.60	0 90	0.14127236	0 12830162	0 91
	31	SPT	4	ML	N	4	4	3	4	11	11	2068	0.99	11	3378	1.63	0.90	0.14336674	0 16855062	1.18
T-9	4	SPT	8	SM	N	8	6	5	5	12	12	448	1.60	20	448	1.00	0.99	0.096213	0.31744	3.30
	6	SPT	4	SM	N	4	3	2	3	10	10	671	1.60	16	671	1.00	0.98	0.0955695	0 24832	2.60
	7.5	SPT	3	SM	N	3	2	2	2	9	9	839	1.38	12	839	1.00	0.98	0.09508688	0.19983938	2 10
	9	SPT	5	SM	N	5	4	3	3	10	10	1007	1.31	14	1007	1.00	0 97	0 09460425	0 21663642	2 29
T-10	4.5	SPT	28	SM	N	28	21	16	19	26	26	504	1.60	41	504	1.00	0.99	0.09605213	0.4	4.16
	6	SPT	10	SM	N	10	8	6	7	14	14	671	1.60	22	671	1.00	0.98	0.0955695	0.352	3 68
	7.5	SPT	5	SM	N	5	4	3	3	10	10	839	1.38	14	839	1.00	0 98	0.09508688	0.22973225	2.42
	9	SPT	6	ML	N	6	5	3	4	11	11	1007	1.31	14	1007	1.00	0 97	0 09460425	0.23073084	2 44
	11	SPT	8	ML	N	8	8	6	7	14	14	1159	1.24	18	1222	1.05	0 96	0 09901781	0 2826601	2 85
	12.5	SPT	2	SM	N	2	2	2	2	9	9	1220	1.22	11	1376	1.13	0 96	0 10543107	0.17206566	1.63
	14	SPT	1	SM	N	1	1	1	1	8	8	1281	1.20	9	1530	1.19	0 95	0.11112113	0.15181662	1.37
																				#DIV/0!

RICHARD L. VOLPE, P.E.
Geotechnical Consultant

RLV-A

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September 13, 1995

Mr. Lou Miller, P.E.
Shepherd Miller, Inc.
1600 Specht Point Drive, Suite F
Fort Collins, CO 80525

Subject: Geotechnical Review Comments
Sherwood Reclamation Plan

Dear Lou:

This letter has been prepared to respond to several issues raised by the State of Washington, Department of Health (State), concerning the Sherwood Tailing Reclamation Plan (TRP) prepared by Shepherd Miller, Inc. on behalf of Western Nuclear, Inc. These issues were presented in a letter from Leo Wainhouse, Radiation Health Physicist for the State to Stephanie Baker, Manager of Environmental Services for Western Nuclear, and dated May 3, 1995. These issues were also discussed in an extended conference call between several State employees, Western Nuclear, SMI, and the writer on March 24, 1995.

Prior to the conference call, the writer was provided a copy of a memorandum prepared by Jerald M. LaVassar, P.E., who was responsible for the review of the geotechnical and earthquake engineering aspects of the TRP for the State. As a part of his review, Mr. LaVassar prepared a memorandum to Leo Wainhouse, Maxine Dunkleman and John Blacklaw of the Division of Radiation Protection, dated March 22, 1995, in which he presented his geotechnical review comments for the Sherwood Project. These issues were thoroughly discussed during the above referenced conference call.

In his letter of May 3, 1995, Mr. Wainhouse requests that we respond to three geotechnical issues related to the dynamic analysis of the tailing impoundment as summarized below:

1) earthquake recurrence interval;

2) expected peak ground acceleration;

3) liquefaction potential and its impact on the cover.

Responses to these issues are presented below.

1. <u>Earthquake Recurrence Interval</u>

In the TRP, on Figure 4 of Appendix L, a map is presented showing contours of equal acceleration for the northwestern United States. This map is taken from 'Earthquake Acceleration and Velocity Maps of the United States and Puerto Rico,' by S. T. Algermissen, et al., and dated 1990. A note is contained on the referenced figure which states... *"Map showing contours of equal ground acceleration in percent of gravity based on probabilistic analysis. The probability of the acceleration shown occurring in the next 250 years is 90%."* In the original notes accompanying the Algermissen map, he states *"...There is a 90 percent probability that the maximum horizontal acceleration ...will not be exceeded in the time period of ... 250 years."* Algermissen also states that the average return period for the 250 year interval is 2,372 years. The annotation on the map in the TRP is incorrect since it implies that there is a 90% chance that the acceleration values shown could occur, whereas, from a probabilistic standpoint, it should state that there is a 90% chance during the next 250 years that the acceleration values shown will not be exceeded.

2. <u>Expected Peak Ground Acceleration</u>

In his letter of May 3, 1995, Mr. Wainhouse states ... *"Although your TRP addresses peak bedrock acceleration, the overlying soil column also influences acceleration. Provide an analysis of peak ground acceleration by considering amplification of the peak bedrock acceleration through the soil column."*

The peak rock acceleration expected to occur at the site during the next 1000 years was computed using probabilistic theory, and corresponding data based on an exhaustive, and region specific, seismotectonic study performed in 1990 for the U.S. Bureau of Reclamation by Geomatrix Consultants. The peak horizontal rock acceleration at the site was computed using current earthquake attenuation concepts for hypothetical random earthquakes varying from M 5.0 to M 6.5, and with epicentral distances at statistically representative distances from the site. Both mean and mean-plus-one peak horizontal acceleration values were computed, and the design level of acceleration, as shown on Fig. 3 of Appendix L of the TRP, varied as follows:

Random E/Q Magnitude	Distance from Site (km)	Peak Horizontal Acceleration, g
5.0	35	0.04
5.5	61	0.025
6.0	104	0.015
6.5	185	0.01

Based on the seismotectonic analysis, a conservative design peak rock acceleration value of 0.05 g was selected to perform the liquefaction analyses.

Mr. LaVassar of the State estimated the peak ground motion at the site by interpolating existing maps prepared by the U.S. Geological Survey for the 1991 Edition of the *National Earthquake Hazard Reduction Program (NEHRP) Recommended Provisions for the Development of Seismic Regulations for New Buildings*. Interpolating between the values for a 10% chance of exceedance in 50 and 250 years, he estimated a peak ground acceleration value of 0.07 g for an annual probability of exceedance of 1 in a thousand. We wish to point out that the peak acceleration value estimated using the NEHRP maps is a peak ground acceleration value compared to a peak rock acceleration value presented in the TRP. Also, the NEHRP data is based on a statistical assessment that was performed for the entire United States, whereas the values presented in the TRP are based on a detailed regional seismotectonic study. Nevertheless, the NEHRP data are published and certainly are based on a rational analytical approach, even though the maps are intended for seismic design for new buildings.

As correctly pointed out by the State, the liquefaction analyses presented in the TRP were performed assuming no amplification or attenuation of the peak rock acceleration values. Although the potential for ground conditions impacting the rock accelerations was not discussed in the TRP, we felt that the peak acceleration values used in the liquefaction analyses were conservative, and that the consideration for ground response (i.e., either to amplify or attenuate the motions) was not warranted due to the relatively low magnitude of the earthquake generating the design acceleration values. A number of articles have been written regarding the potential for site conditions to impact the earthquake motions arriving at a given site. In their classic discussion of this subject, Seed and Idriss (1982) presented an empirical relationship which they believed represented the impact of site conditions on earthquake motions (reproduced herein as Fig. 1). As shown on Figure 1, the measured peak ground acceleration values for soil sites are generally less than corresponding rock sites at the same epicentral distance, especially for rock sites with a peak acceleration value greater than about 0.1 g. The relationships presented in Figure 1 also shows that the difference in peak ground acceleration values at soil sites depends on the stiffness and thickness of the soils. Following the 1985 Mexico City (M 7.8) and the 1989 Loma Prieta (M 7.1) earthquakes, it was recognized that certain soft site conditions could indeed exhibit significant amplification. Idriss published a modified empirical relationship (Idriss, 1990) for soft sites, based on both measured and calculated peak ground acceleration values (reproduced herein as Fig. 2). As shown by this figure, a median relationship indicates that amplification of the peak rock acceleration at soft sites could occur up to a value of 0.4 g.

Clearly, it is possible for significant amplification of bedrock motions to occur at sites with soft ground conditions. It should be noted, however, that the bulk of observed data on which this observation is based are derived from large magnitude earthquakes (M 7.8 and M 7.1) with epicentral distances in excess of 100 km from the sites. Although the saturated tailing material within the Sherwood site can be classified as "soft", it is not clear that significant amplification of earthquake motions would occur in the event one of the random "design" earthquakes were to occur, since all of the potential random events that could impact the site are significantly smaller in magnitude than the two earthquake events cited above. One of the major concerns regarding the potential for ground conditions impacting earthquake acceleration at any site is the tendency for over simplification since the earthquake motions ultimately generated at a site are dependent on a complex inter-relationship of several critical factors, including the following:

- frequency content of the earthquake motions - frequency content is dependent on earthquake magnitude and epicentral distance from the site;
- duration of shaking - duration is directly dependent on earthquake magnitude;
- depth and variability of soil at the site;
- predominant period of the site compared to that of the structure in question.

The soil conditions at the Sherwood site vary depending on location within the impoundment. As shown in Figure 2 of Appendix L of the TRP, which shows a typical cross section through the site, the foundation glacial deposits are approximately 150 feet deep, and the maximum tailing thickness is about 70 feet near the main dam. Near the midpoint of the impoundment, about 1,500 feet from the main dam, the foundation glacial deposits are approximately 75 feet thick, and the maximum tailing thickness is about 50 feet. The site is characterized as having a deep cohesionless foundation (see Figure 1), and would be susceptible to slight attenuation of rock motions. However, due to the relatively low value of expected rock acceleration at the site, we would expect the earthquake motions would travel essentially unimpeded to the base of the tailing, although we would expect some of the high frequency motions to be filtered as they travel through the foundation glacial deposits. If amplification were to occur as motions travel from the foundation contact up through the tailing material, we believe it is more likely that such potential amplification would only be associated with the larger, more distant random earthquakes. Referring to Figure 2, we estimate that the peak rock acceleration values of between 0.01 g and 0.015 g could be amplified to a peak ground acceleration of between 0.04 g and 0.06 g, for the M6.5 and M6.0 events respectively.

In conclusion, although it is possible that amplification of bedrock motions could occur at the Sherwood site, we believe that the 0.05g peak acceleration value used for the liquefaction analysis is both conservative and appropriate.

3. Liquefaction Potential

In his letter of May 3, 1995, Mr. Wainhouse states .. "*There is a potential for liquefaction to disrupt the tails cover in two ways, differential settlement because of rafting and sand boils. The Byrne (1994) paper suggests certain analysis to determine if wholesale movement or rafting could occur. Please perform additional analysis to develop a response to this issue. Please provide an analysis to determine if the final cover could be affected by the phenomenon known as sand boils.*"

Based on the above stated concerns regarding the potential for differential settlement impacting the integrity of the central impermeable clay layer, the reclamation cover was redesigned. The new cover will be comprised of a homogeneous fill; its thickness will be almost doubled over that of the old cover to a new total thickness of 12.5feet. Also, the central clay zone has been excluded. We believe the new reclamation cover will be inherently more stable (less susceptible to cracking) than the original cover in the event of future earthquakes. The reasons for this conclusion are presented in the following discussion.

Effective Stress Considerations

As pointed out in Appendix L of the TRP, the liquefaction analysis was performed using the estimated ultimate effective and total future overburden stresses acting within the tailing pond, and presented in Figure 6 of Appendix L, and the current shear strength within the tailing as inferred by the SPT test results. In other words, the stress increase to be imposed by the reclamation cover was considered with regard to stress conditions; however, no potential increase in the shear strength or relative density was considered as a result of the new stresses to be imposed by the subgrade and cover. The new reclamation cover will impose an even greater loading within the tailing than the original cover. As mentioned previously, in addition to the cover loading, major sections of the impoundment will also receive up to 5 feet of new subgrade fill prior to placement of the cover. A general plot of the current and future effective stress acting within the tailing is presented in Figure 3 for illustrative purposes. The ultimate effective stress values shown in Fig. 3 were computed by adopting the following assumptions: 1) no distinction was made between the total unit weight (87.9 pcf) of the sandy and slimy areas within the pond; 2) a new total cover thickness of 12.5feet; 3) a total unit weight of the cover material equal to 120 lb/cu. ft.; and 4) that the water table within the tailing material will migrate upward from a depth of about 10 feet below the tailing surface to the tailing-cover interface after reclamation is complete. A careful review of the results presented in Figure 3 shows that the effective stress within the tailing, especially within the upper 40 feet will be significantly increased as a result of the new cover. The current and future effective stresses at 10-ft increments within the tailing are presented in tabular form below:

Effective Stress Acting Within the Tailing Pond

Depth Below Top of Tailing	Existing Effective Stress, psf	Ultimate Effective Stress, psf Cover Only Stress, psf	Cover +surcharge Stress, psf	Percent Increase, %
0	0	1500	2100	-
10	879	1755	2355	100-168
20	1365	2241	2841	64-108
30	1851	2727	3327	47-80
40	2337	3213	3813	37-63
50	2823	3699	4299	31-52
60	3309	4185	4785	26-45
70	3798	4674	5274	23-39

The impact of the stress increase due to placement of the reclamation cover will cause considerable settlement of the tailing surface which, in turn, will increase the shear strength and/or relative density of the tailing, as discussed in the following sections.

Settlement Considerations

Total settlements of the tailing surface as a result of constructing the new reclamation cover are estimated to be an average of 3.0 to 4.0 feet, depending on the percentages of slimes and sands at each location. A maximum settlement of up to 8 feet could occur in those areas of the impoundment with higher slimes content. Such settlement of the tailing material will significantly decrease the insitu void ratio within the tailing material. In the sandy portion of the tailing, the relative density will be increased; in the slimy portion of the tailing, the undrained shear strength will be increased.

SMI performed additional field investigations subsequent to submittal of the TRP, which are discussed in more detail in the main SMI report to which this letter is appended. The additional investigation consisted of a series of electronic cone penetrometer (CPT) probes, to more accurately define the variation of material types as a function of depth within the pond area. Although detailed CPT results are not reviewed herein, suffice it to say that the CPT probes confirmed the relatively low shear strength of the tailing, and that there are no continuous pervasive layers at any level within the impoundment.

In order to assess the integrity of the reclamation cover, and whether it was vulnerable to wholesale movement or rafting in the event of liquefaction, stability analyses were performed by assuming that a portion of the tailing material could liquefy. The shear strength assumptions and results of the simplified stability analyses are discussed in the following section.

Shear Strength and Stability Assessments

The effective stress-based shear strength of the tailing material, as measured by consolidated undrained triaxial testing, is considerably higher than that of most soils. As measured by recent triaxial tests, the effective friction angle of the tailing at the Sherwood site, virtually independent of gradation, measures about 38 degrees with no cohesion As a result of this relatively high friction angle, which is most likely a direct result of the angularity of tailing particles imparted during crushing of the ore, the overall stability of the tailing cover under static loading conditions is very high. Based on a cover slope of 2% (2-ft of slope change in 100 feet of length), the infinite slope factor of safety for movement of the cover, relative to the cover-tailing interface (i.e., failure along the interface), is very high (FS>>50). In the event that liquefaction were to develop within the tailing pond, however, we could no longer rely on effective-stress-based shear strength being mobilized within the tailing material. It should be noted in this discussion that there is no concern regarding the stability or the overall performance of the embankment due to earthquake shaking. Due to its material content, compacted state, relatively flat inclination (5H:1V), and the fact that there is no phreatic (free water) surface acting within it, there is no concern regarding the performance of the embankment during future earthquake shaking. Our focus herein deals only with the stability of the reclamation cover overlying the tailing material.

A common misconception regarding liquefaction is that liquefied material has no shear strength. Professor H. B. Seed (Seed, 1986) dispelled this misconception and recommended a technique for evaluating the insitu undrained residual strength (S_r) of liquefied material based on Standard Penetration testing. He presented the results of back-analyses of a number of liquefaction failures from which values of the residual undrained strength could be calculated for soil zones in which SPT data was available, and proposed a correlation between S_r and $(N_1)_{60\text{-}cs}$. $(N_1)_{60\text{-}cs}$ is a corrected penetration resistance defined as follows:

$$(N_1)_{60\text{-}cs} = (N_1)_{60} + N_{corr}$$

where N_{corr} is a function of percent fines, as shown below:

Recommended Fines Correction for Sr Evaluation Using SPT Data

Percent Fines	N_{corr} (blows/ft)
10%	1
25%	2
50%	4
75%	5

It should be noted that this is not the same fines correction as is used in estimating the Cyclic Stress Ratio as described in Appendix L of the TRP for the original liquefaction analyses.

Figure 4 presents an updated (Seed and Harder, 1990) correlation between S_r and $(N_1)_{60-cs}$ based on values back-calculated from and increased number of liquefaction case studies over that presented in the original 1986 article. As shown in Figure 4, the minimum undrained residual shear strength is shown to be about 50 psf, and values as high as 600-800 psf could be developed for materials with equivalent clean sand SPT blowcount values of 16 or so. As discussed in the TRP, the gradation of the tailing material at the Sherwood site is quite variable. For classification purposes, the material is defined as sandy slimes for material having a percentage between about 13% and 50%, and silty to clayey slimes having a percentage of fines greater than 50%. Figures presenting fines content and uncorrected SPT results as a function of depth for each boring were presented in Appendix L of the TRP. Due to the inherent variability of the fines content within the tailing material, it is reasonable to conclude that no continuous or through-going lens of a given type exists within the tailing pond. For purposes of assessing the post-liquefaction stability of the reclamation cover, a conservative residual undrained shear strength of 150 psf was assumed. This value is based on an average minimum $(N_1)_{60}$ value of 7 for both the sandy and slimy tailing, and an N_{corr} value of 2, thus resulting in an equivalent clean sand SPT blow count $(N_1)_{60-cs}$ value of 8. It is likely that the average $(N_1)_{60-cs}$ value for the clayey slimes portion of the tailing pond is equal to 12-14 with a residual undrained shear strength of 300-400 psf.

Although we do not believe that major liquefaction is probable within the tailing material, a special infinite slope stability analysis was performed to determine the likelihood of whether, in the event liquefaction were to occur, wholesale movement or rafting of the cover would occur. The stability analyses were performed using a modified infinite slope analysis technique graphically shown on Figure 5, and discussed below.

The post-liquefaction stability analysis was performed using the following assumptions:

1) the cover material is not susceptible to liquefaction or strength loss during earthquake shaking;

2) a total stress undrained friction angle of the cover material equal to 20°;

3) a residual undrained shear strength of the tailing equal to between 50 and 150 psf;

4) liquefaction within the tailing could develop up to the cover-tailing interface.

The analytical approach using a modified infinite slope analysis is diagrammatically shown in Figure 5, and results are summarized on Table 1, which is a copy of the computerized calculation sheet. As shown in Figure 5, the modified infinite slope approach assesses the stability of a two-dimensional slice of the tailing cover, and simply evaluates the stresses acting within the section, and the Factor of Safety (FS) by comparing the shear strength mobilized within the section to the unbalancing stresses tending to cause failure. The term modified is used to describe the method since infinite slope analysis usually are performed for cohesionless soils and simply defines the FS as the ratio of tan ϕ/tan i, where ϕ is the friction angle of the soil and (i) is the slope inclination. As shown in Figure 5, the equations reduce to tan ϕ/tan i if the failure is infinitely long and the effects of the active and passive wedges, which connect ground surface to the failure plane, are ignored due to a shallow depth of failure. The analytical modification was necessitated by the fact that the cover will be 12.5 feet thick, and it was necessary to evaluate the stability of different potential failure lengths.

As shown by the results presented on Table 1, the FS for the post-earthquake stability analysis indicate that no wholesale rafting or displacement is likely to occur in the event liquefaction were to develop within the tailing, using the assumption cited earlier. The minimum FS is computed for an infinitely long failure surface which, as shown by the results, does not consider the active and passive wedge. The results presented on Table 1 show a FS of 2, 3, and 5 for residual undrained shear strength values of 50, 100, and 150 psf, respectively. For potential rafting failures of less than 100 feet in length, the minimum computed FS is 7 for the lowest assumed residual shear strength of 50 psf. Based on these results, we conclude that even if liquefaction were to develop within the tailing material, it is unlikely that wholesale movement or rafting would develop within the reclamation cover. We recognize, however, that a major difficulty in the simplified liquefaction analysis discussed above is that it does not consider the effect of limiting strain which, upon the development of pervasive liquefaction within the tailing, could significantly soften the material and render it susceptible to an increased lateral strain. A new analytical method which does incorporate this concept is discussed below.

We have reviewed several technical articles sent to us by Mr. LaVassar, dealing with liquefaction and earthquake-induced liquefaction. The most important of these articles (Byrne, 1992) discusses a model for predicting liquefaction induced lateral displacement. The model is similar to that proposed by Newmark (1965) except that a nonlinear spring representing the stiffness of the liquefied layer as well as its residual strength is incorporated, rather than the rigid plastic spring considered by Newmark. Byrne points out that the key parameters for the model are the residual strength (Seed and Harder, 1990) and the limiting strains upon liquefaction (Seed et al, 1984). Byrne does not mention that an equally important parameter in developing lateral strains after the onset of liquefaction is the duration of shaking, which is directly related to the earthquake magnitude. In other words, it is possible that an earthquake could be sufficiently strong to initiate liquefaction, but not sufficiently long in duration of strong shaking to produce adverse lateral strain. This was the case for the onset of liquefaction induced at the Oakland Airport and Treasure Island sites during the 1987 Loma Prieta Earthquake. Fortunately, from a catastrophic damage standpoint, the liquefaction at both of these sites developed late enough in the time history of shaking that even though wholesale liquefaction is known to have developed, strong shaking stopped soon thereafter and major damage due to lateral spreading was fortunately averted.

Another point of concern deals with the potential that liquefaction-induced sand boils could propagate to ground surface following an earthquake. The development of sand boils occurs as a result of excess pore pressures causing a "quick" condition (i.e., zero effective stress), and then carrying fine sands to the surface due to high upward seepage gradients. The fact that a minimum 12.5-ft thick non-liquefiable cover will be used to cover the Sherwood tailing impoundment significantly reduces the probability that sand boils could propagate to the surface. In many areas of the impoundment, the total thickness of material, including the subgrade and cover, will be about 17-ft thick.

In conclusion, we do not believe that the tailing materials at the Sherwood site are susceptible to the development of wholesale liquefaction, lateral spreading, or the development of sand boils, due to following considerations:

1) the new cover design will consist of homogeneous random fill material and is no longer vulnerable to degradation due to cracking or differential settlement;

2) the new cover will be minimum of 12.5-ft thick and will significantly increase the effective stresses within the upper 30 feet, or so, of tailing material;

3) the random earthquakes that are sufficiently strong to possibly induce liquefaction within the sandier portion of the tailing would probably not be of sufficient duration to induce lateral spreading.

We recognize that the original data base relied on conventional SPT data obtained through a hollow stem auger, and that these data indicate very low blow counts within certain sections of the tailing. The fact is, however, that the majority of these tests were obtained from below the water table which could have adversely impacted the results due to high upward seepage gradients within the annulus of the hollow stem auger. The results of the recently completed CPT probes are very important in verifying the discontinuous nature of the tailing, at least with regard to the possibility of continuous sand lenses within the tailing. These results also confirm the relatively low shear strength of the tailing material assumed in the analysis.

I trust this letter adequately addresses the concerns raised by the State in their review of the TRP. If I can be of any further assistance in this matter, please do not hesitate to contact me.

REGISTERED PROFESSIONAL ENGINEER
RICHARD L. VOLPE
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Exp. 9-30-97
GEOTECHNICAL
STATE OF CALIFORNIA

Very truly yours,

R. L. VOLPE & ASSOCIATES, Inc.

Richard L. Volpe, P.E.
G.E. 866, California

Attachments

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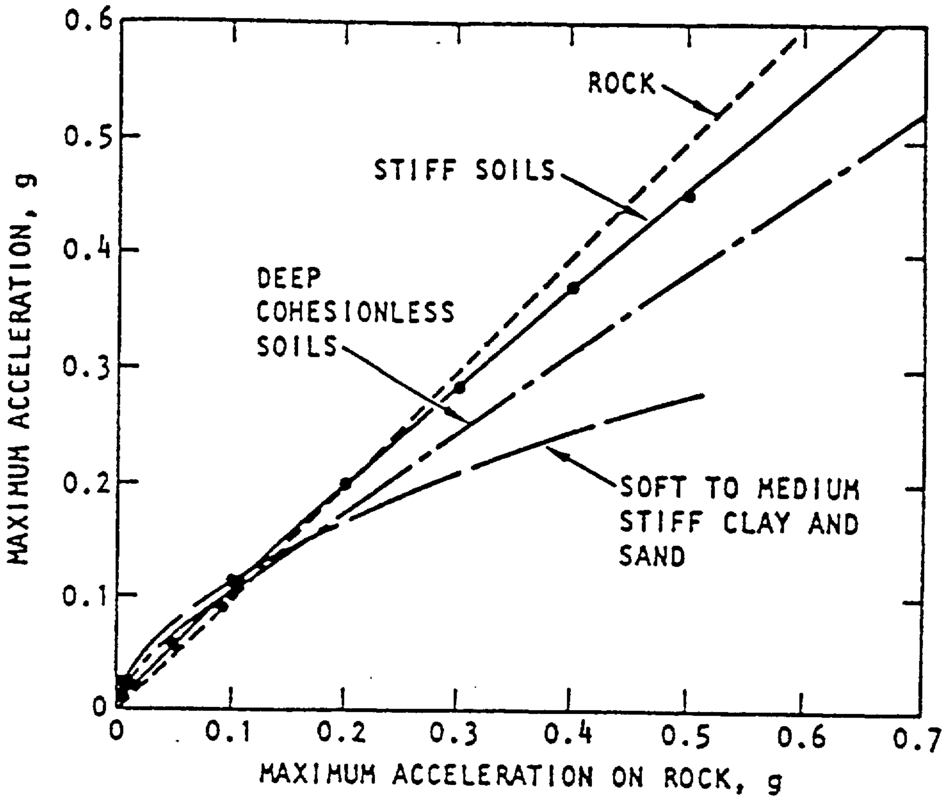
Table 1 - Modified Infinite Slope Stability Analysis

A. Static Analysis						
				gam = 120		
Pa = 1/2 Ka gamma D^2 (Ka = 0.33 for cover soil)	Soil Cover	Ka	Kp	@ D=13'	@ D=13'	
Pp= 1/2 Kp gamma D^2 (Kp = 3.0 for soil cover)	Phi			Pa	Pp	Pp-Pa
Pa = Pp = 0 for tailing						
total unit wt of cover = 120 pcf	20	0.49	2.04	4972	20681.61	15710.07
Strength = N * tan (phi) + c*L + Pp - Pa	25	0.41	2.46	4115	24984 08	20868.67
phi = 35 degrees for tailing ; c = 0	30	0.33	3.00	3380	30420 00	27040 00
S = N * tan (phi) + Pp- Pa						
N = gamma * D * L cos^2 i			Factor of Safety			
Stress = T = gamma * D * cos i * sin i	Length of					
sin i = tan i = 0.02; cos i = 1.0	Failure	Gam*D*L*tan phi	0.5*(Pp-Pa)*gamma*D^	gam*D*L*0.02	Static	
FS = Strength/Stress	Surface				FS	
FS= gam*D*L cos^2 i * tan phi + 0.5*(Pp-Pa) * gam * D^2	(ft)					
divided by (gamma D*L*cos i sin i)	50	54600	211608319	1560	135681.36	
D=Depth of cover = 13 feet	100	109200	211608319	3120	67858.18	
	150	163800	211608319	4680	45250.45	
	200	218400	211608319	6240	33946.59	
B. Post-Liquefaction Analysis						
				gam = 120		
Pa = 1/2 Ka gamma D^2 (Use Ka = 0.494 for cover soil)	Soil Cover	Ka	Kp	@ D=13'	@ D=13'	
Pp= 1/2 Kp gamma D^2 (Use Kp = 2.04 for soil cover)	Phi			Pa	Pp	Pp-Pa
Pa = Pp = 0 for tailing						
total unit wt of cover = 120 pcf	20	0.49	2.04	4972	20681.61	15710.07
Strength = N * tan (phi) + c*L + Pp - Pa	25	0.41	2.46	4115	24984.08	20868.67
phi = 0 for tailing	30	0.33	3.00	3380	30420.00	27040.00
S = c*L + Pp- Pa (c= 50, 100, and 150 psf for tailing)						
			Factor of Safety (Sr = 50 psf)			
Stress = T = gamma * D * cos i * sin i	Length of				Post-Liq.	Post-Liq.
sin i = tan i = 0.02; cos i = 1.0	Failure	c*L	c*L + (Pp-Pa)	gam*D*L*cos i	FS	FS
FS = Strength/Stress = [c*L +Pp - Pa] / [gamma*D*L*cos i]	Surface				(w/Pp & Pa)	(w/o Pp & Pa)
	10	500	16210	312	51.96	1.60
	25	1250	16960	780	21.74	1.60
	50	2500	18210	1560	11.67	1.60
	100	5000	20710	3120	6.64	1.60
	150	7500	23210	4680	4.96	1.60
	200	10000	25710	6240	4.12	1.60
	300	15000	30710	9360	3.28	1.60
	400	20000	35710	12480	2.86	1.60
	500	25000	40710	15600	2.61	1.60
			Factor of Safety (Sr = 100 psf)			
	Length of					
	Failure	c*L	c*L + (Pp-Pa)	gam*D*L*cos i	FS	FS
	Surface				(w/Pp & Pa)	(w/o Pp & Pa)
	10	1000	16710	312	53.56	3.21
	25	2500	18210	780	23.35	3.21
	50	5000	20710	1560	13.28	3.21
	100	10000	25710	3120	8.24	3.21
	150	15000	30710	4680	6.56	3.21
	200	20000	35710	6240	5.72	3.21
	300	30000	45710	9360	4.88	3.21
	400	40000	55710	12480	4.46	3.21
	500	50000	65710	15600	4.21	3.21
			Factor of Safety (Sr = 150 psf)			
	Length of					
	Failure	c*L	c*L + (Pp-Pa)	gam*D*L*cos i	FS	FS
	Surface				(w/Pp & Pa)	(w/o Pp & Pa)
	10	1500	17210	312	55.16	4.81
	25	3750	19460	780	24.95	4.81
	50	7500	23210	1560	14.88	4.81
	100	15000	30710	3120	9.84	4.81
	150	22500	38210	4680	8.16	4.81
	200	30000	45710	6240	7.33	4.81
	300	45000	60710	9360	6.49	4.81
	400	60000	75710	12480	6.07	4.81
	500	75000	90710	15600	5.81	4.81

Note:

See Figure 5 for schematic drawing showing force diagram, definition of terms, and plot of results.

Performed by R. L. Volpe
June 16, 1995



(from Seed and Idriss, 1982)

R.L. VOLPE & ASSOCIATES
Los Gatos, California

SHERWOOD TAILING IMPOUNDMENT

VARIATIONS OF ACCELERATIONS ON SOIL SITES vs ROCK SITES

Checked by ______	Date ______	Project No.	Figure No.
Approved by RLVolpe	Date 9-12-95	SM1-100	1

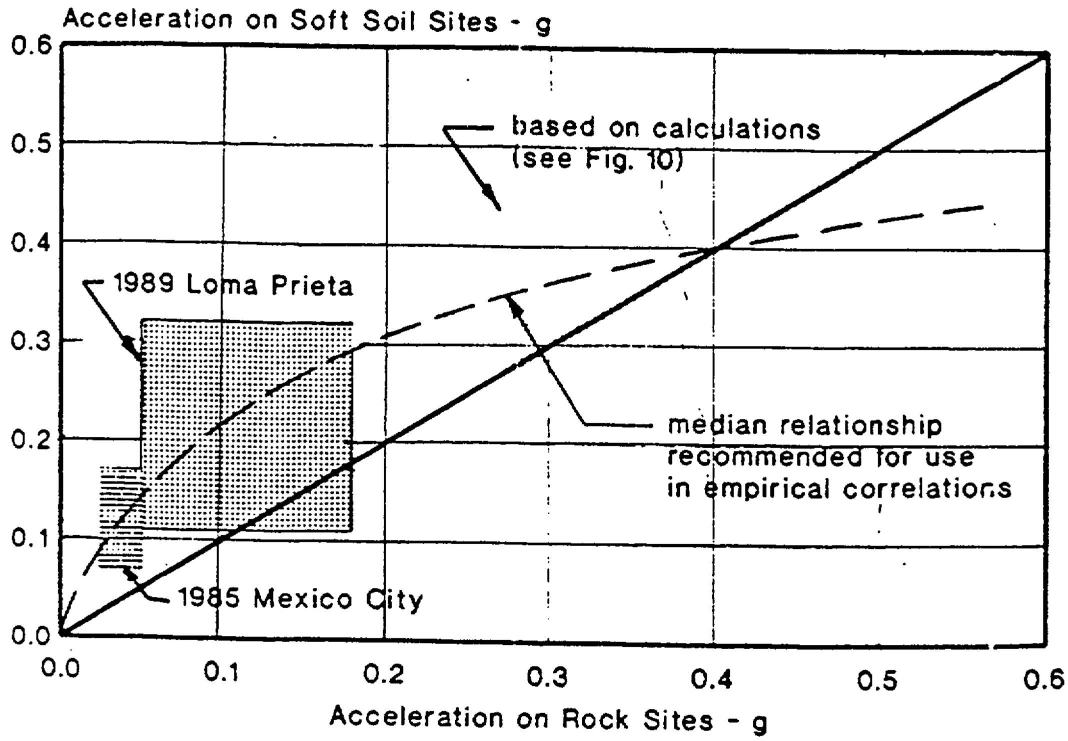


Fig. 11 VARIATIONS OF ACCELERATIONS ON
SOFT SOIL SITES Vs ROCK SITES

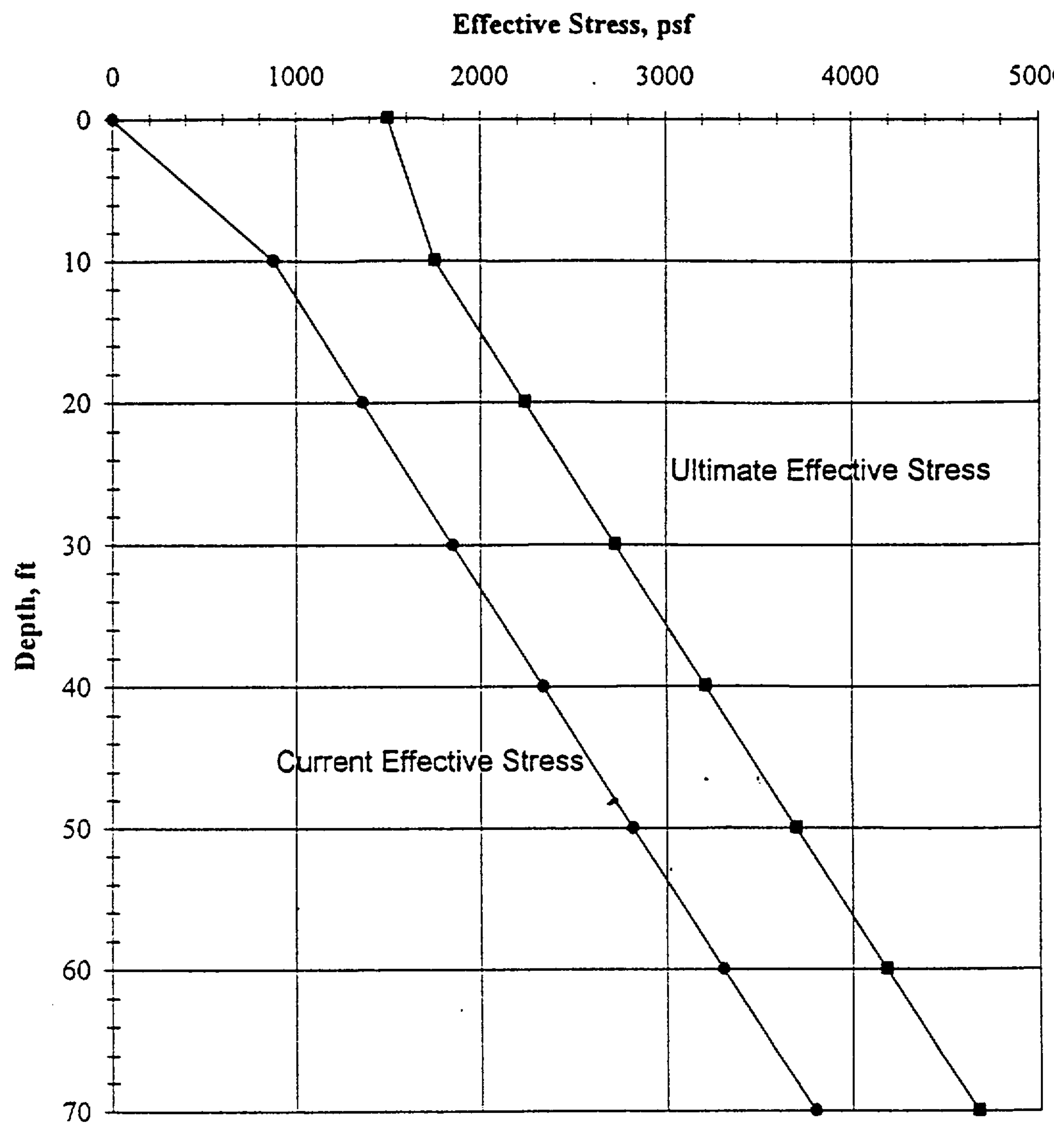
(from Idriss, 1990)

R.L. VOLPE & ASSOCIATES
Los Gatos, California

SHERWOOD TAILING IMPOUNDMENT

VARIATIONS OF ACCELERATIONS ON SOFT SOIL SITES vs ROCK SITES

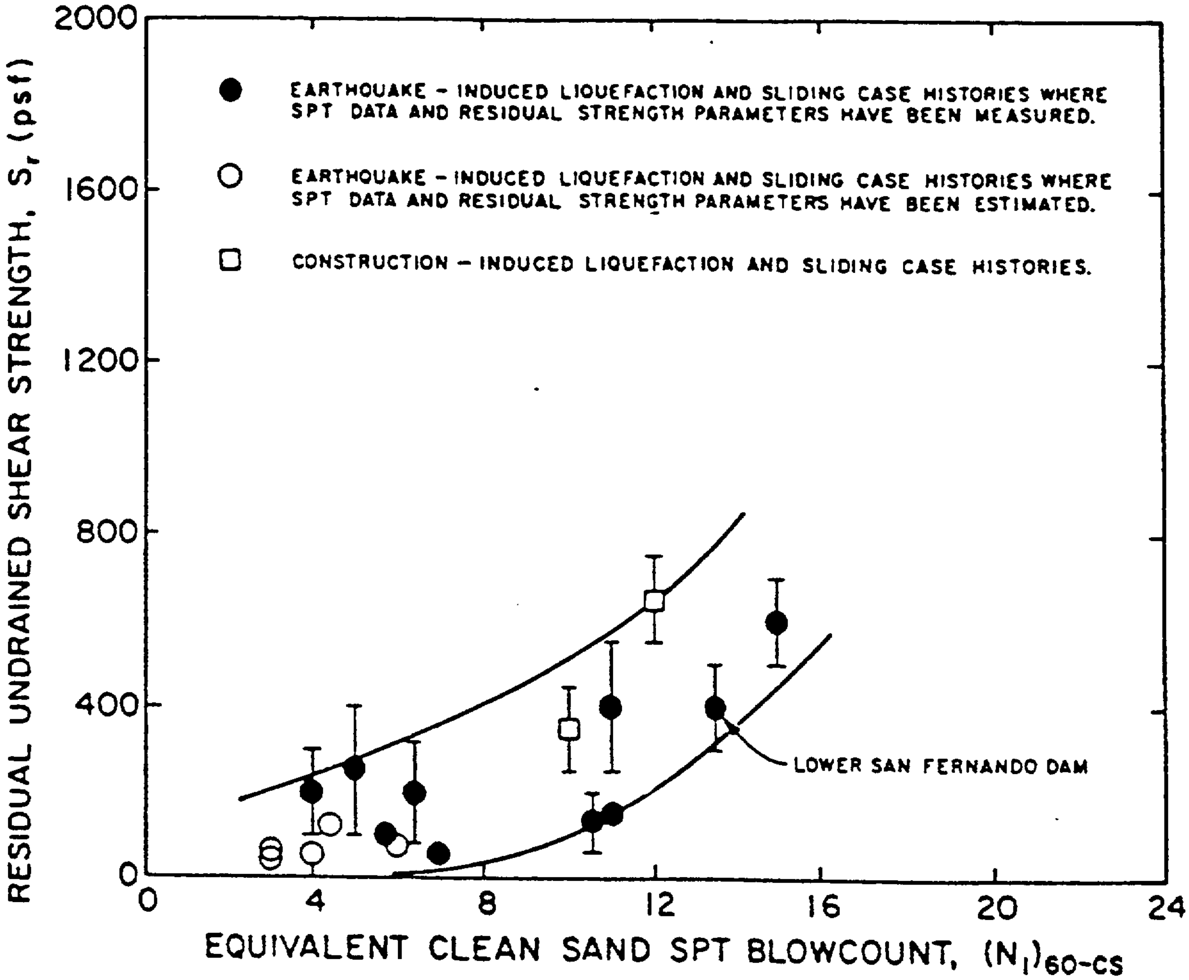
Checked by ______	Date ______	Project No.	Figure No.
Approved by RL Volpe	Date 9-12-95	SMI-100	2



Note:

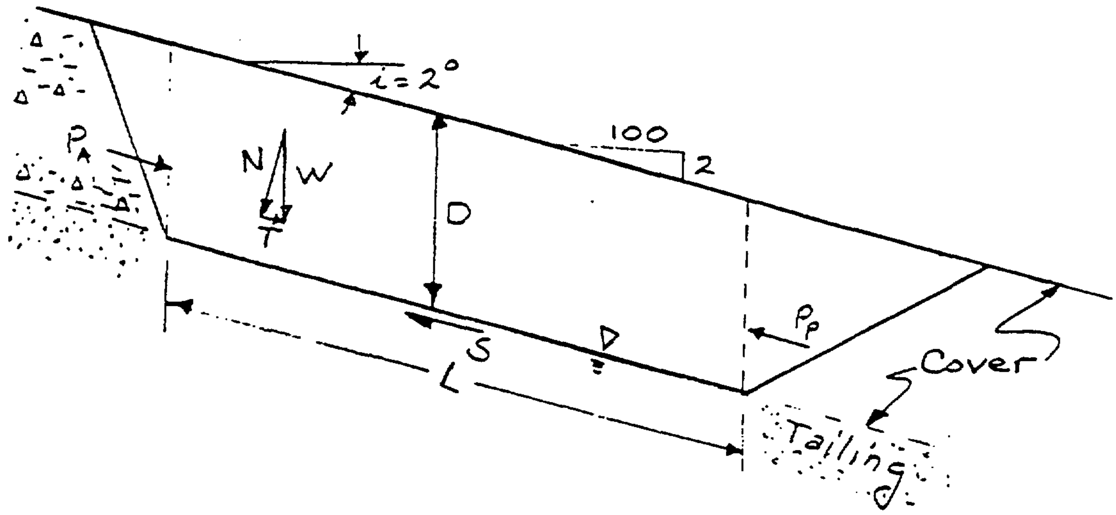
This figure shows the existing and ultimate effective stresses acting with the tailing impoundment. The ultimate effective stress will not be developed until after all settlement has occurred following construction of the 13-ft thick reclamation cover. Depth is measured from the top of the existing impoundment surface.

R.L. VOLPE & ASSOCIATES Los Gatos, California		
SHERWOOD TAILING IMPOUNDMENT CURRENT AND ULTIMATE EFFECTIVE STRESS vs. DEPTH		
Checked by ______ Date ______ Approved by RLVolpe Date 9-12-95	Project No. SMI-100	Figure No. 3



(from Seed and Harder, 1990)

R.L. VOLPE & ASSOCIATES Los Gatos, California			
SHERWOOD TAILING IMPOUNDMENT **RESIDUAL UNDRAINED SHEAR STRENGTH vs EQUIVALENT SPT BLOWCOUNT**			
Checked by ______	Date ______	Project No.	Figure No
Approved by RLVolpe	Date 9-12-95	SM1-100	4



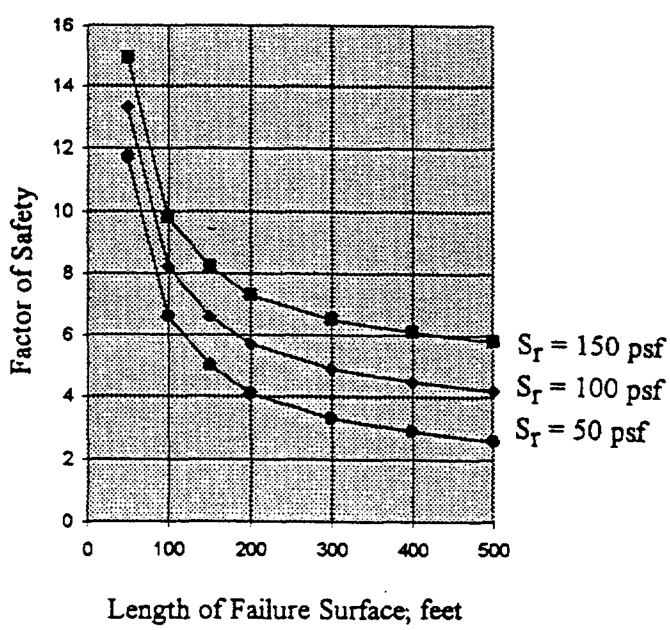
STRENGTH: $S = c*L + N*\tan\phi + P_P - P_A$ $\quad N = \gamma*D*L*\cos^2 i$

STRESS: $T = \gamma*D*L*\cos i*\sin i$

FACTOR OF SAFETY: $FS = \dfrac{STRENGTH}{STRESS} = \dfrac{S}{T}$

$$FS = \frac{\gamma*D*L*\cos^2 i*\tan\phi + c*L + 1/2(2.04-0.49)*\gamma*D^2}{\gamma*D*L*\cos i*\sin i}$$

FACTOR OF SAFETY
vs
LENGTH OF FAILURE SURFACE



R.L. VOLPE & ASSOCIATES
Los Gatos, California

SHERWOOD TAILING IMPOUNDMENT

MODIFIED INFINITE SLOPE STABILITY ANALYSIS

Checked by ______	Date ______	Project No.	Figure No
Approved by RL Volpe	Date 9-12-95	SMI-100	5

STATE OF WASHINGTON
DEPARTMENT OF ECOLOGY
P.O. Box 47600 • Olympia, Washington 98504-7600
(360) 407-6000 • TDD Only (Hearing Impaired) (360) 407-6006

FILE 03-317 4
2.1.3

December 15, 1997

Ms. Stephanie J. Baker
Manager, Environmental Services
Western Nuclear, Inc.
200 Union Blvd., Suite 300
Lakewood, CO 80228

PROJECT: Sherwood Mine Tailings Reclamation
FILE NO.: ST54-378

Dear Ms. Baker:

On September 25, I toured the reclaimed tailings pond area in the company of Mr. Corn Abeyta of WNI and Mr. John Blacklaw of the DOH. Based on the conditions I observed during that tour, it is my opinion that the mine tailings impoundments have been reclaimed in accordance with the approved plans and specifications. In addition, our office has been provided with a copy of the three volume construction control and inspection reports.

As the provisions of the Dam Safety Section's reclamation requirements have been satisfied, the project is hereby reclassified as reclaimed. This office will maintain files on this project. However, no periodic inspections will be made of the facility. Any future involvement of the Dam Safety Section with this project would be at the behest of the project owner and/or the Department of Health.

If you have any questions or comments, I can be reached at (360) 407-6625 or by e-mail at jlsd461@ecy.wa.gov

Sincerely,

Jerald LaVassar

Jerald LaVassar, M.S., P.E.
Water Resources Program
Dam Safety

cc: Lou Miller, SMI ✓
Gary Robertson, DOH-DRP
John Blacklaw, DOH-DRP
Dorothy Stoffel, DOH-DRP
Pat Hallinan, WDOE-WQS
Mary Verner, Spokane Tribe

RECEIVED

JUN 2 7 2000

DIVISION OF RADIATION PROTECTION

STATE OF WASHINGTON

DEPARTMENT OF ECOLOGY

P.O. Box 47600 • Olympia, Washington 98504-7600
(360) 407-6000 • TDD Only (Hearing Impaired) (360) 407-6006

June 23, 2000

Mr. John Blacklaw, P.E.
Department of Health
Division of Radiation Protection
7171 Cleanwater Lane, Bldg. 5
P.O. Box 47827
Olympia, WA 98504-7827

Re: Sherwood Project

Dear Mr. Blacklaw:

At the June 21, site meeting with representatives of the Nuclear Regulatory Commission, the Department of Energy, FERC, your agency, and the project's owner and engineer, the question of whether the reclaimed impounding structure was still a dam figured prominently. This letter serves to clarify Ecology's Dam Safety Office's (DSO) position on the matter.

As stated at the site meeting, the DSO views the reclaimed impounding barrier as a dam. Reclaiming the impounding structure involved reducing the embankment height, flattening the downstream slope and armoring the downstream face. These measures represented a practical scheme to provide a high likelihood of the structure safely impounding the process waste for the thousand-year design life assuming little, if any, maintenance. The DSO's approval of the reclamation plans for the impounding barrier reflected our concurrence as engineers that the design provided adequate static and seismic stability and erosion protection. The DSO remains steadfast in its opinion that the engineering assessment of the reclaimed impounding structure is valid.

On the administrative side the reclaimed dam is considered a jurisdictional dam under the provisions of Washington Administrative Code (WAC) 173-175-020 Applicability, copy attached. The practical consequences of that classification are that the impounding barrier would be inspected on a 6 to 8 year frequency or following the occurrence of an extreme storm or earthquake in the immediate vicinity. The frequency of inspections is dictated by Water Resource Program Policy 5404, copy attached. The project would be removed from our jurisdiction in the event a Federal Agency assumes ownership of the project, provided that it has (or can contract with) a dam safety program which will conduct periodic inspections of the impoundment, see WAC 173-175-020(3) of attachment. Presently, there is no cost for DSO's periodic inspections and the resulting report of findings. The only cost to the project owner would arise should a serious deficiency be found with the integrity of the impounding barrier. In that remote instance, the owner would be required to undertake the necessary repairs to the impounding barrier to address the identified concern.

If there are any questions in this matter, please contact me at (360) 407-6625.

Sincerely,

Jerald M LaVassar

Jerald LaVassar, M.S., P.E.
Water Resources Program
Dam Safety Office

Attachments

POL 5404 **WATER RESOURCES PROGRAM POLICY**

Resource Contact: Dam Safety Office Effective Date: 07-01-91

References: RCW 43.21A.064 Revised: 07-01-1999
RCW 86.16.035
Chapter 173-175 WAC

FREQUENCY OF PERIODIC DAM INSPECTIONS

POLICY STATEMENT:

Periodic inspections of existing dams should be conducted on regularly scheduled intervals. The time interval between inspections should depend on the dam and reservoir size and the potential downstream hazard posed by the facility. Those dams which reside above populated areas should ideally be inspected on a 6 year cycle. Those dams which do not pose a threat to life can be inspected less frequently.

Should staffing levels be insufficient to inspect all dams under Ecology jurisdiction, the dams will be ranked according to size and downstream hazard and a prioritization scheme will be used to aid in the selection of dams for inspection. Those dams which could pose the greatest threat to life and property will be selected for inspection on regular intervals. The remaining dams would be inspected as the workload and time permit.

DISCUSSION:

Guidelines for dam safety prepared by the Federal Emergency Management Agency recommend annual inspections of high hazard dams (3 or more homes at risk), a 2-year interval for significant hazard dams (1 or 2 homes at risk), and a 5-year interval for low hazard dams (no homes at risk). The Bureau of Reclamation currently inspects their high and significant hazard dams on a 3 year interval for an Operation and Maintenance Inspection, and a 6 year interval for a Comprehensive inspection. Considering the large number of high and significant hazard dams to be inspected by the Dam Safety Section and the limited staffing currently available, a goal of a 6 year comprehensive inspection interval was selected and is considered to provide the minimum acceptable level of protection to the public.

This policy also identifies a longer inspection interval for dams with "low" downstream hazards. The primary reason for inspecting low hazard dams is to evaluate the downstream floodplain for new development. If development has occurred and lives could be at risk by a dam failure, then the inspection frequency should be increased.

Staffing is anticipated to be insufficient for the foreseeable future to meet the desirable goals for frequency of periodic inspections. This policy identifies that a ranking and prioritization scheme is to be used to aid in the selection of projects to be inspected with available workforces.

PROCEDURES:

The physical characteristics of dam size, reservoir storage and magnitude of a dam break flood are to be used to assess the consequences of dam failure on lives and property in the downstream valley. This information is to be used to rank the dams according to their potential public safety threat if a dam failure were to occur.

A prioritization scheme is to be used to aid in the selection of dams for inspection from the ranked dam listing. Those dams which could pose the greatest threat to life and property will be selected for inspection on regular intervals. The remaining dams would be inspected as the workload and time permit.

The following periodic inspection schedule is a minor modification of the schedule that was reviewed and accepted by the Ecology Executive Management Team during the 1991 Strategic Budget Planning Process. Table 1 outlines the general format for conducting the periodic inspection program.

Keith E. Phillips

Keith E. Phillips
Program Manager
Water Resources Program

PERIODIC INSPECTION CLASSIFICATIONS

TYPE	PURPOSE	USAGE	DESCRIPTION
CLASS 1	COMPREHENSIVE INSPECTION	First Periodic Inspection	Visual inspection of all project elements; Detailed engineering analysis of project elements under extreme flood and earthquake; Prepare comprehensive report of findings.
CLASS II	INTERMEDIATE LEVEL INSPECTION	Subsequent Periodic Inspections	Visual inspection of all project elements; Some engineering analysis of selected elements; Prepare summary report of findings.
CLASS III	RECONNAISSANCE INSPECTION	Preliminary Inspection	Visual inspection of most project elements; Minimal engineering analyses; Prepare memo to file summarizing inspection.

PRIORITIZATION SCHEME FOR PERIODIC INSPECTION OF EXISTING DAMS

DOWNSTREAM HAZARD CLASSIFICATION	CYCLE	NUMBER OF DAMS	INSPECTIONS	
			NUMBER /YEAR	TYPE
FIRST TIER				
High Downstream Hazard Dams (Downstream Hazard Class 1A, 1B, 1C)	6 years	111	18	Class I or II
Significant Downstream Hazard Dams (Downstream Hazard Class 2) Greater than 20 ft. high	8 years	75	9	Class I or II
SECOND TIER				
Significant Downstream Hazard Dams (Downstream Hazard Class 2) & Low Downstream Hazard Dams (Downstream Hazard Class 3) Greater than 15 ft. high	10 Years	106 119	23	Class III
THIRD TIER				
Low Downstream Hazard Dams (Downstream Hazard Class 3) Less than 15 ft. high	None	471	5	Class III
TOTALS			55	

APPENDIX A
STATE STATUTES AND ADMINISTRATIVE RULES PERTAINING TO DAM SAFETY

Dam Safety Guidelines

Part I:
General Information & Owner Responsibilities

WASHINGTON STATE STATUTES

RCW 43.21A.064 Powers and duties - Water resources.
Subject to RCW 43.21A.068, the director of the department of ecology shall have the following powers and duties:

(2) Insofar as may be necessary to assure safety to life or property, he shall inspect the construction of all dams, canals, ditches, irrigation systems, hydraulic power plants, and all other works, systems and plants pertaining to the use of water, and he may require such necessary changes in the construction or maintenance of said works, to be made from time to time, as will reasonably secure safety to life and property;

RCW 43.21A.068 Federal power act licensees - Exemption from state regulations.
(1) With respect to the safety of any dam , canal, ditch, hydraulic power plant, reservoir, project, or other work, system or plant that requires a license under the federal power act, no licensee shall be required to:

(a) submit proposals, plans, specifications or other documents for approval by the department;
(b) seek a permit, license or other form, permission, or authorization from the department;.
(c) submit to inspection by the department; or
(d) change a design, construction, modification, maintenance, or operation of such facilities at the demand of the department.

(2) For the purposes of this section, "licensee" means an owner or operator, or any employee thereof, of a dam, canal, ditch, hydraulic power plant, reservoir, project, or other work, system, or plant that requires a license under the federal power act.

RCW 86.16.035 Department of Ecology - Control of dams and obstructions.
Subject to RCW 43.21A.068, the department of ecology shall have supervision and control over all dams and obstructions in streams, and may make reasonable regulations with respect thereto concerning the flow of water which he deems necessary for the protection to life and property below such works from flood waters.

RCW 90.03.350 Construction or modification of storage dam - Plans and specifications.
Except as provided in RCW 43.21A.068, any person, corporation or association intending to construct or modify any dam or controlling works for the storage of ten acre feet or more of water, shall before beginning said construction or modification, submit plans and specifications of the same to the department for examination and approval as to its safety. Such plans and specifications shall be submitted in duplicate, one copy of which shall be retained as a public record, by the department, and the other returned with its approval or rejection endorsed thereon. No such dam or controlling works shall be constructed or modified until the same or any modification thereof shall have been approved as to its safety by the department. Any such dam or controlling works constructed or modified in any manner other than in accordance with plans and specifications approved by the department or which shall not be maintained in accordance with the order of the department shall be presumed to be a public nuisance and may be abated in the manner provided by law, and it shall be the duty of the attorney general or prosecuting attorney of the county wherein such dam or controlling works, or the major portion thereof, is situated to

institute abatement proceedings against the owner or owners of such dam or controlling works, wherever he is requested to do so by the department

A metal minings and milling operation regulated under chapter 232, Laws of 1994, is subject to additional dam safety inspection requirements due to the specific hazards associated with failure of a tailings impoundment. The department shall inspect these impoundments at least quarterly during the project's operation and at least annually thereafter for the postclosure monitoring period. in order to ensure the safety of the dam or controlling works. The department shall conduct additional inspections as needed during the construction phase of the mining operation in order to ensure the safe construction of the tailings impoundment.

RCW 90.03.470 Schedule of fees.

The following fees shall be collected by the department in advance:

-
-

(8) For the inspection of any hydraulic works to insure safety to life and property, the actual cost of the inspection, including the expense incident thereto.

(9) For the examination of plans and specifications as to safety of controlling works for storage of ten acre feet or more of water, a minimum fee of ten dollars, or the actual cost.

WASHINGTON STATE ADMINISTRATIVE RULES

DAM SAFETY REGULATIONS
CHAPTER 173-175 WAC

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PART ONE
GENERAL

PART TWO
CONSTRUCTION PERMIT PROCESS

PART THREE
CONSTRUCTION PERMIT FEES

PART FOUR
PROJECT OPERATION

PART FIVE
COMPLIANCE AND ENFORCEMENT

CHAPTER 173-175 WAC
DAM SAFETY REGULATIONS

PART ONE - GENERAL

WAC 173-175-010 Purpose and Authority. These regulations provide for the comprehensive regulation and supervision of dams in order to reasonably secure safety to life and property pursuant to Chapters 43.21A, 43.27A, 86.16, 90.03, 90.28, and 90.54 RCW. The purposes of these regulations are to:

(1) Designate the types of dams to which these regulations are applicable;

(2) Provide for the design, construction, operation, maintenance and supervision of dams in a manner consistent with accepted engineering practice;

(3) Establish and administer a program for permitting of construction work for new dams and for modifications of existing dams;

(4) Establish a fee schedule based on dam size that will reflect the actual cost to the department of engineering review of plans and specifications and for construction inspections;

(5) Establish the requirements and owner responsibilities for developing and executing plans for Operation and Maintenance, Owner Inspection and Emergency Actions; and

(6) Encourage owners to establish a program for the Periodic Inspection of their projects.

WAC 173-175-020 Applicability. (1) These regulations are applicable to dams which can impound a volume of 10 acre-feet or more of water as measured at the dam crest elevation. The 10 acre-feet threshold applies to dams which can impound water on either an intermittent or permanent basis. Only water that can be stored above natural ground level and which could be released by a failure of the dam is considered in assessing the storage volume.

The 10 acre-feet threshold applies to any dam which can impound water of any quality, or which contains any substance in combination with sufficient water to exist in a liquid or slurry state at the time of initial containment.

(2) For a dam whose dam height is six feet or less and which meets the conditions of subsection (1) of this section, the department may elect to exempt the dam from these regulations.

The decision by the department to exempt a dam will be made on a case by case basis for those dams whose failure is not judged to pose a risk to life and minimal property damaged would be expected (Downstream Hazard Class 3).

(3) These regulations do not apply to dams that are, or will be, owned, by an agency of the Federal government which has oversight on operation and maintenance and has its own dam safety program for periodic inspection of completed projects. The department will continue to be the state repository for pertinent plans, reports and other documents related to the safety of Federally owned dams.

(4) These regulations do not apply to transportation facilities such as roads, highways or rail lines which cross watercourses and exist solely for transportation purposes and which are regulated by other governmental agencies.

Those transportation facilities which cross watercourses and which have been, or will be, modified with the intention of impounding water on an intermittent or permanent basis and which meet the conditions of subsection (1) of this section, shall be subject to these regulations.

(5) These regulations do not apply to dikes or levees constructed adjacent to or along a watercourse for protection from natural flooding or for purposes of floodplain management.

SHERWOOD PROJECT
TAILING RECLAMATION PLAN

Volume 3 of 7
APPENDICES A, B, C

Prepared for

Western Nuclear, Inc.
Sherwood Project
Wellpinit, Washington

Prepared by

Shepherd Miller Inc.
1600 Specht Point Drive, Suite F
Fort Collins, CO 80525

December 1994

SMI
Shepherd Miller, Inc.

APPENDIX B
RIPRAP DURABILITY TESTING

TABLE OF CONTENTS

APPENDIX B

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

This Appendix addresses the availability and suitability of both on-site and off-site rock investigated as potential riprap borrow sources.

1.1 On-Site Rock

Three potential types of riprap, available on site, have been identified by WNI: 1) Quartz Monzonite which occurs throughout the mine area, 2) Basalt, primarily concentrated west and south of the clay stockpiles, and 3) a Quartzite Conglomeratic aggregate found mainly in the pit walls.

1.2 Off-Site Rock

Three potential sources of off-site Basaltic rock have been identified by WNI. The sources have been designated the Wellpinit North Site, the Wellpinit South Site, and the Reardan Site. The location of each of these sites is given in Figure 1.

The Wellpinit North Site is located on the Spokane Indian Reservation, approximately 10 road miles northeast of the Sherwood Mine. The Wellpinit South Site is also on the Spokane Reservation, approximately 9 road miles southeast of the Sherwood Mine. The Reardan Site is approximately 22 road miles southeast of the Sherwood Mine.

2.0 SAMPLING

A total of fifteen composite samples, consisting of approximately 150 pounds of rock each (3-5 gallon buckets per sample), were collected from the Sherwood Site, and the two Wellpinit Sites. Samples of each rock type were selected to be representative of macroscopic bulk composition and secondary weathering of the source material. Eight samples were collected from the Sherwood Site; five in September 1991, and three in April 1993. Four samples were collected from the Wellpinit North Site in June 1992, and three samples were taken from the Wellpinit South Site; one in July 1992, and two in April 1993.

The Reardan Site was investigated in June 1992 to determine type, size, and volume of material available for borrow. This site was not sampled because status and ownership has not been established.

2.1 Sherwood Site

Basalt:

Two Basalt cap ridges, identified as North Cap and South Cap in Figure 2, and two basalt stockpiles, also shown in Figure 2, have been investigated as potential rock borrow sources.

Two samples identified as B-1 and B-2 were taken for the Basalt stockpiles and one composite sample identified as B-3 was taken from the North and South Caps.

The Basalt stockpiles are composed of approximately 20,000 to 30,000 cubic yards of angular material varying in size from smaller than 1 inch to a maximum size of 6 inches with an average size of 4 to 6 inches.

The North Cap is composed of approximately 11,800 bank cubic yards of angular rock having sizes in the range of 1 to 12 inches, predominantly 3 to 8 inches. It is estimated that approximately 10 to 20 percent of the North Cap may be composed of material having a diameter of approximately 8 to 12 inches.

The South Cap is composed of approximately 10,900 bank cubic yards of angular rock having sizes in the range of 1 to 8 inches, predominantly 3 to 6 inches.

The Basalt in the North and South Caps could be extracted by ripping and excavated by loader. However, because the basalt is generally mixed with soil, significant screening would be required.

Quartz Monzonite:

The Quartz Monzonite occurs throughout the mine area, ranging from sand to boulder size material, and is typically angular in shape. Because the Quartz Monzonite is found throughout the site, no volume estimate has been made at this time. Samples Q-1, Q-2, Q-3, and Q-4 were taken at the locations shown in Figure 2.

Quartzite Conglomerate:

The Quartzite Conglomerate occurs mainly in the pit walls as a rounded material, ranging from sand size to approximately 3 inches in diameter. No estimate of available volume has been made for this material since the lateral extent of the pitwall deposit is not known. One sample, identified as G-1 was taken at the location shown in Figure 2.

2.2 Wellpinit North Site

Basalt:

Two distinctly different Basalt types were identified at the Wellpinit North Site. The area is characterized by a narrow, localized basalt cap, formed from two side-by-side lava phases. The north phase is composed of approximately 2,800 bank cubic yards of a relatively uniform low density vuggy basalt. The south phase is composed of approximately 2,800 bank cubic yards of three slightly different higher density vesicular to non-vesicular basalt types.

One sample was taken from each of the three basalt types of the south phase, B-4, B-5, and B-6, and one sample, designated B-7, was taken from the north phase.

Visual examination indicates that both phases are composed of angular material with sizes ranging from 2 to 8 inch diameter rock with an average size of approximately 3 to 6 inches.

2.3 Wellpinit South Site

Basalt:

The Wellpinit South Site is a massive, regional basalt cap composed of uniform dense, exceptionally clean, basalt. The site is an abandoned quarry with an adjoining talus slope.

Visual examination indicates that approximately 300,000 bank cubic yards of angular aggregate with sizes in the range of 2 to 24 inches and an average size of approximately 4 to 12 inches could be obtained from this site. Minimal screening of this borrow source could produce an aggregate gradation with a D_{50} ranging from 3 to 18 inches.

Three samples, designated B-8, B-9, and B-10 were taken from this site.

2.4 Reardan Site

Basalt:

The Reardan Site is an existing basalt quarry consisting of high density basalt similar to that at the Sherwood Site but more massive. The quarry was used as a source of crushed rock for county road base material. Oversized material was rejected and stockpiled.

It is estimated that approximately 3,000 to 5,000 cubic yards of material having sizes ranging from 1 to 4 feet in diameter and predominantly 1 to 2 foot diameter is available from the oversize stockpiles. Additionally, a rock ridge south of the main quarry may be a source for 2 to 8 inch diameter aggregate which could be extracted by ripping and excavating by loader.

The two main disadvantages associated with the Reardan Site is that it is both off-reservation and a 22 mile haul to the Sherwood Site.

The Reardan Site was not sampled, however, visual observation indicates that rock available from this site is similar to that found on the Sherwood Site and would likely be a good quality riprap source.

3.0 TESTING

Each of the 15 samples from the Sherwood and Wellpinit Sites were tested for specific gravity and absorption (ASTM C127), sodium sulfate soundness (ASTM C88), LA abrasion (ASTM C535), and Schmidt hammer rebound (ASTM C805) by Empire Laboratories, Fort Collins, Colorado. The original laboratory reports are provided in Attachment A. A microscopic petrographic analysis (ASTM D4992) was performed on each sample, with the exception of the Quartz Monzonite samples, by Theodore P. Paster, Ph.D., Englewood, Colorado. The results of these test are summarized in Table 1, and the original laboratory reports are given in Attachment B. Microscopic petrography was not performed on the Quartz Monzonite samples since a previous analysis, also included in Attachment B, was provided by WNI.

The results of these tests were used to determine the acceptability of the material as a riprap source based on grading criteria and procedures established by the U.S. Nuclear Regulatory Commission (NRC, 1990).

4.0 ROCK GRADING CRITERIA

The NRC has established guidelines for evaluating the suitability of rock to be used as a protective cover on uranium mill tailing impoundments and diversion structures (NRC, 1990). The NRC Staff recommends that "about" 6 test methods be used for final selection and sizing of rock to be used as riprap, and provides procedures to evaluate the suitability of the proposed rock. Five of the 6 recommended test have been conducted on each of the 15 composite samples from the Sherwood and Wellpinit Sites. From Table D1 of NRC, 1990 and the test results given in Table 5.1 the suitability of the borrow sources were determined as shown in Tables 2 through 16.

Acceptance criteria for rock to be used as riprap varies depending on the location where the rock will be used. The NRC has established acceptance criteria for two cases:

1) Rock used in critical areas

2) Rock used in non-critical areas

Critical areas are defined as areas of frequent saturation, all channels, poorly-drained toes and aprons, control structures, and energy dissipation areas. Non-critical areas are defined as being occasionally saturated, top slopes, side slopes, and well-drained toes and aprons.

As shown in Tables 2 through 16, prospective rock samples were scored based on the

NRC weighting system of test results and divided by the maximum possible score to obtain a rating percentage. Rock having a rating of 80 to 100% are acceptable for all applications, i.e., critical and non-critical areas. Rock receiving a rating of 65 to 80% are acceptable for critical areas with oversizing required, while aggregates receiving a rating of less than 65% are rejected for critical areas. For non-critical areas, aggregates receiving a 50 to 80% rating are acceptable with oversizing, and aggregates receiving a rating less than 50% are rejected.

5.0 SUMMARY OF RESULTS

From Tables 2 through 16, it can be seen that samples B-1, B-2, B-3, B-4, B-5, B-8, B-9, and B-10 were determined to be acceptable for all riprap applications. Samples B-6 and G-1 are acceptable for all applications if oversized. Sample B-7 is rejected for critical areas but could be used in non-critical areas if oversized. Samples Q-1 and Q-3 are rejected for all applications, While samples Q-2 and Q-4 are acceptable only for non-critical areas if oversized. A summary of rock sizes and volumes available from each site as well as the acceptability of that rock as a riprap source is given in Table 12.

From these results, the following conclusions have been drawn:

- The Basalt found on the Sherwood Site is of adequate quality to serve as riprap under NRC criteria, however, the total volume is limited to approximately 30,900 to 40,900 cubic yards of rock having a predominant maximum size of 6 inches and 11,800 cubic yards of rock having a predominant maximum size of 8 inches. Additionally, it is not known what actual volume of individual rock sizes can be expected.

- The first Quartz Monzonite sample taken from the Sherwood Site is unacceptable as a riprap source under NRC criteria. Further, only two samples (Q-2 and Q-4) taken from the resistant Quartz Monzonite ridges are acceptable only for non-critical areas if oversized, while the third ridge sample (Q-3) is unacceptable for all applications. Therefore, the Quartz Monzonite ridges must also be rejected as a possible riprap source because of the difficulty involved in distinguishing the two different grades of rock.

- The Quartzite Conglomerate on the Sherwood Site is acceptable for all applications under NRC criteria if oversized. However, with a maximum size of approximately 3 inches, it is not likely that this is a viable riprap source.

- The Wellpinit North Site is composed of a mixture of rocks which, under NRC criteria, range in quality from acceptable if oversized to rejected for critical areas. Because of the limited volume of material available from this site, and the marginal acceptability, this site is not a good riprap borrow source candidate.

- The Basalt found at the Wellpinit South Site is acceptable for all applications according to NRC criteria. It should be noted from Table 9 that sample B-8 from this site received a quality score of 82%. Since 80% is the cutoff score for being acceptable for all application, it appears that rock from this site may border on requiring oversizing. Sufficient volume exists to meet the needs of the project in the 3 to 18 inch size range.

- The Reardan Site was not sampled or tested, however, visual inspection indicates that the Basalt at this site is likely to be of good quality. If the requirements of the Sherwood Project dictate the use of large volumes of riprap greater than 12 inches, the Reardan Site is the only site identified to date where this material can be obtained.

6.0 REFERENCES

American Society for Testing and Materials (ASTM), Annual Book of ASTM Standards, Vol. 04.08, Soils and Rock; Dimension Stone; Geosynthetics, 1990.

ASTM C88-90
Standard Test Method for Soundness of Aggregates by Use of Sodium Sulfate.

ASTM C127-88
Standard Test Method for Specific Gravity and Absorption of Coarse Aggregate.

ASTM C535-89
Standard Test Method for Resistance to Degradation of Large-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine.

ASTM C805-85
Standard Test Method for Rebound Number of Hardened Concrete.

ASTM D4992-89
Standard Practice for Evaluation of Rock to be Used for Erosion Control.

U. S. Nuclear Regulatory Commission (NRC), "Final Staff Technical Position Design of Erosion Protection Covers for Stabilization of Uranium Mill Tailing Sites," 1990.

TABLE 1. SUMMARY OF TEST RESULTS ON ROCK SAMPLES

SAMPLE ID	BULK COMPOSITION	SECONDARY MINERALIZATION AND WEATHERING	SPECIFIC GRAVITY	SODIUM SULFATE SOUNDNESS (% wt. loss)(a)	ABSORPTION (% wt. gain)	L.A. ABRASION (% wt. loss) (b)	SCHMIDT (c) HAMMER
B-1	Dense basalt	No clays and no weathering rinds	2.91	2.0	0.64	1.5	43
B-2	Dense basalt	No clays and no weathering rinds	2.81	0.4	0.77	2.5	35
B-3	Dense basalt	No clays and no weathering rinds	2.86	1.5	0.92	2.4	41
B-4	Dense basalt	No clays and no weathering rinds	2.71	1.0	1.47	2.6	52
B-5	Dense basalt	No clays and no weathering rinds	2.77	2.5	0.88	2.3	53
B-6	Dense basalt	No clays and no weathering rinds	2.69	1.1	1.55	2.4	48
B-7	Low density basalt	No clays and no Weathering rinds	2.46	1.0	3.36	4.1	33
B-8	Dense Basalt	No clays and no weathering rinds	2.68	0.6	1.65	2.7	47
B-9	Dense Basalt	No petrographic analysis	2.77	0.6	0.80	1.1	55
B-10	Dense Basalt	No petrographic analysis	2.75	0.5	0.90	2.2	53
Q-1	K-Feldspar, Quartz, Plagioclase	Clays present as indicated by argilic alteration	2.55	33.5	1.43	12.8	43
Q-2	K-Feldspar, Quartz, Plagioclase	No petrographic analysis	2.60	8.5	0.74	10	42
Q-3	K-Feldspar, Quartz, Plagioclase	No petrographic analysis	2.59	14.2	0.84	8.3	40
Q-4	K-Feldspar, Quartz, Plagioclase	No petrographic analysis	2.60	9.2	0.71	8.2	42
G-1	Quartzite	No clays and no weathering rinds	2.61	6.1	0.62	8.7	33

(a) 5 cycles
(b) 100 revolutions
(c) Average rebound number of 10 measurements

TABLE 2. SCORING OF BASALT SAMPLE B-1

LAB TEST	RESULT	SCORE	WEIGHT	SCORE x WEIGHT	MAXIMUM SCORE
Sp. Gr.	2.91	10	9	90	90
Absorp., %	0.64	7	2	14	20
Sod. Sulf., %	2.0	9	11	99	110
L.A. Abr., %	1.5	9	1	9	10
Sch. Ham.	43	5	3	15	30
TOTALS				227	260

227/260 = .87, or 87% Therefore, B-1 is acceptable for all applications.

TABLE 3. SCORING OF BASALT SAMPLE B-2

LAB TEST	RESULT	SCORE	WEIGHT	SCORE x WEIGHT	MAXIMUM SCORE
Sp. Gr.	2.87	10	9	90	90
Absorp., %	0.77	6	2	12	20
Sod. Sulf., %	0.4	10	11	110	110
L.A. Abr., %	2.5	9	1	9	10
Sch. Ham.	35	4	3	12	30
TOTALS				233	260

233/260 = .90, or 90% Therefore, B-2 is acceptable for all applications.

TABLE 4. SCORING OF BASALT SAMPLE B-3

LAB TEST	RESULT	SCORE	WEIGHT	SCORE x WEIGHT	MAXIMUM SCORE
Sp. Gr.	2.86	10	9	90	90
Absorp., %	0.92	5	2	10	20
Sod. Sulf., %	1.5	9	11	99	110
L.A. Abr., %	2.4	9	1	9	10
Sch. Ham.	41	5	3	15	30
TOTALS				223	260

223/260 = .86, or 86% Therefore, B-3 is acceptable for all applications.

TABLE 5. SCORING OF BASALT SAMPLE B-4

LAB TEST	RESULT	SCORE	WEIGHT	SCORE x WEIGHT	MAXIMUM SCORE
Sp. Gr.	2.71	9	9	81	90
Absorp., %	1.47	4	2	8	20
Sod. Sulf., %	1.0	10	11	110	110
L.A. Abr., %	2.6	9	1	9	10
Sch. Ham.	52	6	3	18	30
TOTALS				226	260

226/260 = .87, or 87% Therefore, B-4 is acceptable for all applications.

TABLE 6. SCORING OF BASALT SAMPLE B-5

LAB TEST	RESULT	SCORE	WEIGHT	SCORE x WEIGHT	MAXIMUM SCORE
Sp. Gr.	2.77	10	9	90	90
Absorp., %	0.88	5	2	10	20
Sod. Sulf., %	2.5	9	11	99	110
L.A. Abr., %	2.3	9	1	9	10
Sch. Ham.	53	6	3	18	30
TOTALS				226	260

226/260 = .87, or 87% Therefore, B-5 is acceptable for all applications.

TABLE 7. SCORING OF BASALT SAMPLE B-6

LAB TEST	RESULT	SCORE	WEIGHT	SCORE x WEIGHT	MAXIMUM SCORE
Sp. Gr.	2.69	8	9	72	90
Absorp., %	1.55	3	2	6	20
Sod. Sulf., %	1.1	9	11	99	110
L.A. Abr., %	2.4	9	1	9	10
Sch. Ham.	48	6	3	18	30
TOTALS				204	260

204/260 = .78, or 78% Therefore, B-6 is acceptable for all applications if oversized.

TABLE 8. SCORING OF BASALT SAMPLE B-7

LAB TEST	RESULT	SCORE	WEIGHT	SCORE x WEIGHT	MAXIMUM SCORE
Sp. Gr.	2.46	4	9	36	90
Absorp., %	3.36	0	2	0	20
Sod. Sulf., %	1.0	10	11	110	110
L.A. Abr., %	4.1	8	1	8	10
Sch. Ham.	33	4	3	12	30
TOTALS				166	260

166/260 = .64, or 64% Therefore, B-7 is rejected for critical areas, and must be oversized for non-critical areas.

TABLE 9. SCORING OF BASALT SAMPLE B-8

LAB TEST	RESULT	SCORE	WEIGHT	SCORE x WEIGHT	MAXIMUM SCORE
Sp. Gr.	2.68	8	9	72	90
Absorp., %	1.65	3	2	6	20
Sod. Sulf., %	0.6	10	11	110	110
L.A. Abr., %	2.7	9	1	9	10
Sch. Ham.	47	6	3	18	30
TOTALS				215	260

215/260 = .82, or 82% Therefore, B-8 is acceptable for all applications.

TABLE 10. SCORING OF BASALT SAMPLE B-9

LAB TEST	RESULT	SCORE	WEIGHT	SCORE x WEIGHT	MAXIMUM SCORE
Sp. Gr.	2.77	10	9	90	90
Absorp., %	0.80	6	2	12	20
Sod. Sulf., %	0.6	10	11	110	110
L.A. Abr., %	1.1	10	1	10	10
Sch. Ham.	55	7	3	21	30
TOTALS				243	260

243/260 = .93, or 93% Therefore, B-9 is acceptable for all applications.

TABLE 11. SCORING OF BASALT SAMPLE B-10

LAB TEST	RESULT	SCORE	WEIGHT	SCORE x WEIGHT	MAXIMUM SCORE
Sp. Gr.	2.75	10	9	90	90
Absorp., %	0.90	5	2	10	20
Sod. Sulf., %	0.5	10	11	110	110
L.A. Abr., %	2.2	9	1	10	10
Sch. Ham.	53	7	3	30	30
TOTALS				240	260

240/260 = .92, or 92% Therefore, B-10 is acceptable for all applications.

TABLE 12. SCORING OF QUARTZ MONZONITE SAMPLE Q-1

LAB TEST	RESULT	SCORE	WEIGHT	SCORE x WEIGHT	MAXIMUM SCORE
Sp. Gr.	2.55	6	9	54	90
Absorp., %	1.43	4	2	8	20
Sod. Sulf., %	33.5	0	11	0	110
L.A. Abr., %	12.8	3	1	3	10
Sch. Ham.	43	5	3	15	30
TOTALS				80	260

80/260 = .31, or 31% Therefore, Q-1 is rejected for all applications.

TABLE 13. SCORING OF QUARTZ MONZONITE SAMPLE Q-2

LAB TEST	RESULT	SCORE	WEIGHT	SCORE x WEIGHT	MAXIMUM SCORE
Sp. Gr.	2.60	7	9	63	90
Absorp., %	0.74	6	2	12	20
Sod. Sulf., %	8.5	6	11	66	110
L.A. Abr., %	10	5	1	5	10
Sch. Ham.	42	5	3	15	20
TOTALS				161	260

161/260 = .62, or 62% Therefore, Q-2 is rejected for critical areas, and must be oversized for non-critical areas.

TABLE 14. SCORING OF QUARTZ MONZONITE SAMPLE Q-3

LAB TEST	RESULT	SCORE	WEIGHT	SCORE x WEIGHT	MAXIMUM SCORE
Sp. Gr.	2.59	7	9	63	90
Absorp., %	0.84	6	2	12	20
Sod. Sulf., %	14.2	3	11	33	110
L.A. Abr., %	8.3	6	1	6	10
Sch. Ham.	40	5	3	15	30
TOTALS				129	260

129/260 = .50, or 50% Therefore, Q-3 is rejected for all cases.

TABLE 15. SCORING OF QUARTZ MONZONITE SAMPLE Q-4

LAB TEST	RESULT	SCORE	WEIGHT	SCORE x WEIGHT	MAXIMUM SCORE
Sp. Gr.	2.60	7	9	63	90
Absorp., %	0.71	6	2	12	20
Sod. Sulf., %	9.2	5	11	55	110
L.A. Abr., %	8.2	6	1	6	10
Sch. Ham.	42	5	3	15	30
TOTALS				151	260

151/260 = .58, or 58% Therefore, Q-4 is rejected for critical areas and must be oversized for non-critical areas.

TABLE 16. SCORING OF QUARTZITE CONGLOMERATE SAMPLE G-1

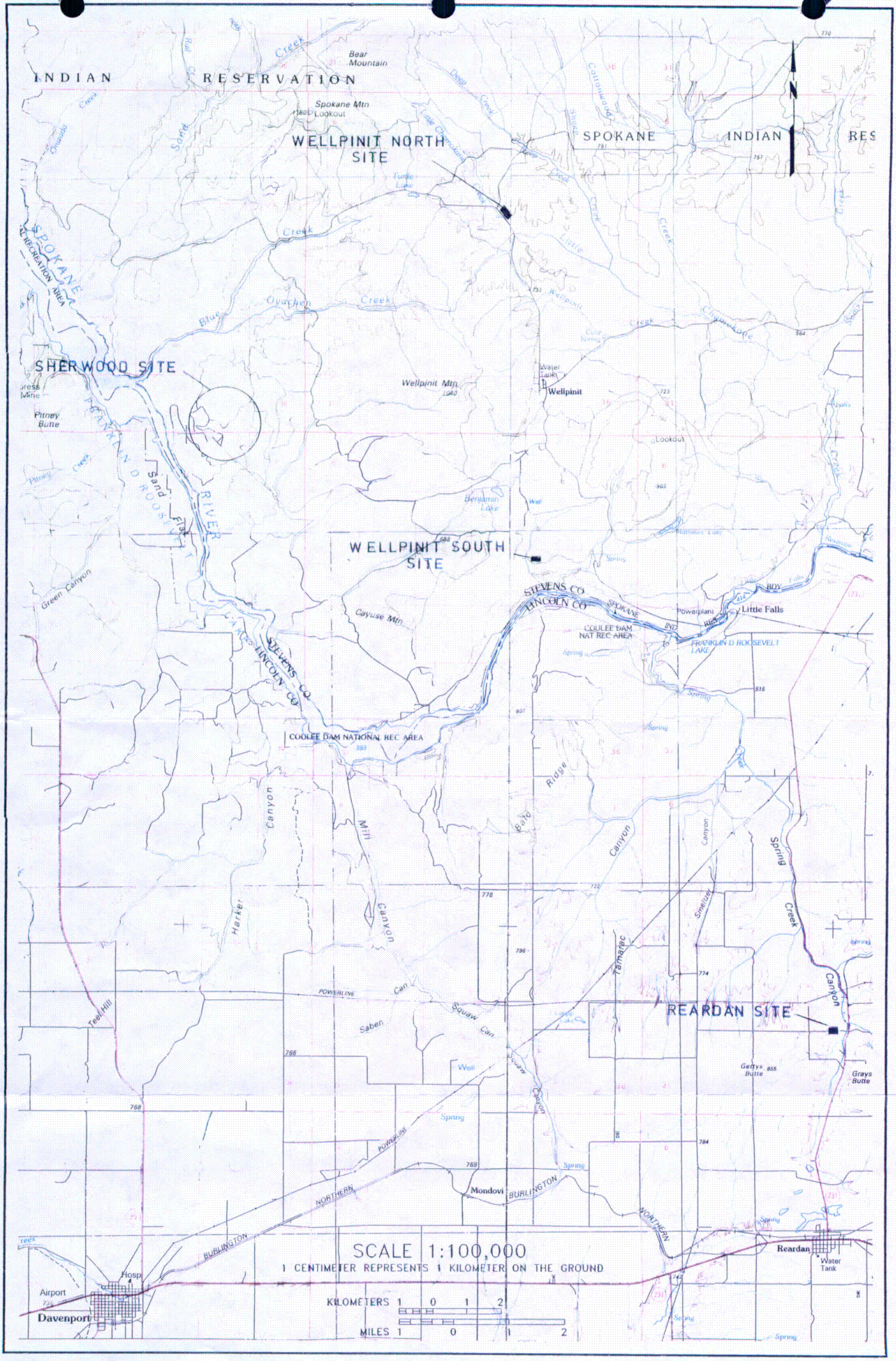
LAB TEST	RESULT	SCORE	WEIGHT	SCORE x WEIGHT	MAXIMUM SCORE
Sp. Gr.	2.61	7	9	63	90
Absorp., %	0.62	7	2	14	20
Sod. Sulf., %	6.1	7	11	77	110
L.A. Abr., %	8.7	5	1	5	10
Sch. Ham.	33	4	3	12	30
TOTALS				171	260

171/260 = .66, or 66% Therefore, G-1 is acceptable for all applications if oversized.

TABLE 17. SUMMARY OF BORROW SOURCES AND VOLUMES

SITE	SIZE RANGE (in.)	PREDOMINANT SIZE (in.)	VOLUME (cubic yards)	ACCEPTABILITY
SHERWOOD SITE				
BASALT - NORTH CAP	1 to 12	3 to 8	11,800	Acceptable for all applications
BASALT - SOUTH CAP	1 to 8	3 to 6	10,900	Acceptable for all applications
BASALT - STOCKPILES	1 to 6	4 to 6	20,000 to 30,000	Acceptable for all applications
QUARTZ MONZONITE	1- to 12+	unknown	unknown	Rejected for all applications
QUARTZITE CONGLOMERATE	1- to 3	unknown	unknown	Acceptable for all applications if oversized
WELLPINIT NORTH				
BASALT - NORTH PHASE	2 to 8	3 to 6	2,800	Acceptable for all applications if oversized[a]
BASALT - SOUTH PHASE	2 to 8	3 to 6	2,800	Rejected for critical areas, acceptable for non-critical areas if oversized
WELLPINIT SOUTH				
BASALT	2 to 24	4 to 12	300,000	Acceptable for all applications
REARDAN				
BASALT	12 to 48	12 to 24	3,000 to 5,000	Not sampled

[a] Samples B-4 and B-5 were acceptable for all applications, however, sample B-6 requires oversizing. Therefore, the assumption is made that in order to use this borrow source all rock must be oversized.

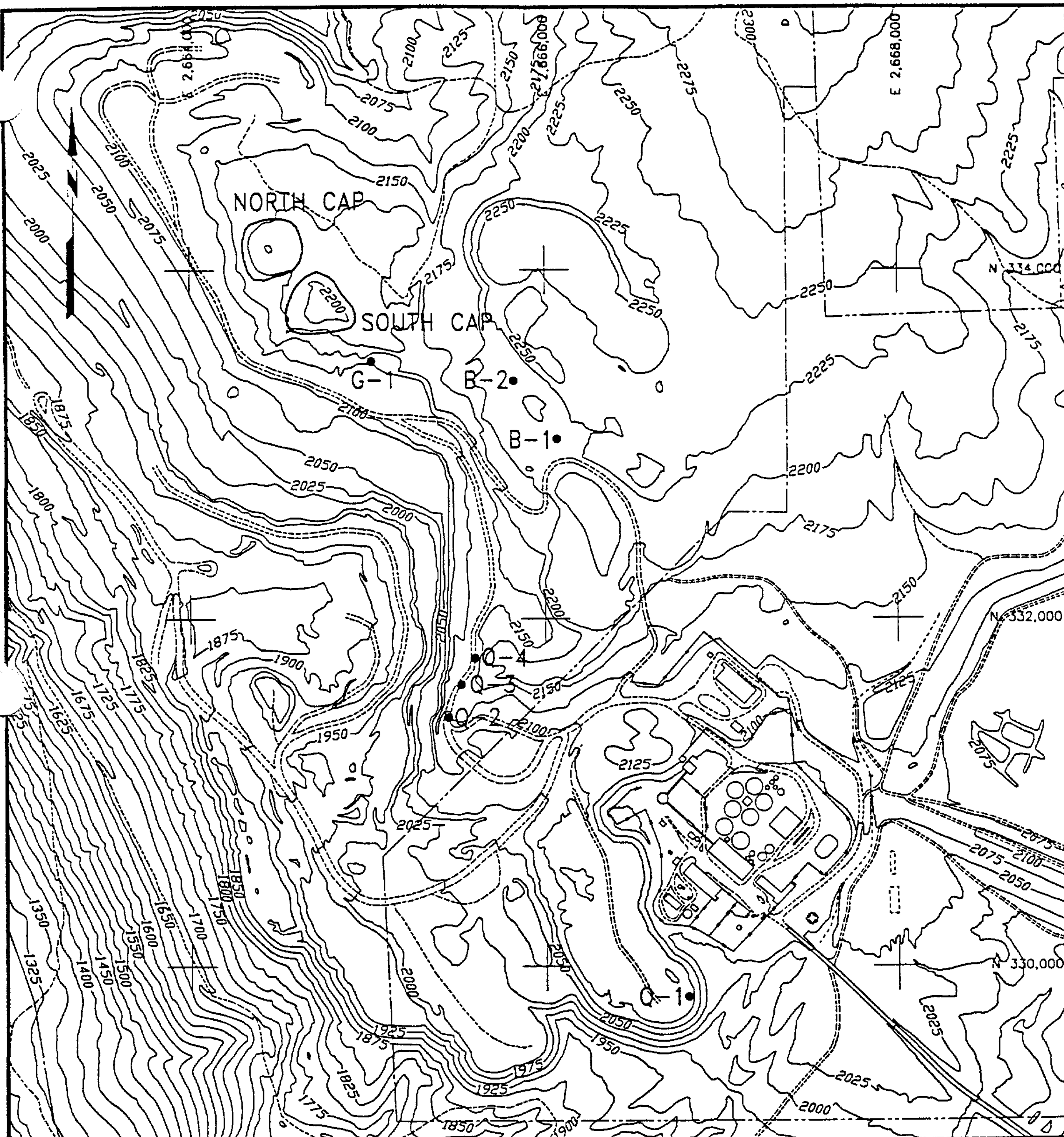


SMI
SHEPHERD MILLER, INC.

FIGURE 1
LOCATION MAP

C01

Date: SEPT., 1992
Project: 317
File:



KEY
B = BASALT
Q = QUARTZ MONZONITE
G = CONGLOMERATE

SCALE IN FEET
800 0 1600

SMI
SHEPHERD MILLER, INC.

FIGURE 2
APPROXIMATE LOCATION OF
ON SITE ROCK SAMPLES

Date:	DEC., 1994
Project:	317
File:	ROKLOC

ATTACHMENT A
LABORATORY TESTING REPORTS

B.A-2

Empire Laboratories, Inc.

GEOTECHNICAL ENGINEERING & MATERIALS TESTING

CORPORATE OFFICE
P.O. Box 503 • 301 No. Howes
Fort Collins, Colorado 80522
(303) 484-0359
FAX No. (303) 484-0454

October 23, 1991

Shepherd Miller, Inc.
1600 Specht Point Drive, Suite F
Fort Collins, Colorado 80525

Attention: Mr. Jim Yahn

Re: Sherwood Project (SMI Project No. 307)
Laboratory Testing of Five (5) Rock Samples
Proposed for Use as Rip Rap

Gentlemen:

Enclosed are results of tests performed on the above-referenced rock samples received in our laboratory on October 1, 1991. As requested, specific gravity and absorption, 5-cycle sodium sulfate soundness, L. A. abrasion and Schmidt hammer tests were run on each of the samples. A wash-sieve analysis was run on Sample G-1.

A representative rock piece was selected out of each sample and was prepared by cutting three (3) smooth faces at approximate right angles. Each sample was placed in a compression machine and subjected to a load of 5000 lbs. While each sample was under load, the Schmidt hammer tests were performed on the smooth-cut vertical face of the sample.

If you have any questions regarding these test results, please feel free to contact us.

Very truly yours,

EMPIRE LABORATORIES, INC.

Carl Tarantola
Staff Geologist

Reviewed by:

Chester C. Smith, P.E.
President

clc

Shepherd Miller, Inc.
Page 2
October 23, 1991

Re: Sherwood Project (SMI Project No. 307)
Laboratory Testing of Five (5) Rock Samples
Proposed for Use as Rip Rap

LABORATORY TEST RESULTS

Sample: B-1

Specific Gravity and Absorption

Bulk Specific Gravity (Saturated Surface Dry Basis): 2.91
Absorption: 0.64%

Soundness of Aggregates by Use of Sodium Sulfate (5 Cycles)

Sieve Size Passing	Sieve Size Retained	Weight of Sample, grams	Loss, %
1-1/2"	1"	1031.6)	1.0
1"	3/4"	471.7)	
3/4"	1/2"	674.2)	0.2
1/2"	3/8"	334.5)	
3/8"	#4	303.8	0.8
		Total:	2.0

Resistance to Degradation of Large-Size Coarse Aggregate By Abrasion and Impact in the Los Angeles Machine

Grading 1

Sample Weight Before Test:	10021.1 g
Sample Weight After 100 Revolutions:	9866.2 g
Sample Weight After 200 Revolutions:	9710.8 g
Sample Weight After 1000 Revolutions:	9025.1 g
Wear at 100 Revolutions:	1.5%
Wear at 200 Revolutions:	3.1%
Wear at 1000 Revolutions:	9.9%

Schmidt Hammer Tests*

Average Rebound Number of Ten (10) Measurements: 43

* Performed on vertical face of sample under 5000 lb. load

Re: Sherwood Project (SMI Project No. 307)
Laboratory Testing of Five (5) Rock Samples
Proposed for Use as Rip Rap

LABORATORY TEST RESULTS

Sample: B-2

Specific Gravity and Absorption

Bulk Specific Gravity (Saturated Surface Dry Basis): 2.87
Absorption: 0.77%

Soundness of Aggregates by Use of Sodium Sulfate (5 Cycles)

Sieve Size Passing	Sieve Size Retained	Weight of Sample, grams	Loss, %
1-1/2"	1"	996.9)	0.1
1"	3/4"	526.2)	
3/4"	1/2"	675.1)	0.3
1/2"	3/8"	334.0)	
3/8"	#4	305.0	0.0
		Total:	0.4

Resistance to Degradation of Large-Size Coarse Aggregate
By Abrasion and Impact in the Los Angeles Machine

Grading 1

Sample Weight Before Test:	10054.7 g
Sample Weight After 100 Revolutions:	9805.2 g
Sample Weight After 200 Revolutions:	9771.7 g
Sample Weight After 1000 Revolutions:	9118.6 g
Wear at 100 Revolutions:	2.5%
Wear at 200 Revolutions:	2.8%
Wear at 1000 Revolutions:	9.3%

Schmidt Hammer Tests*

Average Rebound Number of Ten (10) Measurements: 35

* Performed on vertical face of sample under 5000 lb. load

Re: Sherwood Project (SMI Project No. 307)
Laboratory Testing of Five (5) Rock Samples
Proposed for Use as Rip Rap

LABORATORY TEST RESULTS

Sample: B-3

Specific Gravity and Absorption

Bulk Specific Gravity (Saturated Surface Dry Basis): 2.86
Absorption: 0.92%

Soundness of Aggregates by Use of Sodium Sulfate (5 Cycles)

Sieve Size Passing	Sieve Size Retained	Weight of Sample, grams	Loss, %
1-1/2"	1"	1002.6)	0.5
1"	3/4"	490.6)	
3/4"	1/2"	664.2)	0.2
1/2"	3/8"	328.1)	
3/8"	#4	303.9	0.8
		Total:	1.5

Resistance to Degradation of Large-Size Coarse Aggregate By Abrasion and Impact in the Los Angeles Machine

Grading 1

Sample Weight Before Test: 10000.5 g
Sample Weight After 100 Revolutions: 9760.5 g
Sample Weight After 200 Revolutions: 9679.4 g
Sample Weight After 1000 Revolutions: 8916.0 g
Wear at 100 Revolutions: 2.4%
Wear at 200 Revolutions: 3.2%
Wear at 1000 Revolutions: 10.8%

Schmidt Hammer Tests*

Average Rebound Number of Ten (10) Measurements: 41

* Performed on vertical face of sample under 5000 lb. load

B A L

Re: Sherwood Project (SMI Project No. 307)
Laboratory Testing of Five (5) Rock Samples
Proposed for Use as Rip Rap

LABORATORY TEST RESULTS

Sample: Q-1

Specific Gravity and Absorption

Bulk Specific Gravity (Saturated Surface Dry Basis): 2.55
Absorption: 1.43%

Soundness of Aggregates by Use of Sodium Sulfate (5 Cycles)

Sieve Size Passing	Retained	Weight of Sample, grams	Loss, %
1-1/2"	1"	951.6)	25.5
1"	3/4"	509.0)	
3/4"	1/2"	660.4)	4.7
1/2"	3/8"	328.2)	
3/8"	#4	295.2	3.3
		Total:	33.5

Resistance to Degradation of Large-Size Coarse Aggregate By Abrasion and Impact in the Los Angeles Machine

Grading 1

Sample Weight Before Test:	9944.7 g
Sample Weight After 100 Revolutions:	8674.1 g
Sample Weight After 200 Revolutions:	7677.0 g
Sample Weight After 1000 Revolutions:	4269.8 g
Wear at 100 Revolutions:	12.8%
Wear at 200 Revolutions:	22.8%
Wear at 1000 Revolutions:	57.1%

Schmidt Hammer Tests*

Average Rebound Number of Ten (10) Measurements: 43

* Performed on vertical face of sample under 5000 lb. load

Re: Sherwood Project (SMI Project No. 307)
Laboratory Testing of Five (5) Rock Samples
Proposed for Use as Rip Rap

LABORATORY TEST RESULTS

Sample: G-1

Wash-Sieve Analysis

Sieve Size	% Passing
3-1/2"	100.0
3"	95.1
2-1/2"	92.2
2"	88.7
1-1/2"	79.8
1"	60.5
3/4"	49.5
1/2"	35.2
3/8"	23.9
#4	15.0
#8	12.7
#16	11.5
#30	9.7
#50	5.3
#100	3.6
#200	2.9

Specific Gravity and Absorption

Bulk Specific Gravity (Saturated Surface Dry Basis): 2.61
Absorption: 0.62%

Soundness of Aggregates by Use of Sodium Sulfate (5 Cycles)

Sieve Size Passing	Sieve Size Retained	Weight of Sample, grams	Loss, %
1-1/2"	1"	1016.9)	0.3
1"	3/4"	523.3)	
3/4"	1/2"	673.2)	2.5
1/2"	3/8"	333.3)	
3/8"	#4	304.2	3.3
		Total:	6.1

Re: Sherwood Project (SMI Project No. 307)
Laboratory Testing of Five (5) Rock Samples
Proposed for Use as Rip Rap

LABORATORY TEST RESULTS

Resistance to Degradation of Small-Size Coarse Aggregate By Abrasion and Impact in the Los Angeles Machine

Grading A

Sample Weight Before Test:	5000.9 g
Sample Weight After 100 Revolutions:	4567.5 g
Sample Weight After 500 Revolutions:	3400.7 g
Wear at 100 Revolutions:	8.7%
Wear at 500 Revolutions:	32.0%

Schmidt Hammer Tests*

Average Rebound Number of Ten (10) Measurements: 33

* Performed on vertical face of sample under 5000 lb. load

Empire Laboratories, Inc.
GEOTECHNICAL ENGINEERING & MATERIALS TESTING

CORPORATE OFFICE
P.O. Box 503 • 301 No. Howes
Fort Collins, Colorado 80522
(303) 484-0359
FAX No. (303) 484-0454

August 31, 1992

Shepherd Miller, Inc.
1600 Specht Point Drive, Suite F
Fort Collins, Colorado 80525

Attention: Mr. Lawrence Fiske

Re: Sherwood Project (SMI Project No. 317)
Laboratory Testing of Basalt Samples B-4,
B-5, B-6, B-7 & B-8 Proposed for Use as Rip Rap

Gentlemen:

Enclosed are results of tests performed on the above-referenced rock samples received in our laboratory on July 6 and July 30, 1992. As requested, specific gravity and absorption, 5-cycle sodium sulfate soundness, L. A. abrasion and Schmidt hammer tests were run on each of the samples.

A representative rock piece was selected out of each sample and was prepared by cutting three smooth faces at approximate right angles to each other. Each sample was placed in a compression machine and subjected to a load of 7500 pounds. While each sample was under load, Schmidt hammer readings were taken on the smooth-cut vertical face of the sample.

If you have any questions regarding these tests, please feel free to contact us.

Very truly yours,

EMPIRE LABORATORIES, INC.

Carl Tarantola

Carl Tarantola
Staff Geologist

Reviewed by:

Chester C. Smith

Chester C. Smith, P.E.
Division Manager

CHESTER C. SMITH REGISTERED 4303 PROFESSIONAL LAND SURVEYOR COLORADO

clc

Shepherd Miller, Inc.
Page 2
August 31, 1992

Re: Sherwood Project (SMI Project No. 317)

LABORATORY TEST RESULTS

Sample: B-4

Specific Gravity and Absorption

Bulk Specific Gravity (Saturated Surface Dry Basis): 2.71
Absorption: 1.47%

Soundness of Aggregates by Use of Sodium Sulfate (5 Cycles)

Sieve Size % Passing	% Retained	Weight of Sample, grams	Loss, %
1-1/2"	1"	1027.1	0.4
1"	3/4"	520.2	
3/4"	1/2"	677.7	0.2
1/2"	3/8"	330.0	
3/8"	#4	303.4	0.4
		Total:	1.0

Resistance to Degradation of Large-Size Coarse Aggregate
By Abrasion and Impact in the Los Angeles Machine

Grading I

Sample Weight Before Test:	10016.5 g.
Sample Weight After 100 Revolutions:	9761.1 g.
Sample Weight After 200 Revolutions:	9559.7 g.
Sample Weight After 1000 Revolutions:	8592.2 g.
Wear at 100 Revolutions:	2.6%
Wear at 200 Revolutions:	4.6%
Wear at 1000 Revolutions:	14.2%

Schmidt Hammer Tests*
Average Rebound Number of Ten (10) Measurements: 52

*Performed on smooth-cut vertical face of sample under 7500 lb load

Shepherd Miller, Inc.
Page 3
August 31, 1992

Re: Sherwood Project (SMI Project No. 317)

LABORATORY TEST RESULTS

Sample: B-5

Specific Gravity and Absorption

Bulk Specific Gravity (Saturated Surface Dry Basis): 2.77
Absorption: 0.88%

Soundness of Aggregates by Use of Sodium Sulfate (5 Cycles)

Sieve Size % Passing	% Retained	Weight of Sample, grams	Loss, %
1-1/2"	1"	1042.9)	0.5
1"	3/4"	517.2)	
3/4"	1/2"	675.8)	0.9
1/2"	3/8"	332.7)	
3/8"	#4	304.6	1.1
		Total:	2.5

Resistance to Degradation of Large-Size Coarse Aggregate
By Abrasion and Impact in the Los Angeles Machine

Grading I

Sample Weight Before Test:	10038.1 g.
Sample Weight After 100 Revolutions:	9814.3 g.
Sample Weight After 200 Revolutions:	9627.5 g.
Sample Weight After 1000 Revolutions:	8782.3 g.
Wear at 100 Revolutions:	2.3%
Wear at 200 Revolutions:	4.1%
Wear at 1000 Revolutions:	12.5%

Schmidt Hammer Tests*
Average Rebound Number of Ten (10) Measurements: 53

*Performed on smooth-cut vertical face of sample under 7500 lb load

Shepherd Miller, Inc.
Page 4
August 31, 1992

Re: Sherwood Project (SMI Project No. 317)

LABORATORY TEST RESULTS

Sample: B-6

Specific Gravity and Absorption

Bulk Specific Gravity (Saturated Surface Dry Basis): 2.69
Absorption: 1.55%

Soundness of Aggregates by Use of Sodium Sulfate (5 Cycles)

Sieve Size % Passing	% Retained	Weight of Sample, grams	Loss, %
1-1/2"	1"	1038.4	0.1
1"	3/4"	526.8	
3/4"	1/2"	679.6	0.4
1/2"	3/8"	333.5	
3/8"	#4	304.8	0.6
		Total:	1.1

Resistance to Degradation of Large-Size Coarse Aggregate By Abrasion and Impact in the Los Angeles Machine

Grading I

Sample Weight Before Test:	9996.6 g.
Sample Weight After 100 Revolutions:	9757.7 g.
Sample Weight After 200 Revolutions:	9557.7 g.
Sample Weight After 1000 Revolutions:	8652.1 g.
Wear at 100 Revolutions:	2.4%
Wear at 200 Revolutions:	4.4%
Wear at 1000 Revolutions:	13.5%

Schmidt Hammer Tests*

Average Rebound Number of Ten (10) Measurements: 48

*Performed on smooth-cut vertical face of sample under 7500 lb load

Shepherd Miller, Inc.
Page 5
August 31, 1992

Re: Sherwood Project (SMI Project No. 317)

LABORATORY TEST RESULTS

Sample: B-7

Specific Gravity and Absorption

Bulk Specific Gravity (Saturated Surface Dry Basis): 2.46
Absorption: 3.36%

Soundness of Aggregates by Use of Sodium Sulfate (5 Cycles)

Sieve Size % Passing	Sieve Size % Retained	Weight of Sample, grams	Loss, %
1-1/2"	1"	1020.4	0.1
1"	3/4"	524.1	
3/4"	1/2"	675.6	0.3
1/2"	3/8"	334.6	
3/8"	#4	304.5	0.6
		Total:	1.0

Resistance to Degradation of Large-Size Coarse Aggregate By Abrasion and Impact in the Los Angeles Machine

Grading I

Sample Weight Before Test:	10010.1 g.
Sample Weight After 100 Revolutions:	9604.7 g.
Sample Weight After 200 Revolutions:	9265.3 g.
Sample Weight After 1000 Revolutions:	7653.7 g.
Wear at 100 Revolutions:	4.1%
Wear at 200 Revolutions:	7.4%
Wear at 1000 Revolutions:	23.5%

Schmidt Hammer Tests*

Average Rebound Number of Ten (10) Measurements: 33

*Performed on smooth-cut vertical face of sample under 7500 lb load

Re: Sherwood Project (SMI Project No. 317)

LABORATORY TEST RESULTS

Sample: B-8

Specific Gravity and Absorption

Bulk Specific Gravity (Saturated Surface Dry Basis): 2.68
Absorption: 1.65%

Soundness of Aggregates by Use of Sodium Sulfate (5 Cycles)

Sieve Size % Passing	Sieve Size % Retained	Weight of Sample, grams	Loss, %
1-1/2"	1"	1046.5	0.1
1"	3/4"	525.6	
3/4"	1/2"	678.6	0.2
1/2"	3/8"	333.5	
3/8"	#4	304.4	0.3
		Total:	0.6

Resistance to Degradation of Large-Size Coarse Aggregate By Abrasion and Impact in the Los Angeles Machine

Grading I

Sample Weight Before Test:	10004.1 g.
Sample Weight After 100 Revolutions:	9735.0 g.
Sample Weight After 200 Revolutions:	9516.9 g.
Sample Weight After 1000 Revolutions:	8479.5 g.
Wear at 100 Revolutions:	2.7%
Wear at 200 Revolutions:	4.9%
Wear at 1000 Revolutions:	15.2%

Schmidt Hammer Tests*
Average Rebound Number of Ten (10) Measurements: 47

*Performed on smooth-cut vertical face of sample under 7500 lb load

B A-15

Empire Laboratories, Inc.

A Division of **The Terracon Companies, Inc.**

P.O. Box 503 • 301 No. Howes
Fort Collins, Colorado 80522
(303) 484-0359
FAX No. (303) 484-0454

Chester C. Smith, P.E.
Neil R. Sherrod, C.P.G.

June 10, 1993

Shepherd Miller, Inc.
1600 Specht Point Drive, Suite F
Fort Collins, Colorado 80525

Attention: Mr. Lawrence Fiske

Re: Laboratory Test Results - Sherwood Project (SMI Project No. 317)
Basalt Samples B-9, B-10 and Quartz
Monzonite Samples Q-2, Q-3, Q-4 Proposed for Use as Rip Rap
Project No. 20934017.1

Gentlemen:

Enclosed are results of testing performed on the above-referenced rock samples received in our laboratory on April 14 and May 4, 1993. As requested, the following tests were conducted on each of the samples: Specific gravity and absorption, 5-cycle sodium sulfate soundness, L. A. abrasion and Schmidt rebound hammer.

A representative rock was selected out of each sample group and was prepared by cutting three smooth faces at approximate right angles to each other. Each sample was placed in a compression machine and subjected to a load of 7,500 pounds. While each sample was under load, Schmidt hammer rebound readings were taken on the smooth-cut vertical face of the sample.

If you have any questions regarding the test results, please feel free to contact us.

Very truly yours,

EMPIRE LABORATORIES, INC.
A Division of **The Terracon Companies, Inc.**

Carl Tarantola

Carl Tarantola
Staff Geologist

Reviewed by:

Chester C. Smith

Chester C. Smith, P.E.
Division Manager

clc

copies to: Addressee (3)

CHESTER C. SMITH REGISTERED PROFESSIONAL ENGINEER 4003

Terracon

Re: Sherwood Project (SMI No. 317)
Project No. 20934017.1

LABORATORY TEST RESULTS

Sample: B-9

Specific Gravity and Absorption

Bulk Specific Gravity (Saturated Surface Dry Basis):	2.77
Absorption:	0.80%

Soundness of Aggregates by Use of Sodium Sulfate (5 Cycles)

Sieve Size Passing	Sieve Size Retained	Sample Weight (Before Test) grams	Sample Weight (After Test) grams	Loss, %
1½"	1"	1022.5	1021.4	0.2
1"	3/4"	524.1	522.7	
3/4"	1/2"	678.0	676.7	0.2
1/2"	3/8"	332.4	332.0	
3/8"	#4	304.0	303.3	0.2
			TOTAL:	0.6

Resistance to Degradation of Large-Size Coarse Aggregate By Abrasion and Impact in the Los Angeles Machine

Grading 2	
Sample weight before test:	10001.7 g.
Sample weight after 100 revolutions:	9896.4 g.
Sample weight after 200 revolutions:	9632.2 g.
Sample weight after 1000 revolutions:	8988.3 g.
Wear at 100 revolutions:	1.1%
Wear at 200 revolutions:	3.7%
Wear at 1000 revolutions:	10.1%

Schmidt Hammer Tests*

Average Rebound Number of 10 Measurements: 55

* Performed on smooth-cut vertical face of sample under 7,500 pound compression load

Terracon

Re: Sherwood Project (SMI No. 317)
Project No. 20934017.1

LABORATORY TEST RESULTS

Sample: B-10

Specific Gravity and Absorption

Bulk Specific Gravity (Saturated Surface Dry Basis):	2.75
Absorption:	0.90%

Soundness of Aggregates by Use of Sodium Sulfate (5 Cycles)

Sieve Size Passing	Retained	Sample Weight (Before Test) grams	Sample Weight (After Test) grams	Loss, %
1½"	1"	1047.5	1047.2	0.0
1"	3/4"	524.4	524.0	
3/4"	1/2"	674.6	672.8	0.3
1/2"	3/8"	333.7	332.5	
3/8"	#4	304.1	303.6	0.2
			TOTAL:	0.5

Resistance to Degradation of Large-Size Coarse Aggregate By Abrasion and Impact in the Los Angeles Machine

Grading 2	
Sample weight before test:	9994.6 g.
Sample weight after 100 revolutions:	9776.4 g.
Sample weight after 200 revolutions:	9571.7 g.
Sample weight after 1000 revolutions:	8771.2 g.
Wear at 100 revolutions:	2.2%
Wear at 200 revolutions:	4.2%
Wear at 1000 revolutions:	12.2%

Schmidt Hammer Tests*

Average Rebound Number of 10 Measurements: 53

* Performed on smooth-cut vertical face of sample under 7,500 pound compression load

Re: Sherwood Project (SMI No. 317)
Project No. 20934017.1

LABORATORY TEST RESULTS

Sample: Q-2

Specific Gravity and Absorption

Bulk Specific Gravity (Saturated Surface Dry Basis):	2.60
Absorption:	0.74%

Soundness of Aggregates by Use of Sodium Sulfate (5 Cycles)

Sieve Size Passing	Sieve Size Retained	Sample Weight (Before Test) grams	Sample Weight (After Test) grams	Loss, %
1½"	1"	1006.1	969.3	4.0
1"	3/4"	529.7	504.7	
3/4"	1/2"	677.1	664.3	2.5
1/2"	3/8"	334.0	321.5	
3/8"	#4	304.9	298.7	2.0
			TOTAL:	8.5

Resistance to Degradation of Large-Size Coarse Aggregate By Abrasion and Impact in the Los Angeles Machine

Grading 1

Sample weight before test:	9995.7 g.
Sample weight after 100 revolutions:	8995.3 g.
Sample weight after 200 revolutions:	8244.4 g.
Sample weight after 1000 revolutions:	5318.2 g.
Wear at 100 revolutions:	10.0%
Wear at 200 revolutions:	17.5%
Wear at 1000 revolutions:	46.8%

Schmidt Hammer Tests*

Average Rebound Number of 10 Measurements: 42

* Performed on smooth-cut vertical face of sample under 7,500 pound compression load

Terracon

Re: Sherwood Project (SMI No. 317)
Project No. 20934017.1

LABORATORY TEST RESULTS

Sample: Q-3

Specific Gravity and Absorption

Bulk Specific Gravity (Saturated Surface Dry Basis):	2.59
Absorption:	0.84%

Soundness of Aggregates by Use of Sodium Sulfate (5 Cycles)

Sieve Size Passing	Sieve Size Retained	Sample Weight (Before Test) grams	Sample Weight (After Test) grams	Loss, %
1½"	1"	1029.5	989.5	5.0
1"	3/4"	523.4	486.3	
3/4"	1/2"	671.2	633.1	5.5
1/2"	3/8"	332.6	315.3	
3/8"	#4	304.1	292.9	3.7
			TOTAL:	14.2

Resistance to Degradation of Large-Size Coarse Aggregate By Abrasion and Impact in the Los Angeles Machine

Grading 1

Sample weight before test:	10011.6 g.
Sample weight after 100 revolutions:	9184.9 g.
Sample weight after 200 revolutions:	8503.3 g.
Sample weight after 1000 revolutions:	5844.6 g.
Wear at 100 revolutions:	8.3%
Wear at 200 revolutions:	15.1%
Wear at 1000 revolutions:	41.6%

Schmidt Hammer Tests*

Average Rebound Number of 10 Measurements: 40

* Performed on smooth-cut vertical face of sample under 7,500 pound compression load

Terracon

Re: Sherwood Project (SMI No. 317)
Project No. 20934017.1

LABORATORY TEST RESULTS

Sample: Q-4

Specific Gravity and Absorption

Bulk Specific Gravity (Saturated Surface Dry Basis):	2.60
Absorption:	0.71%

Soundness of Aggregates by Use of Sodium Sulfate (5 Cycles)

Sieve Size Passing	Sieve Size Retained	Sample Weight (Before Test) grams	Sample Weight (After Test) grams	Loss, %
1½"	1"	1047.3	987.0	5.0
1"	3/4"	521.8	503.2	
3/4"	1/2"	679.0	667.8	1.8
1/2"	3/8"	330.9	323.8	
3/8"	#4	304.4	297.2	2.4
			TOTAL:	9.2

Resistance to Degradation of Large-Size Coarse Aggregate By Abrasion and Impact in the Los Angeles Machine

Grading 1	
Sample weight before test:	10001.9 g.
Sample weight after 100 revolutions:	9178.5 g.
Sample weight after 200 revolutions:	8572.1 g.
Sample weight after 1000 revolutions:	5989.5 g.
Wear at 100 revolutions:	8.2%
Wear at 200 revolutions:	14.3%
Wear at 1000 revolutions:	40.1%

Schmidt Hammer Tests*

Average Rebound Number of 10 Measurements: 42

* Performed on smooth-cut vertical face of sample under 7,500 pound compression load

ATTACHMENT B
PETROGRAPHIC ANALYSES

THEODORE P. PASTER, Ph.D.
Consultant
11425 East Cimmarron Drive
Englewood, Colorado 80111
(303) 771-8219

August 12, 1992

Lawrence E. Fiske
Shepherd Miller, Incorporated
1600 Specht Point Drive, Ste. F
Fort Collins, CO. 80525

RE: Petrography of Five Basalt Samples.

SUMMARY

Rock Types and Composition

The rocks are essentially fresh basalts whose mineralogy are given in **TABLE 1** and whose descriptions are in **APPENDIX I.**

Weathering

The rocks show no weathering effects other than some slight oxidation resulting in Fe-stained glass and chlorophaeite. They contain no clay.

Secondary Alteration

Olivine in two of the basalt samples was partially altered to a soft chlorite-like mineral (chlorophaeite) during original cooling of the basalt lavas.

Respectfully submitted:

INTRODUCTION

Five rock samples were sent to this laboratory for petrographic analysis by Shepherd Miller, Incorporated (SMI).

The samples were selected by SMI as being representative of degree of weathering and alteration of the rock to be used. It was agreed that this report should include the following information:

1) Bulk composition.
2) Secondary minerals and weathering.

SAMPLES

The five samples received from SMI are labeled: B-4, B-5, B-6, B-7 and B-8. One fist-sized hand specimen of each sample was received. The samples are megascopically uniform and non-fractured.

RESULTS

TABLE 1 gives the mineralogy and composition of the rocks. **APPENDIX I** gives a detailed petrographic description of each rock.

****

TABLE 1
MINERALOGY OF 5 BASALT SAMPLES
(FOR SMI)

Contained Mineral	Percent of Mineral B-4	B-5	B-6	B-7	B-8
Glass Opaque	43.9 ± 3.6	59.2 ± 3.6	51.2 ± 3.6	34.7 ± 3.3 7.7 ± 1.5	61.5 ± 3.6
Plagioclase	25.3 ± 3.1	20.2 ± 2.9	19.7 ± 2.8	23.4 ± 2.8	22.2 ± 3.0
Pyroxene	27.3 ± 3.2	18.9 ± 2.8	23.6 ± 3.0	18.3 ± 2.6	14.5 ± 2.5
Vesicles	3.5 ± 1.1	1.7 ± 0.8	3.3 ± 1.0	13.7 ± 2.2	1.3 ± 0.8
Chlorophaeite	tr	0	*2.2 ± 0.9	*2.2 ± 0.9	*0.5 ± 0.4

* Note that this value is higher than true value because counting was near joint.

****

Rock Types

All of the rocks are fresh basalts and are slightly vesicular. In some cases much of the phase reported as glass in **TABLE 1** also contains skeletal pyroxene crystals.

Weathering

All of the samples are practically unweathered. There are no secondary clays present in the samples. Some minor goethite staining is present in the chlorophaeite where present which indicates some slight oxidation.

Alteration

Minor secondary high-temperature alteration occurred during cooling of the lava samples B-4 and B-6. This alteration resulted in partial alteration of glass to chlorophaeite. Chlorophaeite is a fine-grained, soft, green to reddish-brown chlorite-like mineral of variable composition.

August 10, 1992

APPENDIX I
PETROGRAPHIC DESCRIPTIONS

B-4; Fresh Basalt

40.2%	Glass	-	Dark brown to opaque. Contains plagioclase crystallites and opaque grains and skeletal crystals.
25.3%	Plagioclase (Pl, An_{58})	0.015-1.0mm long	Fresh laths with no preferred orientation.
27.3%	Pyroxene (Px, Pigeonite)	0.02-0.6mm long	Bimodal size distribution. Larger are stubby prisms and smaller (<0.1mm) are sub-anhedral granules.
3.7%	Opaque	3u-0.1mm	Grains and skeletal crystals in glass.
3.5%	Vesicles	0.01-1.3mm	Irregular-shaped voids - usually in clusters to circular vesicles with sharp walls.
tr	Chlorophaeite	<0.03mm	Yellowish-green to orange flakes in radiate clusters which fill voids interstitial to other phases. Occurs within 1.5mm away from some joint surfaces. Not along surfaces which are not reddish Fe-stained.

Weathering is limited to <1.5mm penetration of rock along only portions of joint surfaces. Composed of slightly hydrated glass and goethite-replaced opaques. Deposition of chlorophaeite in this zone is probably an early cooling phenomenon.

B-5; Fresh Basalt

59.2%	Glass	-	Dark brown predominately opaque except on thin edges. Contains needle-like crystals of feldspar.
20.2%	Plagioclase	0.02-0.8mm long	Fresh subhedral laths with ragged ends. No preferred orientation.
18.9%	Pyroxene (Pigeonite)	0.03-0.4mm long	Fresh. Larger are subhedral stubby prisms with included glass blebs. Smaller are anhedral granular to thin prismatic.
tr	Opaque	<3u	As small grains in glass. Generally not seen in glass except on thin edges.
1.7%	Vesicles	0.02-0.8mm	Predominately irregular-shaped

			voids in interconnected clusters interstitial to glass and containing protruding crystals. Occasionally rounded.

This rock is very similar to B-4 except it appears to have slightly coarser crystals than previous sample although glass content is higher. Probably due to fewer small crystals which would form during slower cooling.

Alteration and weathering along joint surfaces are negligible.

B-6; Fresh Basalt

50.2%	Glass	-	Dark brown opaque glass.
19.7%	Plagioclase (An_{72})	0.01-0.9mm long	Fresh laths, commonly with irregular ends. No preferred orientation. Some needle-like skeletal crystals seen in glass.
23.6%	Pyroxene (Pigeonite)	0.01-0.4mm long	Rarely as prisms up to 0.7mm long. Predominately as fresh equant granules and as short stubby prisms.
1.0%	Opaque	<0.03mm	Skeletal crystals in glass. Not seen except where glass is very thin.
3.3%	Vesicles	0.01-1.2mm	Predominately as irregular-shaped voids lined with glass. Interstitial to crystals in interconnected clusters. Partially circular voids are sparse.
tr	Chlorophaeite	<0.06mm	Lines or fills cavities next to one joint. Red-iron-stained next to joint.

Alteration has penetrated one joint surface to depth of 2-4mm where chlorophaeite has filled or lined vesicles. From 1.5 to 2mm depth from joint surface the chlorophaeite is stained red due to hematite (or goethite) weathering.

B-7; Fresh Basalt

34.7%	Glass	-	Dark brown translucent turbid glass with skeletal opaques.
23.4%	Plagioclase	0.01-1.0mm long	Fresh subhedral laths with ragged ends. No preferred orientation. Also as needle-like sparse skeletal crystals in glass.

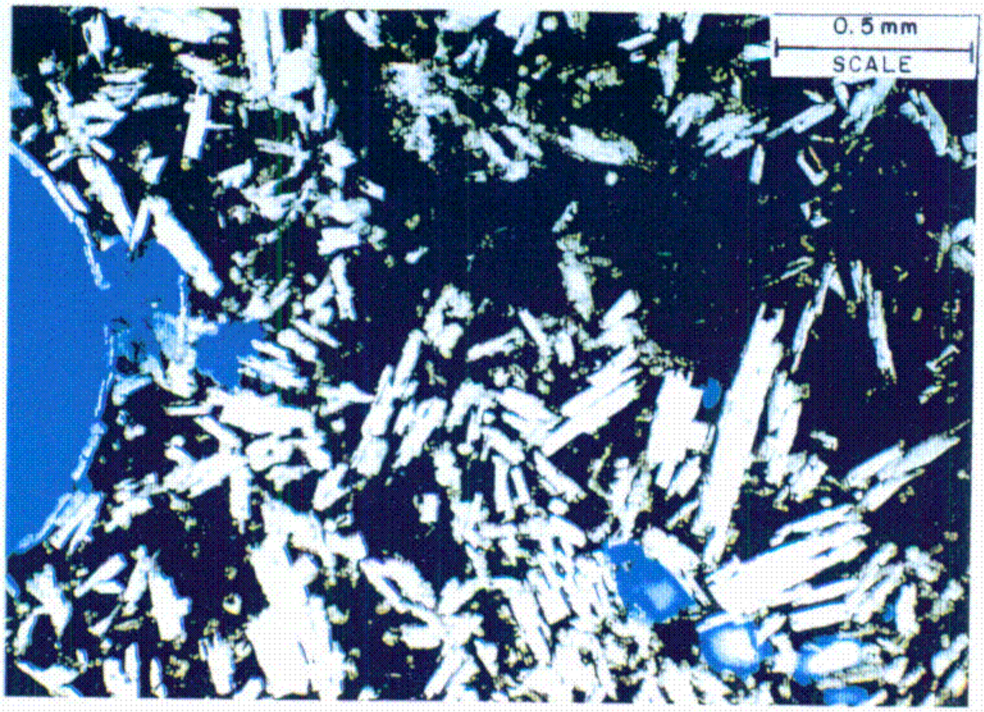
18.3%	Pyroxene (Pigeonite)	0.02-0.9mm long	Fresh. Smaller are granules and these grade to fresh larger prisms.
7.7%	Opaque	<0.06mm	Skeletal crystals in glass.
13.7%	Vesicles	0.02-4.0mm	Predominately as interconnected voids interstitial to crystals in diffuse clusters with large void in center. Occasionally as large rounded vesicles. Some of these are lined on one side with colorless glass.
tr	Glass(?)	-	10u thick layer lines vesicles up to 6.0mm from joint surfaces. Yellow. Rarely goethite-stained and fills vesicles next to joint surface.

No visible alteration or weathering next to joint surfaces.

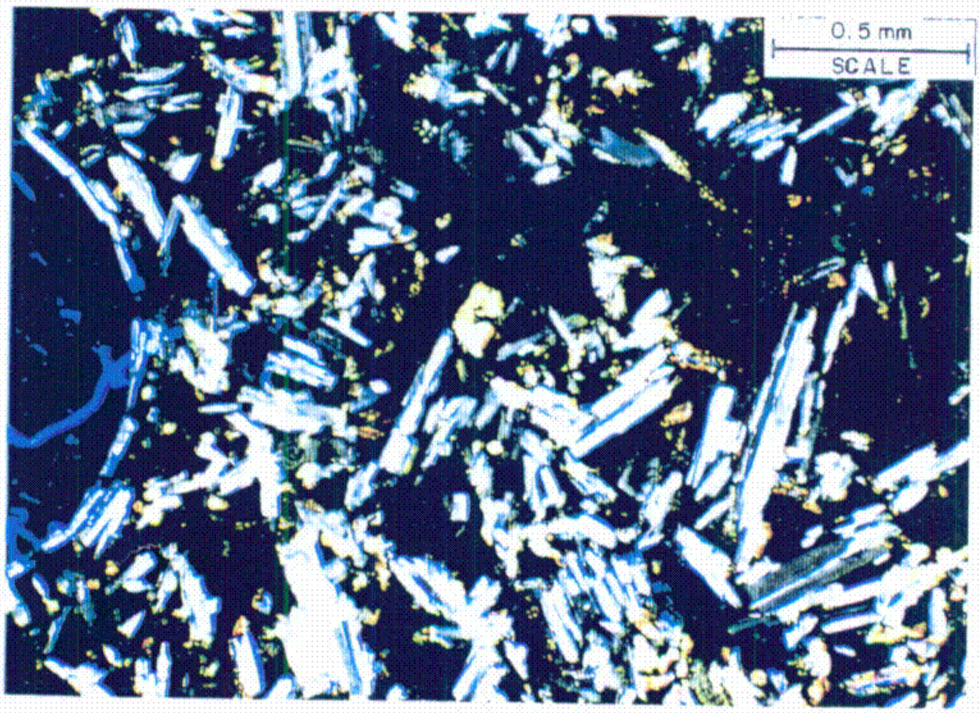
B-8; Fresh Basalt

61.5%	Glass	-	Dark brown and opaque.
22.2%	Plagioclase (An_{60})	0.02-0.8mm long	Fresh tabular crystals with no preferred orientation.
14.5%	Pyroxene	0.03-0.5mm	Ragged fresh subhedra.
1.3%	Vesicles	0.04-0.6mm	Irregular-shaped voids. Commonly in clusters. Also approximately 5% relict circular vesicles which are filled with opaque glass indistinguishable from groundmass glass.
0.5%	Chlorophaeite	<0.01mm long	Yellow to red flakes in radiate clusters or colloform linings which fill voids up to 2.5mm from joints.

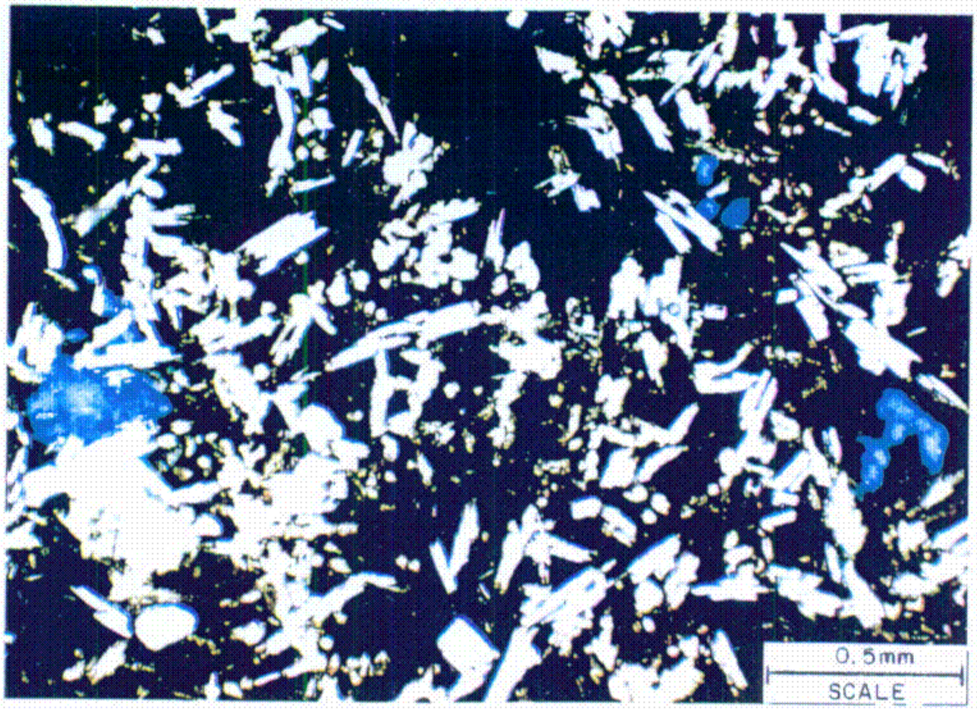
Weathering is restricted to minor Fe-staining of chlorophaeite within 2.5mm of joint surfaces and minor (trace) hydration of glass from 0 to 0.04mm thick on joint surfaces.



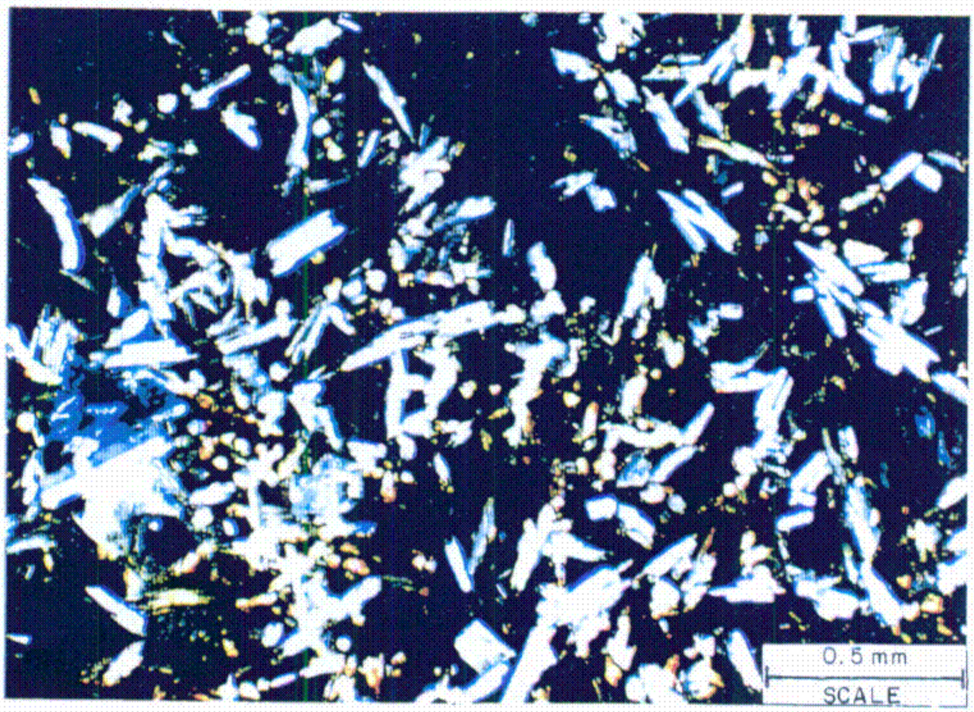
B-4; top - plane polarized light (pl); bottom - crossed polarized light (xpl); Same view in both photos. **Fresh Basalt.** Upper photo: Voids filled or lined with blue epoxy. White laths of plagioclase. Pyroxene is grayish and glass is black. Lower photo: Plagioclase is twinned white and gray. Pyroxene is multi-colored.



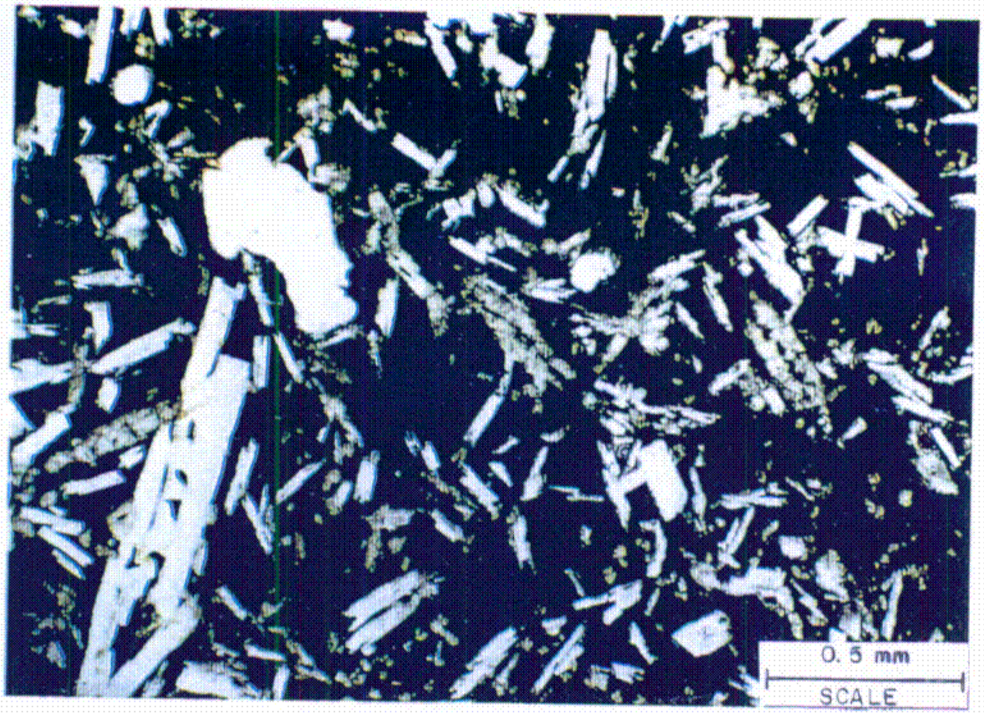
C02



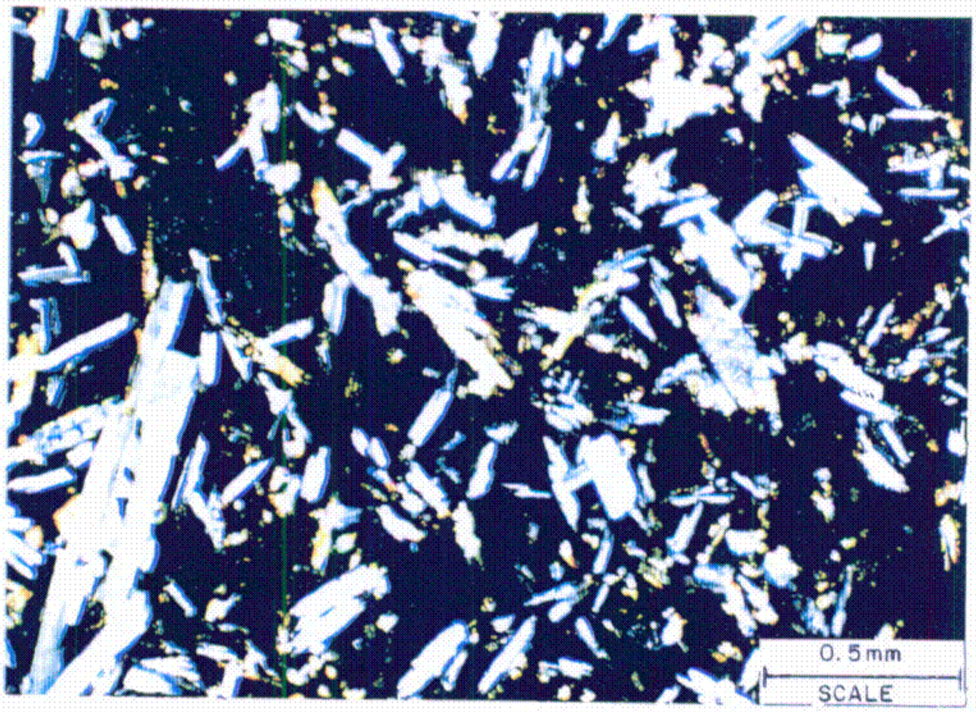
B-5; top - pl; bottom - xpl; same view. **Fresh Basalt.** Upper photo shows blue and white irregular voids and crystals in opaque glass. Lower photo shows multi-colored granular pyroxene and white/gray twinned laths of plagioclase.



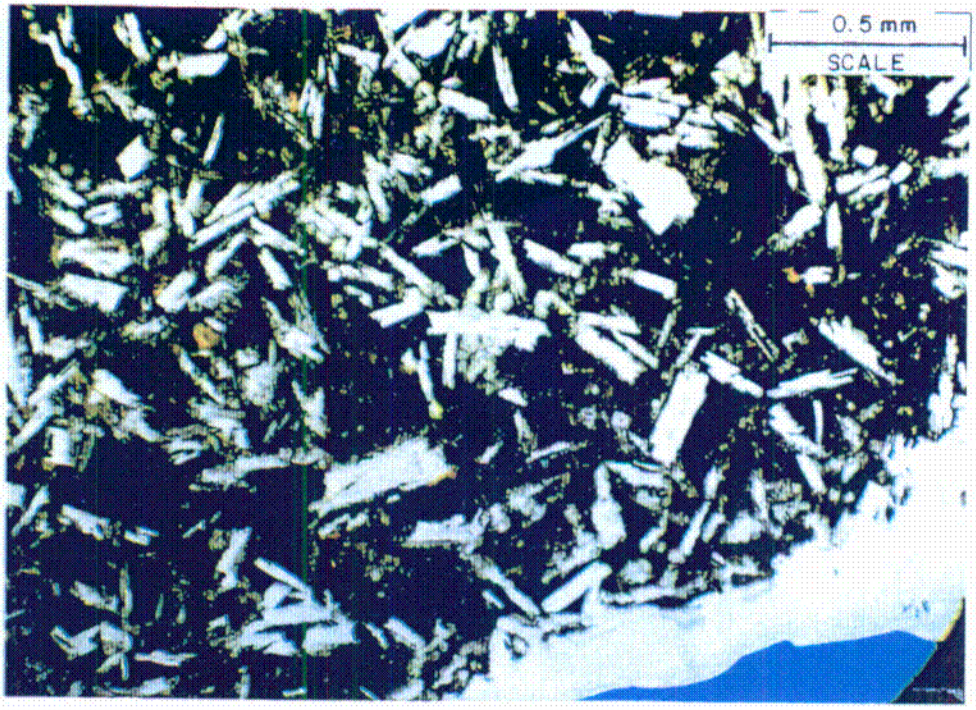
C03



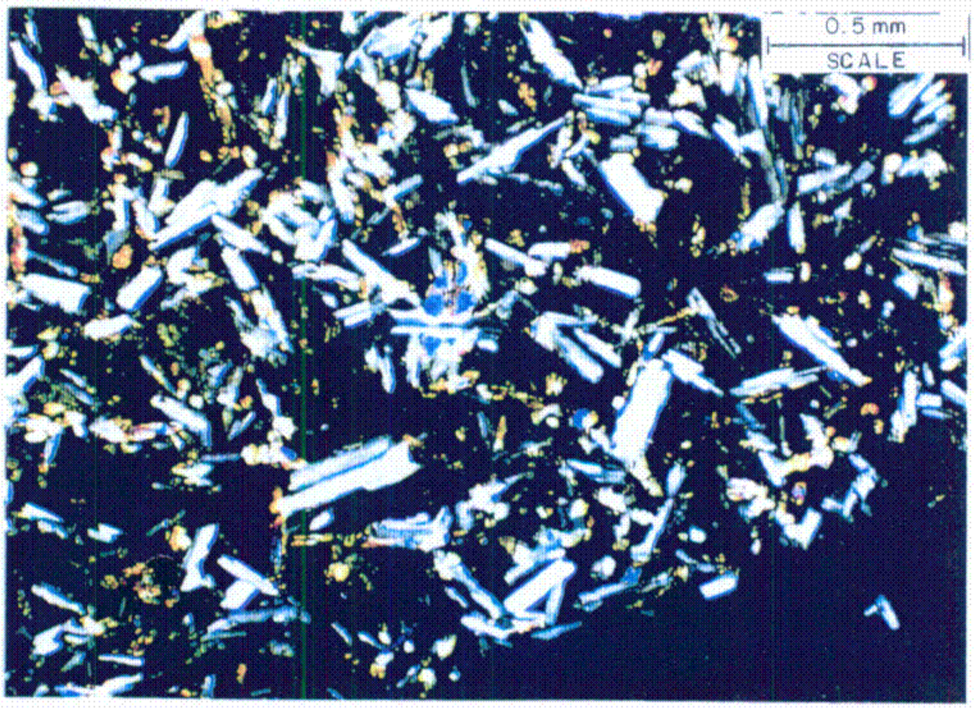
B-6; top - pl; bottom - xpl; same view. **Fresh Basalt.** Upper photo shows white irregular-shaped voids, white plagioclase laths and gray granular to elongate pyroxene in opaque glass. Lower photo shows twinned white to gray plagioclase and multi-colored pyroxene.



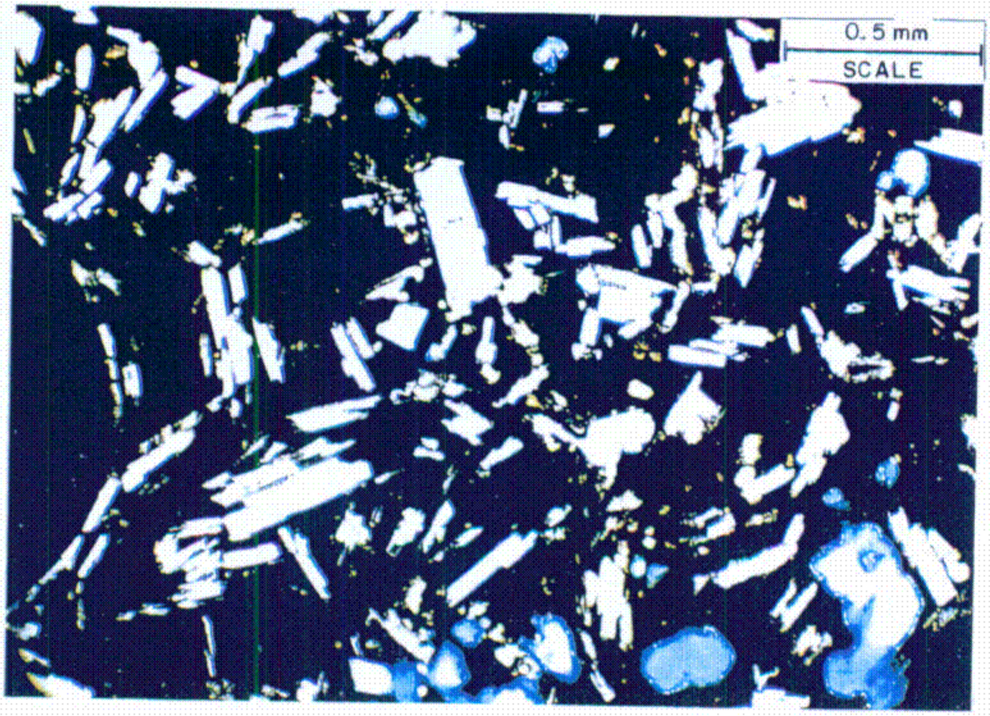
C04



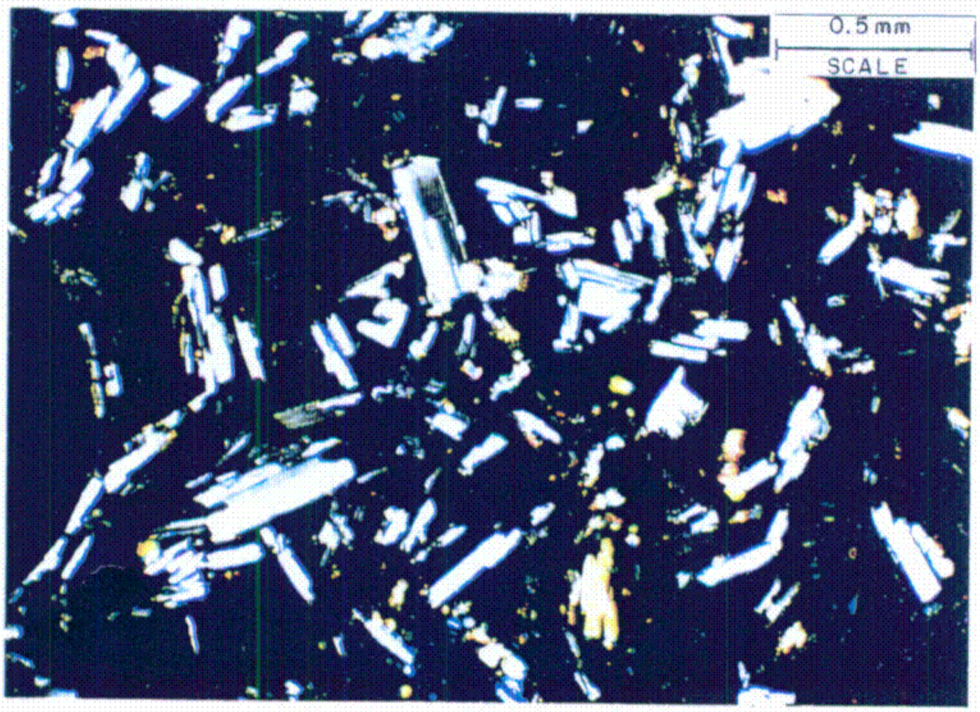
B-7; top - pl; bottom - xpl; same view. **Fresh Basalt.** Upper photo shows brown to opaque glass containing black opaques. Orange spots are chlorophaeite in voids. SE corner of photo is edge of blue epoxy-filled vesicle which is lined with colorless glass. lower photo shows multi-colored pyroxene.



C05



B-8; top - pl; bottom - xpl; same view. **Fresh Basalt.** Upper photo shows colorless plagioclase laths and sparse brownish pyroxene in opaque glass. Note large round vesicle which is filled with opaque glass on W edge of photo. Compare with vesicle in photos of B-4, p. 7. Other voids contain blue epoxy.



C06

THEODORE P. PASTER, Ph.D.
Consultant
11425 East Cimmarron Drive
Englewood, Colorado 80111
(303) 771-8219

January 15, 1992

Lawrence E. Fiske
Shepherd Miller, Incorporated
1600 Specht Point Drive, Ste. F
Fort Collins, CO. 80525

RE: Petrography of Four Representative Riprap Samples, Eastern Washington State.

SUMMARY

Rock Types and Composition

Samples B-1, -2 and -3 are olivine basalts whose mineralogy are given in **TABLE 1** and whose descriptions are in **APPENDIX I**.

G-1 is a medium-grained quartzite.

Weathering

The rocks show no weathering effects and contain no clay.

Secondary Alteration

Olivine in two of the basalt samples was partially altered to a soft chlorite-like mineral during original cooling of the basalt lavas.

Respectfully submitted:

[signature]

INTRODUCTION

Four representative rock samples from eastern Washington State which are to be used for riprap were sent to this laboratory for petrographic analysis by Shepherd Miller, Incorporated (SMI).

The samples were selected by SMI as being representative of degree of weathering and alteration of the rock to be used. It was agreed that this report should include the following information:

1) Bulk composition.
2) Secondary minerals and weathering.

SAMPLES

The four samples received from SMI are labeled: B-1, B-2, B-3 and G-1. One fist-sized hand specimen of each sample was received. The samples are megascopically uniform and non-fractured.

RESULTS

TABLE 1 gives the mineralogy and composition of the rocks. **APPENDIX I** gives a detailed petrographic description of each rock.

****

TABLE 1
PETROGRAPHY OF 4 RIPRAP SAMPLES
FROM
EASTERN WASHINGTON STATE.
(FOR SMI)

Contained Mineral	Percent of Mineral B-1	B-2	B-3	G-1
Glass	78.9 ± 3.2	17.5 ± 3.3 (Glass + Opaque)	13.1 ± 3.0 (Glass + Opaque)	-
Opaque	-			0.5 ± 0.5
Plagioclase	14.0 ± 2.6	24.9 ± 3.8	24.0 ± 3.8	-
Olivine	4.2 ± 1.5	6.8 ± 2.3	6.9 ± 2.2	-
Pyroxene	-	47.3 ± 4.4	48.2 ± 4.5	-
Carbonate	1.6 ± 0.8	trace	-	-
Vesicles	1.1 ± 0.6	3.5 ± 1.4 (Vesicles + Chlorophaeite)	-	-
Chlorophaeite	-		7.7 ± 2.4	-
Quartz	-	-	-	90.5 ± 2.5
Muscovite	-	-	-	7.3 ± 2.0
Sphene + Rutile	-	-	-	1.7 ± 1.0

****

Rock Types

Olivine basalts include samples B-1, B-2 and B-3. G-1 is a quartzite.

RESULTS, cont.

Weathering

All of the samples are practically unweathered. There are no secondary clays present in the samples except for about 2 mm along the jointing of B-3. This jointing measures from 2 inches in spacing upward in this particular hand specimen.

Alteration

Secondary high-temperature alteration occurred during cooling of the lava samples B-2 and B-3. This alteration resulted in partial alteration of olivine to chlorophaeite. Chlorophaeite is a fine-grained, soft, green to reddish-brown chlorite-like mineral of variable composition.

January 15, 1992

APPENDIX I
PETROGRAPHIC DESCRIPTIONS

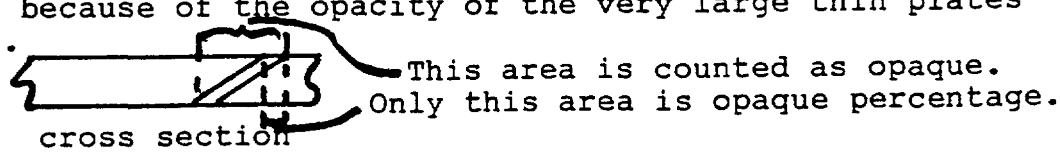
B-1; Olivine Basalt

Groundmass (79%):		
78.9% Glass	-	Opaque. Deep reddish-brown on thin edges.
Crystals (18%):		
14.0% Plagioclase	0.02-0.4mm long	Fresh laths.
4.2% Olivine	0.02-0.3mm	Commonly fractured and fresh subhedra.
Vesicles (1%):	0.01-0.5mm	Partly filled with chlorophaeite on walls. Occasionally contains carbonate.
Carbonate (2%):	1 mm	With goethite coats fractures in rock which are frequently exterior coatings on the crushed specimen. The mineral is probably dolomite.

B-2; Olivine Basalt

Crystals (32%):		
24.9% Plagioclase (An_{59})	0.015-1mm long	Fresh laths. Not oriented to any particular direction.
6.8% Olivine	0.02-0.1mm	Fresh equant subhedra.
Groundmass (68%):		
47.3% Pyroxene> Feldspar	0.01-0.25mm long	Predominately skeletal laths.
17.5% Opaque + Glass(?)	0.01-0.3mm long	Skeletal plates of hematite &/or ilmenite and glass(?) interstitial to other silicates.
3.5% Vesicles	0.04-0.3mm	Irregular angular-shaped voids lined and generally filled with colloform chlorophaeite.
tr Carbonate	0.1-0.2mm	Fills 1mm cluster of vesicles.

There is an error on the high side of the Opaque + Glass percentage because of the opacity of the very large thin plates of opaques.



B-3; Olivine Basalt

Crystals (32%):

24.0%	Plagioclase (An_{69})	0.04-0.5mm long	Fresh ragged-appearing laths with occasional thin zones of parallel alignment along relict flow slippage planes.
6.9%	Olivine	0.06-0.12mm	Subhedra commonly partly replaced by chlorophaeite.
0.8%	Pyroxene	0.04-0.2mm	Equant fresh subhedra.

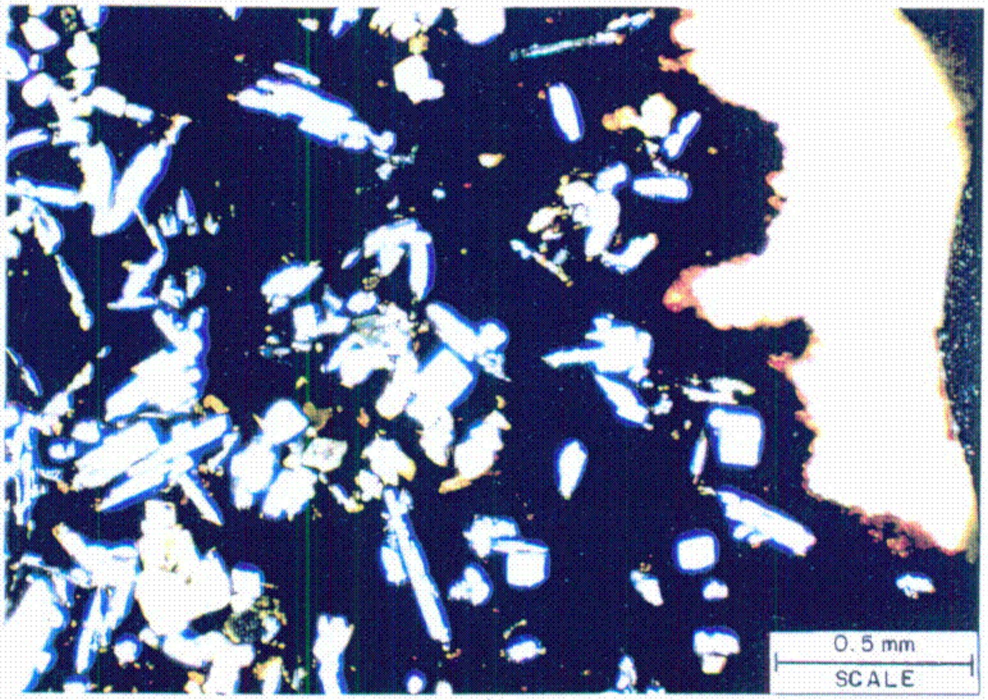
Groundmass (67%):

47.4%	Pyroxene	0.02-0.5mm long	Skeletal bladed crystals commonly in radiate aggregates.
7.7%	Chlorophaeite	-	Fine-grained aggregates as colloform fillings lining relict olivine and vesicles.
13.1%	Opaque	0.01-0.7mm long	Skeletal plates of opaques which lace groundmass pyroxene.

This is the coarsest basalt of the suite. The same problem exists with the opaque percentage as described in B-2.

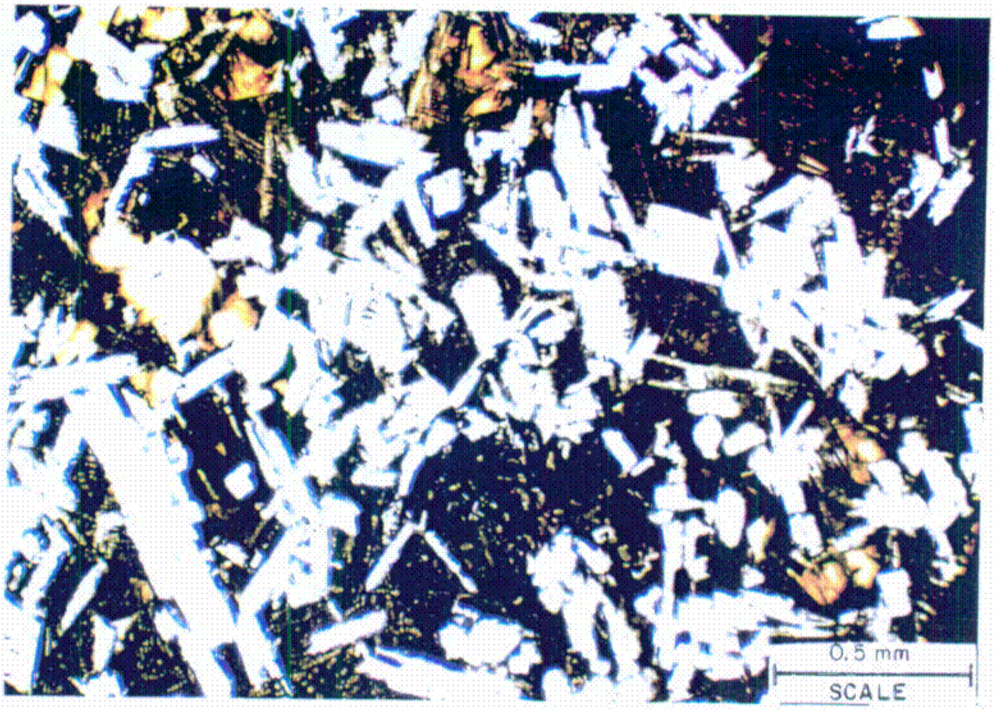
G-1; Quartzite

90.5%	Quartz	0.02-1mm	Equant anhedra with sutured boundaries. Moderately strained.
7.3%	Muscovite	0.01-0.15mm long	Scattered flakes and strings of flakes in sub-parallel schistose alignment. Interstitial to quartz.
0.5%	Opaque	2-30u	Ilmenite, magnetite or hematite.
1.7%	Sphene + Rutile	0.03-0.07mm	Scattered grains and clumps.

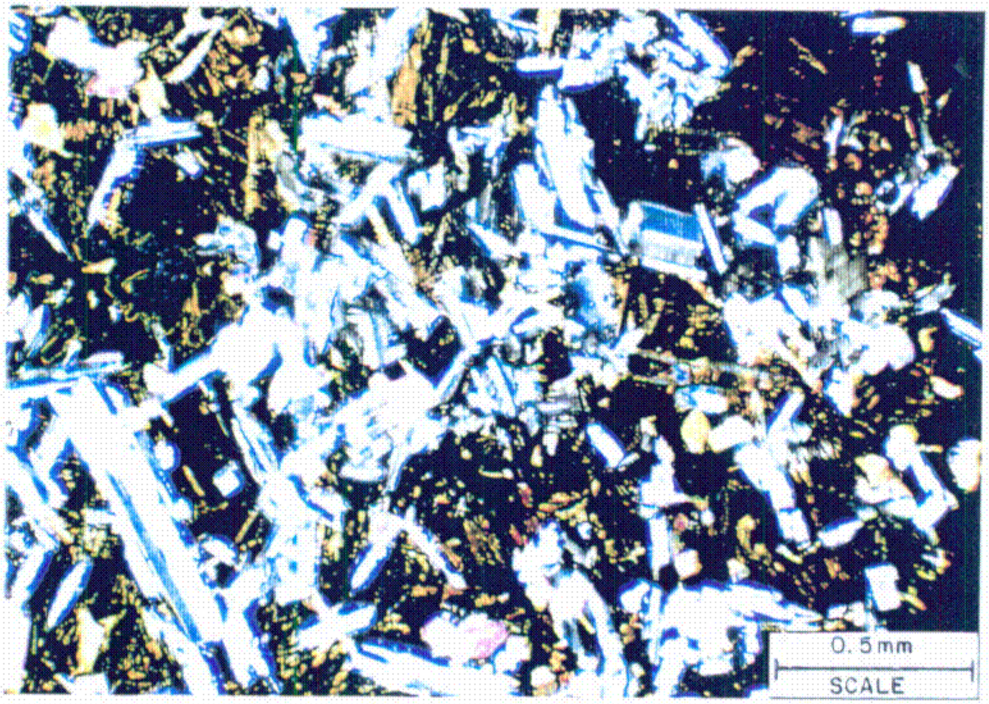


B-1; crossed polarized light (xpl). Olivine Basalt in thin section. White laths of plagioclase and colored equant olivine crystals in groundmass of black glass. View near joint surface at right. Surface is irregular, has a thin coating of brown goethite and ½mm coating of dolomite (white).

C07



B-2; plane light (pl) in upper photo and xpl in lower photo. Same view in both photos. Olivine Basalt. Laths of plagioclase, smaller equant grains of olivine which are colored in lower photo and large vesicle near left edge center. Note skeletal brown crystals of pyroxene in groundmass.



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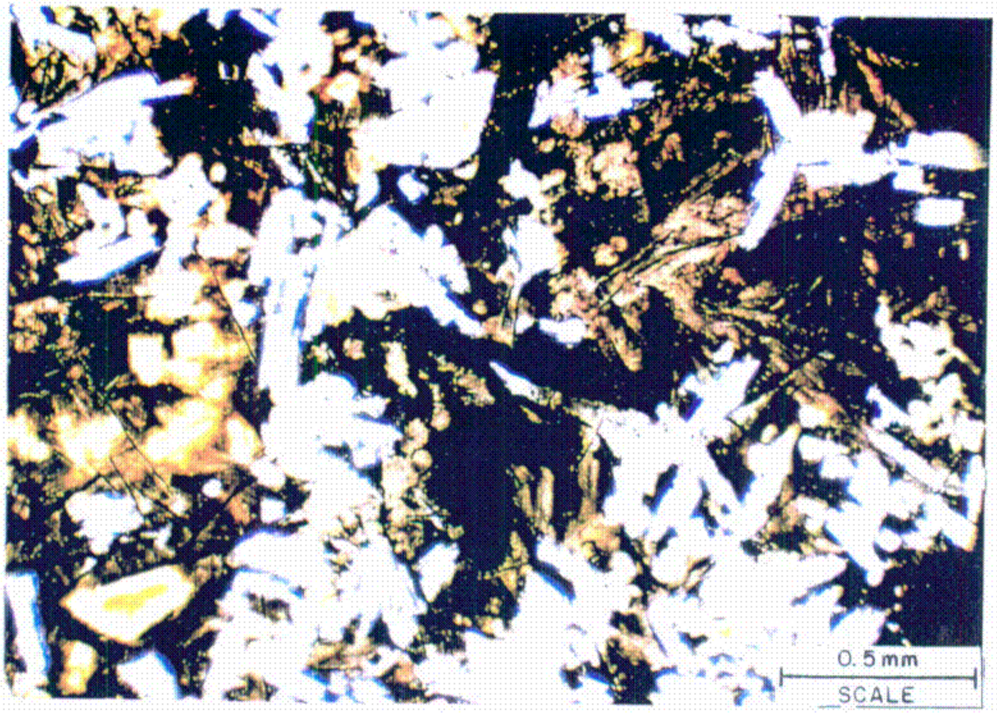
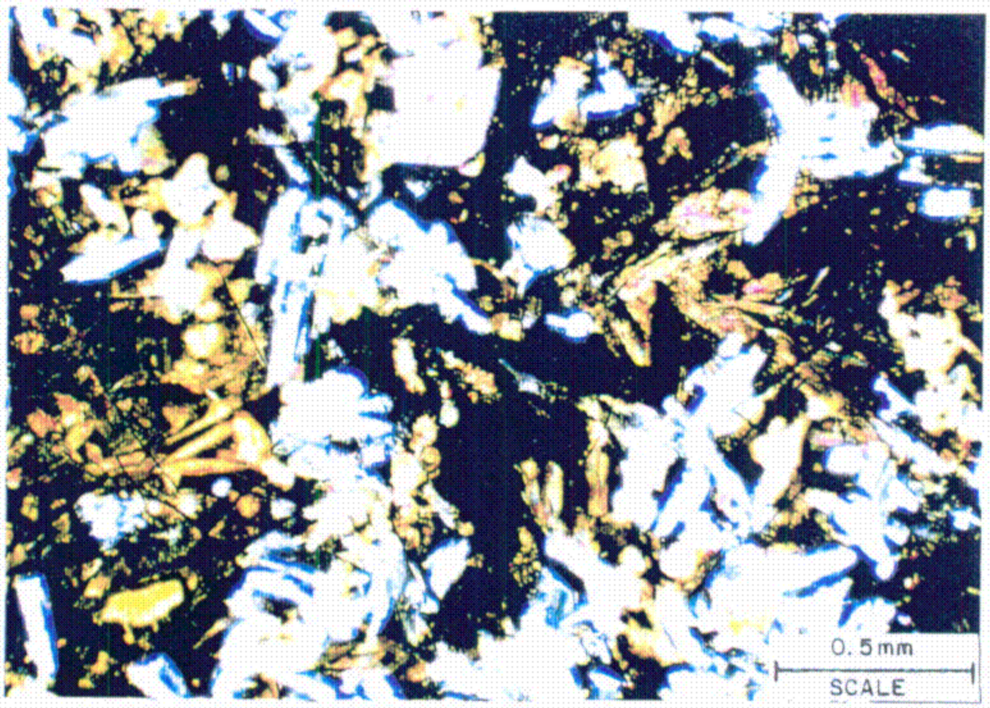


B-3; pl upper photo, xpl lower photo. Olivine Basalt. Same general description as B-2. Groundmass is slightly better crystallized than in B-2. Note black laths of opaque mineral(s).



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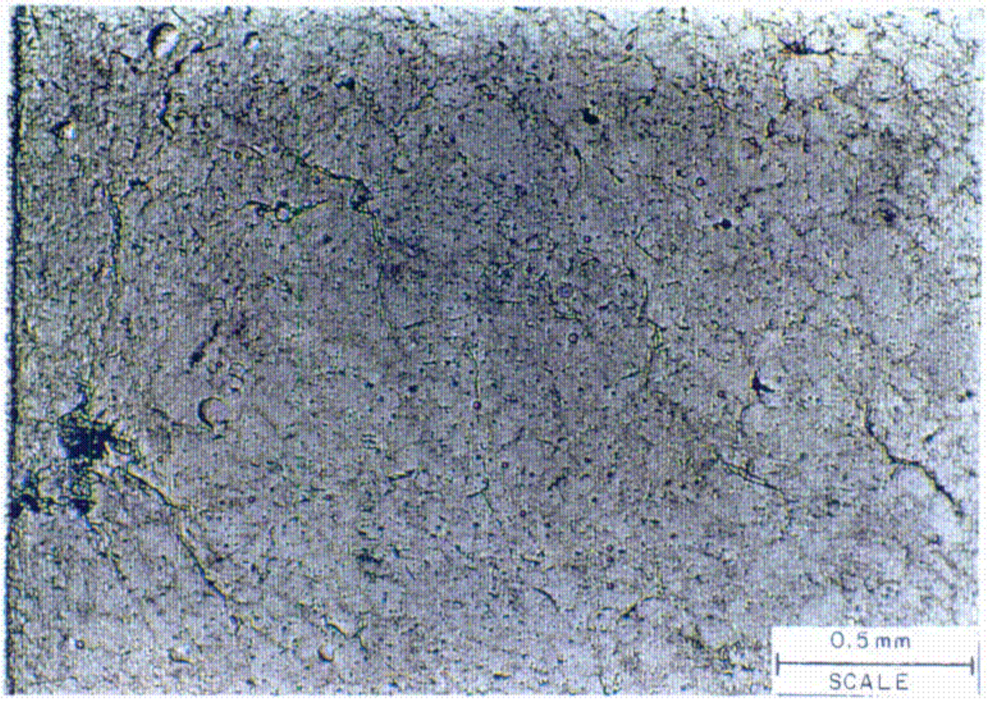
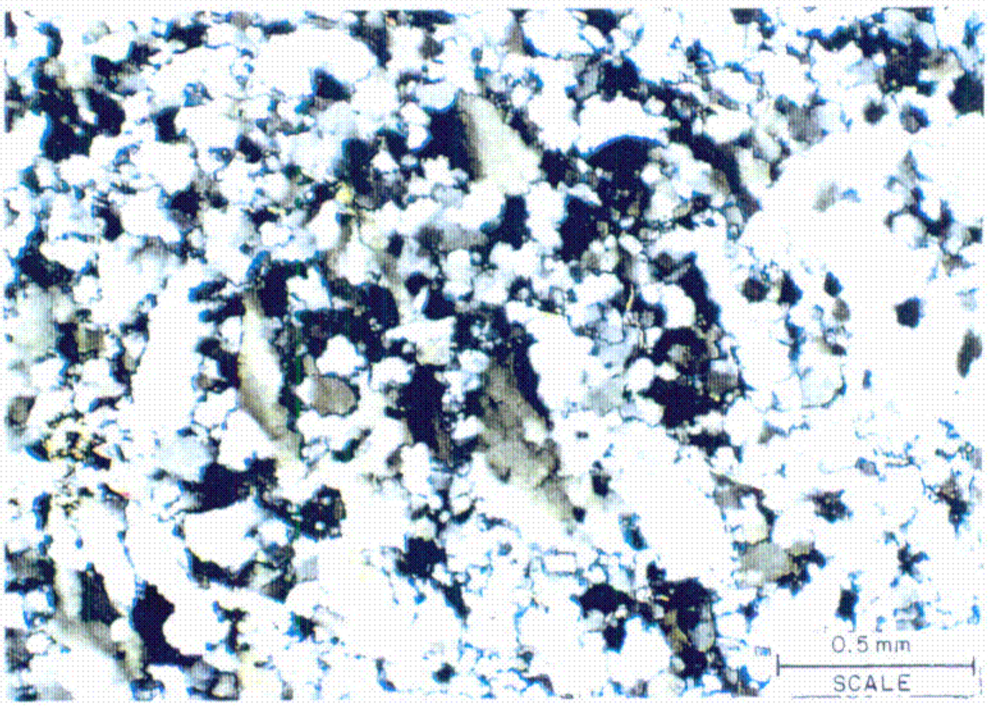


G-1; pl upper photo, xpl lower photo. Quartzite. Sample is 90% quartz and 7% muscovite which can be easily seen in upper photo as flaky mineral which has a general alignment of NW - SE (direction of foliation).



Prepared For:

WESTERN NUCLEAR, INC.
SHERWOOD PROJECT
Wellpinit, Washington

SHERWOOD TAILING RECLAMATION

CONSTRUCTION COMPLETION REPORT

VOLUME 1 of 3

Prepared By:

SHEPHERD MILLER, INC.
Fort Collins, Colorado

JUNE 1997

report submitted to WDOH on April 23, 1996, and is included in this report as Appendix C.

2.1.6 Monitoring Well Abandonment

Monitoring wells MW-5, -6, -7, -8 and -9 were abandoned during construction activities. Well abandonment was performed in accordance with Washington Department of Ecology (WDOE) requirements and was documented in a submittal to the WDOH on November 7, 1995. A copy of this submittal is included in this report as Appendix D.

2.1.7 Rock Durability and Gradation Tests

A volumetric bank measure of total rock utilized in the production of two filters and riprap was taken from ground surveys of two sources which included the Quartz Monzonite Quarry and a basaltic rock stockpile. The total volume of rock utilized measured 82,056 cubic yards of quartz monzonite plus 7,626 cubic yards of basalt. Both of these volumes included reject rock. On the basis of in situ volume, 11 durability tests were required which included 2 pre-production tests, one for each of the two sources. Twelve rock durability tests were performed. The requirement of one durability test per every 10,000 cubic yards produced indicates that one extra durability test was performed.

A swell factor of 1.389 was experienced in the production of filters and riprap produced. Sized rock was measured and weighed and, in addition, production stockpiles including reject rock at its disposal site were surveyed. Rock durability tests conducted on the basis of loose volume produced, meeting the requirement of one test per every 10,000 cubic yards, and one pre-production test per source totals 12. Twelve tests were required and 12 tests were conducted. The test results are

TABLE 1 - ROCK DURABILITY TEST RESULTS

Test No.	Bulk Specific Gravity	Absorption %	Sodium Sulfate Soundness %	Schmidt Impact Hammer	Actual (Calculated) Rock Durability Rating	Design (Required) Minimum Rock Durability Rating Without Oversizing
1	2.62	0.15	2.6	57.10	80	80
2	2.86	1.2	1.5	66.60	90	80
3	2.82	1.5	1.7	67.20	90	80
4	2.61	0.7	2.5	54.60	79 (a)	80
5	2.63	0.4	1.9	56.20	80	80
6	2.63	0.4	2.2	56.70	80	80
7	2.63	0.3	1.7	57.60	80	80
8	2.63	0.3	1.7	57.50	81	80
9	2.64	0.4	1.4	62.20	81	80
10	2.64	0.4	1.5	61.90	80	80
11	2.62	0.3	2.2	57.00	80	80
12	2.63	0.4	2.1	58.10		80

(a) The produced rock durability rating of 79 is below the required rating of 80 which, in accordance with the NRC, needs to be oversized by 1%. In this case, the rock represented by Test No.4 was placed in Confluences B, F_2, and F which required a D_{50} of 8 inches, Confluence G which required a D_{50} of 10 inches, and in Confluences E_1 and E which required a D_{50} of 12 inches. A D_{50} of 15 inches riprap was actually provided in the above confluences. Therefore, the rock was oversized by 88% in Confluences B, F2, and F, by 50% in Confluence G, and by 25% in Confluences E_1 and E.

APPENDIX E

GRADATION AND DURABILITY TEST RESULTS

WESTERN NUCLEAR, INC.

UNION PLAZA SUITE 300, 200 UNION BOULEVARD, LAKEWOOD, COLORADO 80228
TELECOPIER (303) 989-8993 TELEPHONE (303) 989-8675

February 5, 1996

Mr. Gary Robertson, Head
Waste Management Section
Washington Department of Health
Division of Radiation Protection
Airdustrial Park, Bldg. 5
P.O. Box 47827
Olympia, WA 98504-7827

RE: WN-I0133-1, SHERWOOD PROJECT, TAILING RECLAMATION PLAN, ROCK PETROGRAPHIC ANALYSIS

Dear Mr. Robertson:

As discussed during our January 24-25, 1996 meeting, please find attached the petrographic analysis and associated engineering evaluation regarding the rock from the proposed rock quarry, situated in the Western Nuclear, Inc. Sherwood mine area, that will be used for erosional stability during the forthcoming 1996 tailing reclamation construction.

In accordance with our July 20-21, 1995 and other recent discussions, seven [7] copies of this submittal are being transmitted to you in Olympia. We would appreciate if you would transmit the copies as you previously indicated, as listed below:

- Spokane Tribe of Indians (1 copy)
- Bureau of Indian Affairs (1 copy)
- Nuclear Regulatory Commission (1 copy)
- Clean file copy (1 copy)
- WDOH [Olympia, WA] (3 copies)

In addition, copies are being transmitted directly to the following parties:

- o Two copies of this particular submittal are being sent by WNI directly to Ms. Stoffel [WDOH; Spokane, WA].
- o One [1] copy is being sent directly to Mr. Fordham [WDOH; Richland, WA].

We request your prompt review and approval of the attached information, so that permitting and quarrying of the rock borrow source may be completed as soon as possible in support of the forthcoming reclamation construction season.

Should you have any questions, please contact us at your earliest convenience.

Sincerely,

Stephanie J. Baker
Manager of Environmental Services
SJB/tic doh\rockpetr.f96

w/enclosures

cc: CA [w/ attach.]
KCB [w/o attach.]
MAP [w/o attach.]
L. Pruett, Esq. [w/ attach.]
LLM [SMI; w/ attach.]
D. Stoffel [WDOH; w/ attach.]
E. Fordham [WDOH; w/ attach.]

SHEPHERD MILLER
INCORPORATED

February 6, 1996

Ms. Stephanie Baker
Western Nuclear, Inc.
Union Plaza
200 Union Boulevard, Suite 300
Lakewood, Colorado 80228

SMI #03-317

Dear Stephanie:

Enclosed you will find the results of petrographic analysis performed on the three rock samples Corn Abeyta collected from the proposed quartz monzonite quarry near the mine. These analyses, performed by Dr. Theodore Pastor, provided the data necessary to evaluate the rock samples durability relative to NRC guidance. The analyses did not indicate any smectite or expanding lattice clays in any of the samples.

These results have been evaluated relative to the guidelines presented in the NRC "Staff Technical Position - Design of Erosion Protection for Stabilization of Uranium Mill Tailings Sites," August, 1990 and NUREG 4620 "Methodologies for Evaluating Long-Term Stability of Uranium Mill Tailing Impoundments," 1986.

Based upon Dr. Pastor's analyses we found the following:

1) The quartz monzonite samples would be classified in group 2 according to Table 6.1 from NUREG 4620 since they are coarser grained felsic granites.

2) The samples would be classified as fair according to Table 6.4 from NUREG 4620 as they are in group 2, exhibit no significant weathering, and only have trace amounts of clay.

The Staff Technical Position indicates that rock must score at least "fair" according to the procedures presented in NUREG 4620. The appropriate pages from both the STP and NUREG 4620 are attached.

Since the analyses did not identify any smectites or expanding lattice clays and the rock quality score is "fair" (Table 6.4 from NUREG 4620), the quartz monzonite samples pass the petrographic requirements of the rock quality criteria for use as riprap.

Consulting Environmental & Geotechnical Engineers & Scientists

1600 Specht Point Dr., Suite F
Fort Collins, CO 80525
Phone (970) 484-4414
Fax (970) 484-7540

If you have any question or need additional information, please contact me at your convenience.

Sincerely,

SHEPHERD MILLER, INC.

Louis Miller/mp

Louis L. Miller, P.E.
Vice President

LLM:mmp
Enclosures

cc: Corn Abeyta w/enclosures

THEODORE P. PASTER, Ph.D.
Consultant
11425 East Cimmarron Drive
Englewood, Colorado 80111
(303) 771-8219

January 11, 1996

Lawrence E. Fiske
Shepherd Miller, Incorporated
1600 Specht Point Drive, Ste. F.
Fort Collins, CO. 80525

RE: Petrography of Three Quartz Monzonite Samples.

SUMMARY

Rock Type and Composition
The three samples are fresh quartz monzonite with the same mineralogy and composition (**TABLE 1**). They differ in grain size. A complete description is given in **APPENDIX I.**

Weathering
The samples are unweathered.

Secondary Alteration
Some minor (up to 15%) disseminated white mica alteration occurs in the plagioclase (Pl). Carbonate occurs as disseminations and in fractures in Pl in sample C. The magnetite (Mt) in the rocks is partially replaced by hematite. All of this alteration is minor.

Fractures
Some moderately spaced micro-fractures are present in the larger Pl crystals. Through-going fractures were not seen in the over-sized thin sections.

Respectfully submitted:

INTRODUCTION

Three rock samples were sent to this laboratory by Shepherd Miller, Incorporated (SMI) for petrographic analyses.

The samples were selected by SMI as being representative of degree of weathering and alteration of the rock to be used as rip rap. The primary focus of this description is to include:

1) Bulk composition.
2) Secondary minerals and weathering.

SAMPLES

The three samples from SMI are labeled: SM-A, SM-B and SM-C. One double-fisted-sized hand specimen of each sample was received. The samples are uniform (Except for their porphyritictexture.) and non-fractured megascopically. They contain 2.5- 6.0" - spaced joints which are not visibly weathered either megascopically or microscopically.

An over-sized thin section measuring 2" x 2" was cut from each sample to minimize the effect of the coarse crystal size of the rock.

RESULTS

TABLE 1 gives the mineralogy and composition of the rocks. **APPENDIX I** gives a detailed petrographic description of the samples. Inasmuch as the three samples are the same rock, the description applies to all samples.

TABLE 1
MINERALOGY OF 3 QUARTZ MONZONITE SAMPLES
(for SMI)

	percent of mineral			
mineral	SM-A	SM-B	SM-C	average
Quartz	35.9 ±3.6	34.5 ±3.9	32.3 ±4.0	34.4 ±6.6
Plagioclase (Pl)	34.5 ±3.6	31.7 ±3.8	32.9 ±4.0	33.1 ±6.6
Carbonate in Pl	0.7 ±0.7	0	0	-
Microperthite	24.8 ±3.2	29.0 ±3.7	26.6 ±3.7	26.7 ±6.1
Biotite (Bt)	3.6 ±1.4	2.4 ±1.3	3.4 ±1.5	
Chlorite from Bt	0.8 ±0.7	0.7 ±0.7	2.3 ±1.3	4.8 ±3.2
Muscovite from Bt	0.3 ±0.3	1.0 ±0.8	0.5 ±0.5	
Magnetite	0.1 ±0.1	0.7 ±0.7	1.6 ±1.1	-
Hematite	-	-	0.4 ±0.4	-
totals	100.0	100.0	100.0	99.0

****

Rock Type

All samples are quartz monzonite as indicated in the average column of the table. The samples have the same mineralogy within counting statistics.

Grain Size

There is some variability in grain size among the samples. From coarsest to finest average grain size the samples are; B, C and A.

Weathering

There is no significant weathering in the samples.

Alteration

Sample C contains a trace of clay in short, discontinuous fractures in Pl. This clay appears to be a deuteric rather than a weathering product. Hematite does not stain the rocks and whatever is present is a partial deuteric oxidation product of Mt. A small amount of carbonate occurs as disseminated patches in Pl in sample A.

Fractures

Fracturing in thin section is mostly healed except for that in Pl where it is moderate. In other words, fracturing is not continuous across mineral grain boundaries.

APPENDIX I
PETROGRAPHIC DESCRIPTION

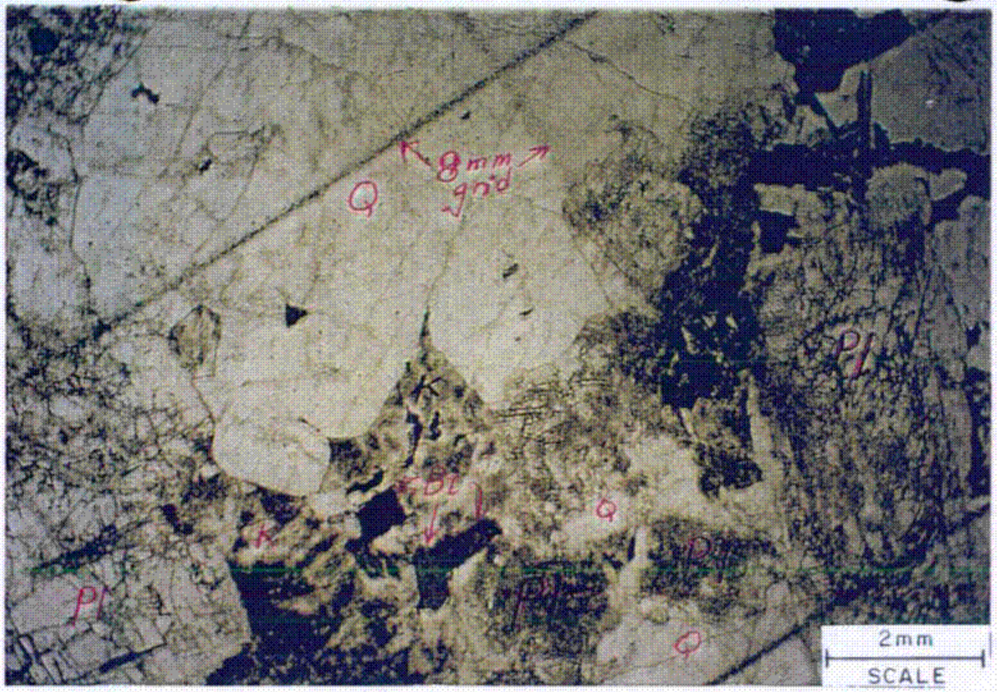
SM-A, B, and C; Fresh Quartz Monzonite.

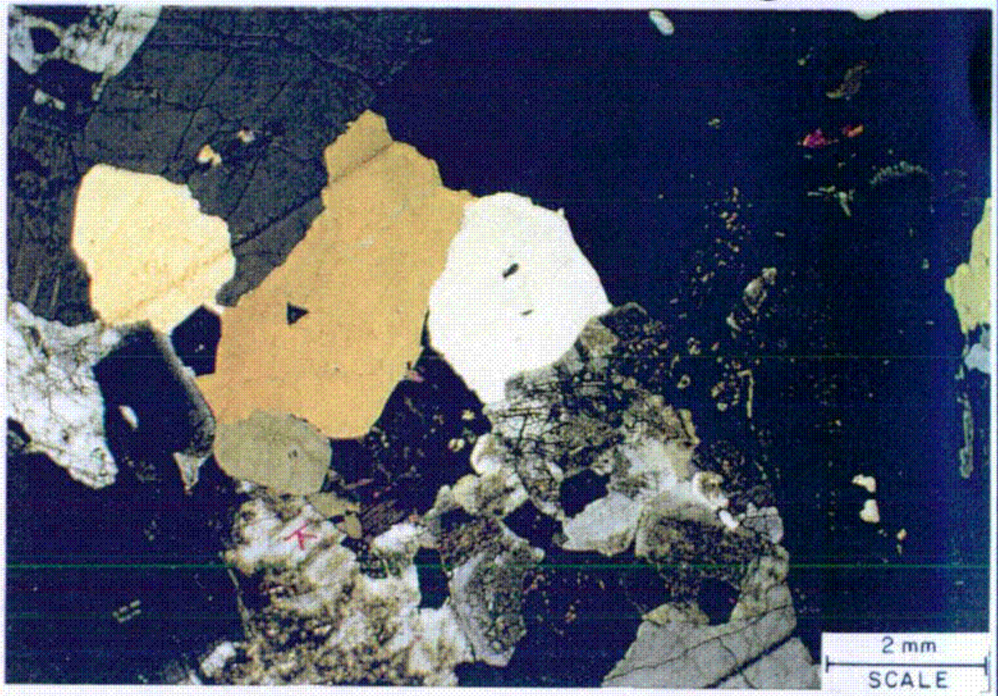
34.4% Quartz (Q)	0.6-8.0mm	Commonly in clumps of equant anhedra. Non-strained but commonly with mutual sutured boundaries. Contain discontinuous, partly healed occasional fractures spaced 1-3mm. Rarely contain small inclusions of biotite which is partly altered to chlorite or muscovite.
33.1% Plagioclase (Pl, An_{36})	0.4-7.0mm	Subhedra and smaller euhedra as inclusions in K-spar. Larger crystals are fractured. Fractures contain clay in C and carbonate in A. Many contain up to 15% muscovite alteration in disseminated patches.
26.7% Microperthite (K-spar)	0.6-20mm	Poikilitic, fresh anhedra with 3-10%, 0.06-1.5mm, inclusions of anhedral Q, magnetite, biotite and euhedral crystals of Pl. Occasionally 5% altered to disseminated flakes of white mica. Non-fractured. Often contains incipient alteration.
4.8% Biotite (Bt)	0.04-1.6mm	Anhedral blocky books. 20-30% replaced by chlorite >> muscovite.
tr Magnetite (Mt)	0.02-0.5mm	An-Subhedra in clusters. Interstitial to silicates and occasionally included in perthite. Partly altered to Ht.

The rock has a porphyritic texture with larger crystals of K-spar and clumps of Q surrounded by smaller groundmass crystals of all minerals. Pl is occasionally as phenos.

a & b) SM-A; a is plane polarized light (pl) and b is crossed polarized light (xpl); Same view in both photos. Note pencil-lined 8mm grid used in counting which is evident in all photos. Quartz (Q) is colorless in a and polycrystalline as shown in b. Note mostly healed fractures in Q. In "a" plagioclase (Pl) is moderately fractured with sharp to fuzzy lines and patches. Perthite (K) is variably colored with fuzzy brown to tan patches of incipient alteration. Biotite (Bt) is small brown to black subhedral books interstitial to other minerals. Pink mineral in NE corner of b is secondary muscovite (Ms) after Bt.

c & d) SM-A; a is pl and b is xpl; same view in both photos. Non-homogeneity of section in a is shown here where field of view mostly large crystals of colorless Q and K-spar. Small euhedral Pl inclusions are in K-spar and some are marked with arrows in c.





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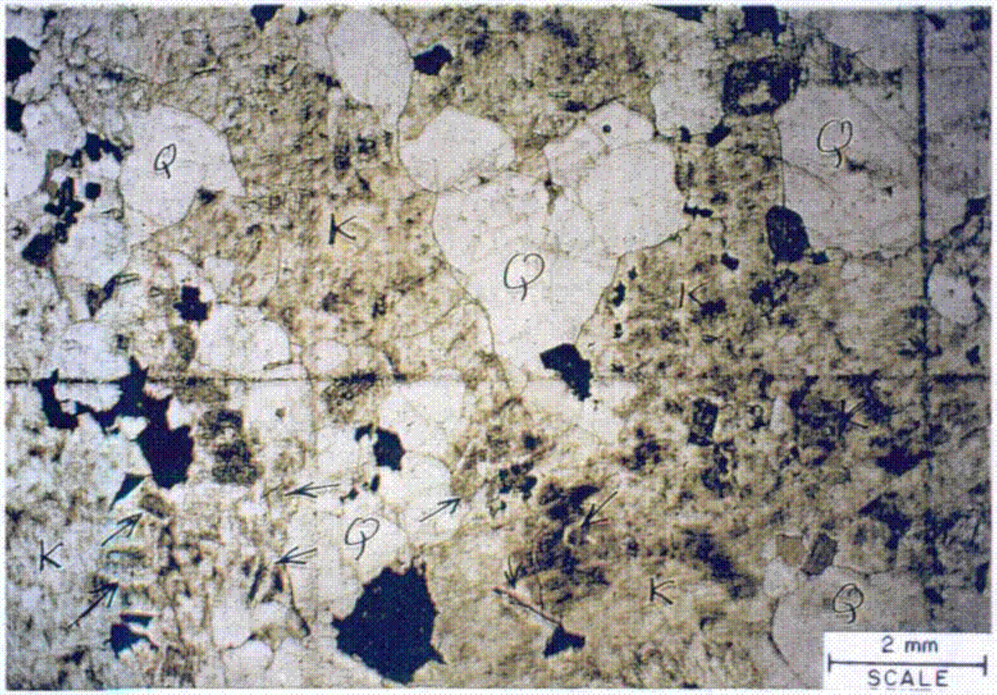
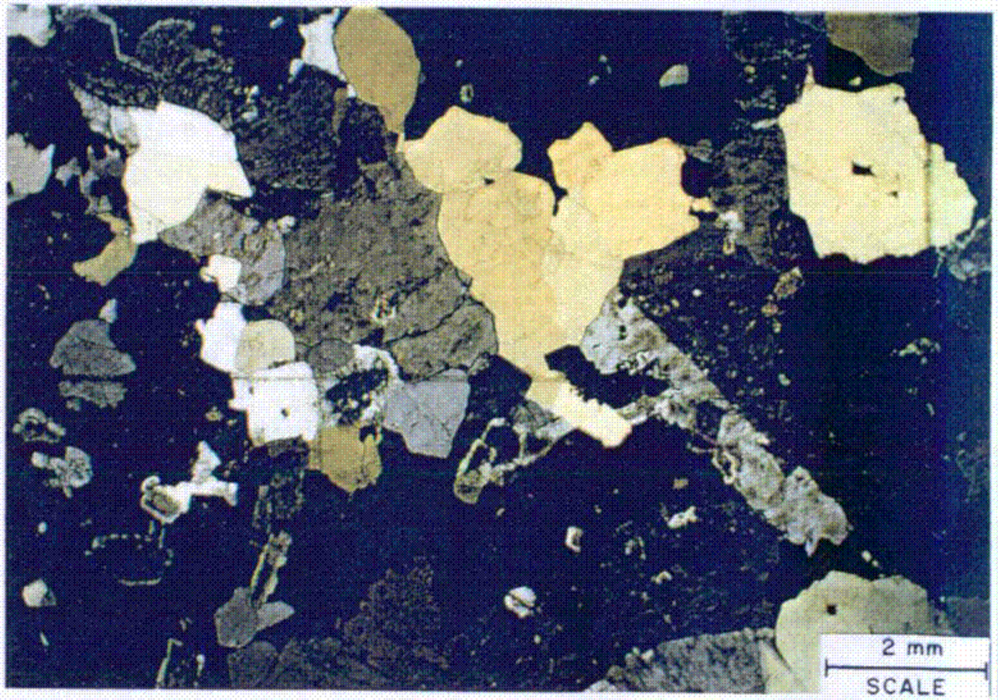
a b

c d

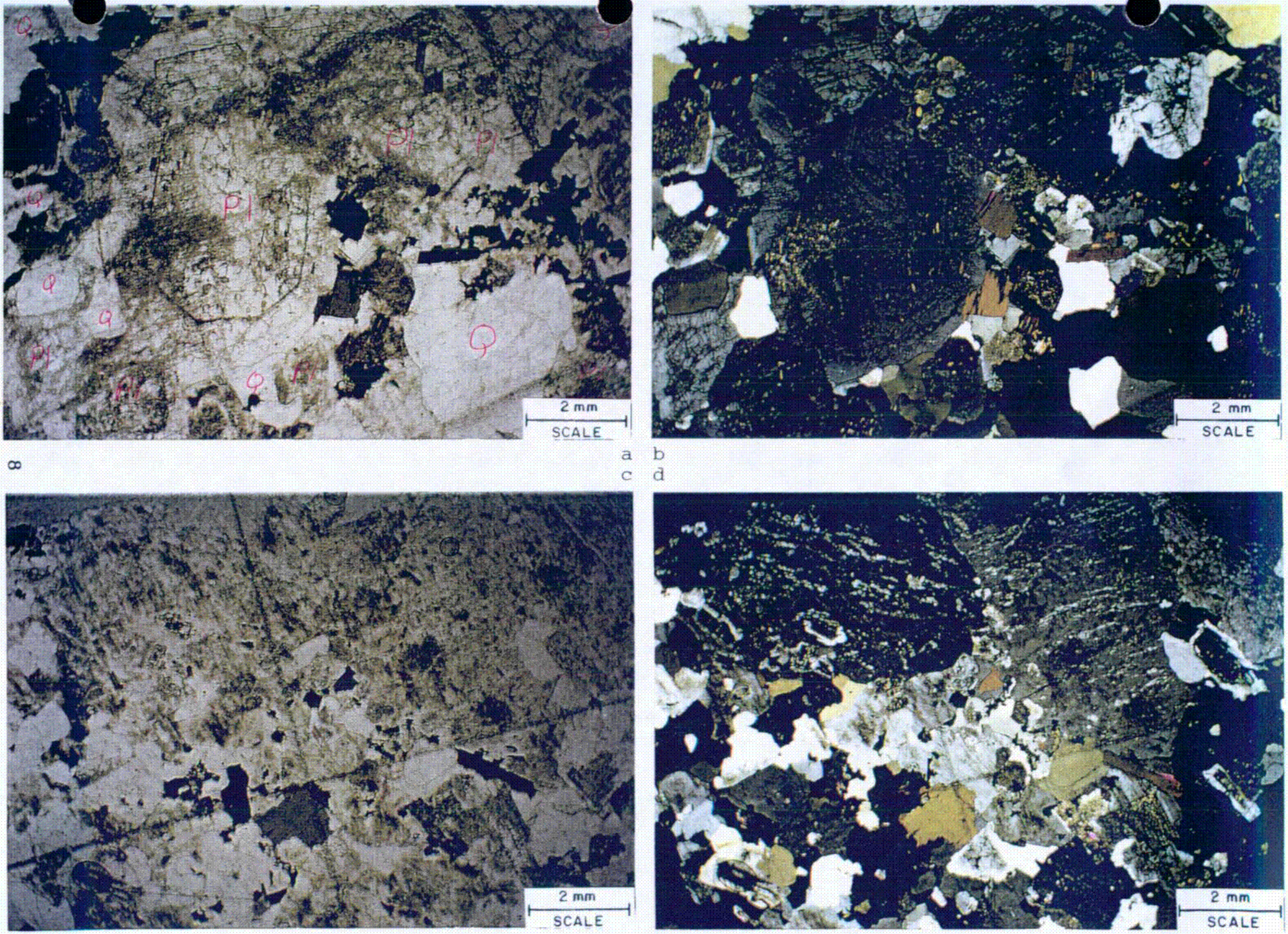




C11

a & b) SM-B; a is pl and b is xpl; same view in both photos. In contrast to a and K-spar in c & d, p. 6. This set of photos shows predominately Q and Pl. Black Bt and magnetite (Mt) are concentrated in center E quarter of photo a.

c & d) SM-C; c is pl and d is xpl; same view in both photos upper portion of photo affords excellent view of white microperthitic inclusions of Pl in K-spar. Below the K-spar is finer-grained cluster of silicate/Mt+Ht which more or less represents the fine-grained portion of the porphyry.



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a b
c d

C12

PETROGRAPHIC ABBREVIATIONS

Ab = albite
Act = actinolite
Ad = adularia
Amph = amphibole
An = anorthite
Ap = apatite
Aspy = arsenopyrite
Ba = barite
Bn = bornite
Bt = biotite
Cal = calcite
Car = carrollite
Carb = carbonate
Ch = chrysocolla
Chl = chlorite
Cv = covellite
Di = diopside
Dm = dumortierite
Dol = dolomite
Ep = epidote
F = feldspar
FM = ferromagnesian
Ga = galena
Gn = gneiss
Gp = graphite
Gr = garnet
Gt = goethite
Hb = hornblende
Ht = hematite
Il = illite
Ilm = ilmenite
K-spar = potassium feldspar
Lm = limonite
Lx = leucoxene
Mo = molybdenite
Mont = montmorillonite
Ms = muscovite
Mt = magnetite
pl = plane polarized light
Pl = plagioclase
Po = pyrrhotite
pts = polished thin section
Px = pyroxene
Py = pyrite
Q = quartz
Rt = rutile
Sp = sphalerite
Sph = sphene
Tm = tourmaline
ts = thin section
u = micron
WM = white mica
xpl = crossed polarized light
Zr = zircon

FINAL

STAFF TECHNICAL POSITION

DESIGN OF EROSION PROTECTION COVERS FOR STABILIZATION OF URANIUM MILL TAILINGS SITES

U. S. Nuclear Regulatory Commission

August 1990

6.3 Recommendations

Based on the performance histories of various rock types and the overall intent of achieving long-term stability, the following recommendations should be considered in assessing rock quality and determining riprap requirements for a particular design.

1. The rock that is to be used should first be qualitatively rated at least "fair" in a petrographic examination conducted by a geologist or engineer experienced in petrographic analysis. See NUREG/CR-4620, Table 6.4 (see Ref. D2), for general guidance on qualitative petrographic ratings. In addition, if a rock contains smectites or expanding lattice clay minerals, it will not be acceptable.

2. An occasionally-saturated area is defined as an area with underlying filter blankets and slopes that provide good drainage and are steep enough to preclude ponding, considering differential settlement, and are located well above normal groundwater levels; otherwise, the area is classified as frequently-saturated. Natural channels and relatively flat man-made diversion channels should be classified as frequently-saturated. Generally, any toe or apron located below grade should be classified as frequently-saturated; such toes and aprons are considered to be poorly-drained in most cases.

3. Using the scoring criteria given in Table D1, the results of a durability test determines the score; this score is then multiplied by the weighting factor for the particular rock type. The final rating should be calculated as the percentage of the maximum possible score for all durability tests that were performed. See example of procedure application for additional guidance on determining final rating.

4. For final selection and oversizing, the rating may be based on the durability tests indicated in the scoring criteria. Other tests may also

NUREG/CR-4620
ORNL/TM-10067

Methodologies for Evaluating Long-Term Stabilization Designs of Uranium Mill Tailings Impoundments

Manuscript Completed: May 1986
Date Published: June 1986

Prepared by
J. D. Nelson, S. R. Abt, R. L. Volpe, D. van Zyl, Colorado State University
'. E. Hinkle, W. P. Staub, Oak Ridge National Laboratory

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Under Contract to:
Oak Ridge National Laboratory
Oak Ridge, TN 37831

Prepared for
Division of Waste Management
Office of Nuclear Material Safety and Safeguards
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555
NRC FIN B0279

relatively resistant to weathering. Table 6.1 lists these rocks in three priority groupings. Groups 1 and 2 are igneous and metamorphic rocks of preferred and acceptable rank, respectively. Group 3 rocks are carbonates which are vulnerable to decomposition in an acidic environment and are not generally recommended for frequently saturated areas.

Table 6.1 Rock Priority Groupings for External Use as Building Stone

Group	Type
1	Quartzites, noncalcareous slates, fine- to medium-grained felsic granites or granitic gneisses
2	Coarser grained granites or gneisses, dense basalts/or diabases
3	Marbles, limestones, dolomites

Source: Jahns, 1982

6.3.1.1 Prospecting

Extensive data files are available for locating suitable and accessible igneous and metamorphic rock quarries in the western United States. Among them are the open-file data of the U.S. Army Corps of Engineers and the U.S. Bureau of Reclamation (USBR). A limited amount of data may also be available from various state highway departments. These data provide quarry location, petrographic analyses, results of various durability tests, and intended uses for the rock. Also, Esmiol (1968) provides an analysis of performance of riprap at 149 USBR dams. It should be possible to identify several candidate sources of durable riprap within 100 km of a mill tailings site.

It may not be practical to open a new quarry closer than an existing quarry in cases where relatively small quantities of riprap are required. Exploration and development costs would likely exceed the savings in transportation costs that might be achieved from hauling a relatively small volume of rock.

6.3.1.2 Selection

Foley's slake-abrasion test should be used to qualify rock for more extensive testing for long-term durability. Candidate sources of riprap can then be compared with one another by examining the results of standard durability tests. At the present time the USBR routinely performs petrographic analysis, specific gravity, absorption, the sulfate soundness, freeze-thaw, and Los Angeles abrasion tests (see Appendix B for details). Table 6.2 is a list of acceptance criteria for USBR routine tests (DePuy and Ensign, 1965). The Corps of Engineers also performs the above tests

Table 6.4 Additional Petrographic Analysis Acceptance Criteria

Criteria	Quality Poor (N=1)[a]	 Fair (N=2)	 Good (N=3)
Bulk composition [b]	Group 3, other	Group 2	Group 1
Secondary minerals and weathering	Smectites and thick weathering rinds[c]	Other clays and thin weathering rinds	No clays no weathering rinds

[a]Quality scores
[b]Groups 1, 2, and 3 rocks, see Table 6.1
[c]Greater than 1 cm thick

Acceptance criteria are tentative at this time. The maximum test score for the complete set of seven tests in Tables 6.2 to 6.4 is 17.25. It is suggested that if a riprap source has a test score exceeding 80% of the maximum possible score, it would be considered conditionally acceptable for use on frequently saturated areas. To be accepted, a sample would be required to score higher than 16.2 for the complete set of tests in Tables 6.2 to 6.4. A sample calculation is presented in Appendix C.

X-ray diffraction analysis should be performed on all candidate sources of riprap being seriously considered for use in frequently saturated environments. If smectite clay minerals or carbonate minerals are identified by X-ray diffraction analysis, further chemical tests may be necessary. The ethylene glycol test is used in many Corps of Engineer districts when the presence of smectites is suspected (Lutton et al, 1981). Joints in rocks are often sealed by secondary mineralization. Carbonate mineralization is the second most common form of secondary mineralization (quartz veins being most common). Their presence could be ascertained by placing fairly large rock specimens in a strongly acidic solution. Reaction to either ethylene glycol or acid and marginally acceptable performance in physical durability tests should result in exclusion from frequently saturated areas.

6.3.1.3 Design Modifications

For frequently saturated areas, project design modifications are sometimes possible to make use of rock containing carbonates or rock that is marginally acceptable as indicated by physical durability tests. Table 6.5 lists design modifications for various test results.

Appendix E

Durability Test Results

WESTERN NUCLEAR, INC. — SHERWOOD TAILINGS RECLAMATION
QUALITY COMPLIANCE REPORT

Rock Durability Test

DATE: 7/11/96

DOCUMENT: RD – 1

SHEET: 1 OF 6

SPECIFICATION REFERENCE: Table 3

Construction Segment: Rock Production

Rock Source: Rock Quarry – 2140-2100 Level

Frequency of Rock Durability Testing: One test series prior to placement and one test series for every 10,000 CY of material produced from the rock source.

Acceptance Criteria: Rock shall have a minimum durability rating of 80.
Rock having a durability rating of less than 80 shall require oversizing.
For oversizing, refer to Specification Reference : Page TS–39, 5.2.2

Rock Durability

Test Date	Test No.	Cum. Vol. Produced	Rating	Oversize	
7/03/96	1	10,000 yd³ (shot)	80	Yes ☐ No ☒	Attach Test Results

Non–Conformances: NONE

Description: N/A

Corrective action required: Yes ☐ No ☒

If Yes, Corrective Action Report No.: ______

Test Performed by: Agra Earth & Environmental, Inc Date: 7/03/96

WNI Construction Manager: C. Abeyta Date: 7/11/96

Audit Review By:
WNI QA/QC Engineering Manager: M A Parks Date: 7/23/96

04/23/96

E65

AGRA
Earth & Environmental

AGRA Earth &
Environmental, Inc.
[illegible]
[illegible]
[illegible]
[illegible]
Tel [illegible]
Fax [illegible]

July 11, 1996

Western Nuclear, Inc.
P.O. Box 358
Wellpinit, Washington 99040

Attention: Mr. Corn Abeyta

Regarding: Laboratory Determination of Aggregate Durability Rating
Sample # 1
Sherwood Mine Project

Dear Mr. Abeyta:

In accordance with your request, on July 2, 1996 we obtained a bulk sample of Quarry rock from the Sherwood site for laboratory analysis and Durability Rating determination at our Spokane laboratory. As of this date, that has been completed. All laboratory testing has been performed in accordance with the most current ASTM standards available, and in accordance with the project specifications.

The Durability Rating determination was performed according to Table D1 of the NRC's Staff Technical Position (STP) Design of Erosion Protection Covers for Stabilization of Uranium Mill Tailing Sites, August 1990. Table A shows the test results and calculations for sample #1. Additionally, the laboratory testing worksheets are attached for your records.

If there are any questions, or we may be of further assistance, please do not hesitate to contact us at (509) 482-0104.

Respectfully Submitted
AGRA EARTH & ENVIRONMENTAL, INC.

Jay C. Martin, SET
Laboratory Supervisor

Bob Arnold
Technical Director

TABLE A

ROCK TYPE: IGNEOUS - GRANITIC QUARTZ MONZANITE
ROCK SAMPLE: #1, AGRA LABORATORY SAMPLE # 530
TEST No. 1

Laboratory Test	Result	Score	Weight	Score x Weight	Maximum Score
Apparent Specific Gravity ASTM C127	2.627	N/A	N/A	N/A	N/A
Bulk Saturated Surface Dry Specific Gravity ASTM C127	2.620	N/A	N/A	N/A	N/A
Bulk Specific Gravity ASTM C127	2.616	7	9	63	90
Absorption, % ASTM C127	0.15	9	2	18	20
Sodium Sulfate Soundness, % Loss, ASTM C88	2.6	9	11	99	110
Schmidt Hammer Rebound Number ASTM C805	57.1	7	3	21	30
Total Score				**201**	**250**

DURABILITY RATING = 201 / 250 x 100 = 80

AGRA
Earth & Environmental
E 520 North Foothills Drive, Suite 600
Spokane, Washington, U.S.A. 99207

Client: Western Nuclear | Date: 7-3-96 | Lab No: 530

Project: Sherwood Mine | Proj. No.: 6-929-1396-0

Description: Proposed Rip-Rap | TEST No: 1 (Marble)

SPECIFIC GRAVITY AND/OR UNIT WEIGHT

Method Used: ASTM C-127 | Method Used: ______

SOILS - SPECIFIC GRAVITY

(Wo) - Mass of Dry Sample in Air = ______
(Wf) - Mass of Pycnometer = ______
(Wa-Ti) - Mass of Pycnometer & Water = ______ At 20°C (Calibration Temp)
(Wa-Tx) - Mass of Pycnometer & Water = ______ At ____°C (Test Run Temp)
(Wa-Tx) - Mass of Pycnometer, Water & Soil = ______ At ____°C (Test Run)
Specific Gravity at 20°C = ______

FINE AGGREGATE - SPECIFIC GRAVITY AND ABSORPTION

Mass of Dry Sample in Air = ______
Mass of SSD Sample = ______
Mass of Pycnometer = ______
Mass of Pycnometer & Water = ______
Mass of Pycnometer with Sample & Water = ______
(Concrete) - Bulk Specific Gravity = ______
Bulk Specific Gravity (SSD) = ______
Apparent Specific Gravity = ______
Absorption = ______

COARSE AGGREGATE - SPECIFIC GRAVITY AND ABSORPTION

Mass of Dry Sample in Air = 19889.6
Mass of SSD Sample = 19919.7
Mass of Sample in Water = 12317.3
(Concrete) - Bulk Specific Gravity = 2.616
Bulk Specific Gravity (SSD) = 2.620
Apparent Specific Gravity = 2.627
Absorption = 0.15

Fri 7-5 @ 14:10

UNIT WEIGHT OF AGGREGATRE - PROCEDURE USED:

Weight of Container = ______
Weight of Containre & Sample = ______
Weight of Sample = ______
Volume of Container = ______
Unit Weight = ______

REMARKS: ______

Sampled by: JM | Tested by: JM | Reviewed by: Bob Arnold

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Earth & Environmental
E ... North Foothills Drive, Suite 600
...ne, Washington, U.S.A. 99207

SOUNDNESS TEST ASTM C88

DATE: 7-3-96
LAB NO: 53C

CLIENT: Western Nuclear
PROJECT NO: 6-929-1396-C

PROJECT: Sherwood Mine
SOURSE: Pit, Blast #1

SAMPLE DESCRIPTION: Proposed Rip-Rap
TEST No. 1 (Makeshe)

SIEVE SIZE	INDIVIDUAL GRADING %- RETAINED	WEIGHT BEFORE TEST	WEIGHT AFTER TEST	PERCENT LOSS AFTER TEST	WEIGHT% LOSS	
MINUS NO. 100						
#50 TO #100						
#30 TO #50						
#16 TO #30						
#8 TO #16						
#4 TO #8						
3/8 TO #4						
TOTAL						
2 1/2" to 2" 3058.9				(65)		
2" to 1 1/2" 2056.4		5115.3	5069.1	0.9	0.6	
1 1/2" TO 1" 993.9				(19)		
1" TO 3/4" 514.4		1508.3	1444.4	4.3	0.8	
3/4" TO 1"		-				
... 1/2" 677.0				(13)		
TO 3/8" 331.4		1008.4	945.8	6.2	0.8	
3/8" TO #4		301.7	270.1	10.5 (4)	0.4	
TOTAL					2.6	(3)

SOLUTION TEMP. 72.3 OVEN TEMP. 232°F SPECIFIC GRAVITY 1.165 TYPE OF SALT Sodium Sulfate

QUALITIVE EXAMINATION OF COARSE SIZES

SIEVE SIZE	SPLITTING	DISINTEGRATION	CRACKING	FLAKING	# OF PARTICLES BEFORE TEST
1 1/2" TO 1"					
1" TO 3/4"					

CYCLE NO.	DATE	TIME	IN SOLUTION		OUT SOLUTION		IN OVEN		OUT OVEN			
1	7-5	1:30pm	→		7-6	7:00Am	7-6	7:18	7-6	12:10		
2			7-6	1:10	7-7	7:10Am	7-7	7:30	7-7	12:30		
3			7-7	1:00pm	7-8	6:55Am	7-8	7:15	7-8	12:15		
4			7-8	12:55	7-9	7:05	7-9	7:25	7-9	12:25		
5			7-9	1:05	7-10							

SAMPLED BY: JM TESTED BY: JM REVIEWED BY: Bob Ball

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AGRA
Earth & Environmental

AGRA Earth &
Environmental, Inc.
E 520 North Foothills Drive
Suite 600
Spokane, Washington
U.S.A. 99207
Tel (509) 482-0104
Fax (509) 482-0202

SCHMIDT HAMMER TEST
ASTM C-805

TEST No. 1 (no Pad)

LAB # 530 **PROJECT #** 6-929-1396-0
PROJECT NAME: Sherwood Mine

TEST A		TEST B	
1.	60	1.	58
2.	59	2.	52
3.	58	3.	57
4.	55	4.	58
5.	60	5.	56
6.	56	6.	60
7.	52	7.	58
8.	56	8.	60
9.	59	9.	53
10.	60	10.	55

TEST A AVERAGE= 57.5 **TEST B AVERAGE=** 56.7

GRAND AVERAGE = 57.1

TEST PERFORMED BY: J. Martin **DATE:** 7-3-96

REVIEWED BY: Bob Arnold

TABLE

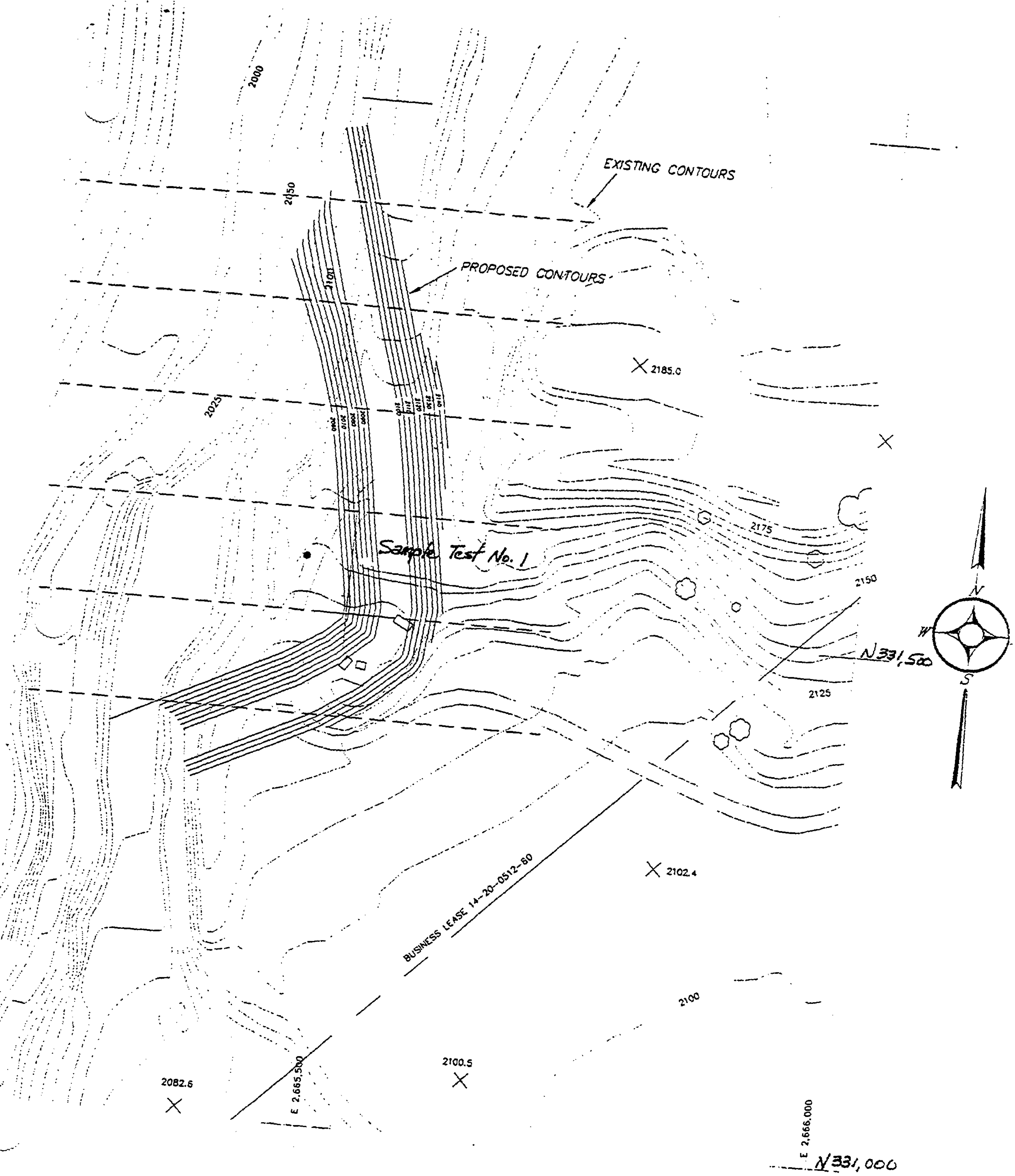
Scoring Criteria for Determining Rock Quality

Laboratory Test	Weighting Factor			Score										
	Limestone	Sandstone	Igneous	10	9	8	7	6	5	4	3	2	1	0
					Good			Fair			Poor			
Sp. Gravity	12	6	9	2.75	2.70	2.65	2.60	2.55	2.50	2.45	2.40	2.35	2.40	2.25
Absorption, %	13	5	2	.1	.3	.5	.67	.83	1.0	1.5	2.0	2.5	3.0	3.5
Sodium Sulfate, %	4	3	11	1.0	3.0	5.0	6.7	8.3	10.0	12.5	15.0	20.0	25.0	30.0
L/A Abrasion (100 revs), %	1	8	1	1.0	3.0	5.0	6.7	8.3	10.0	12.5	15.0	20.0	25.0	30.0
Schmidt Hammer	11	13	3	70.0	65.0	60.0	54.0	47.0	40.0	32.0	24.0	16.0	8.0	0.0
Tensile Strength, psi	6	4	10	1400	1200	1000	833	666	500	400	300	200	100	0

1. Scores were derived from Tables 6.2, 6.5, and 6.7 of NUREG/CR-2642 - "Long-Term Survivability of Riprap for Armoring Uranium Mill Tailings and Covers: A Literature Review," 1982 (see Ref. D13).

2. Weighting Factors are derived from Table 7 of "Petrographic Investigations of Rock Durability and Comparisons of Various Test Procedures," by G. W. DuPuy, Engineering Geology, July, 1965 (see Ref. D15). Weighting factors are based on inverse of ranking of test methods for each rock type. Other tests may be used; weighting factors for these tests may be derived using Table 7, by counting upward from the bottom of the table.

3. Test methods should be standardized, if a standard test is available and should be those used in NUREG/CR-2642 (see Ref. D13), so that proper correlations can be made. This is particularly important for the tensile strength test, where several methods may be used; the method discussed by Nilsson (1962, see Ref. D16) for tensile strength was used in the scoring procedure.



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REVISIONS		
DATE	BY	
1/19/96	C.R.	CROSS SECTION LABELS

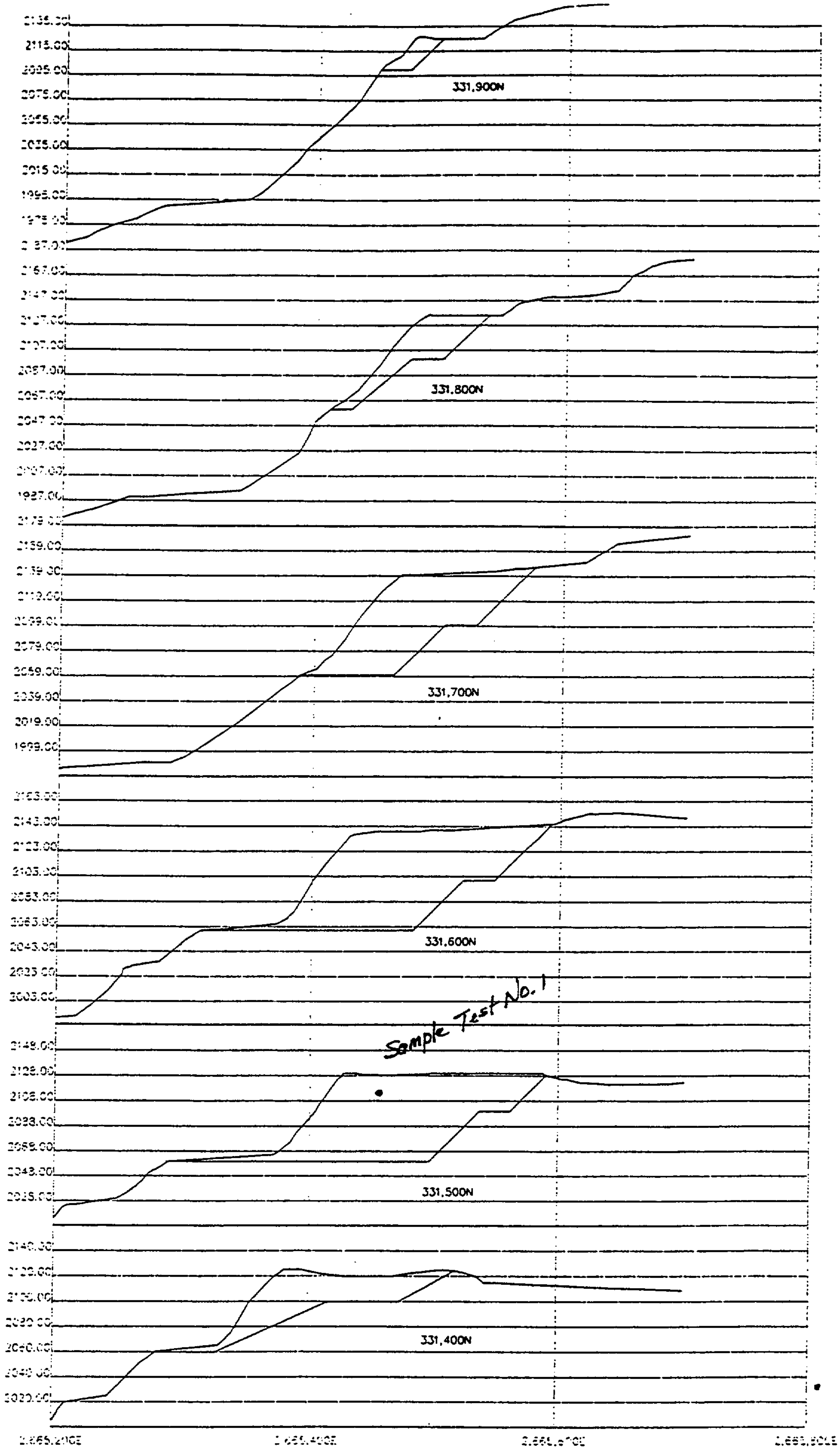
SHERWOOD PROJECT

STATE WASHINGTON COUNTY STEVENS

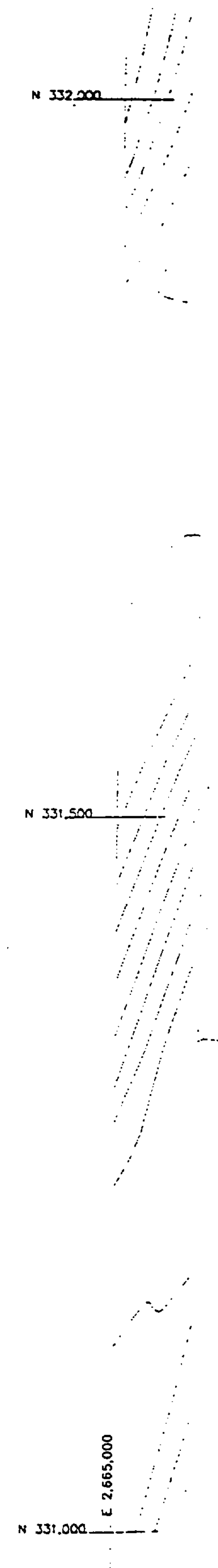
SECTION ____ TWP. ____ RGE. ____

TITLE:

ROCK QUARRY



VOLUME: 126,000CY



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WESTERN NUCLEAR, INC. – SHERWOOD TAILINGS RECLAMATION QUALITY COMPLIANCE REPORT

Rock Durability Test

DATE : 7/24/96

DOCUMENT : RD – 2

SHEET : 1 OF 69

SPECIFICATION REFERENCE Table 3

Construction Segment: Rock Production

Rock Source: Basalt Stockpile

Frequency of Rock Durability Testing: One test series prior to placement and one test series for every 10,000 CY of material produced from the rock source.

Acceptance Criteria : Rock shall have a minimum durability rating of 80.
Rock having a durability rating of less than 80 shall require oversizing.
For oversizing, refer to Specification Reference : Page TS–39, 5.2.2

Rock Durability

Test Date	Test No.	Cum. Vol. Produced	Rating	Oversize	
7/24/96	2	10,000 CY (basalt) No. 1	90	Yes ☐ No ☒	Attach Test Results

Non–Conformances: NONE

Description N/A

Corrective action required: Yes ☐ No ☒

If Yes, Corrective Action Report No.: ______

Test Performed by: AGRA Earth & Environmental Date: 7/24/96

'NI Construction Manager: C. Abeyta Date: 8/05/96

Audit Review By:
WNI QA/QC Engineering Manager: [signature] Date: 8/8/96

07/25/96

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AGRA
Earth & Environmental

AGRA Earth &
Environmental, Inc.
E 520 North Foothills Drive
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Spokane, Washington
U.S.A. 99207
Tel (509) 482-0104
Fax (509) 482-0202

July 31, 1996

Western Nuclear, Inc.
P.O. Box 358
Wellpinit, Washington 99040

Attention: Mr. Corn Abeyta

Regarding: Laboratory Determination of Aggregate Durability Rating
Test No. 2
Sherwood Mine Project

Dear Mr. Abeyta:

In accordance with your request, on July 23, 1996 we obtained a bulk sample of Basalt rock from a stockpile at the Quarry at the Sherwood site for laboratory analysis and Durability Rating determination at our Spokane laboratory. As of this date, that has been completed. All laboratory testing has been performed in accordance with the most current ASTM standards available, and in accordance with the project specifications.

The Durability Rating determination was performed according to Table D1 of the NRC's Staff Technical Position (STP) Design of Erosion Protection Covers for Stabilization of Uranium Mill Tailing Sites, August 1990. Table A shows the test results and calculations for Test No. 2. Additionally, the laboratory testing worksheets are attached for your records.

If there are any questions, or we may be of further assistance, please do not hesitate to contact us at (509) 482-0104.

Respectfully Submitted
AGRA EARTH & ENVIRONMENTAL, INC.

Jay C. Martin, SET
Laboratory Supervisor

Bob Arnold
Technical Director

TABLE A

ROCK TYPE: IGNEOUS - BASALT
ROCK SAMPLE: TEST NO. 2
AGRA LABORATORY SAMPLE # 547

Laboratory Test	Result	Score	Weight	Score x Weight	Maximum Score
Apparent Specific Gravity ASTM C127	2.96	N/A	N/A	N/A	N/A
Bulk Saturated Surface Dry Specific Gravity ASTM C127	2.89	N/A	N/A	N/A	N/A
Bulk Specific Gravity ASTM C127	2.86	10	9	90	90
Absorption, % ASTM C127	1.2	4	2	8	20
Sodium Sulfate Soundness, % Loss, ASTM C88	1.5	9	11	99	110
Schmidt Hammer Rebound Number ASTM C805	66.6	9	3	27	30
Total Score				**224**	**250**

DURABILITY RATING = 224 / 250 x 100 = 90

AGRA
Earth & Environmental
E. 520 North Foothills Drive, Suite 600
Spokane, Washington, U.S.A. 99207

Client: Western Nuclear

Date: 7-24-96 Lab No. 547

Project: Sherwood Mine

Proj. No.: 6-929-1396-0

Description: Basalt

Test No.: 2

SPECIFIC GRAVITY AND/OR UNIT WEIGHT
ASTM C-127

COARSE AGGREGATE - SPECIFIC GRAVITY AND ABSORPTION

Mass of Sample in Air Dry	=	5960.1	Grams
Mass of Sample, SSD	=	6034.0	Grams
Mass of Sample in Water	=	3946.6	Grams
Aggregate -Bulk Specific Gravity	=	2.86	
Bulk Specific Gravity (SSD)	=	2.89	
Apparent Specific Gravity	=	2.96	
Absorption	=	1.2	(%)

SSD = SATURATED SURFACE DRY

Remarks:

Sampled by: D. Lehn Date: 7-23-96

Tested by: J. Martin Date: 7-25-96

Reviewed by: Date:

AGRA
Earth & Environmental
E. 520 North Foothills Drive, Suite 600
Spokane, Washington, U.S.A. 99207

SULFATE SOUNDNESS TEST
ASTM C-88

Client: Western Nuclear
Project: Sherwood Mine
Description: Basalt

Date: 7-25-96 Lab No. 547
Proj. No.: 6-929-1396-0
Test No.: 2

SIEVE SIZE	INDIVIDUAL GRADING % RETAINED	WEIGHT BEFORE TEST (GRAMS)	WEIGHT AFTER TEST (GRAMS)	PERCENT LOSS AFTER TEST (%)	WEIGHTED % LOSS
2 ½" TO 2" 2" TO 1 ½"	64	3010.8 2052.0	4999.9	1.2	0.8
1 ½" TO 1" 1" TO 3/4"	19	1013.5 506.5	1493.7	1.7	0.3
3/4" TO 1"					
3/4" TO ½" ½" TO 3/8"	13	471.5 330.1	983.4	1.8	0.2
3/8" TO #4	4	301.8	288.9	4.3	0.2
TOTAL	100	7886.2			1.5

SOLUTION TEMP: 71.5°F OVEN TEMP: 230°F SPECIFIC GRAVITY: 1.168 TYPE OF SALT: Sodium

QUALITIVE EXAMINATION OF COARSE SIZES

SIEVE SIZE	SPLITTING	DISINTEGRATION	CRACKING	FLAKING	#OF PARTICLES
1 ½" TO 1"		4			28
1' TO 3/4"	1	4	1		22

CYCLE NO.	DATE	TIME	IN SOLUTION		OUT SOLUTION		IN OVEN		OUT OVEN			
1			7-26	1400	7-27	0700	7-27	0715	7-27	1115		
2			7-27	1210	7-28	0610	7-28	0625	7-28	1025		
3			7-28	1115	7-29	0515	7-29	0530	7-29	0930		
4			7-29	1015	7-30	0415	7-30	0430	7-30	0830		
5			7-30	0915	7-31	0315	7-31	0330	7-31	0730		

PLED BY: D. Lehn TESTED BY: J. Martin REVIEWED BY:

TE: 7-23-96 DATE: 7-31-96 DATE:

AGRA
Earth & Environmental

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AGRA
Earth & Environmental
E. 520 North Foothills Drive, Suite 600
Spokane, Washington, U.S.A. 99207

SCHMIDT HAMMER TEST
ASTM C-805

Test No: 2

Client: Western Nuclear
Date: 7-26-96 Lab No. 547
Project: Sherwood Mine
Proj. No.: 6-929-1396-0
Sample location: Basalt Stockpile, areas 1-3
Surface characteristics: Specimens were saw-cut

Sample A/Rebound Number	Sample B/Rebound Number
1. 66	1. 66
2. 68	2. 66
3. 67	3. 66
4. 66	4. 67
5. 66	5. 66
6. 68	6. 66
7. 67	7. 66
8. 67	8. 67
9. 67	9. 67
10. 67	10. 67

Sample A Avg: 66.9

Sample B Avg: 66.4

Grand average rebound number 66.6

Remarks: Schmidt Hammer - model N-34, Serial No. 137281

Sampled By: D. Lehn Date: 7-23-96

Test Performed By: J. Martin Date: 7-30-96

Reviewed By: Date:

TABLE D1

Scoring Criteria for Determining Rock Quality

boratory Test	Weighting Factor			Score										
	Limestone	Sandstone	Igneous	10	9	8	7	6	5	4	3	2	1	0
					Good			Fair			Poor			
. Gravity	12	6	9	2.75	2.70	2.65	2.60	2.55	2.50	2.45	2.40	2.35	2.40	2.25
sorption, %	13	5	2	.1	.3	.5	.67	.83	1.0	1.5	2.0	2.5	3.0	3.5
dium ilfate, %	4	3	11	1.0	3.0	5.0	6.7	8.3	10.0	12.5	15.0	20.0	25.0	30.0
'A Abrasion 100 revs), %	1	8	1	1.0	3.0	5.0	6.7	8.3	10.0	12.5	15.0	20.0	25.0	30.0
hmidt Hammer	11	13	3	70.0	65.0	60.0	54.0	47.0	40.0	32.0	24.0	16.0	8.0	0.0
ensile Strength, si	6	4	10	1400	1200	1000	833	666	500	400	300	200	100	0

. Scores were derived from Tables 6.2, 6.5, and 6.7 of NUREG/CR-2642 - "Long-Term Survivability of Riprap for Armoring Uranium Mill Tailings and Covers: A Literature Review," 1982 (see Ref. D13).

. Weighting Factors are derived from Table 7 of "Petrographic Investigations of Rock Durability and Comparisons of Various Test Procedures," by G. W. DuPuy, Engineering Geology, July, 1965 (see Ref. D15). Weighting factors are based on inverse of ranking of test methods for each rock type. Other tests may be used; weighting factors for these tests may be derived using Table 7, by counting upward from the bottom of the table.

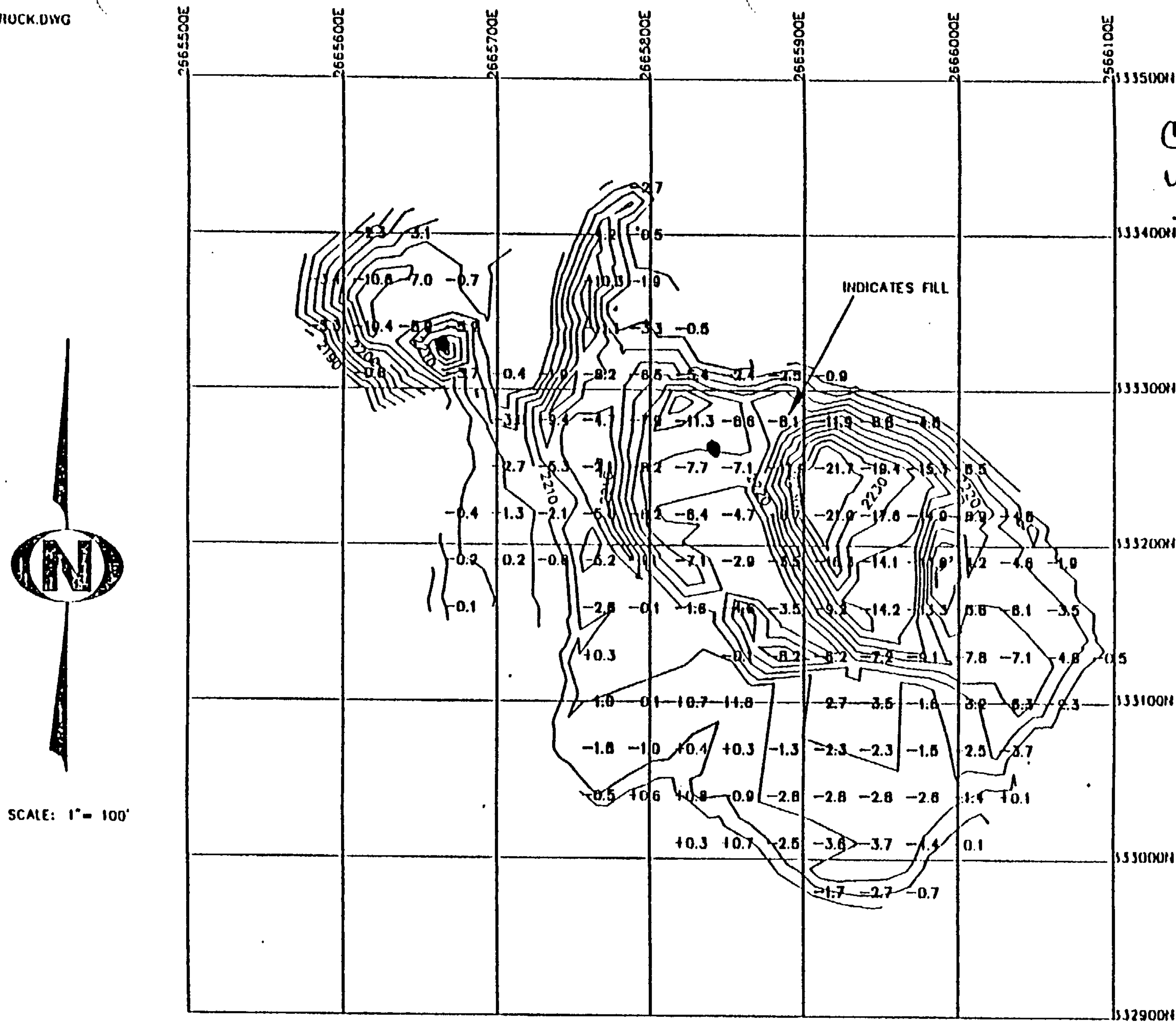
. Test methods should be standardized, if a standard test is available and should be those used in NUREG/CR-2642 (see Ref. D13), so that proper correlations can be made. This is particularly important for the tensile strength test, where several methods may be used; the method discussed by Nilsson (1962, see Ref. D16) for tensile strength was used in the scoring procedure.

FROM T... E OF:
C.E. SP... ASSOC.
LANDER, ...

SHERUCK.DWG

• CENTER OF MASS

Composite sample was taken from the entire stockpile at random locations



FILL VOLUME: 21,500CY

map showing
EARTH & ROCK STOCKPILE
AT SHERWOOD MILLSITE

JUNE 23, 1995

WESTERN NUCLEAR, INC. – SHERWOOD TAILINGS RECLAMATION
QUALITY COMPLIANCE REPORT

Rock Durability Test

DATE : 7/25/96

DOCUMENT : RD – 3

SHEET : 1 OF 9

SPECIFICATION REFERENCE Table 3

Construction Segment: Rock Production

Rock Source: Basalt Stockpile

Frequency of Rock Durability Testing: One test series prior to placement and one test series for every 10,000 CY of material produced from the rock source.

Acceptance Criteria : Rock shall have a minimum durability rating of 80.
Rock having a durability rating of less than 80 shall require oversizing.
For oversizing, refer to Specification Reference : Page TS–39, 5.2.2

Rock Durability

Test Date	Test No.	Cum. Vol. Produced	Rating	Oversize	
7/25-29	3	20,000 cy (basalt) No. 2	90	Yes [ ] No [X]	Attach Test Results

Non–Conformances: NONE

Description N/A

Corrective action required: Yes [ ] No [X]

If Yes, Corrective Action Report No.: ______

Test Performed by: Agra Earth & Environmental Date: 7/25/96

WNI Construction Manager: C. Aceyta Date: 8/05/96

Audit Review By:
WNI QA/QC Engineering Manager: M A Park Date: 8/8/96

07/25/96

E82

AGRA
Earth & Environmental

AGRA Earth &
Environmental, Inc.
E 520 North Foothills Drive
Suite 600
Spokane, Washington
U.S.A. 99207
Tel (509) 482-0104
Fax (509) 482-0202

July 31, 1996

Western Nuclear, Inc.
P.O. Box 358
Wellpinit, Washington 99040

Attention: Mr. Corn Abeyta

Regarding: Laboratory Determination of Aggregate Durability Rating
Test No.3
Sherwood Mine Project

Dear Mr. Abeyta:

In accordance with your request, on July 23, 1996 we obtained a bulk sample of Basalt rock from a stockpile at the Quarry at the Sherwood site for laboratory analysis and Durability Rating det ermination at our Spokane laboratory. As of this date, that has been completed. All laboratory testing has been performed in accordance with the most current ASTM standards available, and in accordance with the project specifications.

The Durability Rating determination was performed according to Table D1 of the NRC's Staff Technical Position (STP) Design of Erosion Protection Covers for Stabilization of Uranium Mill Tailing Sites, August 1990. Table A shows the test results and calculations for Test No. 3. Additionally, the laboratory testing worksheets are attached for your records.

If there are any questions, or we may be of further assistance, please do not hesitate to contact us at (509) 482-0104.

Respectfully Submitted
AGRA EARTH & ENVIRONMENTAL, INC.

Jay C. Martin, SET
Laboratory Supervisor

Bob Arnold
Technical Director

TABLE A

ROCK TYPE: IGNEOUS - BASALT
ROCK SAMPLE: TEST NO.3
AGRA LABORATORY SAMPLE # 548

Laboratory Test	Result	Score	Weight	Score x Weight	Maximum Score
Apparent Specific Gravity ASTM C127	2.95	N/A	N/A	N/A	N/A
Bulk Saturated Surface Dry Specific Gravity ASTM C127	2.87	N/A	N/A	N/A	N/A
Bulk Specific Gravity ASTM C127	2.82	10	9	90	90
Absorption, % ASTM C127	1.5	4	2	8	20
Sodium Sulfate Soundness, % Loss, ASTM C88	1.7	9	11	99	110
Schmidt Hammer Rebound Number ASTM C805	67.2	9	3	27	30
Total Score				**224**	**250**

DURABILITY RATING = 224 / 250 x 100 = 90

AGRA
Earth & Environmental
E. 520 North Foothills Drive, Suite 600
Spokane, Washington, U.S.A. 99207

Client: Western Nuclear | Date: 7-24-96 | Lab No. 548

Project: Sherwood Mine | Proj. No.: 6-929-1396-0

Description: Basalt | Test No.: 3

SPECIFIC GRAVITY AND/OR UNIT WEIGHT
ASTM C-127

COARSE AGGREGATE - SPECIFIC GRAVITY AND ABSORPTION

Mass of Sample in Air Dry	=	6602.4	Grams
Mass of Sample, SSD	=	6701.8	Grams
Mass of Sample in Water	=	4363.1	Grams
Aggregate -Bulk Specific Gravity	=	2.82	
Bulk Specific Gravity (SSD)	=	2.87	
Apparent Specific Gravity	=	2.95	
Absorption	=	1.5	(%)

SSD = SATURATED SURFACE DRY

Remarks:

Sampled by: D. Lehn | Date: 7-23-96

Tested by: J. Martin | Date: 7-25-96

Reviewed by: | Date:

AGRA
Earth & Environmental
E. 520 North Foothills Drive, Suite 600
Spokane, Washington, U.S.A. 99207

SULFATE SOUNDNESS TEST
ASTM C-88

Client: Western Nuclear | Date: 7-25-96 | Lab No. 542
Project: Sherwood Mine | Proj. No.: 6-929-1396-0
Description: [illegible] | Test No.: 3

SIEVE SIZE	INDIVIDUAL GRADING % RETAINED	WEIGHT BEFORE TEST (GRAMS)	WEIGHT AFTER TEST (GRAMS)	PERCENT LOSS AFTER TEST (%)	WEIGHTED % LOSS
2 ½" TO 2" 2" TO 1 ½"	65	3195.0 [illegible]	~~Loss~~ 5169.7	0.8	0.5
1 ½" TO 1" 1" TO 3/4"	19	[illegible] [illegible]	1453.7	3.2	0.6
3/4" TO 1"					
3/4" TO ½" ½" TO 3/8"	12	669.3 [illegible]	978.0	2.2	0.3
3/8" TO #4	4	[illegible]	278.4	7.3	0.3
TOTAL	100	[illegible]			1.7

SOLUTION TEMP: 71.5°F OVEN TEMP: 230°F SPECIFIC GRAVITY: 1.168 TYPE OF SALT: [illegible]

QUALITIVE EXAMINATION OF COARSE SIZES

SIEVE SIZE	SPLITTING	DISINTEGRATION	CRACKING	FLAKING	#OF PARTICLES
1 ½" TO 1"		3	1		22
1" TO 3/4"		5			30

CYCLE NO.	DATE	TIME	IN SOLUTION		OUT SOLUTION		IN OVEN		OUT OVEN			
1			7-26	1400	7-27	0700	7-27	0715	7-27	1115		
2			7-27	1210	7-28	0610	7-28	0625	7-28	1025		
3			7-28	1115	7-29	0515	7-29	0530	7-29	0930		
4			7-29	1015	7-30	0415	7-30	0430	7-30	0830		
5			7-30	0915	7-31	0315	7-31	0330	7-31	0730		

SAMPLED BY: D. Leh[illegible] TESTED BY: J. Martin REVIEWED BY:
DATE: 7-23-96 DATE: 7-31-96 DATE:

AGRA
Earth & Environmental

F810

AGRA
Earth & Environmental
E. 520 North Foothills Drive, Suite 600
Spokane, Washington, U.S.A. 99207

SCHMIDT HAMMER TEST
ASTM C-805

Test No: 3

Client: Western Nuclear   Date: 7-26-96   Lab No. 548
Project: Sherwood Mine   Proj. No.: 6-929-1396-0
Sample location: Basalt Stockpile, areas 4-6
Surface characteristics: Specimens were saw-cut

Sample A/Rebound Number	Sample B/Rebound Number
1. 68	1. 68
2. 66	2. 67
3. 67	3. 68
4. 66	4. 66
5. 66	5. 67
6. 67	6. 67
7. 67	7. 68
8. 67	8. 68
9. 68	9. 67
10. 68	10. 68

Sample A Avg: 67.0   Sample B Avg: 67.4

Grand average rebound number 67.2

Remarks: Schmidt Hammer - model N-34, Serial No. 137281

Sampled By: D. Lehn   Date: 7-23-96

Te[illegible] Performed By: J. Martin   Date: 7-30-96

[illegible]viewed By: Date:

TABLE D1

Scoring Criteria for Determining Rock Quality

Laboratory Test	Weighting Factor			Score										
	Limestone	Sandstone	Igneous	10	9	8	7	6	5	4	3	2	1	0
				Good				Fair			Poor			
Sp. Gravity	12	6	9	2.75	2.70	2.65	2.60	2.55	2.50	2.45	2.40	2.35	2.40	2.25
Absorption, %	13	5	2	.1	.3	.5	.67	.83	1.0	1.5	2.0	2.5	3.0	3.5
Sodium Sulfate, %	4	3	11	1.0	3.0	5.0	6.7	8.3	10.0	12.5	15.0	20.0	25.0	30.0
L/A Abrasion (100 revs), %	1	8	1	1.0	3.0	5.0	6.7	8.3	10.0	12.5	15.0	20.0	25.0	30.0
Schmidt Hammer	11	13	3	70.0	65.0	60.0	54.0	47.0	40.0	32.0	24.0	16.0	8.0	0.0
Tensile Strength, psi	6	4	10	1400	1200	1000	833	666	500	400	300	200	100	0

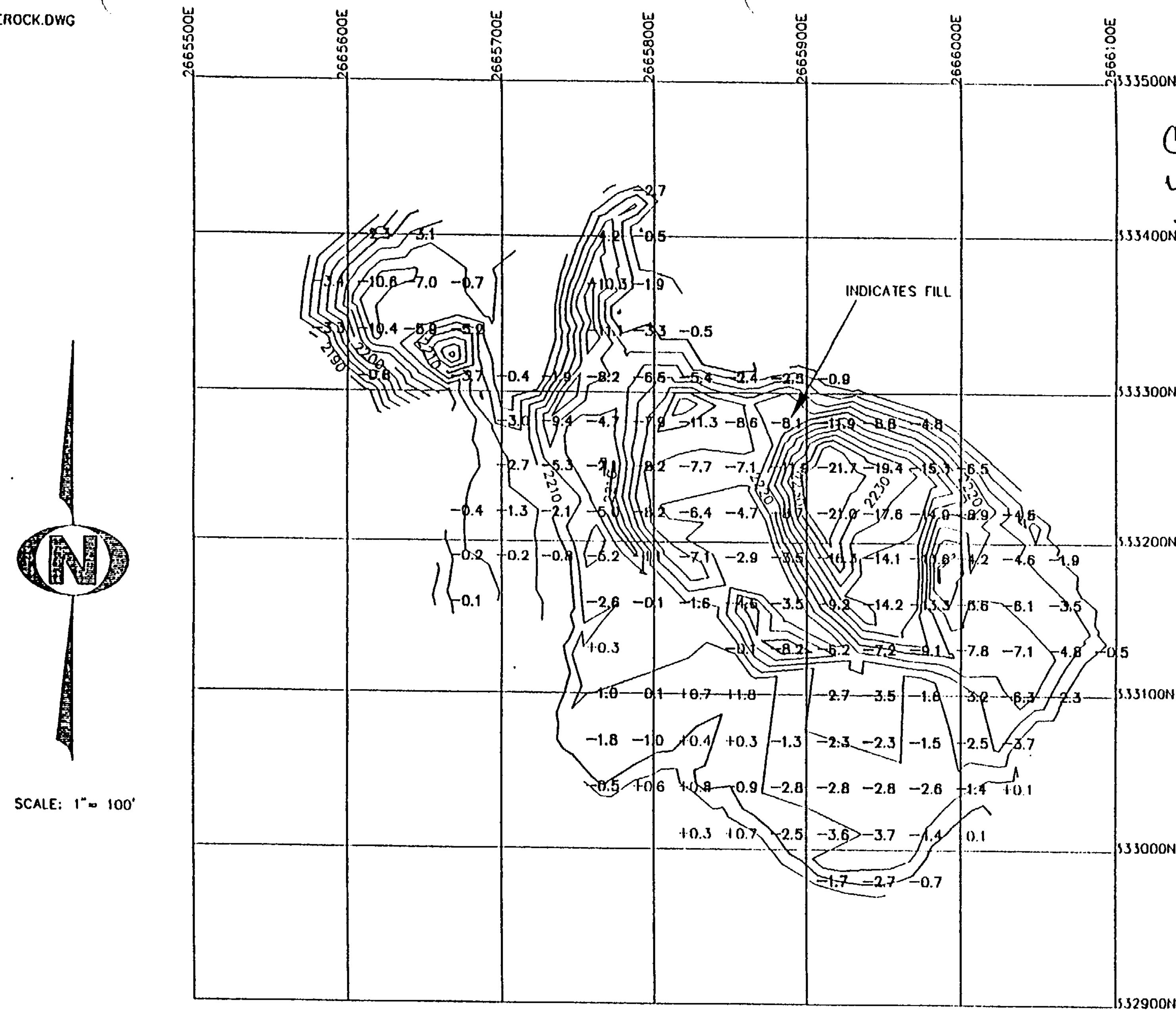
1. Scores were derived from Tables 6.2, 6.5, and 6.7 of NUREG/CR-2642 - "Long-Term Survivability of Riprap for Armoring Uranium Mill Tailings and Covers: A Literature Review," 1982 (see Ref. D13).

2. Weighting Factors are derived from Table 7 of "Petrographic Investigations of Rock Durability and Comparisons of Various Test Procedures," by G. W. DuPuy, Engineering Geology, July, 1965 (see Ref. D15). Weighting factors are based on inverse of ranking of test methods for each rock type. Other tests may be used; weighting factors for these tests may be derived using Table 7, by counting upward from the bottom of the table.

3. Test methods should be standardized, if a standard test is available and should be those used in NUREG/CR-2642 (see Ref. D13), so that proper correlations can be made. This is particularly important for the tensile strength test, where several methods may be used; the method discussed by Nilsson (1962, see Ref. D16) for tensile strength was used in the scoring procedure.

FROM THE
C.E. SPU... ASSOC.
LANDER, W.

SHEROCK.DWG



Composite sample was taken from the entire stockpile at random locations

FILL VOLUME: 21,500CY

map showing
EARTH & ROCK STOCKPILE
AT SHERWOOD MILLSITE

JUNE 23, 1995

WESTERN NUCLEAR, INC. – SHERWOOD TAILINGS RECLAMATION QUALITY COMPLIANCE REPORT

Rock Durability Test

DATE: 8/26/96

DOCUMENT: RD – 4

SHEET: 1 OF 10

SPECIFICATION REFERENCE Table 3

Construction Segment: Rock Production

Rock Source: SHERWOOD Mine – Quartz Monzonite Quarry

Frequency of Rock Durability Testing: One test series prior to placement and one test series for every 10,000 CY of material produced from the rock source.

Acceptance Criteria: Rock shall have a minimum durability rating of 80.
Rock having a durability rating of less than 80 shall require oversizing.
For oversizing, refer to Specification Reference : Page TS–39, 5.2.2

Rock Durability

Test Date	Test No.	Cum. Vol. Produced	Rating	Oversize	
8/19/96	4	20,000 Qtz Monzonite No. 2	79	Yes [X] No [ ]	Attach Test Results

Non–Conformances: Rating of 79 is below the acceptance criteria.

Description same as above

Corrective action required: Yes [X] No [ ]

If Yes, Corrective Action Report No.: CA-3

Test Performed by: AGRA Earth & Environmental Date: 8/19/96

WNI Construction Manager: C. Aleyta Date: 8/26/96

Audit Review By:
WNI QA/QC Engineering Manager: MA Parke Date: 9/5/96

07/25/96

E90

AGRA
Earth & Environmental

AGRA Earth &
Environmental, Inc.
E 520 North Foot[illegible] Drive
Suite 600
Spokane, Washington
U.S.A. 99207
Tel (509) 482-0104
Fax (509) 482-0202

August 26 , 1996

Western Nuclear, Inc.
P.O. Box 358
Wellpinit, Washington 99040

Attention: Mr. Corn Abeyta

Regarding: Laboratory Determination of Aggregate Durability Rating
Test No. 4
Sherwood Mine Project

Dear Mr. Abeyta:

In accordance with your request, on August 19, 1996 we obtained a bulk sample of Quarry rock from the Sherwood site for laboratory analysis and Durability Rating determination at our Spokane laboratory. As of this date, that has been completed. All laboratory testing has been performed in accordance with the most current ASTM standards available, and in accordance with the project specifications.

The Durability Rating determination was performed according to Table D1 of the NRC's Staff Technical Position (STP) Design of Erosion Protection Covers for Stabilization of Uranium Mill Tailing Sites, August 1990. Table A shows the test results and calculations for Test No. 4. Additionally, the laboratory testing worksheets are attached for your records.

If there are any questions, or we may be of further assistance, please do not hesitate to contact us at (509) 482-0104.

Respectfully Submitted
AGRA EARTH & ENVIRONMENTAL, INC.

Jay C. Martin, SET
Laboratory Supervisor

Bob Arnold
Technical Director

TABLE A

ROCK TYPE: IGNEOUS - GRANITIC QUARTZ MONZANITE
ROCK SAMPLE: TEST NO. 4
AGRA LABORATORY SAMPLE # 611

Laboratory Test	Result	Score	Weight	Score x Weight	Maximum Score
Apparent Specific Gravity ASTM C127	2.66	N/A	N/A	N/A	N/A
Bulk Saturated Surface Dry Specific Gravity ASTM C127	2.63	N/A	N/A	N/A	N/A
Bulk Specific Gravity ASTM C127	2.61	7	9	63	90
Absorption, % ASTM C127	0.7	7	2	14	20
Sodium Sulfate Soundness, % Loss, ASTM C88	2.5	9	11	99	110
Schmidt Hammer Rebound Number ASTM C805	54.6	7	3	21	30
Total Score				**197**	**250**

DURABILITY RATING = 197 / 250 x 100 = 79

E92

AGRA
Earth & Environmental
E. 520 North Foothills Drive, Suite 600
Spokane, Washington, U.S.A. 99207

Client: Western Nuclear Date: 8-19-96 Lab No. 611

Project: Sherwood Mine Proj. No.: 6-929-1396-0

Description: Quartz Monzanite Test No.: 4

SPECIFIC GRAVITY AND/OR UNIT WEIGHT
ASTM C-127

COARSE AGGREGATE - SPECIFIC GRAVITY AND ABSORPTION

Mass of Sample in Air Dry	=	5291.8	Grams
Mass of Sample, SSD	=	5328.8	Grams
Mass of Sample in Water	=	3301.3	Grams
Aggregate -Bulk Specific Gravity	=	2.61	
Bulk Specific Gravity (SSD)	=	2.63	
Apparent Specific Gravity	=	2.66	
Absorption	=	0.7	(%)

SSD = SATURATED SURFACE DRY

Remarks:

Sampled by: J. Johnson Date: 8-19-96

T[illegible]ed by: J. Martin Date: 8-23-96

[illegible]viewed by: [signature] Date: 8/23/96

AGRA
Earth & Environmental
E. 520 North Foothills Drive, Suite 600
Spokane, Washington, U.S.A. 99207

SULFATE SOUNDNESS TEST
ASTM C-88

Client: Western Nuclear
Project: Sherwood Mine
Description: Quartz Monzonite
Date: 8-19-96
Lab No. 611
Proj. No.: 6-929-1396-0
Test No.: 4

SIEVE SIZE	INDIVIDUAL GRADING % RETAINED	WEIGHT BEFORE TEST (GRAMS)	WEIGHT AFTER TEST (GRAMS)	PERCENT LOSS AFTER TEST (%)	WEIGHTED % LOSS
2½" TO 2" 2" TO 1½"	38.3 26.4	3017.8 2079.8	5046.6	1.0	0.6
1½" TO 1" 1" TO 3/4"	12.6 6.3	990.8 500.1	1435.7	3.7	0.7
3/4" TO 1"					
3/4" TO ½" ½" TO 3/8"	8.4 4.2	665.5 332.7	946.3	5.2	0.7
3/8" TO #4	3.8	300.4	263.2	12.4	0.5
TOTAL	100.0	7887.1			2.5

SOLUTION TEMP: 72°F OVEN TEMP: 230°F SPECIFIC GRAVITY: 1.166 TYPE OF SALT: Sodium

QUALITIVE EXAMINATION OF COARSE SIZES

SIEVE SIZE	SPLITTING	DISINTEGRATION	CRACKING	FLAKING	#OF PARTICLES
1½" TO 1"	3	2	1		24
1" TO 3/4"		4	2	1	35

CYCLE NO.	DATE	TIME	IN SOLUTION		OUT SOLUTION		IN OVEN		OUT OVEN			
1	8-20-96		8-20	1425	8-21	0725	8-21	0740	8-21	1140		
2			8-21	1340	8-22	0740	8-22	0755	8-22	1155		
3			8-22	1305	8-23	0650	8-23	0705	8-23	1105		
4			8-23	1250	8-24	0650	8-24	0705	8-24	1105		
5	8-25-96		8-24	1210	8-25	0700	8-25	0715	8-25	1115		

SAMPLED BY: J. Johnson
8-19-96

TESTED BY: J. Martin
DATE: 8-25-96

REVIEWED BY: [signature]
DATE: 8/23

AGRA
Earth & Environmental

AGRA
Earth & Environmental
E. 520 North Foothills Drive, Suite 600
kane, Washington, U.S.A. 99207

SCHMIDT HAMMER TEST
ASTM C-805

Test No: 4

Client: Western Nuclear
Date: 8-19-96 Lab No. 611
Project: Sherwood Mine
Proj. No.: 6-929-1396-0
Sample location: Quarry
Surface characteristics: Specimens have saw-cut

	Sample A/Rebound Number	Sample B/Rebound Number
1.	55	56
2.	54	54
3.	54	55
4.	54	54
5.	55	55
6.	54	55
7.	55	54
8.	55	54
9.	55	55
10.	55	55

Sample A Avg: 54.6

Sample B Avg: 54.7

Grand average rebound number 54.6

Remarks: Schmidt Hammer - model N-34, Serial No. 137281

Sampled By: S. Johnson Date: 8-19-96

T erformed By: S. Martin Date: 8-23-96

viewed By: [signature] Date: 8/23/96

TABLE D.

Scoring Criteria for Determining Rock Quality

boratory Test	Weighting Factor			Score										
	Limestone	Sandstone	Igneous	10	9 Good	8	7	6 Fair	5	4	3 Poor	2	1	0
. Gravity	12	6	9	2.75	2.70	2.65	2.60	2.55	2.50	2.45	2.40	2.35	2.40	2.25
sorption, %	13	5	2	.1	.3	.5	.67	.83	1.0	1.5	2.0	2.5	3.0	3.5
dium lfate, %	4	3	11	1.0	3.0	5.0	6.7	8.3	10.0	12.5	15.0	20.0	25.0	30.0
'A Abrasion 00 revs), %	1	8	1	1.0	3.0	5.0	6.7	8.3	10.0	12.5	15.0	20.0	25.0	30.0
chmidt Hammer	11	13	3	70.0	65.0	60.0	54.0	47.0	40.0	32.0	24.0	16.0	8.0	0.0
ensile Strength, si	6	4	10	1400	1200	1000	833	666	500	400	300	200	100	0

. Scores were derived from Tables 6.2, 6.5, and 6.7 of NUREG/CR-2642 - "Long-Term Survivability of Riprap for Armoring Uranium Mill Tailings and Covers: A Literature Review," 1982 (see Ref. D13).

. Weighting Factors are derived from Table 7 of "Petrographic Investigations of Rock Durability and Comparisons of Various Test Procedures," by G. W. DuPuy, Engineering Geology, July, 1965 (see Ref. D15). Weighting factors are based on inverse of ranking of test methods for each rock type. Other tests may be used; weighting factors for these tests may be derived using Table 7, by counting upward from the bottom of the table.

. Test methods should be standardized, if a standard test is available and should be those used in NUREG/CR-2642 (see Ref. D13), so that proper correlations can be made. This is particularly important for the tensile strength test, where several methods may be used; the method discussed by Nilsson (1962, see Ref. D16) for tensile strength was used in the scoring procedure.

WESTERN NUCLEAR, INC.
SHERWOOD TAILINGS RECLAMATION

CORRECTIVE ACTION REPORT

CORRECTIVE ACTION REPORT NO. CA-3

QA/QC Contractor Field Engineer: J. Martin AGRA Earth & Environ. Date: 8/26/96

Document: RD-4

Description of Non-conformances:
Durability rating of ~~78~~ 79 CP was below acceptance criteria rating of 80.

Description of Cause:
Lower than previous results for Bulk Specific gravity and Schmidt Hammer tests.

Is regulatory notification required? Yes ☐ No ☒

If Yes, describe:

Corrective actions taken:
Produced rock durability rating is well above that required for placement in locations with inherent oversizing. This production will be utilized in Confluences except A & D. In addition to the inherent oversizing by design, Confluences B, F2, F and G are being changed from a D_{50} 10 inch to D_{50} 15 inch riprap. resulting in additional oversizing. This segment of production will be utilized in locations where inherent oversizing by design will allow a durability rating of ~~78~~ 79 or less.

Corrective Action Inspection Performed by: C. Aveyta, J. Martin Date: 8/26/96

Corrective action performed by: Industrial Constructors

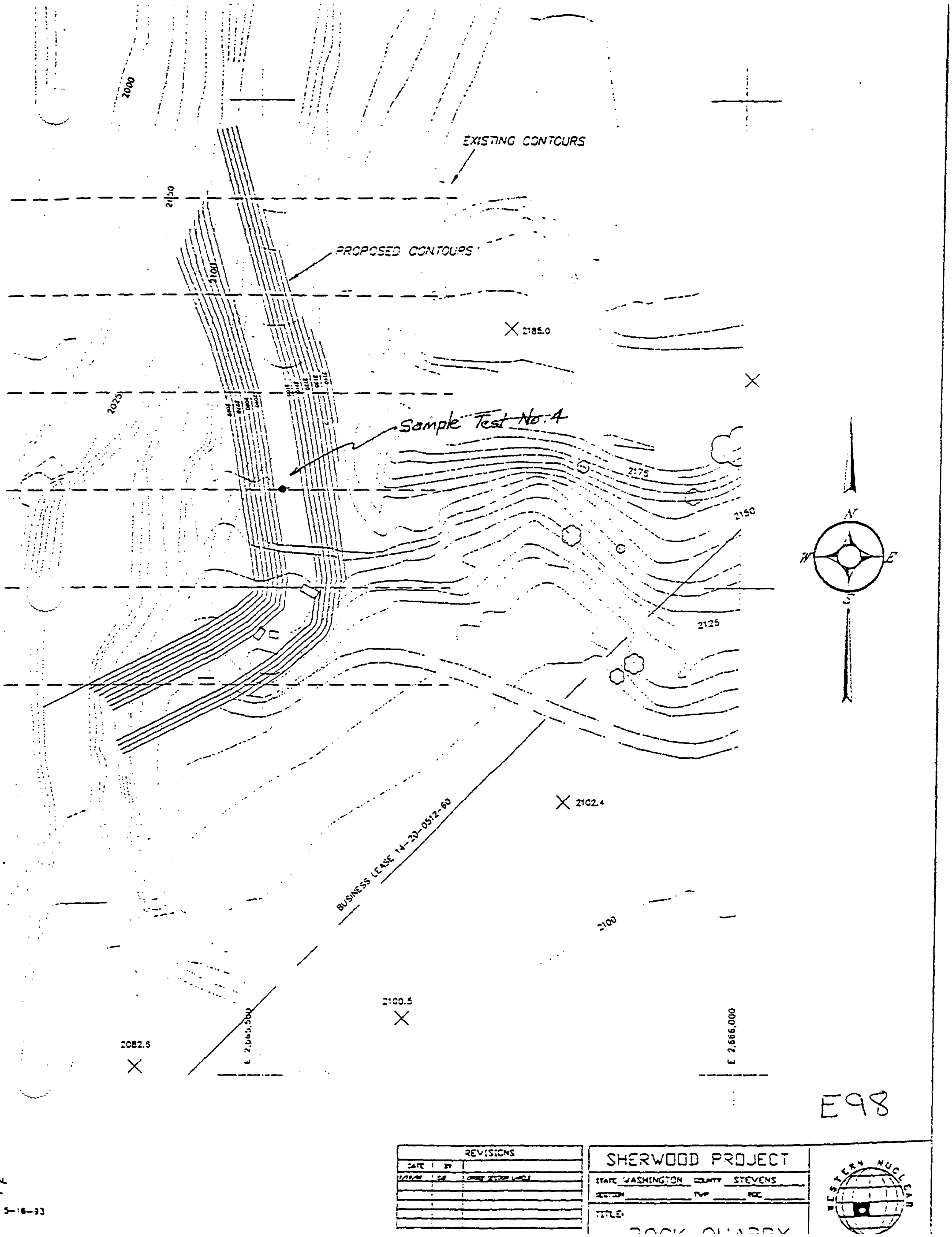
Field acknowledgement of corrective action:
WNI Construction Manager: C. Aveyta Date: 8/26/96

Follow-up acknowledgement:
Comments:

Audit Review By:
WNI QA/QC Engineering Manager: M A Peele Date: 9/5/96

04/23/96

E97



2000
EXISTING CONTOURS
2150
PROPOSED CONTOURS
2100
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2025
Sample Test No. 4
2175
2150
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W
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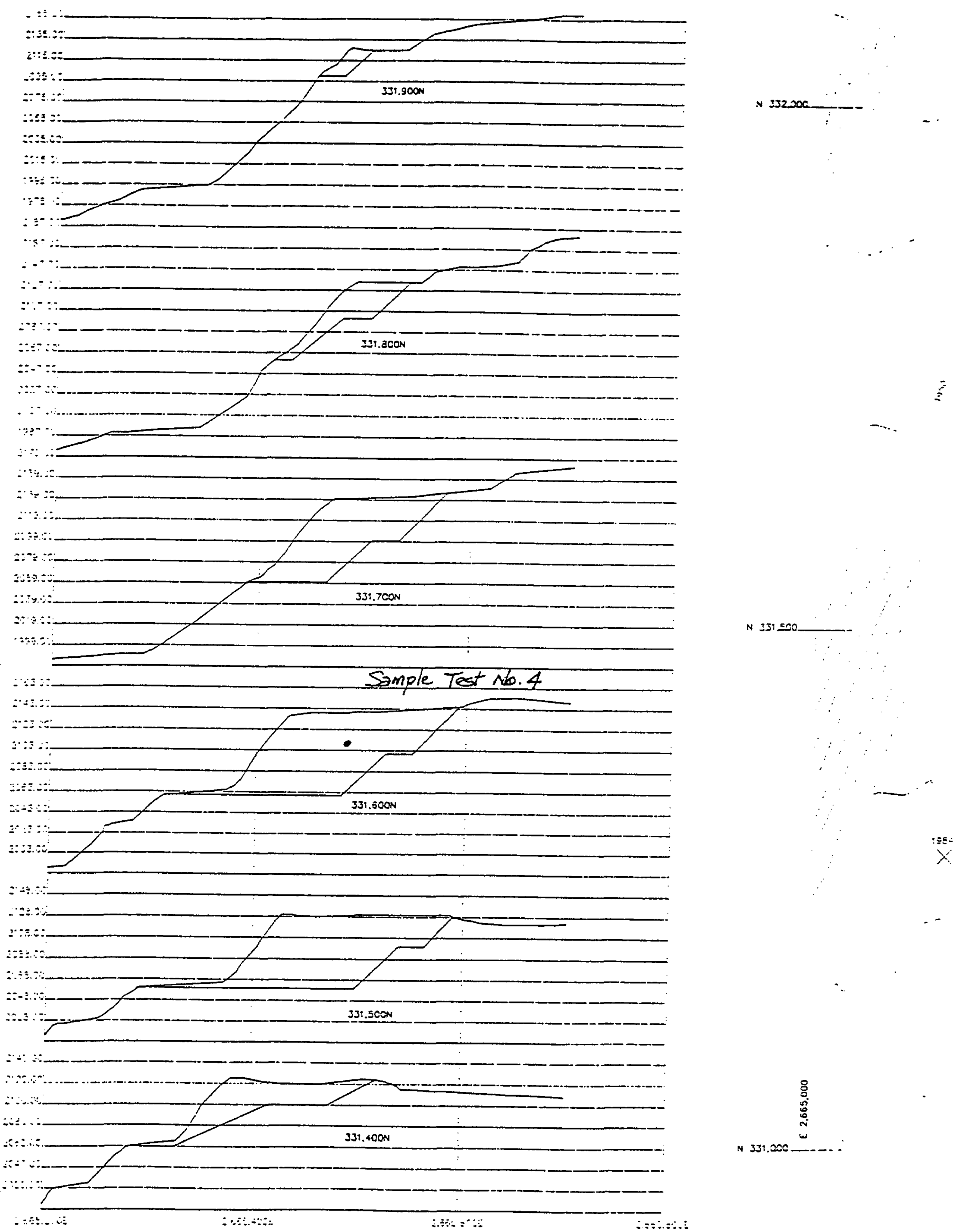
2125
2102.4
BUSINESS LEASE 14-20-0512-60
2100
2100.5
E 2,665,500
E 2,666,000
2082.5
REVISIONS
SHERWOOD PROJECT
STATE WASHINGTON COUNTY STEVENS
SECTION TWP RGE
TITLE:
WESTERN NUCLEAR

E98

5-16-93



VOLUME: 125,000CY

E99

WESTERN NUCLEAR, INC. – SHERWOOD TAILINGS RECLAMATION
QUALITY COMPLIANCE REPORT

Rock Durability Test

DATE: 8/30/96

DOCUMENT: RD – 5

SHEET: 1 OF 9

SPECIFICATION REFERENCE Table 3

Construction Segment: Rock Production

Rock Source: SHERWOOD MINE – QUARTZ MONZONITE QUARRY

Frequency of Rock Durability Testing: One test series prior to placement and one test series for every 10,000 CY of material produced from the rock source.

Acceptance Criteria: Rock shall have a minimum durability rating of 80.
Rock having a durability rating of less than 80 shall require oversizing.
For oversizing, refer to Specification Reference : Page TS–39, 5.2.2

Rock Durability

Test Date	Test No.	Cum. Vol. Produced	Rating	Oversize	
8/27/96	5	30 000 yd³ Qtz Monzonite	80	Yes ☐ No ☒	Attach Test Results

Non–Conformances: NONE

Description: N/A

Corrective action required: Yes ☐ No ☒

If Yes, Corrective Action Report No.: ______

Test Performed by: J. Martin – AGRA Earth & Environmental Date: 8/27/96

WNI Construction Manager: C. Aveyta Date: 8/30/96

Audit Review By:
WNI QA/QC Engineering Manager: M A Bark Date: 9/5/96

07/25/96

E10C

AGRA
Earth & Environmental

AGRA Earth &
Environmental, Inc.
E 520 North Foothills Drive
Suite 600
Spokane, Washington
U.S.A. 99207
Tel (509) 482-0104
Fax (509) 482-0202

August 30, 1996

Western Nuclear, Inc.
P.O. Box 358
Wellpinit, Washington 99040

Attention: Mr. Corn Abeyta

Regarding: Laboratory Determination of Aggregate Durability Rating
Test No. 5
Sherwood Mine Project

Dear Mr. Abeyta:

In accordance with your request, on August 21, 1996 we obtained a bulk sample of Quarry rock from the Sherwood site for laboratory analysis and Durability Rating determination at our Spokane laboratory. As of this date, that has been completed. All laboratory testing has been performed in accordance with the most current ASTM standards available, and in accordance with the project specifications.

The Durability Rating determination was performed according to Table D1 of the NRC's Staff Technical Position (STP) <u>Design of Erosion Protection Covers for Stabilization of Uranium Mill Tailing Sites</u>, August 1990. Table A shows the test results and calculations for Test No.5. Additionally, the laboratory testing worksheets are attached for your records.

If there are any questions, or we may be of further assistance, please do not hesitate to contact us at (509) 482-0104.

Respectfully Submitted
AGRA EARTH & ENVIRONMENTAL, INC.

Jay C. Martin, SET
Laboratory Supervisor

Bob Arnold
Technical Director

TABLE A

ROCK TYPE: IGNEOUS - GRANITIC QUARTZ MONZANITE
ROCK SAMPLE: TEST NO. 5
AGRA LABORATORY SAMPLE # 612

Laboratory Test	Result	Score	Weight	Score x Weight	Maximum Score
Apparent Specific Gravity ASTM C127	2.66	N/A	N/A	N/A	N/A
Bulk Saturated Surface Dry Specific Gravity ASTM C127	2.64	N/A	N/A	N/A	N/A
Bulk Specific Gravity ASTM C127	2.63	7	9	63	90
Absorption, % ASTM C127	0.4	8	2	16	20
Sodium Sulfate Soundness, % Loss, ASTM C88	1.9	9	11	99	110
Schmidt Hammer Rebound Number ASTM C805	56.2	7	3	21	30
Total Score				**199**	**250**

√

DURABILITY RATING = 199 / 250 x 100 = 80

E102

AGRA
Earth & Environmental
E. 520 North Foothills Drive, Suite 600
~kane, Washington, U.S.A. 99207

Client: Western Nuclear | Date: 8-21-96 | Lab No. 612

Project: Sherwood Mine | Proj. No.: 6-929-1396-0

Description: Quartz Monzonite | Test No.: 5

SPECIFIC GRAVITY AND/OR UNIT WEIGHT
ASTM C-127

COARSE AGGREGATE - SPECIFIC GRAVITY AND ABSORPTION

Mass of Sample in Air Dry		= 6026.2	Grams
Mass of Sample, SSD		= 6049.7	Grams
Mass of Sample in Water		= 3760.0	Grams
Aggregate	-Bulk Specific Gravity	= 2.63	
	Bulk Specific Gravity (SSD)	= 2.64	
	Apparent Specific Gravity	= 2.66	
	Absorption	= 0.4	(%)

SSD = SATURATED SURFACE DRY

Remarks:

Sampled by: J. Martin Date: 8-21-96

T~~d by: J. Martin Date: 8-27-96

~eviewed by: [signature] Date: 8/28/96

E103

AGRA
Earth & Environmental
E. 520 North Foothills Drive, Suite 600
Spokane, Washington, U.S.A. 99207

SULFATE SOUNDNESS TEST
ASTM C-88

Client: Western Nuclear
Project: Sherwood Mine
Description: Quartz Monzanite

Date: 8-21-96 Lab No. 612
Proj. No.: 6-929-1396-0
Test No.: 5

SIEVE SIZE	INDIVIDUAL GRADING % RETAINED	WEIGHT BEFORE TEST (GRAMS)	WEIGHT AFTER TEST (GRAMS)	PERCENT LOSS AFTER TEST (%)	WEIGHTED % LOSS
2 ½" TO 2" 2" TO 1 ½"	38.5 25.7	3010.8 2009.1	4975.1	0.9	0.6
1 ½" TO 1" 1" TO 3/4"	12.7 6.5	992.8 508.7	1462.5	2.6	0.5
3/4" TO 1"					
3/4" TO ½" ½" TO 3/8"	8.5 4.2	663.2 330.2	930.8	6.3	0.5
3/8" TO #4	3.8	299.5	275.8	7.9	0.3
TOTAL	99.9	7814.3			1.9

SOLUTION TEMP: 72 OVEN TEMP: 230°F SPECIFIC GRAVITY: 1.167 TYPE OF SALT: Sodium

QUALITIVE EXAMINATION OF COARSE SIZES

SIEVE SIZE	SPLITTING	DISINTEGRATION	CRACKING	FLAKING	#OF PARTICLES
1 ½" TO 1"	2		1		21
1" TO 3/4"	3	1	2	1	30

CYCLE NO.	DATE	TIME	IN SOLUTION		OUT SOLUTION		IN OVEN		OUT OVEN			
1	8-24		8-24	1401	8-25	0815	8-25	0830	8-25	1230		
2	8-25		8-25	1410	8-26	0810	8-26	0825	8-26	1220		
3			8-26	1405	8-27	0740	8-27	0755	8-27	1155		
4			8-27	1330	8-28	0705	8-28	0720	8-28	1120		
5			8-28	1350	8-29	0710	8-29	0725	~~8-28~~ 8-29	1130		

SAMPLED BY: J. Martin TESTED BY: J. Martin REVIEWED BY: [signature]
DATE: 8-21-96 DATE: 8-29-96 DATE: 8/29/96

AGRA
Earth & Environmental

E104

AGRA
Earth & Environmental
E. 520 North Foothills Drive, Suite 600
Spokane, Washington, U.S.A. 99207

SCHMIDT HAMMER TEST
ASTM C-805

Test No: 5

Client: Western Nuclear | Date: 8-21-96 | Lab No. 612
Project: Sherwood Mine | Proj. No.: 6-929-1396-0
Sample location: Quarry
Surface characteristics: Specimens were Saw-cut

	Sample A/Rebound Number	Sample B/Rebound Number
1.	56	57
2.	56	57
3.	57	57
4.	55	56
5.	55	55
6.	56	56
7.	57	55
8.	57	57
9.	56	56
10.	56	57

Sample A Avg: 56.1 Sample B Avg: 56.3

Grand average rebound number 56.2

Remarks: Schmidt Hammer - model N-34, Serial No. 137281

Sampled By: J. Martin Date: 8-21-96
Tested/Performed By: J. Martin Date: 8-27-96
Reviewed By: [signature] Date: 8/28/96

AGRA Earth & Environmental E105

TABLE

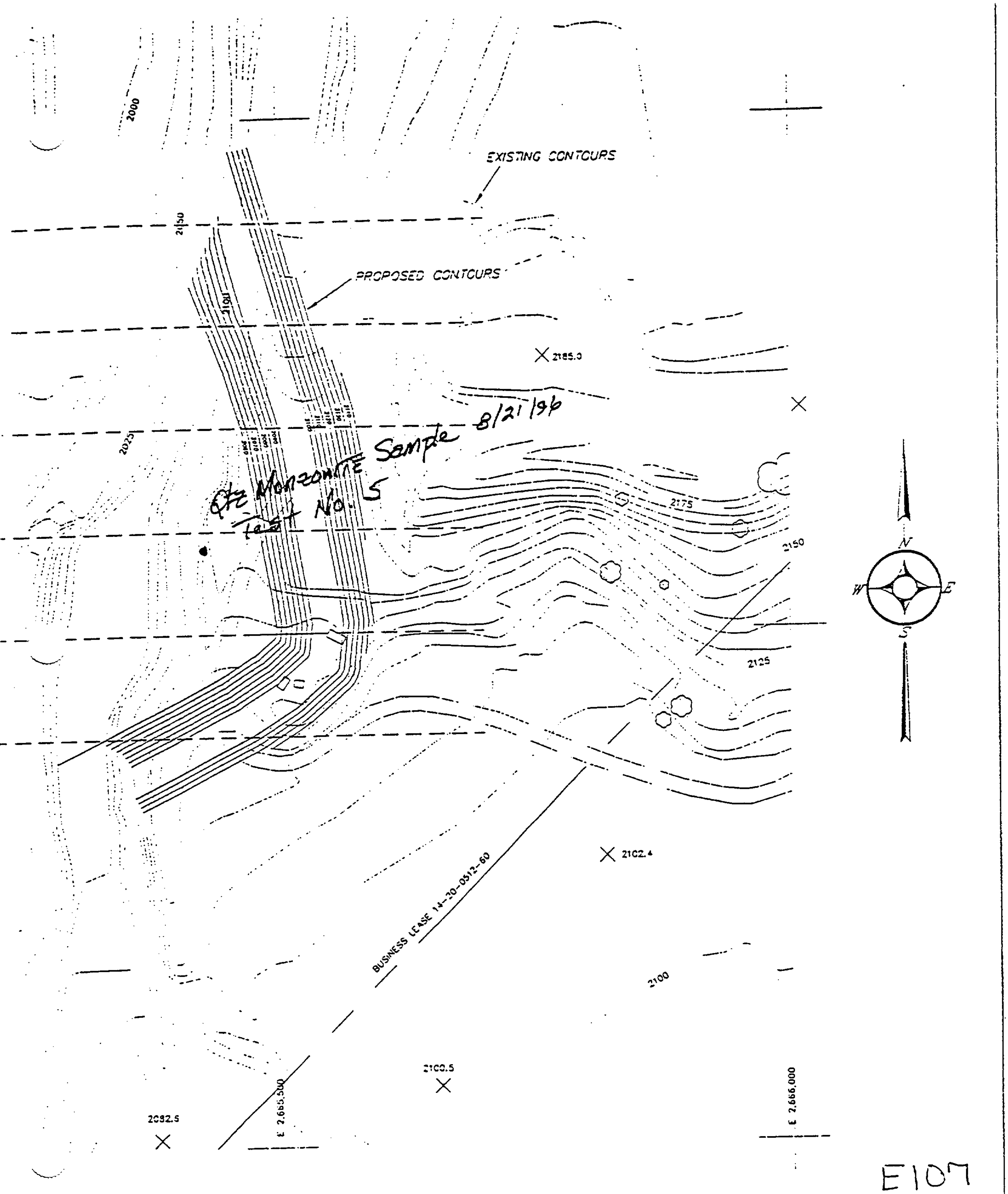
Scoring Criteria for Determining Rock Quality

Laboratory Test	Weighting Factor			Score										
	Limestone	Sandstone	Igneous	10	9	8	7	6	5	4	3	2	1	0
					Good			Fair			Poor			
Sp. Gravity	12	6	9	2.75	2.70	2.65	2.60	2.55	2.50	2.45	2.40	2.35	2.40	2.25
Absorption, %	13	5	2	.1	.3	.5	.67	.83	1.0	1.5	2.0	2.5	3.0	3.5
Sodium Sulfate, %	4	3	11	1.0	3.0	5.0	6.7	8.3	10.0	12.5	15.0	20.0	25.0	30.0
L/A Abrasion (100 revs), %	1	8	1	1.0	3.0	5.0	6.7	8.3	10.0	12.5	15.0	20.0	25.0	30.0
Schmidt Hammer	11	13	3	70.0	65.0	60.0	54.0	47.0	40.0	32.0	24.0	16.0	8.0	0.0
Tensile Strength, psi	6	4	10	1400	1200	1000	833	666	500	400	300	200	100	0

1. Scores were derived from Tables 6.2, 6.5, and 6.7 of NUREG/CR-2642 - "Long-Term Survivability of Riprap for Armoring Uranium Mill Tailings and Covers: A Literature Review," 1982 (see Ref. D13).

2. Weighting Factors are derived from Table 7 of "Petrographic Investigations of Rock Durability and Comparisons of Various Test Procedures," by G. W. DuPuy, Engineering Geology, July, 1965 (see Ref. D15). Weighting factors are based on inverse of ranking of test methods for each rock type. Other tests may be used; weighting factors for these tests may be derived using Table 7, by counting upward from the bottom of the table.

3. Test methods should be standardized, if a standard test is available and should be those used in NUREG/CR-2642 (see Ref. D13), so that proper correlations can be made. This is particularly important for the tensile strength test, where several methods may be used; the method discussed by Nilsson (1962, see Ref. D16) for tensile strength was used in the scoring procedure.



E107

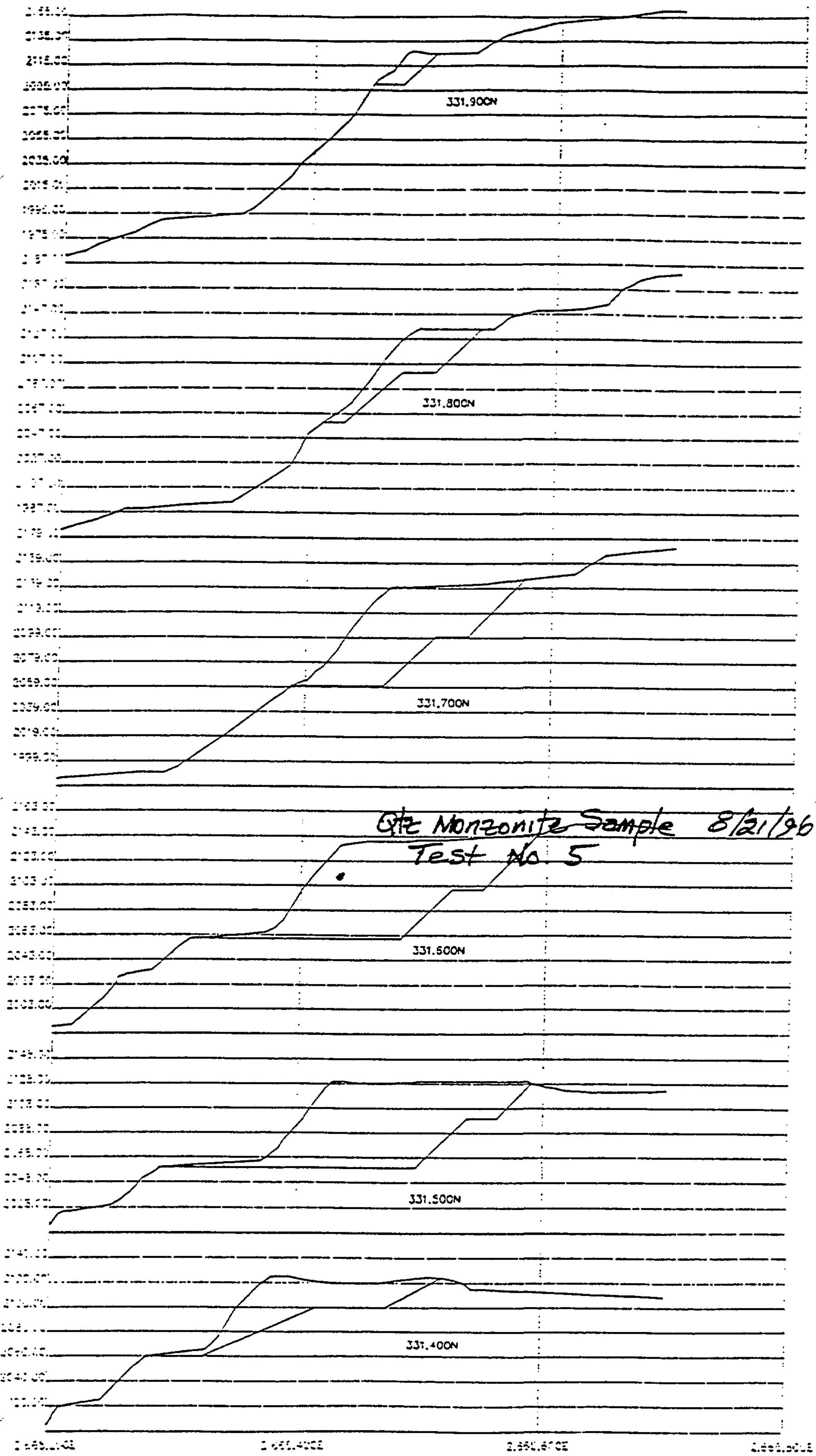
REVISIONS		
DATE	BY	

SHERWOOD PROJECT

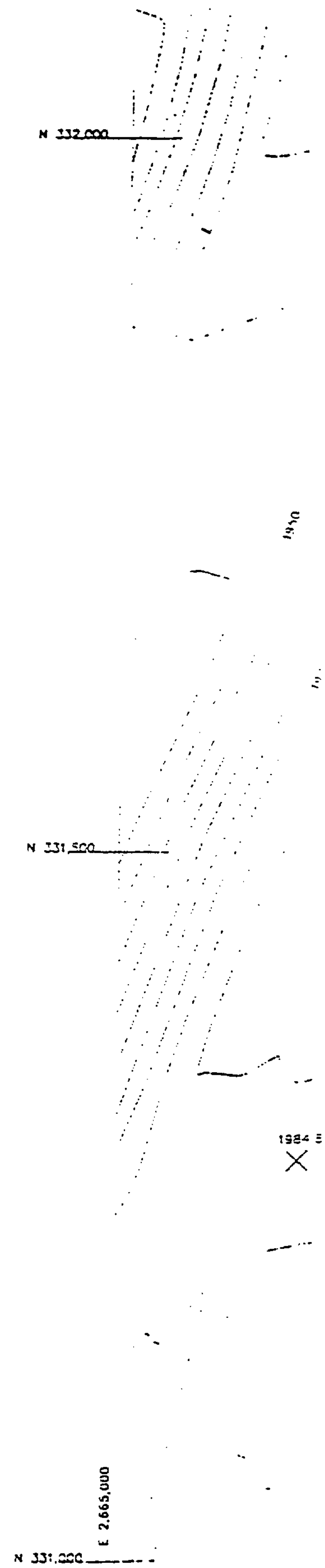
STATE WASHINGTON COUNTY STEVENS

SECTION ______ TWP ______ RGE ______

TITLE: ROCK QUARRY



VOLUME: 125,000CY



E108

WESTERN NUCLEAR, INC. – SHERWOOD TAILINGS RECLAMATION QUALITY COMPLIANCE REPORT

Rock Durability Test

DATE: 9/16/96

DOCUMENT: RD – 6

SHEET: 1 OF 8

SPECIFICATION REFERENCE Table 3

Construction Segment: Rock Production

Rock Source: Rock Quarry – Quartz Monzonite, Sherwood Mine

Frequency of Rock Durability Testing: One test series prior to placement and one test series for every 10,000 CY of material produced from the rock source.

Acceptance Criteria: Rock shall have a minimum durability rating of 80.
Rock having a durability rating of less than 80 shall require oversizing.
For oversizing, refer to Specification Reference : Page TS–39, 5.2.2

Rock Durability

Test Date	Test No.	Cum. Vol. Produced	Rating	Oversize	
9/11/96	6	40,000 yd^3	80	Yes ☐ No ☒	Attach Test Results

Non–Conformances: None

Description: N/A

Corrective action required: Yes ☐ No ☒

If Yes, Corrective Action Report No.: ____

Test Performed by: Jay Martin, AGRA Earth & Environmental Date: 9/11/96

VNI Construction Manager: C. Abeyta Date: 9/16/96

Audit Review By:
WNI QA/QC Engineering Manager: M A Bash Date: 9/19/96

07/25/96

E109

AGRA
Earth & Environmental

AGRA Earth &
Environmental, Inc.
E 520 North Foothills Drive
Suite 800
Spokane, Washington
U.S.A. 9920[illegible]
Tel (509) 482-0104
Fax (509) 482-[illegible]

September 16, 1996

Western Nuclear, Inc.
P.O. Box 358
Wellpinit, Washington 99040

Attention: Mr. Corn Abeyta

Regarding: Laboratory Determination of Aggregate Durability Rating
Test No. 6
Sherwood Mine Project

Dear Mr. Abeyta:

In accordance with your request, on September 9, 1996 we obtained a bulk sample of Quarry rock from the Sherwood site for laboratory analysis and Durability Rating determination at our Spokane laboratory. As of this date, that has been completed. All laboratory testing has been performed in accordance with the most current ASTM standards available, and in accordance with the project specifications.

The Durability Rating determination was performed according to Table D1 of the NRC's Staff Technical Position (STP) Design of Erosion Protection Covers for Stabilization of Uranium Mill Tailing Sites, August 1990. Table A shows the test results and calculations for Test No. 6. Additionally, the laboratory testing worksheets are attached for your records.

If there are any questions, or we may be of further assistance, please do not hesitate to contact us at (509) 482-0104.

Respectfully Submitted
AGRA EARTH & ENVIRONMENTAL, INC.

Jay C. Martin, SET
Laboratory Supervisor

Bob Arnold
Technical Director

TABLE A

ROCK TYPE: IGNEOUS - GRANITIC QUARTZ MONZANITE
ROCK SAMPLE: TEST NO.6
AGRA LABORATORY SAMPLE # 671

Laboratory Test	Result	Score	Weight	Score x Weight	Maximum Score
Apparent Specific Gravity ASTM C127	2.66	N/A	N/A	N/A	N/A
Bulk Saturated Surface Dry Specific Gravity ASTM C127	2.64	N/A	N/A	N/A	N/A
Bulk Specific Gravity ASTM C127	2.63	7	9	63	90
Absorption, % ASTM C127	0.4	8	2	16	20
Sodium Sulfate Soundness, % Loss, ASTM C88	2.2	9	11	99	110
Schmidt Hammer Rebound Number ASTM C805	56.7	7	3	21	30
Total Score				**199**	**250**

DURABILITY RATING = 199 / 250 x 100 = 80

AGRA
Earth & Environmental
E. 520 North Foothills Drive, Suite 600
Spokane, Washington, U.S.A. 99207

Client: Western Nuclear | Date: 9-~~8~~ 10-96 | Lab No. 671

Project: Sherwood Mine | Proj. No.: 6-929-1396-0

Description: Quartz Monzonite | Test No.: 6

SPECIFIC GRAVITY AND/OR UNIT WEIGHT
ASTM C-127

COARSE AGGREGATE - SPECIFIC GRAVITY AND ABSORPTION

Mass of Sample in Air Dry	= 6591.7	Grams
Mass of Sample, SSD	= 6618.1	Grams
Mass of Sample in Water	= 4113.9	Grams
Aggregate -Bulk Specific Gravity	= 2.63	
Bulk Specific Gravity (SSD)	= 2.64	
Apparent Specific Gravity	= 2.66	
Absorption	= 0.4	(%)

SSD = SATURATED SURFACE DRY

Remarks:

Sampled by: S. Martin — Date: 9-9-96

Tested by: S. Martin — Date: 9-11-96

Reviewed by: Bob All — Date: 9/16/96

E112

AGRA
Earth & Environmental

AGRA
Earth & Environmental
E. 520 North Foothills Drive, Suite 600
Spokane, Washington, U.S.A. 99207

SULFATE SOUNDNESS TEST
ASTM C-88

Client: Western Nuclear
Date: 9-10-96 Lab No. 671
Project: Sherwood Mine
Proj. No.: 6-929-1396-0
Description: Quartz Monzonite
Test No.: 6

SIEVE SIZE	INDIVIDUAL GRADING % RETAINED	WEIGHT BEFORE TEST (GRAMS)	WEIGHT AFTER TEST (GRAMS)	PERCENT LOSS AFTER TEST (%)	WEIGHTED % LOSS
2 ½" TO 2" 2" TO 1 ½"	38.6 25.7	3007.5 2004.4	4957.3	1.1	0.7
1 ½" TO 1" 1" TO 3/4"	12.8 6.4	998.0 496.8	1455.9	2.6	0.5
3/4" TO 1"					
3/4" TO ½" ½" TO 3/8"	8.4 4.2	658.7 329.1	940.4	4.8	0.6
3/8" TO #4	3.9	301.4	270.4	10.3	0.4
TOTAL	100.0	7795.9			2.2

SOLUTION TEMP: 72 OVEN TEMP: 230°F SPECIFIC GRAVITY: 1.162 TYPE OF SALT: Sodium

QUALITIVE EXAMINATION OF COARSE SIZES

SIEVE SIZE	SPLITTING	DISINTEGRATION	CRACKING	FLAKING	#OF PARTICLES
1 ½" TO 1"	1		1		23
1" TO 3/4"	1		1	1	29

CYCLE NO.	DATE	TIME	IN SOLUTION		OUT SOLUTION		IN OVEN		OUT OVEN			
1	9-10		9-10	~~10:30~~ 1320	9-11	0645	0700	9-11	9-11	1050		
2			9-11	1310	9-12	0650	9-12	0705	9-12	1105		
3			9-12	1305	9-13	0630	9-13	0645	9-13	1045		
4			9-13	1235	9-14	0625	9-14	0640	9-14	1040		
5			9-14	1215	9-15	0600	9-15	0615	9-15	1015		

SAMPLED BY: J. Martin
9-9-96

TESTED BY: J. Martin / J. Johnson / C. Hitchcock
DATE: 9-15-96

REVIEWED BY: [signature]
DATE: 9/16/96

AGRA
Earth & Environmental
E. 520 North Foothills Drive, Suite 600
Spokane, Washington, U.S.A. 99207

SCHMIDT HAMMER TEST
ASTM C-805

Test No: 6

Client: Western Nuclear
Date: 9-10-96 Lab No. 671
Project: Sherwood Mine
Proj. No.: 6-929-1396-0
Sample location: Quarry
Surface characteristics: Specimans were Saw-cut

	Sample A/Rebound Number	Sample B/Rebound Number
1.	57	57
2.	56	57
3.	56	57
4.	57	56
5.	57	57
6.	56	57
7.	56	57
8.	56	57
9.	56	57
10.	57	57

Sample A Avg: 56.4

Sample B Avg: 56.9

Grand average rebound number 56.7

Remarks: Schmidt Hammer - Model N-34, Serial No. 137281

Sampled By: J. Martin
Date: 9-9-96

Test Performed By: J. Martin
Date: 9-10-96

Reviewed By: Bob [signature]
Date: 9/16/96

TABLE

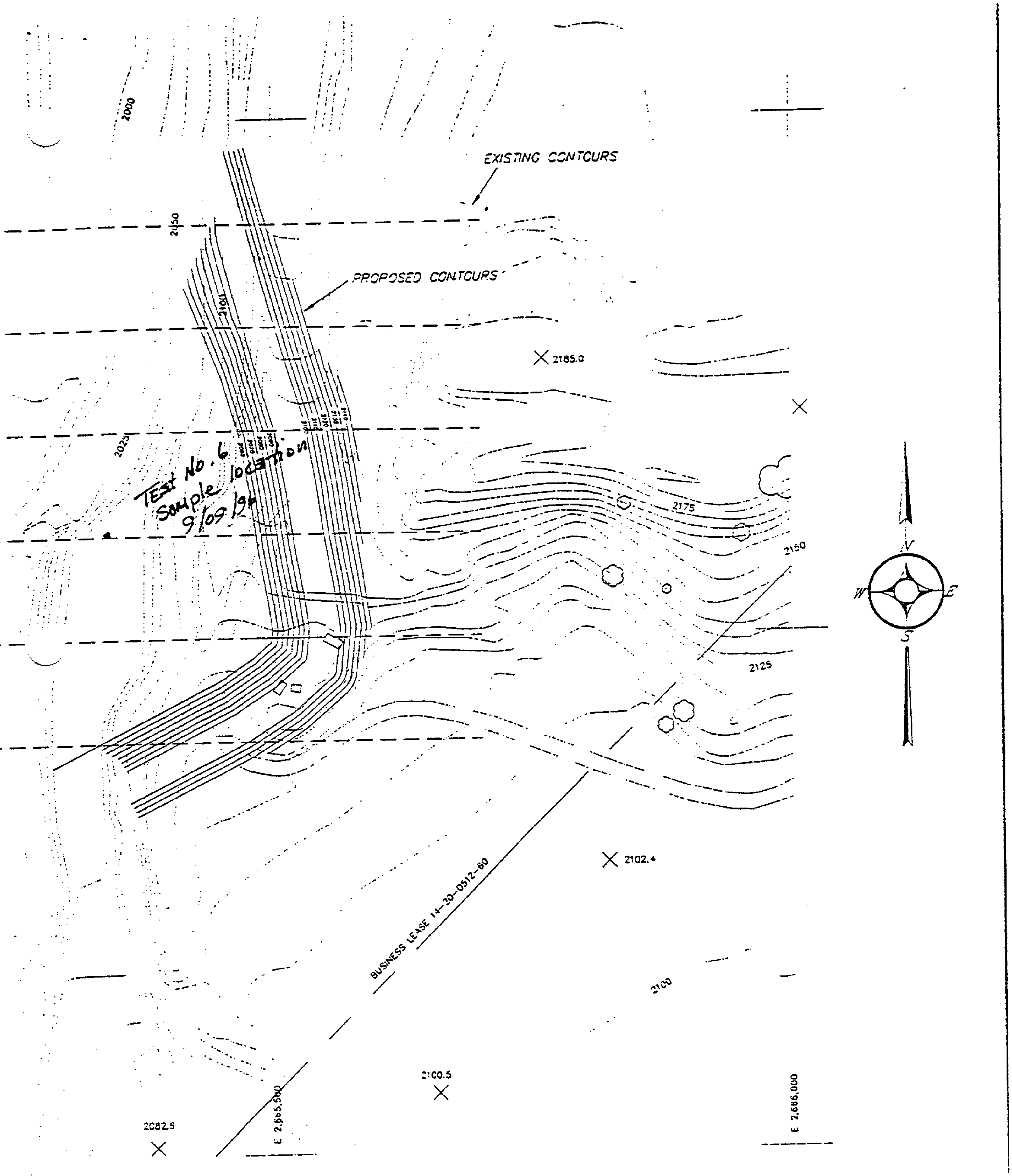
Scoring Criteria for Determining Rock Quality

Laboratory Test	Weighting Factor			Score										
	Limestone	Sandstone	Igneous	10	9 Good	8	7	6 Fair	5	4	3 Poor	2	1	0
Sp. Gravity	12	6	9	2.75	2.70	2.65	2.60	2.55	2.50	2.45	2.40	2.35	2.40	2.25
Absorption, %	13	5	2	.1	.3	.5	.67	.83	1.0	1.5	2.0	2.5	3.0	3.5
Sodium Sulfate, %	4	3	11	1.0	3.0	5.0	6.7	8.3	10.0	12.5	15.0	20.0	25.0	30.0
L/A Abrasion (100 revs), %	1	8	1	1.0	3.0	5.0	6.7	8.3	10.0	12.5	15.0	20.0	25.0	30.0
Schmidt Hammer	11	13	3	70.0	65.0	60.0	54.0	47.0	40.0	32.0	24.0	16.0	8.0	0.0
Tensile Strength, psi	6	4	10	1400	1200	1000	833	666	500	400	300	200	100	0

1. Scores were derived from Tables 6.2, 6.5, and 6.7 of NUREG/CR-2642 - "Long-Term Survivability of Riprap for Armoring Uranium Mill Tailings and Covers: A Literature Review," 1982 (see Ref. D13).

2. Weighting Factors are derived from Table 7 of "Petrographic Investigations of Rock Durability and Comparisons of Various Test Procedures," by G. W. DuPuy, Engineering Geology, July, 1965 (see Ref. D15). Weighting factors are based on inverse of ranking of test methods for each rock type. Other tests may be used; weighting factors for these tests may be derived using Table 7, by counting upward from the bottom of the table.

3. Test methods should be standardized, if a standard test is available and should be those used in NUREG/CR-2642 (see Ref. D13), so that proper correlations can be made. This is particularly important for the tensile strength test, where several methods may be used; the method discussed by Nilsson (1962, see Ref. D16) for tensile strength was used in the scoring procedure.



E116

REVISIONS		
DATE	BY	
[illegible]	C.E.	CROSS SECTION LABELS

SHERWOOD PROJECT

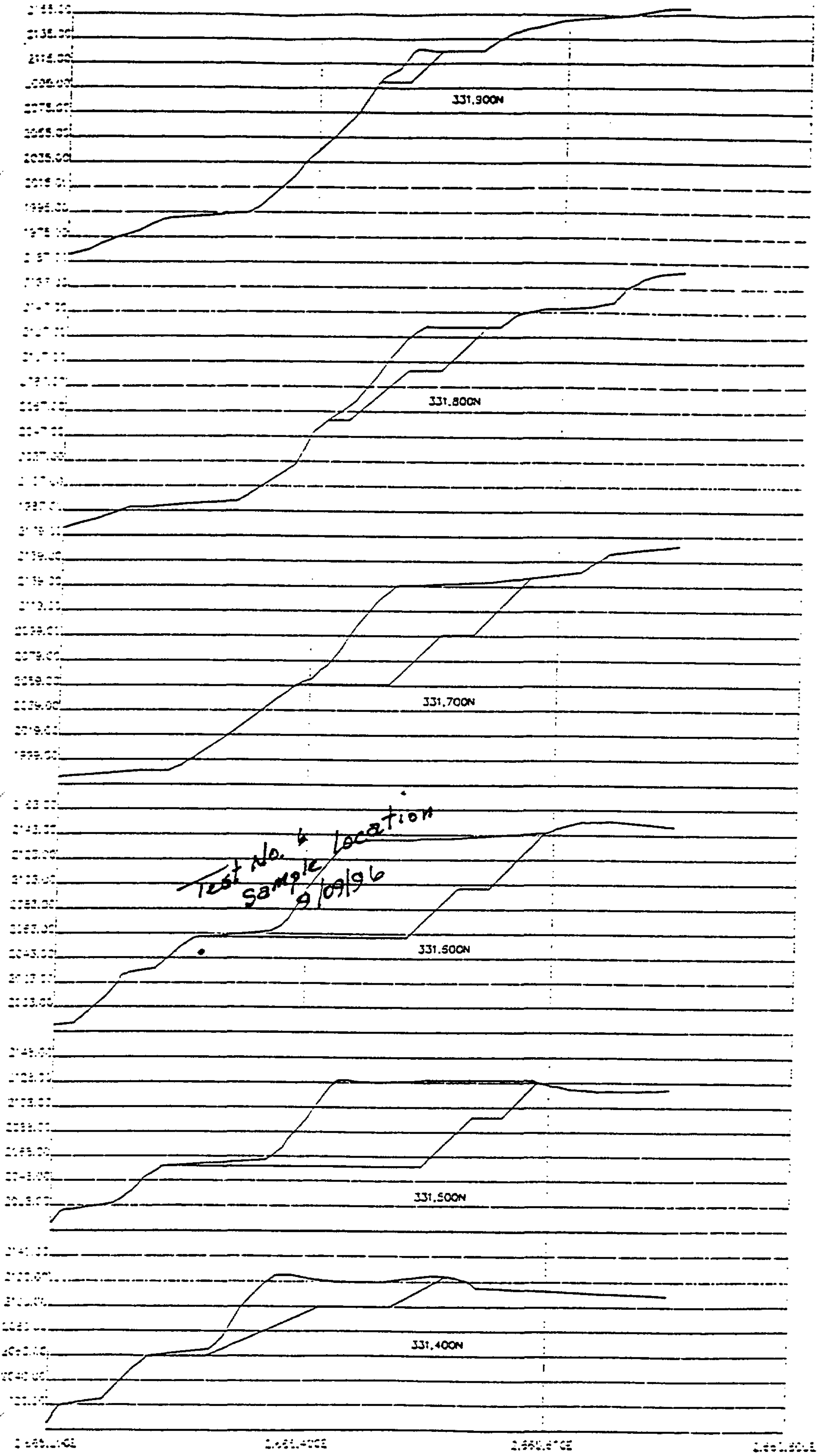
STATE WASHINGTON COUNTY STEVENS

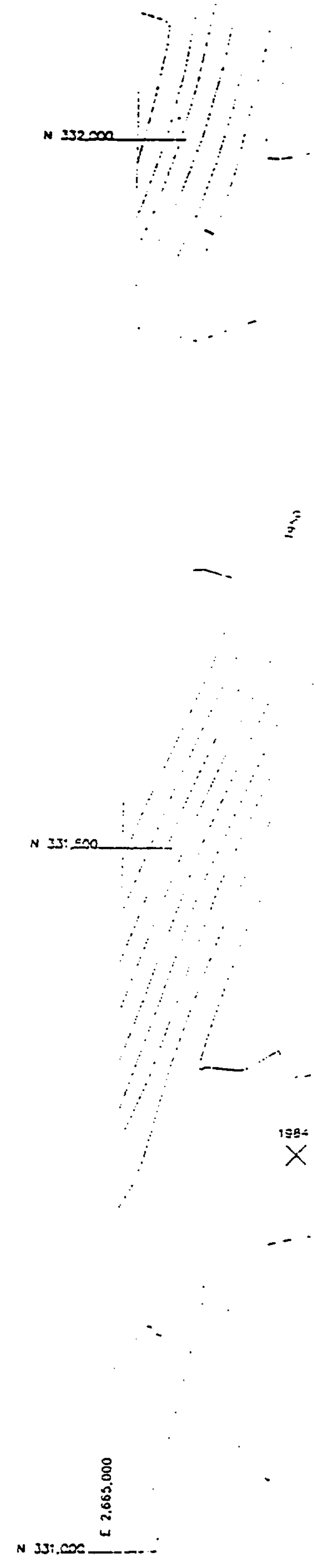
SECTION TWP RGE

TITLE: ROCK QUARRY

WESTERN NUCLEAR

...NTAL
...CAL
... 5-16-93





VOLUME: 125,000CY

E117

WESTERN NUCLEAR, INC. – SHERWOOD TAILINGS RECLAMATION
QUALITY COMPLIANCE REPORT

Rock Durability Test

DATE: 9/18/96

DOCUMENT: RD – 7

SHEET: 1 OF 10

SPECIFICATION REFERENCE Table 3

Construction Segment: Rock Production

Rock Source: Rock Quarry – Quartz Monzonite – Sherwood Mine

Frequency of Rock Durability Testing: One test series prior to placement and one test series for every 10,000 CY of material produced from the rock source.

Acceptance Criteria: Rock shall have a minimum durability rating of 80.
Rock having a durability rating of less than 80 shall require oversizing.
For oversizing, refer to Specification Reference : Page TS–39, 5.2.2

Rock Durability

Test Date	Test No.	Cum. Vol. Produced	Rating	Oversize	
9/11/96	7	50,000 yd3	80	Yes [ ] No [X]	Attach Test Results

Non–Conformances: None

Description N/A

Corrective action required: Yes [ ] No [X]

If Yes, Corrective Action Report No.: ______

Test Performed by: J. Martin AGRA Earth & Environmental Date: 9/11/96

WNI Construction Manager: C. Abeyta Date: 9/20/96

Audit Review By:
WNI QA/QC Engineering Manager: M A Park Date: 10/1/96

AGRA
Earth & Environmental

AGRA Earth &
Environmental, Inc.
E 320 North Foothills Drive
Suite 600
Spokane Washington
U.S.A. 99207
Tel (509) 482-0104
Fax (509) 482-0202

September 18, 1996

Western Nuclear, Inc.
P.O. Box 358
Wellpinit, Washington 99040

Attention: Mr. Corn Abeyta

Regarding: Laboratory Determination of Aggregate Durability Rating
Test No. 7
Sherwood Mine Project

Dear Mr. Abeyta:

In accordance with your request, on September 11, 1996 we obtained a bulk sample of Quarry rock from the Sherwood site for laboratory analysis and Durability Rating determination at our Spokane laboratory. As of this date, that has been completed. All laboratory testing has been performed in accordance with the most current ASTM standards available, and in accordance with the project specifications.

The Durability Rating determination was performed according to Table D1 of the NRC's Staff Technical Position (STP) Design of Erosion Protection Covers for Stabilization of Uranium Mill Tailing Sites, August 1990. Table A shows the test results and calculations for Test No. 7. Additionally, the laboratory testing worksheets are attached for your records.

If there are any questions, or we may be of further assistance, please do not hesitate to contact us at (509) 482-0104.

Respectfully Submitted
AGRA EARTH & ENVIRONMENTAL, INC.

Jay C. Martin, SET
Laboratory Supervisor

Bob Arnold
Technical Director

TABLE A

ROCK TYPE: IGNEOUS - GRANITIC QUARTZ MONZANITE
ROCK SAMPLE: TEST NO. 7
AGRA LABORATORY SAMPLE # 672

Laboratory Test	Result	Score	Weight	Score x Weight	Maximum Score
Apparent Specific Gravity ASTM C127	2.66	N/A	N/A	N/A	N/A
Bulk Saturated Surface Dry Specific Gravity ASTM C127	2.64	N/A	N/A	N/A	N/A
Bulk Specific Gravity ASTM C127	2.63	7	9	63	90
Absorption, % ASTM C127	0.3	9	2	18	20
Sodium Sulfate Soundness, % Loss, ASTM C88	1.7	9	11	99	110
Schmidt Hammer Rebound Number ASTM C805	57.6	7	3	21	30
Total Score				**201**	**250**

DURABILITY RATING = 201 / 250 x 100 = 80

AGRA
Earth & Environmental
E. 520 North Foothills Drive, Suite 600
Spokane, Washington, U.S.A. 99207

Client: Western Nuclear
Date: 9-11-96 Lab No. 672

Project: Sherwood Mine
Proj. No.: 6-929-1396-0

Description: Quartz Monzonite
Test No.: 7

SPECIFIC GRAVITY AND/OR UNIT WEIGHT
ASTM C-127

COARSE AGGREGATE - SPECIFIC GRAVITY AND ABSORPTION

Mass of Sample in Air Dry		= 6577.7	Grams
Mass of Sample, SSD		= 6597.4	Grams
Mass of Sample in Water		= 4100.6	Grams
Aggregate	-Bulk Specific Gravity	= 2.63	
	Bulk Specific Gravity (SSD)	= 2.64	
	Apparent Specific Gravity	= 2.66	
	Absorption	= 0.3	(%)

SSD = SATURATED SURFACE DRY

Remarks:

Sampled by: J. Martin
Date: 9-11-96

Tested by: J. Martin
Date: 9-13-96

Reviewed by: Bob Alli
Date: 9/18/96

AGRA
Earth & Environmental
E. 520 North Foothills Drive, Suite 600
Spokane, Washington, U.S.A. 99207

SULFATE SOUNDNESS TEST
ASTM C-88

Client: Western Nuclear
Project: Sherwood Mine
Description: Quartz Monzonite

Date: 9-11-96
Lab No. 672
Proj. No.: 6-929-1396-0
Test No.: 7

SIEVE SIZE	INDIVIDUAL GRADING % RETAINED	WEIGHT BEFORE TEST (GRAMS)	WEIGHT AFTER TEST (GRAMS)	PERCENT LOSS AFTER TEST (%)	WEIGHTED % LOSS
2 ½" TO 2" 2" TO 1 ½"	38.7 25.6	3012.7 1990.8	4963.5	0.8	0.5
1 ½" TO 1" 1" TO 3/4"	12.9 6.4	1006.5 499.9	1468.7	2.5	0.5
3/4" TO 1"					
3/4" TO ½" ½" TO 3/8"	8.3 4.2	650.4 325.8	945.0	3.2	0.4
3/8" TO #4	3.9	303.3	280.0	7.7	0.3
TOTAL	100.0	7789.4			1.7

SOLUTION TEMP: 72 OVEN TEMP: 230°F SPECIFIC GRAVITY: 1.162 TYPE OF SALT: Sodium

QUALITIVE EXAMINATION OF COARSE SIZES

SIEVE SIZE	SPLITTING	DISINTEGRATION	CRACKING	FLAKING	#OF PARTICLES
1 ½" TO 1"			1		24
1" TO 3/4"	1				29

CYCLE NO.	DATE	TIME	IN SOLUTION		OUT SOLUTION		IN OVEN		OUT OVEN			
1	9-12		9-12	1815	9-13	1130	9-13	1145	9-13	1545		
2			9-13	1645	9-14	10:35	9-14	1050	9-14	1450		
3			9-14	1650	9-15	1005	9-15	1020	9-15	1420		
4			9-15	1635	9-16	0950	9-16	1005	9-16	1405		
5			9-16	1650	9-17	1020	9-17	1035	9-17	1435		

SAMPLED BY: J Martin
DATE: 9-11-96

TESTED BY: J. Martin / J. Johnson, B. Arnold
DATE: 9-17-96

REVIEWED BY: [signature]
DATE: 9/18/96

AGRA
Earth & Environmental
E. 520 North Foothills Drive, Suite 600
Spokane, Washington, U.S.A. 99207

SCHMIDT HAMMER TEST
ASTM C-805

Test No: 7

Client: Western Nuclear — Date: 9-11-96 — Lab No. 672

Project: Sherwood Mine — Proj. No.: 6-929-1396-0

Sample location: Quarry

Surface characteristics: Specimens were Saw-cut

	Sample A/Rebound Number	Sample B/Rebound Number
1.	58	58
2.	57	58
3.	57	58
4.	58	58
5.	57	57
6.	57	58
7.	57	58
8.	57	58
9.	58	58
10.	57	58

Sample A Avg: 57.3

Sample B Avg: 57.9

Grand average rebound number 57.6

Remarks: Schmidt Hammer - Model N-34, Serial No 137281

Sampled By: J. Martin — Date: 9-11-96

Test Performed By: J. Martin — Date: 9-12-96

Reviewed By: [signature] — Date: 9/18/96

TABLE [illegible]

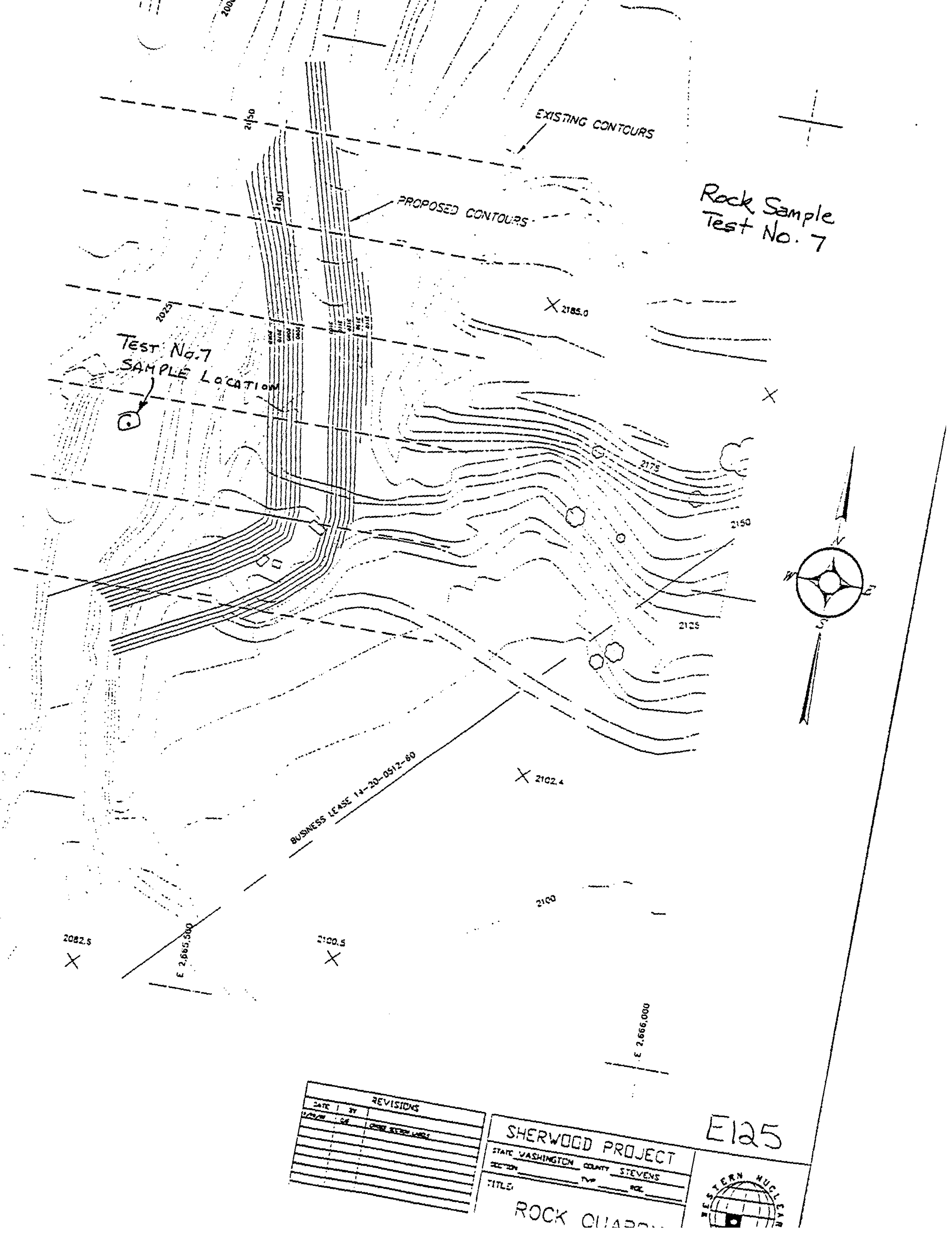
Scoring Criteria for Determining Rock Quality

Laboratory Test	Weighting Factor			Score										
	Limestone	Sandstone	Igneous	10	9	8	7	6	5	4	3	2	1	0
					Good			Fair			Poor			
Sp. Gravity	12	6	9	2.75	2.70	2.65	2.60	2.55	2.50	2.45	2.40	2.35	2.40	2.25
Absorption, %	13	5	2	.1	.3	.5	.67	.83	1.0	1.5	2.0	2.5	3.0	3.5
Sodium Sulfate, %	4	3	11	1.0	3.0	5.0	6.7	8.3	10.0	12.5	15.0	20.0	25.0	30.0
L/A Abrasion (100 revs), %	1	8	1	1.0	3.0	5.0	6.7	8.3	10.0	12.5	15.0	20.0	25.0	30.0
Schmidt Hammer	11	13	3	70.0	65.0	60.0	54.0	47.0	40.0	32.0	24.0	16.0	8.0	0.0
Tensile Strength, psi	6	4	10	1400	1200	1000	833	666	500	400	300	200	100	0

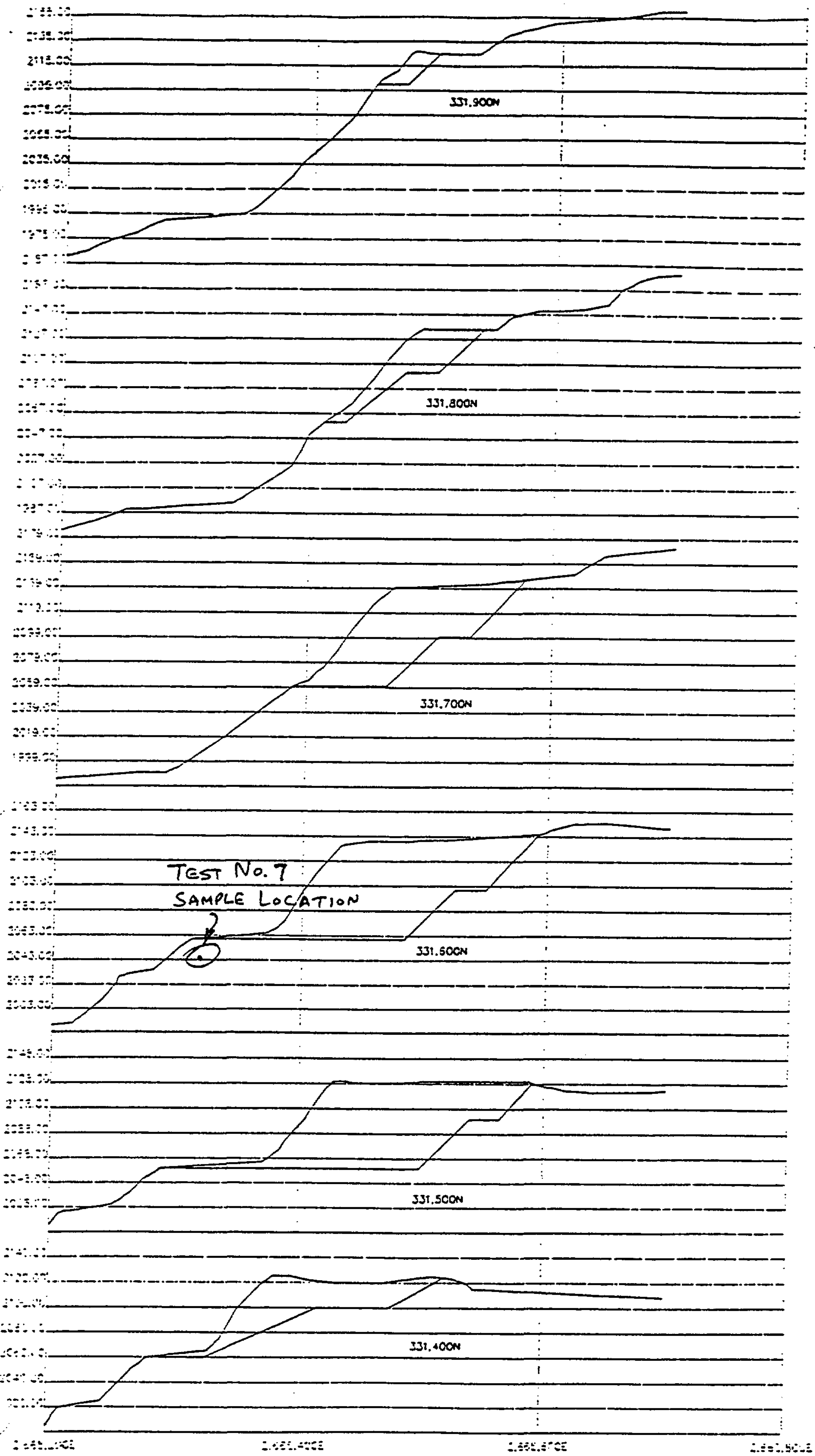
1. Scores were derived from Tables 6.2, 6.5, and 6.7 of NUREG/CR-2642 - "Long-Term Survivability of Riprap for Armoring Uranium Mill Tailings and Covers: A Literature Review," 1982 (see Ref. D13).

2. Weighting Factors are derived from Table 7 of "Petrographic Investigations of Rock Durability and Comparisons of Various Test Procedures," by G. W. DuPuy, Engineering Geology, July, 1965 (see Ref. D15). Weighting factors are based on inverse of ranking of test methods for each rock type. Other tests may be used; weighting factors for these tests may be derived using Table 7, by counting upward from the bottom of the table.

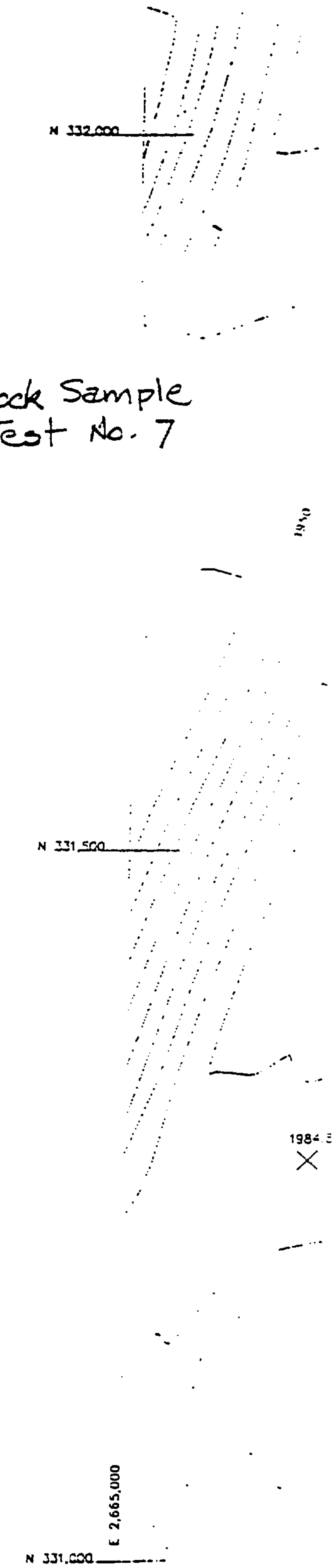
3. Test methods should be standardized, if a standard test is available and should be those used in NUREG/CR-2642 (see Ref. D13), so that proper correlations can be made. This is particularly important for the tensile strength test, where several methods may be used; the method discussed by Nilsson (1962, see Ref. D16) for tensile strength was used in the scoring procedure.



EXISTING CONTOURS
PROPOSED CONTOURS
Rock Sample
Test No. 7
Test No.7
SAMPLE Location
2185.0
2175
2150
2125
2102.4
2100
2082.5
2100.5
BUSINESS LEASE 14-20-0512-60
E 2,665,500
E 2,666,000
REVISIONS
DATE
BY
SHERWOOD PROJECT
STATE WASHINGTON
COUNTY STEVENS
SECTION
TWP
RGE
TITLE:
ROCK QUARRY
E125
WESTERN NUCLEAR



VOLUME: 125,000CY



E126

DATE OF

WESTERN NUCLEAR, INC. – SHERWOOD TAILINGS RECLAMATION QUALITY COMPLIANCE REPORT

Rock Durability Test

DATE : 9/20/96

DOCUMENT : RD – 8

SHEET : 1 of 18

SPECIFICATION REFERENCE Table 3

Construction Segment: Rock Production

Rock Source: Rock Quarry – Quartz Monzonite – Sherwood Mine

Frequency of Rock Durability Testing: One test series prior to placement and one test series for every 10,000 CY of material produced from the rock source.

Acceptance Criteria : Rock shall have a minimum durability rating of 80.
Rock having a durability rating of less than 80 shall require oversizing.
For oversizing, refer to Specification Reference : Page TS–39, 5.2.2

Rock Durability

Test Date	Test No.	Cum. Vol. Produced	Rating	Oversize	
9/12/96	8	60,000 yd³	80	Yes [ ] No [X]	Attach Test Results

Non–Conformances: NONE

Description N/A

Corrective action required: Yes [ ] No [X]

If Yes, Corrective Action Report No.: ________

Test Performed by: J. Martin - AGRA Earth & Environmental Date: 9/12/96

WNI Construction Manager: C. Abeyta Date: 9/20/96

Audit Review By:
WNI QA/QC Engineering Manager: [signature] Date: 10/16/96

07/25/96

E127

AGRA
Earth & Environmental

AGRA Earth &
Environmental, Inc.
[illegible]
Tel [illegible]
Fax [illegible]

September 18 , 1996

Western Nuclear, Inc.
P.O. Box 358
Wellpinit, Washington 99040

Attention: Mr. Corn Abeyta

Regarding: Laboratory Determination of Aggregate Durability Rating
Test No. 8
Sherwood Mine Project

Dear Mr. Abeyta:

In accordance with your request, on September 11, 1996 we obtained a bulk sample of Quarry rock from the Sherwood site for laboratory analysis and Durability Rating determination at our Spokane laboratory. As of this date, that has been completed. All laboratory testing has been performed in accordance with the most current ASTM standards available, and in accordance with the project specifications.

The Durability Rating determination was performed according to Table D1 of the NRC's Staff Technical Position (STP) Design of Erosion Protection Covers for Stabilization of Uranium Mill Tailing Sites, August 1990. Table A shows the test results and calculations for Test No. 8. Additionally, the laboratory testing worksheets are attached for your records.

If there are any questions, or we may be of further assistance, please do not hesitate to contact us at (509) 482-0104.

Respectfully Submitted
AGRA EARTH & ENVIRONMENTAL, INC.

Jay C. Martin, SET
Laboratory Supervisor

Bob Arnold
Technical Director

TABLE A

ROCK TYPE: IGNEOUS - GRANITIC QUARTZ MONZANITE
ROCK SAMPLE: TEST NO. 8
AGRA LABORATORY SAMPLE # 673

Laboratory Test	Result	Score	Weight	Score x Weight	Maximum Score
Apparent Specific Gravity ASTM C127	2.66	N/A	N/A	N/A	N/A
Bulk Saturated Surface Dry Specific Gravity ASTM C127	2.64	N/A	N/A	N/A	N/A
Bulk Specific Gravity ASTM C127	2.63	7	9	63	90
Absorption, % ASTM C127	0.3	9	2	18	20
Sodium Sulfate Soundness, % Loss, ASTM C88	1.7	9	11	99	110
Schmidt Hammer Rebound Number ASTM C805	57.5	7	3	21	30
Total Score				**201**	**250**

DURABILITY RATING = 201 / 250 x 100 = 80

AGRA
Earth & Environmental
E. 520 North Foothills Drive, Suite 600
Spokane, Washington, U.S.A. 99207

Client: Western Nuclear | Date: 9-11-96 | Lab No. 673

Project: Sherwood Mine | Proj. No.: 6-929-1396-0

Description: Quartz Monzanite | Test No.: 8

SPECIFIC GRAVITY AND/OR UNIT WEIGHT
ASTM C-127

COARSE AGGREGATE - SPECIFIC GRAVITY AND ABSORPTION

Mass of Sample in Air Dry	=	5897.0	Grams
Mass of Sample, SSD	=	5915.3	Grams
Mass of Sample in Water	=	3675.6	Grams
Aggregate -Bulk Specific Gravity	=	2.63	
Bulk Specific Gravity (SSD)	=	2.64	
Apparent Specific Gravity	=	2.66	
Absorption	=	0.3	(%)

SSD = SATURATED SURFACE DRY

Remarks:

Sampled by: J. Martin | Date: 9-11-96

Tested by: J. Martin | Date: 9-13-96

Reviewed by: [signature] | Date: 9/18/96

E130

AGRA
Earth & Environmental
E. 520 North Foothills Drive, Suite 600
Spokane, Washington, U.S.A. 99207

SULFATE SOUNDNESS TEST
ASTM C-88

Client: Western Nuclear
Project: Sherwood Mine
Description: Quartz Monzanite

Date: 9-11-96 Lab No. 673
Proj. No.: 6-929-1396-0
Test No.: 8

SIEVE SIZE	INDIVIDUAL GRADING % RETAINED	WEIGHT BEFORE TEST (GRAMS)	WEIGHT AFTER TEST (GRAMS)	PERCENT LOSS AFTER TEST (%)	WEIGHTED % LOSS
2 ½" TO 2" 2" TO 1 ½"	38.5 25.5	3000.7 1990.8	4946.6	0.9	0.6
1 ½" TO 1" 1" TO 3/4"	12.9 6.4	1004.9 502.6	1475.8	2.1	0.4
3/4" TO 1"					
3/4" TO ½" ½" TO 3/8"	8.4 4.3	658.7 334.7	961.6	3.2	0.4
3/8" TO #4	3.9	301.0	277.8	7.7	0.3
TOTAL	99.9	7793.4			1.7

SOLUTION TEMP: 72 OVEN TEMP: 230°F SPECIFIC GRAVITY: 1.162 TYPE OF SALT: Sodium

QUALITIVE EXAMINATION OF COARSE SIZES

SIEVE SIZE	SPLITTING	DISINTEGRATION	CRACKING	FLAKING	#OF PARTICLES
1 ½" TO 1"	1		1		20
1" TO 3/4"	2				22

CYCLE NO.	DATE	TIME	IN SOLUTION		OUT SOLUTION		IN OVEN		OUT OVEN			
1	9-12		9-12	1815	9-13	1130	9-13	1145	9-13	1545		
2			9-13	1645	9-14	1035	9-14	1050	9-14	1450		
3			9-14	1650	9-15	1005	9-15	1020	9-15	1420		
4			9-15	1635	9-16	0950	9-16	1005	9-16	1405		
5			9-16	1650	9-17	1020	9-17	1035	9-17	1435		

SAMPLED BY: J. Martin TESTED BY: J. Martin / J. Johnson, B. Arnold REVIEWED BY: [signature]

DATE: 9-11-96 DATE: 9-17-96 DATE: 9/18/96

AGRA
Earth & Environmental
E. 520 North Foothills Drive, Suite 600
Spokane, Washington, U.S.A. 99207

SCHMIDT HAMMER TEST
ASTM C-805

Test No: 8

Client: Western Nuclear Date: 9-11-96 Lab No. 673
Project: Sherwood Mine Proj. No.: 6-929-1396-0
Sample location: Quarry
Surface characteristics: Specimans were Saw-cut

	Sample A/Rebound Number	Sample B/Rebound Number
1.	58	57
2.	57	57
3.	58	58
4.	58	58
5.	57	58
6.	57	58
7.	57	58
8.	57	57
9.	58	57
10.	58	57

Sample A Avg: 57.5

Sample B Avg: 57.5

Grand average rebound number 57.5

Remarks: Schmidt Hammer - Model N-34, Serial No. 137281

Sampled By: J. Martin Date: 9-11-96

Te[st P]erformed By: J. Martin Date: 9-12-96

Reviewed By: [signature] Date: 9/18/96

E132

TABLE [illegible]

Scoring Criteria for Determining Rock Quality

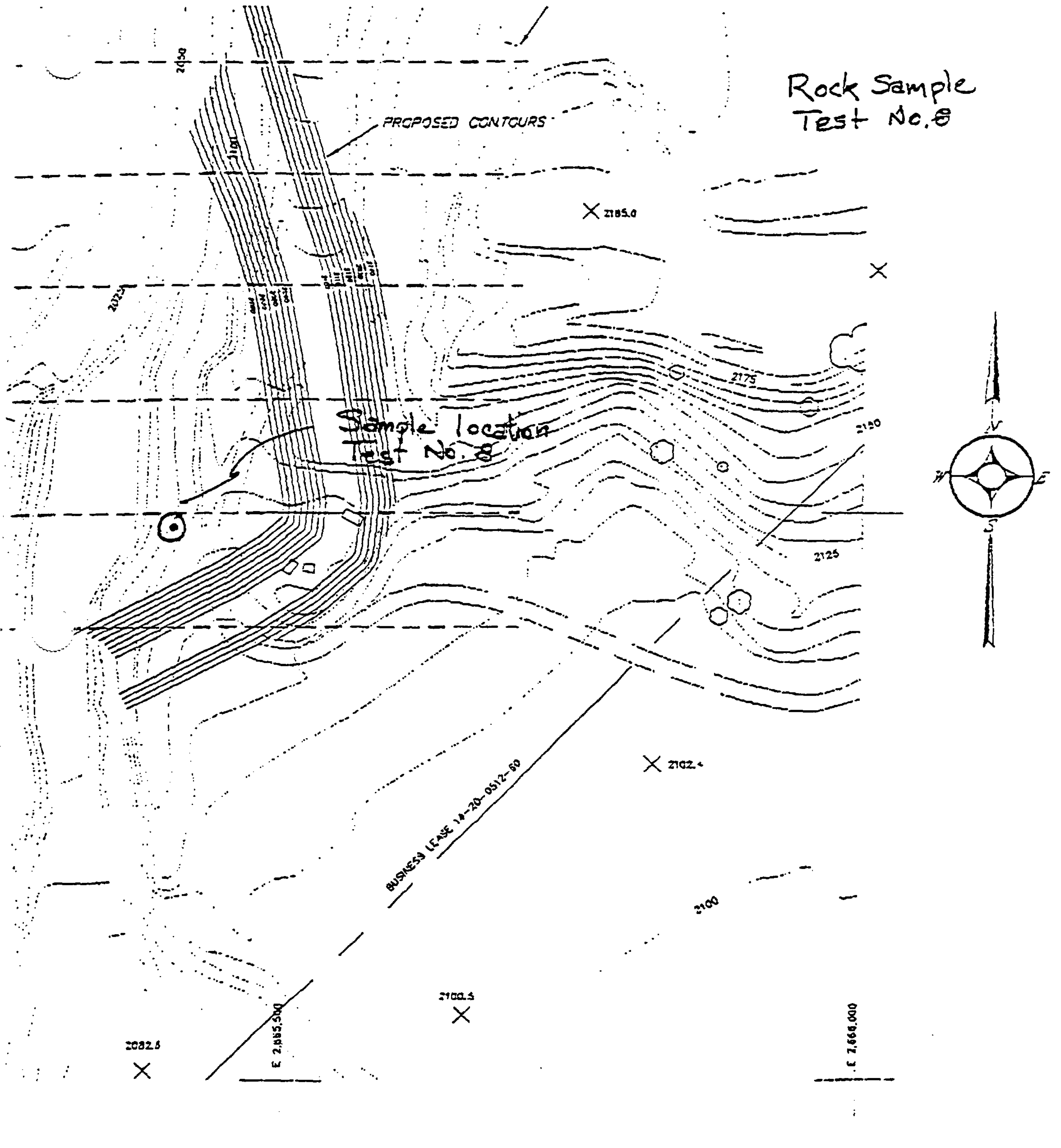
Laboratory Test	Weighting Factor			Score										
	Limestone	Sandstone	Igneous	10	9	8	7	6	5	4	3	2	1	0
					Good			Fair			Poor			
Sp. Gravity	12	6	9	2.75	2.70	2.65	2.60	2.55	2.50	2.45	2.40	2.35	2.40	2.25
Absorption, %	13	5	2	.1	.3	.5	.67	.83	1.0	1.5	2.0	2.5	3.0	3.5
Sodium Sulfate, %	4	3	11	1.0	3.0	5.0	6.7	8.3	10.0	12.5	15.0	20.0	25.0	30.0
L/A Abrasion (100 revs), %	1	8	1	1.0	3.0	5.0	6.7	8.3	10.0	12.5	15.0	20.0	25.0	30.0
Schmidt Hammer	11	13	3	70.0	65.0	60.0	54.0	47.0	40.0	32.0	24.0	16.0	8.0	0.0
Tensile Strength, psi	6	4	10	1400	1200	1000	833	666	500	400	300	200	100	0

1. Scores were derived from Tables 6.2, 6.5, and 6.7 of NUREG/CR-2642 - "Long-Term Survivability of Riprap for Armoring Uranium Mill Tailings and Covers: A Literature Review," 1982 (see Ref. D13).

2. Weighting Factors are derived from Table 7 of "Petrographic Investigations of Rock Durability and Comparisons of Various Test Procedures," by G. W. DuPuy, Engineering Geology, July, 1965 (see Ref. D15). Weighting factors are based on inverse of ranking of test methods for each rock type. Other tests may be used; weighting factors for these tests may be derived using Table 7, by counting upward from the bottom of the table.

3. Test methods should be standardized, if a standard test is available and should be those used in NUREG/CR-2642 (see Ref. D13), so that proper correlations can be made. This is particularly important for the tensile strength test, where several methods may be used; the method discussed by Nilsson (1962, see Ref. D16) for tensile strength was used in the scoring procedure.

E133



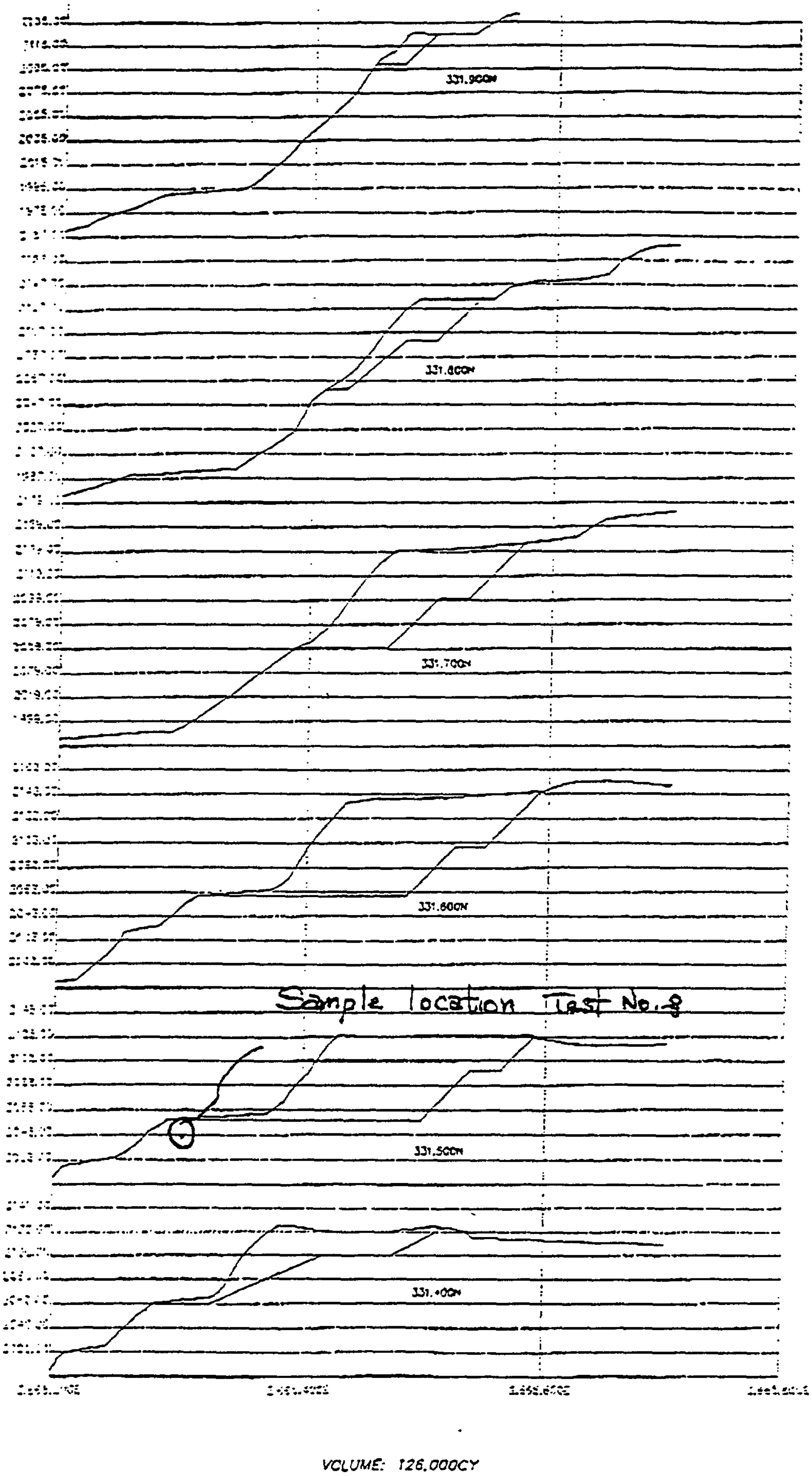
REVISIONS		
DATE	BY	

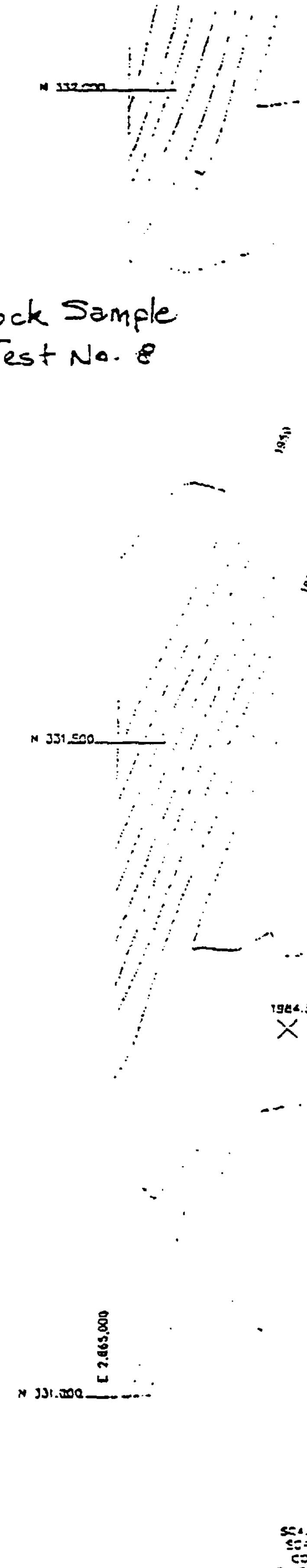
SHERWOOD PROJECT
STATE VASHINGTON COUNTY STEVENS
SECTION TWP. RGE.
TITLE: ROCK QUARRY

WESTERN NUCLEAR INC

16-93

E134


331.900N
331.800N
331.700N
331.600N
Sample location Test No. 8
331.500N
331.400N
VOLUME: 126,000CY


N 332,000
Rock Sample
Test No. 8
N 331,500
1984.2
E 2,865,000
N 331,000
DATE OF

E135

WESTERN NUCLEAR, INC. – SHERWOOD TAILINGS RECLAMATION QUALITY COMPLIANCE REPORT

Rock Durability Test

DATE : 9/30/96

DOCUMENT : RD – 9

SHEET : 1 of 9

SPECIFICATION REFERENCE Table 3

Construction Segment: Rock Production

Rock Source: Rock Quarry - Quartz Monzonite - Sherwood MINE

Frequency of Rock Durability Testing: One test series prior to placement and one test series for every 10,000 CY of material produced from the rock source.

Acceptance Criteria : Rock shall have a minimum durability rating of 80.
Rock having a durability rating of less than 80 shall require oversizing.
For oversizing, refer to Specification Reference : Page TS–39, 5.2.2

Rock Durability

Test Date	Test No.	Cum. Vol. Produced	Rating	Oversize	
9/26/96	9	70,000 yd^3	81	Yes ☐ No ☒	**Attach Test Results**

Non–Conformances: None

Description N/A

Corrective action required: Yes ☐ No ☒

If Yes, Corrective Action Report No.: ____________

Test Performed by: J. Martin, AGRA Earth & Environmental **Date:** 9/26/96

WNI Construction Manager: C. Abeyta **Date:** 9/30/96

Audit Review By:
WNI QA/QC Engineering Manager: MA Bosh **Date:** 10/16/96

07/25/96

E136

AGRA
Earth & Environmental

AGRA Earth &
Environmental, Inc.
E 520 North Foothills Drive
Suite 600
Spokane, Washington
U.S.A. 99207
Tel (509) 482-0104
Fax (509) 482-0202

September 30, 1996

Western Nuclear, Inc.
P.O. Box 358
Wellpinit, Washington 99040

Attention: Mr. Corn Abeyta

Regarding: Laboratory Determination of Aggregate Durability Rating
Test No. 9
Sherwood Mine Project

Dear Mr. Abeyta:

In accordance with your request, on September 24, 1996 we obtained a bulk sample of Quarry rock from the Sherwood site for laboratory analysis and Durability Rating determination at our Spokane laboratory. As of this date, that has been completed. All laboratory testing has been performed in accordance with the most current ASTM standards available, and in accordance with the project specifications.

The Durability Rating determination was performed according to Table D1 of the NRC's Staff Technical Position (STP) Design of Erosion Protection Covers for Stabilization of Uranium Mill Tailing Sites, August 1990. Table A shows the test results and calculations for Test No. 9. Additionally, the laboratory testing worksheets are attached for your records.

If there are any questions, or we may be of further assistance, please do not hesitate to contact us at (509) 482-0104.

Respectfully Submitted
AGRA EARTH & ENVIRONMENTAL, INC.

Jay C. Martin, SET
Laboratory Supervisor

Bob Arnold
Technical Director

TABLE A

ROCK TYPE: IGNEOUS - GRANITIC QUARTZ MONZANITE
ROCK SAMPLE: TEST NO. 9
AGRA LABORATORY SAMPLE # 677

Laboratory Test	Result	Score	Weight	Score x Weight	Maximum Score
Apparent Specific Gravity ASTM C127	2.67	N/A	N/A	N/A	N/A
Bulk Saturated Surface Dry Specific Gravity ASTM C127	2.65	N/A	N/A	N/A	N/A
Bulk Specific Gravity ASTM C127	2.64	7	9	63	90
Absorption, % ASTM C127	0.4	8	2	16	20
Sodium Sulfate Soundness, % Loss, ASTM C88	1.4	9	11	99	110
Schmidt Hammer Rebound Number ASTM C805	62.2	8	3	24	30
Total Score				**202** ✓	**250**

DURABILITY RATING = 202 / 250 x 100 = 81

AGRA Earth & Environmental

E138

AGRA
Earth & Environmental
E. 520 North Foothills Drive, Suite 600
Spokane, Washington, U.S.A. 99207

Client: Western Nuclear — Date: 9-24-96 — Lab No. 677

Project: Sherwood Mine — Proj. No.: 6-929-1396-0

Description: Quartz Monzonite — Test No.: 9

SPECIFIC GRAVITY AND/OR UNIT WEIGHT
ASTM C-127

COARSE AGGREGATE - SPECIFIC GRAVITY AND ABSORPTION

Mass of Sample in Air Dry	=	7578.0	Grams
Mass of Sample, SSD	=	7608.3	Grams
Mass of Sample in Water	=	4735.7	Grams
Aggregate -Bulk Specific Gravity	=	2.64	
Bulk Specific Gravity (SSD)	=	2.65	
Apparent Specific Gravity	=	2.67	
Absorption	=	0.4	(%)

SSD = SATURATED SURFACE DRY

Remarks:

Sampled by: J. Martin — Date: 9-24-96

Tested by: J. Martin — Date: 9-26-96

ïewed by: Bob Bell — Date: 9/30/96

AGRA
Earth & Environmental
E. 520 North Foothills Drive, Suite 600
Spokane, Washington, U.S.A. 99207

SULFATE SOUNDNESS TEST
ASTM C-88

Client: Western Nuclear
Project: Sherwood Mine
Description: Quartz Monzanite

Date: 9/24/96 Lab No. 677
Proj. No.: 6-929-1396-0
Test No.: 9

SIEVE SIZE	INDIVIDUAL GRADING % RETAINED	WEIGHT BEFORE TEST (GRAMS)	WEIGHT AFTER TEST (GRAMS)	PERCENT LOSS AFTER TEST (%)	WEIGHTED % LOSS
2 ½" TO 2" 2" TO 1 ½"	38.4 25.6	2996.0 2001.5	4957.5	0.8	0.5
1 ½" TO 1" 1" TO 3/4"	12.8 6.5	1000.6 5113	1480.2 ~~1629.8~~	2.1	0.4
3/4" TO 1"					
3/4" TO ½" ½" TO 3/8"	8.6 4.2	671.1 328.7	976.8	2.3	0.3
3/8" TO #4	3.8	300.0	284.1	5.3	0.2
TOTAL		7809.2			1.4

SOLUTION TEMP: 72 OVEN TEMP: 230°F SPECIFIC GRAVITY: 1.159 TYPE OF SALT: Sodium

QUALITIVE EXAMINATION OF COARSE SIZES

SIEVE SIZE	SPLITTING	DISINTEGRATION	CRACKING	FLAKING	#OF PARTICLES
1 ½" TO 1"			2		24
1" TO 3/4"			1		31

CYCLE NO.	DATE	TIME	IN SOLUTION		OUT SOLUTION		IN OVEN		OUT OVEN			
1	9-25		9-25	1540	9-26	0805	9-26	0820	9-26	1220		
2			9-26	1530	9-27	0800	9-27	0815	9-27	1215		
3			9-27	1530	9-28	0730	9-28	0745	9-28	1145		
4			9-28	1400	9-29	0700	9-29	0715	9-29	1115		
5			9-29	1440	9-30	0840	9-30	0855	9-30	1255		

SAMPLED BY: J. Martin
DATE: 9-24-96

TESTED BY: J. Martin/C. Johnson B. Arnold
DATE: 9-30-96

REVIEWED BY: [signature]
DATE: 9/30/96

AGRA
Earth & Environmental
E. 520 North Foothills Drive, Suite 600
Spokane, Washington, U.S.A. 99207

SCHMIDT HAMMER TEST
ASTM C-805

Test No: 9

Client: Western Nuclear   Date: 9/24/96   Lab No. 677
Project: Sherwood Mine   Proj. No.: 6-929-1396-0
Sample location: Quarry
Surface characteristics: Saw-cut Specimens

	Sample A/Rebound Number	Sample B/Rebound Number
1.	63	62
2.	63	61
3.	63	61
4.	62	62
5.	62	62
6.	63	62
7.	62	62
8.	62	62
9.	62	63
10.	62	63

Sample A Avg: 62.4   Sample B Avg: 62.0

Grand average rebound number 62.2

Remarks: Schmidt Hammer- Model N-34, Serial No 137281

Sampled By: J. Martin   Date: 9-24-96

Test Performed By: J. Martin   Date: 9-27-96

Reviewed By: [signature]   Date: 9/30/96

TABLE 1

Scoring Criteria for Determining Rock Quality

Laboratory Test	Weighting Factor			Score										
	Limestone	Sandstone	Igneous	10	9 Good	8	7	6 Fair	5	4	3 Poor	2	1	0
Sp. Gravity	12	6	9	2.75	2.70	2.65	2.60	2.55	2.50	2.45	2.40	2.35	2.40	2.25
Absorption, %	13	5	2	.1	.3	.5	.67	.83	1.0	1.5	2.0	2.5	3.0	3.5
Sodium Sulfate, %	4	3	11	1.0	3.0	5.0	6.7	8.3	10.0	12.5	15.0	20.0	25.0	30.0
L/A Abrasion (100 revs), %	1	8	1	1.0	3.0	5.0	6.7	8.3	10.0	12.5	15.0	20.0	25.0	30.0
Schmidt Hammer	11	13	3	70.0	65.0	60.0	54.0	47.0	40.0	32.0	24.0	16.0	8.0	0.0
Tensile Strength, psi	6	4	10	1400	1200	1000	833	666	500	400	300	200	100	0

1. Scores were derived from Tables 6.2, 6.5, and 6.7 of NUREG/CR-2642 - "Long-Term Survivability of Riprap for Armoring Uranium Mill Tailings and Covers: A Literature Review," 1982 (see Ref. D13).

2. Weighting Factors are derived from Table 7 of "Petrographic Investigations of Rock Durability and Comparisons of Various Test Procedures," by G. W. DuPuy, Engineering Geology, July, 1965 (see Ref. D15). Weighting factors are based on inverse of ranking of test methods for each rock type. Other tests may be used; weighting factors for these tests may be derived using Table 7, by counting upward from the bottom of the table.

3. Test methods should be standardized, if a standard test is available and should be those used in NUREG/CR-2642 (see Ref. D13), so that proper correlations can be made. This is particularly important for the tensile strength test, where several methods may be used; the method discussed by Nilsson (1962, see Ref. D16) for tensile strength was used in the scoring procedure.

E-42

E143

REVISIONS		
DATE	BY	

SHERWOOD PROJECT

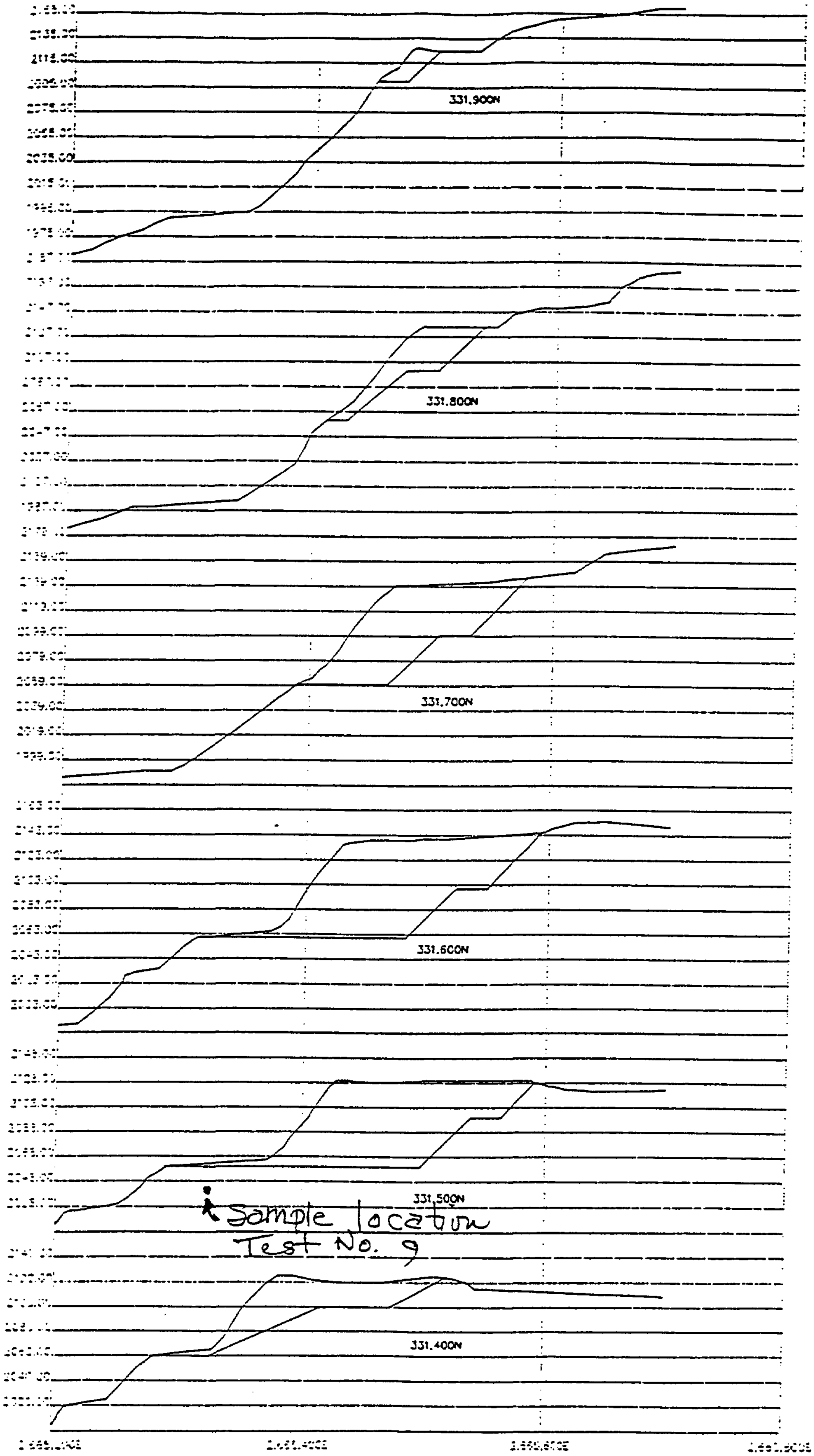
STATE WASHINGTON COUNTY STEVENS

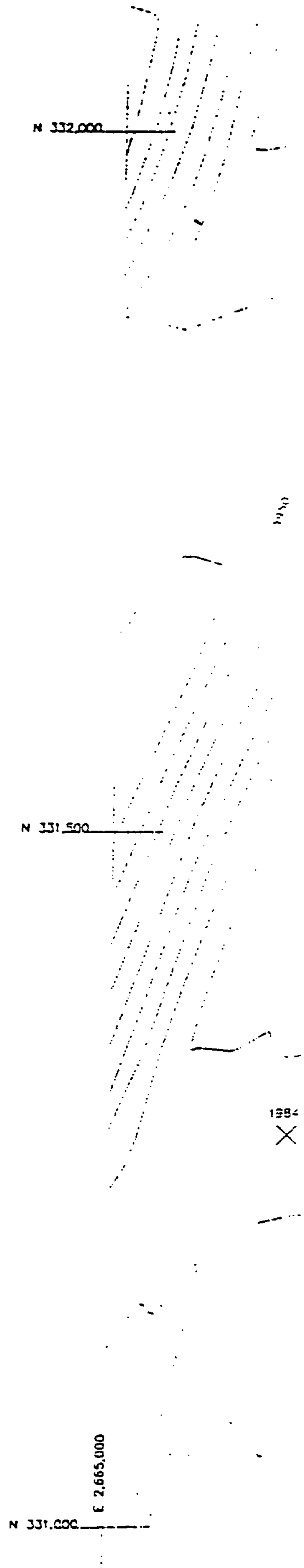
SECTION TWP RGE.

TITLE: ROCK QUARRY

WESTERN NUCLEAR INC.

5'
5-16-93





VOLUME: 126,000CY

E144

DATE OF A

WESTERN NUCLEAR, INC. – SHERWOOD TAILINGS RECLAMATION QUALITY COMPLIANCE REPORT

Rock Durability Test

DATE: 9/30/96

DOCUMENT: RD – 10

SHEET: 1 OF 9

SPECIFICATION REFERENCE Table 3

Construction Segment: Rock Production

Rock Source:

Frequency of Rock Durability Testing: One test series prior to placement and one test series for every 10,000 CY of material produced from the rock source.

Acceptance Criteria: Rock shall have a minimum durability rating of 80.
Rock having a durability rating of less than 80 shall require oversizing.
For oversizing, refer to Specification Reference : Page TS–39, 5.2.2

Rock Durability

Test Date	Test No.	Cum. Vol. Produced	Rating	Oversize	
9/27/96	10	80,000 yd3 (Qtz monzonite)	81	Yes ☐ No ☒	Attach Test Results

Non–Conformances: None

Description N/A

Corrective action required: Yes ☐ No ☒

If Yes, Corrective Action Report No.:

Test Performed by: J. Martin AGRA Earth & Environmental Date: 9/27/96

WNI Construction Manager: C. Abeyta Date: 9/30/96

Audit Review By:
WNI QA/QC Engineering Manager: [signature] Date: 10/16/96

07/25/96

E145

AGRA
Earth & Environmental

AGRA Earth &
Environmental, Inc.
E 520 North Foothills Drive
Suite 600
Spokane, Washington
U.S.A. 99207
Tel (509) 482-0104
Fax (509) 482-0202

September 30, 1996

Western Nuclear, Inc.
P.O. Box 358
Wellpinit, Washington 99040

Attention: Mr. Corn Abeyta

Regarding: Laboratory Determination of Aggregate Durability Rating
Test No. 10
Sherwood Mine Project

Dear Mr. Abeyta:

In accordance with your request, on September 24, 1996 we obtained a bulk sample of Quarry rock from the Sherwood site for laboratory analysis and Durability Rating determination at our Spokane laboratory. As of this date, that has been completed. All laboratory testing has been performed in accordance with the most current ASTM standards available, and in accordance with the project specifications.

The Durability Rating determination was performed according to Table D1 of the NRC's Staff Technical Position (STP) Design of Erosion Protection Covers for Stabilization of Uranium Mill Tailing Sites, August 1990. Table A shows the test results and calculations for Test No. 10. Additionally, the laboratory testing worksheets are attached for your records.

If there are any questions, or we may be of further assistance, please do not hesitate to contact us at (509) 482-0104.

Respectfully Submitted
AGRA EARTH & ENVIRONMENTAL, INC.

Jay C. Martin, SET
Laboratory Supervisor

Bob Arnold
Technical Director

E146

TABLE A

ROCK TYPE: IGNEOUS - GRANITIC QUARTZ MONZANITE
ROCK SAMPLE: TEST NO. 10
AGRA LABORATORY SAMPLE # 678

Laboratory Test	Result	Score	Weight	Score x Weight	Maximum Score
Apparent Specific Gravity ASTM C127	2.67	N/A	N/A	N/A	N/A
Bulk Saturated Surface Dry Specific Gravity ASTM C127	2.65	N/A	N/A	N/A	N/A
Bulk Specific Gravity ASTM C127	2.64	7	9	63	90
Absorption, % ASTM C127	0.4	8	2	16	20
Sodium Sulfate Soundness, % Loss, ASTM C88	1.5	9	11	99	110
Schmidt Hammer Rebound Number ASTM C805	61.9	8	3	24	30
Total Score				**202**	**250**

DURABILITY RATING = 202 / 250 x 100 = 81

AGRA
Earth & Environmental
E. 520 North Foothills Drive, Suite 600
Spokane, Washington, U.S.A. 99207

Client: Western Nuclear Date: 9-24-96 Lab No. 678

Project: Sherwood Mine Proj. No.: 6-929-1396-0

Description: Quartz Monzanite Test No.: 10

SPECIFIC GRAVITY AND/OR UNIT WEIGHT
ASTM C-127

COARSE AGGREGATE - SPECIFIC GRAVITY AND ABSORPTION

Mass of Sample in Air Dry		= 6071.8	Grams
Mass of Sample, SSD		= 6096.1	Grams
Mass of Sample in Water		= 3795.3	Grams
Aggregate	-Bulk Specific Gravity	= 2.64	
	Bulk Specific Gravity (SSD)	= 2.65	
	Apparent Specific Gravity	= 2.67	
	Absorption	= 0.4	(%)

SSD = SATURATED SURFACE DRY

Remarks:

Sampled by: J Martin Date: 9-24-96

Tested by: J Martin Date: 9-26-96

Reviewed by: [signature] Date: 9/30/96

AGRA
Earth & Environmental

E148

AGRA
Earth & Environmental
E. 520 North Foothills Drive, Suite 600
Spokane, Washington, U.S.A. 99207

SULFATE SOUNDNESS TEST
ASTM C-88

Client: Western Nuclear
Project: Sherwood Mine
Description: Quartz Monzanite

Date: 9/24/96 Lab No. 678
Proj. No.: 6-929-1396-0
Test No.: 10

SIEVE SIZE	INDIVIDUAL GRADING % RETAINED	WEIGHT BEFORE TEST (GRAMS)	WEIGHT AFTER TEST (GRAMS)	PERCENT LOSS AFTER TEST (%)	WEIGHTED % LOSS
2 ½" TO 2" 2" TO 1 ½"	38.4 25.6	3000.1 1999.5	4959.6	0.8	0.5
1 ½" TO 1" 1" TO 3/4"	12.8 6.4	1002.3 502.5	1473.2	2.1	0.4
3/4" TO 1"					
3/4" TO ½" ½" TO 3/8"	8.6 4.2	671.5 329.5	970.0	3.1	0.4
3/8" TO #4	3.8	299.5	283.6	5.3	0.2
TOTAL	99.8	7804.9			1.5

SOLUTION TEMP: 72 OVEN TEMP: 230°F SPECIFIC GRAVITY: 1.159 TYPE OF SALT: Sodium

QUALITIVE EXAMINATION OF COARSE SIZES

SIEVE SIZE	SPLITTING	DISINTEGRATION	CRACKING	FLAKING	#OF PARTICLES
1 ½" TO 1"			1		27
1" TO 3/4"	1				32

CYCLE NO.	DATE	TIME	IN SOLUTION		OUT SOLUTION		IN OVEN		OUT OVEN			
1	9-25		9-25	1540	9-26	0805	9-26	0820	9-26	1220		
2			9-26	1530	9-27	0800	9-27	0815	9-27	1215		
3			9-27	1530	9-28	0730	9-28	0745	9-28	1145		
4			9-28	1400	9-29	0700	9-29	0715	9-29	1115		
5			9-29	1440	9-30	0840	9-30	0855	9-30	1255		

SAMPLED BY: J. Martin
DATE: 9-24-96

TESTED BY: J. Martin / C. [illegible] B. Arnold
DATE: 9-30-96

REVIEWED BY: [signature]
DATE: 9/30/96

AGRA
Earth & Environmental
E149

AGRA
Earth & Environmental
E. 520 North Foothills Drive, Suite 600
Spokane, Washington, U.S.A. 99207

SCHMIDT HAMMER TEST
ASTM C-805

Test No: 10

Client: Western Nuclear
Date: 9/24/96 Lab No. 678
Project: Sherwood Mine
Proj. No.: 6-929-1396-0
Sample location: Quarry
Surface characteristics: Saw-cut Specimens

	Sample A/Rebound Number	Sample B/Rebound Number
1.	60	63
2.	61	62
3.	62	62
4.	61	62
5.	62	63
6.	62	62
7.	62	63
8.	61	62
9.	62	61
10.	62	62

Sample A Avg: 61.5
Sample B Avg: 62.2

Grand average rebound number 61.9

Remarks: Schmidt Hammer - Model N-34, Serial NO. 137281

Sampled By: J. Martin Date: 9-24-96

Test Performed By: J. Martin Date: 9-27-96

Reviewed By: [signature] Date: 9/30/96

TABLE D1

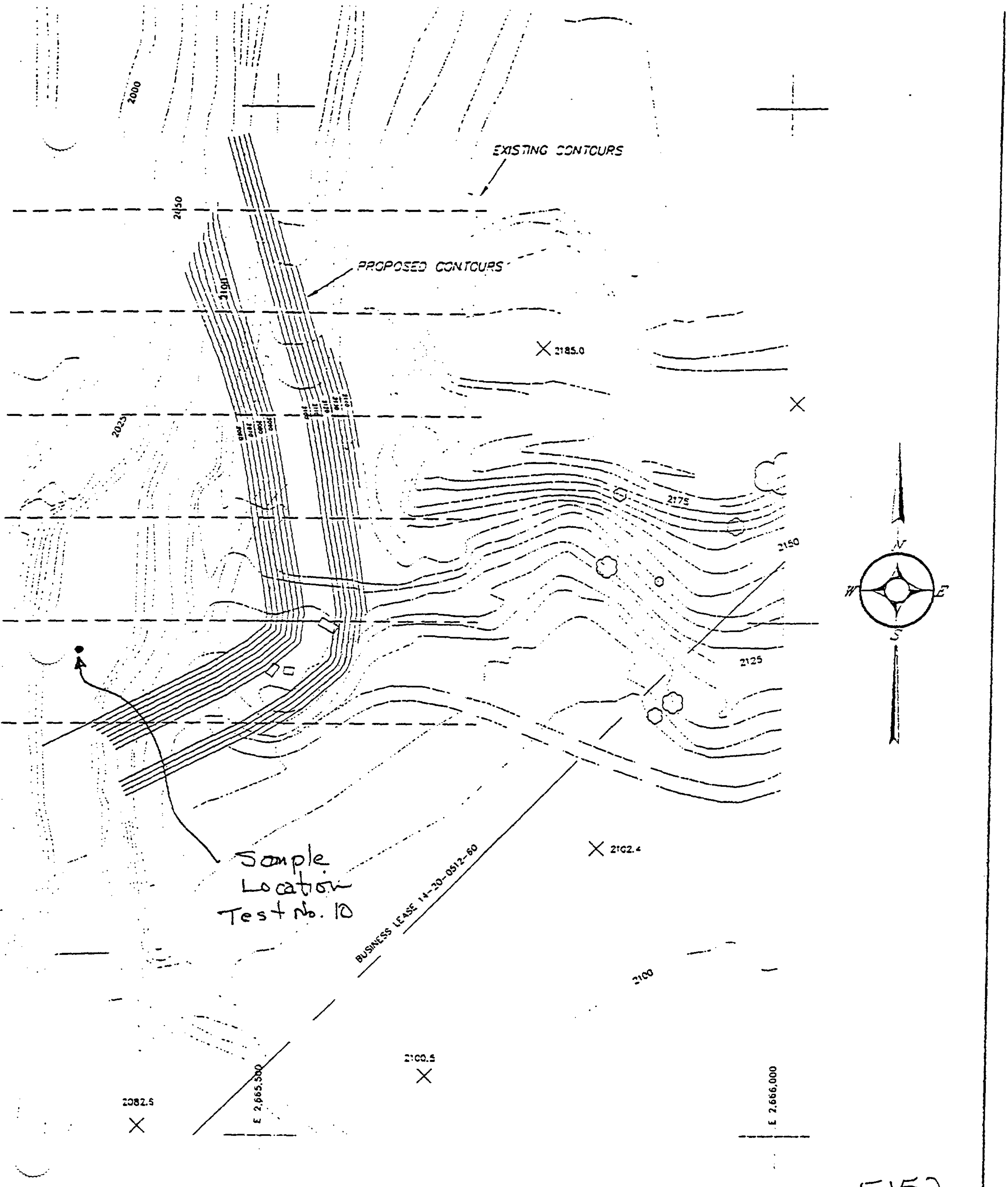
Scoring Criteria for Determining Rock Quality

Laboratory Test	Weighting Factor			Score										
	Limestone	Sandstone	Igneous	10	9	8	7	6	5	4	3	2	1	0
					Good			Fair			Poor			
Sp. Gravity	12	6	9	2.75	2.70	2.65	2.60	2.55	2.50	2.45	2.40	2.35	2.40	2.25
Absorption, %	13	5	2	.1	.3	.5	.67	.83	1.0	1.5	2.0	2.5	3.0	3.5
Sodium Sulfate, %	4	3	11	1.0	3.0	5.0	6.7	8.3	10.0	12.5	15.0	20.0	25.0	30.0
L/A Abrasion (100 revs), %	1	8	1	1.0	3.0	5.0	6.7	8.3	10.0	12.5	15.0	20.0	25.0	30.0
Schmidt Hammer	11	13	3	70.0	65.0	60.0	54.0	47.0	40.0	32.0	24.0	16.0	8.0	0.0
Tensile Strength, psi	6	4	10	1400	1200	1000	833	666	500	400	300	200	100	0

1. Scores were derived from Tables 6.2, 6.5, and 6.7 of NUREG/CR-2642 - "Long-Term Survivability of Riprap for Armoring Uranium Mill Tailings and Covers: A Literature Review," 1982 (see Ref. D13).

2. Weighting Factors are derived from Table 7 of "Petrographic Investigations of Rock Durability and Comparisons of Various Test Procedures," by G. W. DuPuy, Engineering Geology, July, 1965 (see Ref. D15). Weighting factors are based on inverse of ranking of test methods for each rock type. Other tests may be used; weighting factors for these tests may be derived using Table 7, by counting upward from the bottom of the table.

3. Test methods should be standardized, if a standard test is available and should be those used in NUREG/CR-2642 (see Ref. D13), so that proper correlations can be made. This is particularly important for the tensile strength test, where several methods may be used; the method discussed by Nilsson (1962, see Ref. D16) for tensile strength was used in the scoring procedure.



E152

REVISIONS		
DATE	BY	

SHERWOOD PROJECT

STATE WASHINGTON COUNTY STEVENS

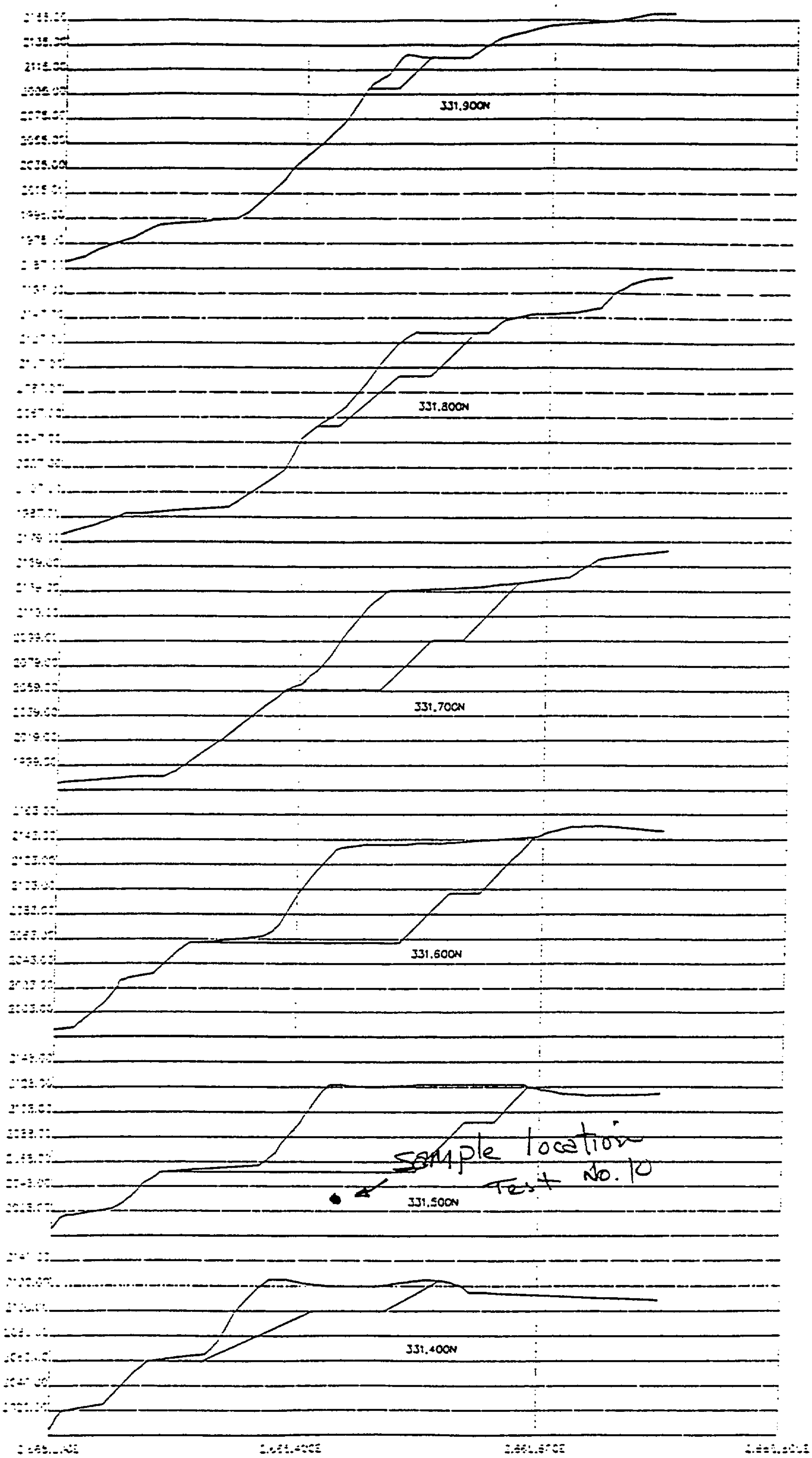
SECTION TWP RGE

TITLE:

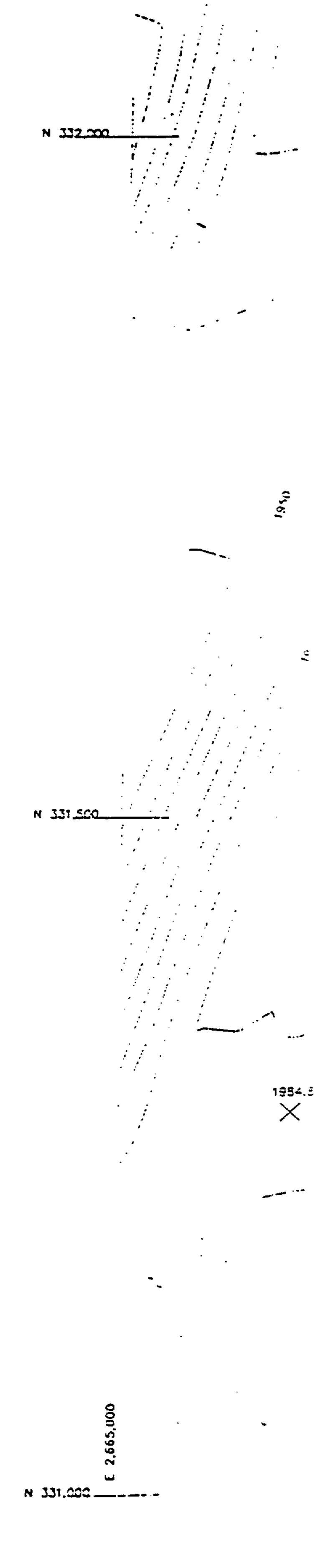
ROCK QUARRY

WESTERN NUCLEAR INC.

5-16-93



VOLUME: 125.000CY



E153

WESTERN NUCLEAR, INC. – SHERWOOD TAILINGS RECLAMATION
QUALITY COMPLIANCE REPORT

Rock Durability Test

DATE : Oct. 10, 1996

DOCUMENT : RD – 11

SHEET : 1 OF 9

SPECIFICATION REFERENCE Table 3

Construction Segment: Rock Production

Rock Source: Rock Quarry (Quartz Monzonite) – SHERWOOD MINE

Frequency of Rock Durability Testing: One test series prior to placement and one test series for every 10,000 CY of material produced from the rock source.

Acceptance Criteria : Rock shall have a minimum durability rating of 80.
Rock having a durability rating of less than 80 shall require oversizing.
For oversizing, refer to Specification Reference : Page TS–39, 5.2.2

Rock Durability

Test Date	Test No.	Cum. Vol. Produced	Rating	Oversize	
10/05/96	11	90,000 * (Qtz Monzonite) Based on loose Vol. produced.	80	Yes [ ] No [X]	Attach Test Results

*Note: Cumulative volumes include oversize reject estimated

Non–Conformances: None

Description N/A

Corrective action required: Yes [ ] No [X]

If Yes, Corrective Action Report No.: ________

Test Performed by: Jay Martin – AGRA Earth & Environmental Date: 10/10/96

WNI Construction Manager: C. Abeyta Date: 10/10/96

Audit Review By:
WNI QA/QC Engineering Manager: [signature] Date: 10/16/96

07/25/96

E154

AGRA
Earth & Environmental

AGRA Earth &
Environmental, Inc.
E 520 North Foothills Drive
Suite 800
Spokane, Washington
U.S.A. 99207
Tel (509) 482-0104
Fax (509) 482-0202

October 10, 1996

Western Nuclear, Inc.
P.O. Box 358
Wellpinit, Washington 99040

Attention: Mr. Corn Abeyta

Regarding: Laboratory Determination of Aggregate Durability Rating
Test No. 11
Sherwood Mine Project

Dear Mr. Abeyta:

In accordance with your request, on October 3, 1996 we obtained a bulk sample of Quarry rock from the Sherwood site for laboratory analysis and Durability Rating determination at our Spokane laboratory. As of this date, that has been completed. All laboratory testing has been performed in accordance with the most current ASTM standards available, and in accordance with the project specifications.

The Durability Rating determination was performed according to Table D1 of the NRC's Staff Technical Position (STP) Design of Erosion Protection Covers for Stabilization of Uranium Mill Tailing Sites, August 1990. Table A shows the test results and calculations for Test No.11. Additionally, the laboratory testing worksheets are attached for your records.

If there are any questions, or we may be of further assistance, please do not hesitate to contact us at (509) 482-0104.

Respectfully Submitted
AGRA EARTH & ENVIRONMENTAL, INC.

Jay C. Martin, SET
Laboratory Supervisor

Bob Arnold
Technical Director

TABLE A

ROCK TYPE: IGNEOUS - GRANITIC QUARTZ MONZANITE
ROCK SAMPLE: TEST NO. 11
AGRA LABORATORY SAMPLE # 683

Laboratory Test	Result	Score	Weight	Score x Weight	Maximum Score
Apparent Specific Gravity ASTM C127	2.64	N/A	N/A	N/A	N/A
Bulk Saturated Surface Dry Specific Gravity ASTM C127	2.63	N/A	N/A	N/A	N/A
Bulk Specific Gravity ASTM C127	2.62	7	9	63	90
Absorption, % ASTM C127	0.3	9	2	18	20
Sodium Sulfate Soundness, % Loss, ASTM C88	2.2	9	11	99	110
Schmidt Hammer Rebound Number ASTM C805	57.0	7	3	21	30
Total Score				**201**	**250**

DURABILITY RATING = 201 / 250 x 100 = 80

AGRA
Earth & Environmental
E. 520 North Foothills Drive, Suite 600
Spokane, Washington, U.S.A. 99207

Client: Western Nuclear Date: 10-3-96 Lab No. 683

Project: Sherwood Mine Proj. No.: 6-929-1396-0

Description: Quartz Monzonite Test No.: 11

SPECIFIC GRAVITY AND/OR UNIT WEIGHT
ASTM C-127

COARSE AGGREGATE - SPECIFIC GRAVITY AND ABSORPTION

Mass of Sample in Air Dry	=	5540.2	Grams
Mass of Sample, SSD	=	5556.8	Grams
Mass of Sample in Water	=	3445.4	Grams
Aggregate -Bulk Specific Gravity	=	2.62	
Bulk Specific Gravity (SSD)	=	2.63	
Apparent Specific Gravity	=	2.64	
Absorption	=	0.3	(%)

SSD = SATURATED SURFACE DRY

Remarks:

Sampled by: S. Martin Date: 10-3-96

Tested by: S. Martin Date: 10-6-96

Reviewed by: Bob Abl Date: 10/10/96

AGRA
Earth & Environmental
E. 520 North Foothills Drive, Suite 600
Spokane, Washington, U.S.A. 99207

SULFATE SOUNDNESS TEST
ASTM C-88

Client: Western Nuclear
Project: Sherwood Mine
Description: Quartz Monzanite

Date: 10-3-96 Lab No. 683
Proj. No.: 6-929-1396-0
Test No.: 11

SIEVE SIZE	INDIVIDUAL GRADING % RETAINED	WEIGHT BEFORE TEST (GRAMS)	WEIGHT AFTER TEST (GRAMS)	PERCENT LOSS AFTER TEST (%)	WEIGHTED % LOSS
2 ½" TO 2" 2" TO 1 ½"	38.4 25.7	2994.8 2001.8	4936.6	1.2	0.8
1 ½" TO 1" 1" TO 3/4"	12.8 6.5	998.6 507.1	1459.0	3.1	0.6
3/4" TO 1"					
3/4" TO ½" ½" TO 3/8"	8.7 4.2	672.3 328.7	962.0	3.9	0.5
3/8" TO #4	3.8	299.5	275.8	7.9	0.3
TOTAL	100.1	7802.8			2.2

SOLUTION TEMP: 71.5°F OVEN TEMP: 230°F SPECIFIC GRAVITY: 1.160 TYPE OF SALT: Sodium

QUALITIVE EXAMINATION OF COARSE SIZES

SIEVE SIZE	SPLITTING	DISINTEGRATION	CRACKING	FLAKING	#OF PARTICLES
1 ½" TO 1"	1				24
1" TO 3/4"	1			1	25

CYCLE NO.	DATE	TIME	IN SOLUTION		OUT SOLUTION		IN OVEN		OUT OVEN			
1	10-4		10-4	15:30	10-5	08:30	10-5	08:45	10-5	12:45		
2			10-5	14:15	10-6	08:10	10-6	08:25	10-6	12:25		
3			10-6	14:05	10-7	07:30	10-7	07:45	10-7	11:45		
4			10-7	13:30	10-8	06:40	10-8	06:55	10-8	10:55		
5			10-8	12:15	10-9	05:15	10-9	05:30	10-9	09:30		

SAMPLED BY: J. Martin TESTED BY: J. Martin / B. Arnold, J. Johnson REVIEWED BY: [signature]

DATE: 10-3-96 DATE: 10-9-96 DATE: 10/10/96

AGRA
Earth & Environmental

E158

AGRA
Earth & Environmental
E. 520 North Foothills Drive, Suite 600
Spokane, Washington, U.S.A. 99207

SCHMIDT HAMMER TEST
ASTM C-805

Test No: 11

Client: Western Nuclear   Date: 10-3-96   Lab No. 683

Project: Sherwood Mine   Proj. No.: 6-929-1396-0

Sample location: Quarry

Surface characteristics: Saw-cut Specimens

Sample A/Rebound Number	Sample B/Rebound Number
1. 57	1. 56
2. 58	2. 56
3. 57	3. 56
4. 58	4. 57
5. 57	5. 56
6. 57	6. 57
7. 58	7. 57
8. 56	8. 57
9. 58	9. 56
10. 58	10. 57

Sample A Avg: 57.4   Sample B Avg: 56.5

Grand average rebound number 57.0

Remarks: Schmidt Hammer - Model N-34, Serial No. 137281

Sampled By: J. Martin   Date: 10-3-96

Test Performed By: J. Martin   Date: 10-5-96

Reviewed By: [signature]   Date: 10/10/96

TABLE

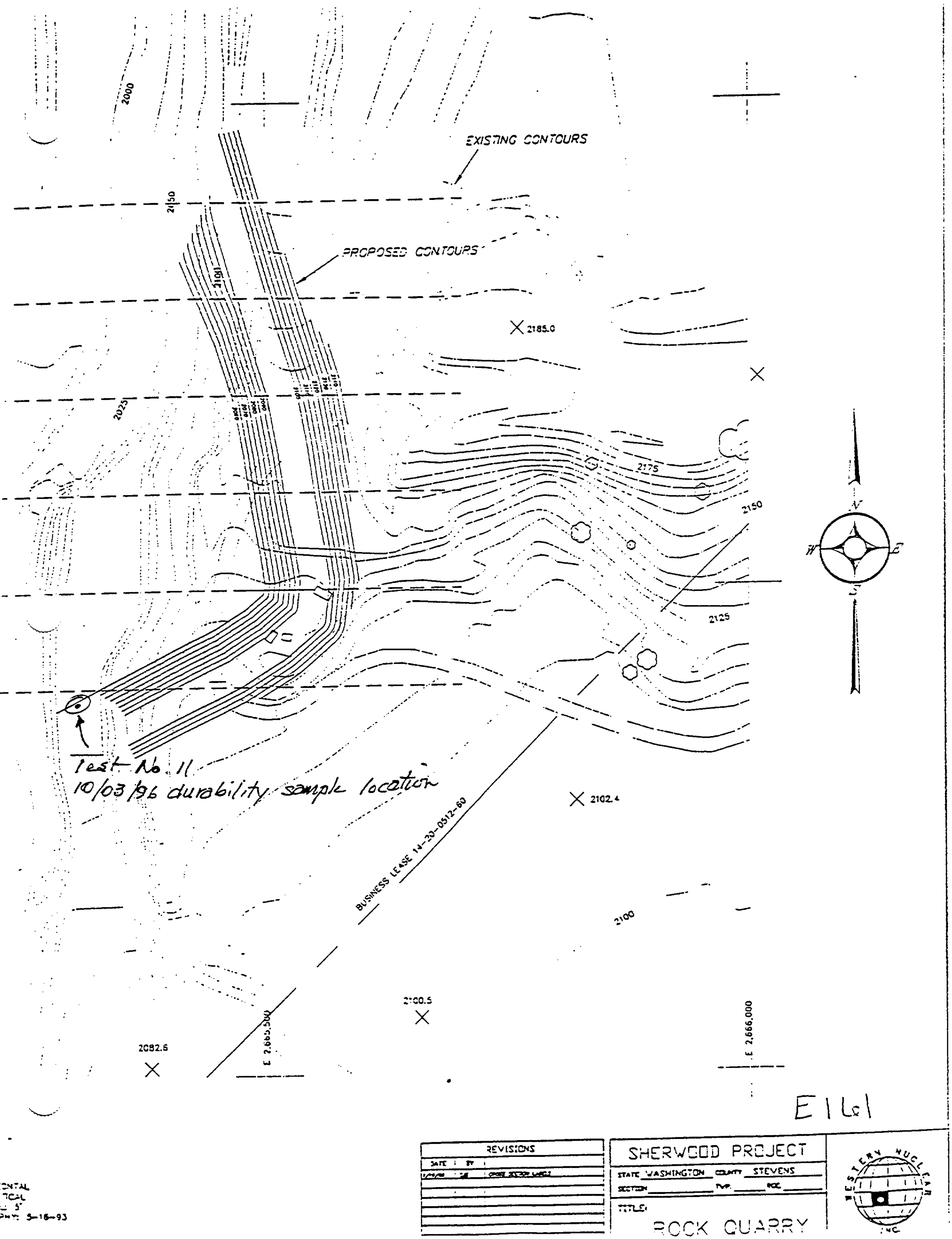
Scoring Criteria for Determining Rock Quality

Laboratory Test	Weighting Factor			Score										
				10	9	8	7	6	5	4	3	2	1	0
	Limestone	Sandstone	Igneous		Good			Fair			Poor			
Sp. Gravity	12	6	9	2.75	2.70	2.65	2.60	2.55	2.50	2.45	2.40	2.35	2.40	2.25
Absorption, %	13	5	2	.1	.3	.5	.67	.83	1.0	1.5	2.0	2.5	3.0	3.5
Sodium Sulfate, %	4	3	11	1.0	3.0	5.0	6.7	8.3	10.0	12.5	15.0	20.0	25.0	30.0
L/A Abrasion (100 revs), %	1	8	1	1.0	3.0	5.0	6.7	8.3	10.0	12.5	15.0	20.0	25.0	30.0
Schmidt Hammer	11	13	3	70.0	65.0	60.0	54.0	47.0	40.0	32.0	24.0	16.0	8.0	0.0
Tensile Strength, psi	6	4	10	1400	1200	1000	833	666	500	400	300	200	100	0

1. Scores were derived from Tables 6.2, 6.5, and 6.7 of NUREG/CR-2642 - "Long-Term Survivability of Riprap for Armoring Uranium Mill Tailings and Covers: A Literature Review," 1982 (see Ref. D13).

2. Weighting Factors are derived from Table 7 of "Petrographic Investigations of Rock Durability and Comparisons of Various Test Procedures," by G. W. DuPuy, Engineering Geology, July, 1965 (see Ref. D15). Weighting factors are based on inverse of ranking of test methods for each rock type. Other tests may be used; weighting factors for these tests may be derived using Table 7, by counting upward from the bottom of the table.

3. Test methods should be standardized, if a standard test is available and should be those used in NUREG/CR-2642 (see Ref. D13), so that proper correlations can be made. This is particularly important for the tensile strength test, where several methods may be used; the method discussed by Nilsson (1962, see Ref. D16) for tensile strength was used in the scoring procedure.


EXISTING CONTOURS
PROPOSED CONTOURS
2000
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2025
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Test No. 11
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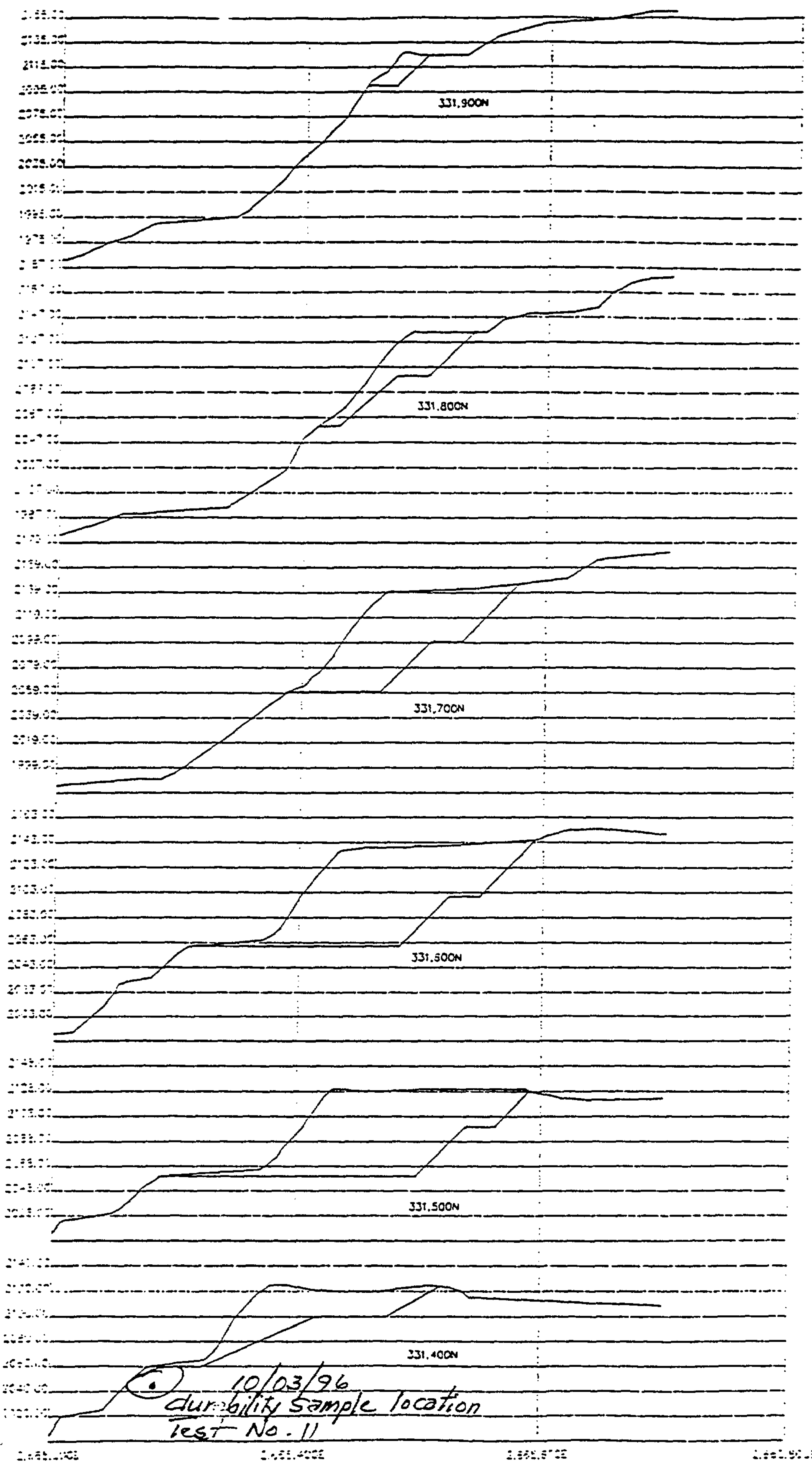
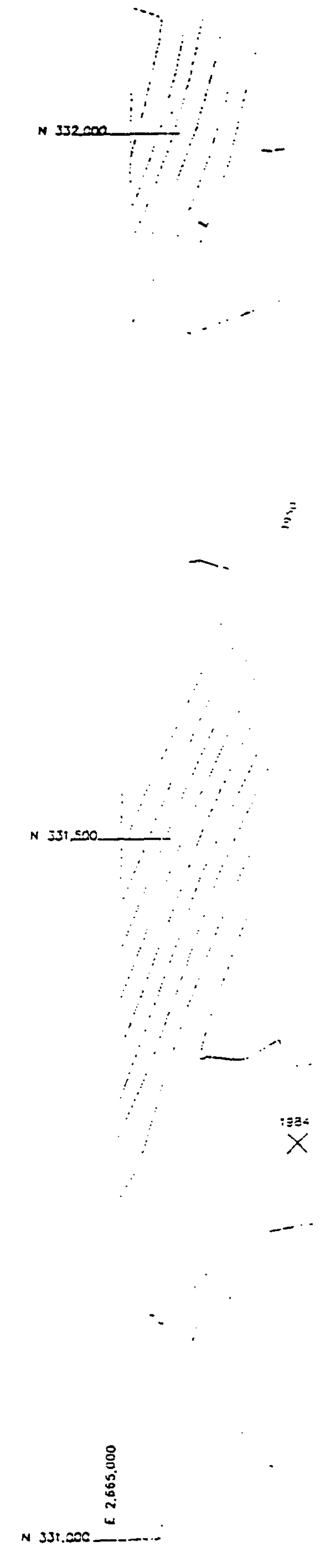
2102.4
BUSINESS LEASE 14-20-0512-60
2100
2100.5
2082.6
E 2,665,500
E 2,666,000
N
E
W
E161
REVISIONS
DATE
BY
SHERWOOD PROJECT
STATE WASHINGTON
COUNTY STEVENS
SECTION
TWP.
RGE.
TITLE:
ROCK QUARRY
WESTERN NUCLEAR
INC.



VOLUME: 126,000CY



E162

DATE OF

WESTERN NUCLEAR, INC. – SHERWOOD TAILINGS RECLAMATION
QUALITY COMPLIANCE REPORT

Rock Durability Test

DATE : 11/07/96

DOCUMENT : RD-12

SHEET : 1 OF 9

SPECIFICATION REFERENCE Table 3

Construction Segment: Rock Production

Rock Source: Quartz Monzonite Rock Quarry – SHERWOOD MINE

Frequency of Rock Durability Testing: One test series prior to placement and one test series for every 10,000 CY of material produced from the rock source.

Acceptance Criteria : Rock shall have a minimum durability rating of 80.
Rock having a durability rating of less than 80 shall require oversizing.
For oversizing, refer to Specification Reference : Page TS–39, 5.2.2

Rock Durability

Test Date	Test No.	Cum. Vol. Produced	Rating	Oversize	
10/19/96 through 10/24/96	12	100,000 yd3 Qtz. Monzonite	80	Yes ☐ No ☒	Attach Test Results

Non–Conformances: None

Description N/A

Corrective action required: Yes ☐ No ☒

If Yes, Corrective Action Report No.: ______

Test Performed by: C. Hitchcock, D. Lehn AGRA Earth & Environ. reviewed B. Arnold Date: 11/04/96

WNI Construction Manager: C. Abeyta Date: 11/07/96

Audit Review By:
WNI QA/QC Engineering Manager: [signature] Date: 11/7/96

07/25/96

E163

AGRA
Earth & Environmental

AGRA Earth &
Environmental, Inc.
E 620 North Foothills Drive
Suite 600
Spokane, Washington
U.S.A. [illegible]
Tel (509) 482-0104
Fax (509) 482-0202

November 4 , 1996

Western Nuclear, Inc.
P.O. Box 358
Wellpinit, Washington 99040

Attention: Mr. Corn Abeyta

Regarding: Laboratory Determination of Aggregate Durability Rating
Test No. 12
Sherwood Mine Project

Dear Mr. Abeyta:

In accordance with your request, on October 18, 1996 we obtained a bulk sample of Quarry rock from the Sherwood site for laboratory analysis and Durability Rating determination at our Spokane laboratory. As of this date, that has been completed. All laboratory testing has been performed in accordance with the most current ASTM standards available, and in accordance with the project specifications.

The Durability Rating determination was performed according to Table D1 of the NRC's Staff Technical Position (STP) Design of Erosion Protection Covers for Stabilization of Uranium Mill Tailing Sites, August 1990. Table A shows the test results and calculations for Test No.12. Additionally, the laboratory testing worksheets are attached for your records.

If there are any questions, or we may be of further assistance, please do not hesitate to contact us at (509) 482-0104.

Respectfully Submitted
AGRA EARTH & ENVIRONMENTAL, INC.

Jay C. Martin, SET
Laboratory Supervisor

Bob Arnold
Technical Director

TABLE A

ROCK TYPE: IGNEOUS - GRANITIC QUARTZ MONZANITE
ROCK SAMPLE: TEST NO. 12
AGRA LABORATORY SAMPLE # 714

Laboratory Test	Result	Score	Weight	Score x Weight	Maximum Score
Apparent Specific Gravity ASTM C127	2.66	N/A	N/A	N/A	N/A
Bulk Saturated Surface Dry Specific Gravity ASTM C127	2.64	N/A	N/A	N/A	N/A
Bulk Specific Gravity ASTM C127	2.63	7	9	63	90
Absorption, % ASTM C127	0.4	8	2	16	20
Sodium Sulfate Soundness, % Loss, ASTM C88	2.1	9	11	99	110
Schmidt Hammer Rebound Number ASTM C805	58.1	7	3	21	30
Total Score				**199**	**250**

DURABILITY RATING = 199 / 250 x 100 = 80

AGRA
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E. 520 North Foothills Drive, Suite 600
Spokane, Washington, U.S.A. 99207

Client: Western Nuclear   Date: 10-18-96   Lab No. 714

Project: Sherwood Mine   Proj. No.: 6-929-1396-0

Description: Quartz Monzonite   Test No.: 12

SPECIFIC GRAVITY AND/OR UNIT WEIGHT
ASTM C-127

COARSE AGGREGATE - SPECIFIC GRAVITY AND ABSORPTION

Mass of Sample in Air Dry	=	6276.7	Grams
Mass of Sample, SSD	=	6301.8	Grams
Mass of Sample in Water	=	3918.8	Grams
Aggregate -Bulk Specific Gravity	=	2.63	
Bulk Specific Gravity (SSD)	=	2.64	
Apparent Specific Gravity	=	2.66	
Absorption	=	0.4	(%)

SSD = SATURATED SURFACE DRY

Remarks:

Sampled by: J. Johnson   Date: 10-18-96

Tested by: C. Hitchcock   Date: 10-23-96

Reviewed by: Bob [signature]   Date: 11/4/96

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SULFATE SOUNDNESS TEST
ASTM C-88

Client: Western Nuclear
Project: Sherwood Mine
Description: Quartz Monzonite
Date: 10-18-96 Lab No. 714
Proj. No.: 6-929-1396-0
Test No.: 12

SIEVE SIZE	INDIVIDUAL GRADING % RETAINED	WEIGHT BEFORE TEST (GRAMS)	WEIGHT AFTER TEST (GRAMS)	PERCENT LOSS AFTER TEST (%)	WEIGHTED % LOSS
2 ½" TO 2" 2" TO 1 ½"	38.6 25.6 (64.2)	3011.8 1995.7	4947.4	1.2	0.8
1 ½" TO 1" 1" TO 3/4"	12.8 6.4 (19.2)	998.1 500.7	1452.3	3.1	0.6
3/4" TO 1"					
3/4" TO ½" ½" TO 3/8"	8.6 4.2 (12.8)	671.0 329.4	969.4	3.1	0.4
3/8" TO #4	3.8	300.2	276.5	7.9	0.3
TOTAL	100	7806.9			2.1

SOLUTION TEMP: 71.8°F OVEN TEMP: 230°F SPECIFIC GRAVITY: 1.162 TYPE OF SALT: Sodium

QUALITIVE EXAMINATION OF COARSE SIZES

SIEVE SIZE	SPLITTING	DISINTEGRATION	CRACKING	FLAKING	#OF PARTICLES
1 ½" TO 1"			1	2	23
1" TO 3/4"				1	25

CYCLE NO.	DATE	TIME	IN SOLUTION		OUT SOLUTION		IN OVEN		OUT OVEN			
1	10-19		10-19	15:40	10-20	0840	10-20	0855	10-20	1255		
2			10-20	1500	10-21	0900	10-21	0915	10-21	1315		
3			10-21	1505	10-22	0810	10-22	0825	10-22	1225		
4			10-22	1430	10-23	0740	10-23	0755	10-23	(Jim) 1155		
5			10-23	1405	10-24	0705	10-24	0720	10-24	1220		

SAMPLED BY: J. Johnson TESTED BY: D. Lehn, C. Hitchcock REVIEWED BY: [signature]

DATE: 10-18-96 DATE: 10-24-96 DATE: 10/4/96

AGRA Earth & Environmental E167

AGRA
Earth & Environmental
E. 529 North Foothills Drive, Suite 600
Spokane, Washington, U.S.A. 99207

SCHMIDT HAMMER TEST
ASTM C-805

Test No: 12

Client: Western Nuclear
Date: 10-18-96 Lab No. 714
Project: Sherwood Mine
Proj. No.: 6-929-1396-0
Sample location: Quarry
Surface characteristics: Saw-cut specimens

	Sample A/Rebound Number	Sample B/Rebound Number
1.	58	57
2.	58	58
3.	57	58
4.	59	57
5.	59	59
6.	58	59
7.	58	58
8.	59	58
9.	59	57
10.	59	57

Sample A Avg: 58.4
Sample B Avg: 57.8

Grand average rebound number 58.1

Remarks: Schmidt Hammer - Model N-34, Serial No 137281

Sampled By: J. Johnson Date: 10-18-96
Performed By: D. Lehn Date: 10-22-96
Reviewed By: [signature] Date: 11/4/96

AGRA Earth & Environmental E168

TABLE D1

Scoring Criteria for Determining Rock Quality

Laboratory Test	Weighting Factor			Score										
	Limestone	Sandstone	Igneous	10	9	8	7	6	5	4	3	2	1	0
					Good			Fair			Poor			
Sp. Gravity	12	6	9	2.75	2.70	2.65	2.60	2.55	2.50	2.45	2.40	2.35	2.40	2.25
Absorption, %	13	5	2	.1	.3	.5	.67	.83	1.0	1.5	2.0	2.5	3.0	3.5
Sodium Sulfate, %	4	3	11	1.0	3.0	5.0	6.7	8.3	10.0	12.5	15.0	20.0	25.0	30.0
L/A Abrasion (100 revs), %	1	8	1	1.0	3.0	5.0	6.7	8.3	10.0	12.5	15.0	20.0	25.0	30.0
Schmidt Hammer	11	13	3	70.0	65.0	60.0	54.0	47.0	40.0	32.0	24.0	16.0	8.0	0.0
Tensile Strength, psi	6	4	10	1400	1200	1000	833	666	500	400	300	200	100	0

1. Scores were derived from Tables 6.2, 6.5, and 6.7 of NUREG/CR-2642 - "Long-Term Survivability of Riprap for Armoring Uranium Mill Tailings and Covers: A Literature Review," 1982 (see Ref. D13).

2. Weighting Factors are derived from Table 7 of "Petrographic Investigations of Rock Durability and Comparisons of Various Test Procedures," by G. W. DuPuy, Engineering Geology, July, 1965 (see Ref. D15). Weighting factors are based on inverse of ranking of test methods for each rock type. Other tests may be used; weighting factors for these tests may be derived using Table 7, by counting upward from the bottom of the table.

3. Test methods should be standardized, if a standard test is available and should be those used in NUREG/CR-2642 (see Ref. D13), so that proper correlations can be made. This is particularly important for the tensile strength test, where several methods may be used; the method discussed by Nilsson (1962, see Ref. D16) for tensile strength was used in the scoring procedure.

REVISIONS	
DATE	BY

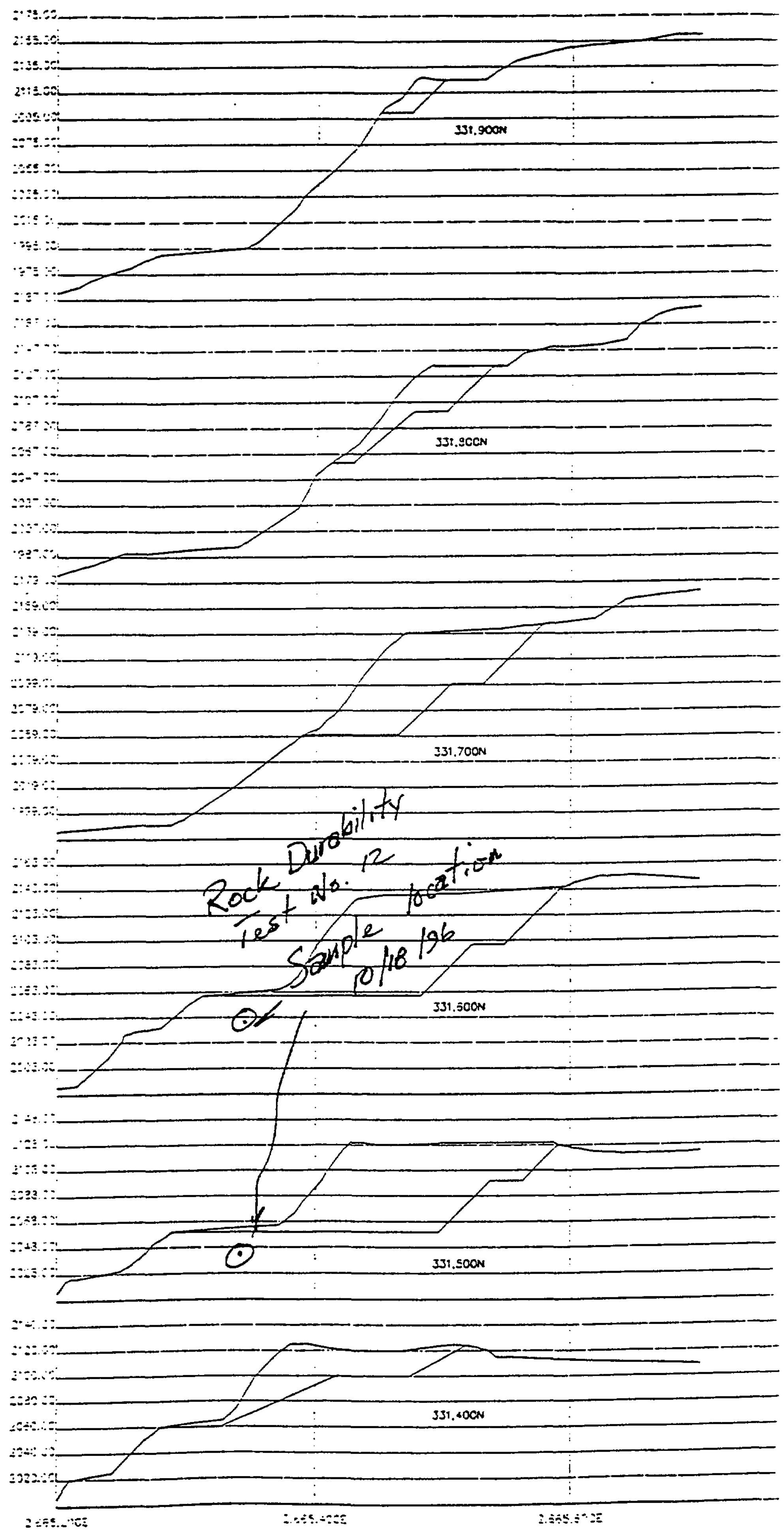
E170

SHERWOOD PROJECT

STATE WASHINGTON COUNTY STEVENS

SECTION TWP RGE

TITLE:



VOLUME: 125,000CY

E171

Memorandum

Date: November 7, 1996

To: QA/QC File (Rock Durability)

From: WNI Construction Manager

Subject: Rock Durability Test Requirement

Bank Volume

A volumetric bank measure of total rock utilized in the production of two filters and riprap was taken from ground surveys of two sources which included the Quartz Monzonite Quarry and a Basaltic rock stockpile. The total volume of rock utilized, measured 89,682 BCY including reject rock. On the basis of insitu volume, eleven (11) durability samples were required which included two pre-production samples and tests, one for each of the two sources. Twelve rock durability tests were conducted. The requirement of one durability test per every 10,000 cubic yards produced indicates that one extra durability test was conducted.

89,682 BCY / 1 Test/10,000 CY + 2 Pre-production tests = 11 Required tests

Loose Volume

A swell factor of 1.209 was experienced in the production of Filters and riprap produced. Sized rock was measured and weighed and in addition, production stockpiles including reject rock at it's disposal site were surveyed. Rock durability tests conducted on the basis of loose volume produced, meeting the requirement of one test per every 10,000 cubic yards, and one pre-production test per source also totals eleven. Twelve tests were conducted, therefore, one extra test was conducted.

89,682 BCY x 1.209	=	108,426 LCY
108,426 LCY - 19,200 LCY Reject	=	89,226 LCY

89,226 LCY / 1 Test/10,000 CY + 2 Pre-production tests = 11 Required tests

C. Abeyta

C. Abeyta
WNI Construction Manager

attachments: Survey drawings

E172

FILL QUANTITIES:

VOLUME AS OF 10/11/96 = 82,556 CY

NOTE:

EXISTING GROUND ELEVATIONS BASED ON DATAMAP AERIAL PHOTO CONTOURS.

NO SHRINK FACTOR APPLIED.

ALL VOLUMES BASED ON 25 FOOT GRID FROM DATA TAKEN ON 10/11/96.

ASCII FILE:

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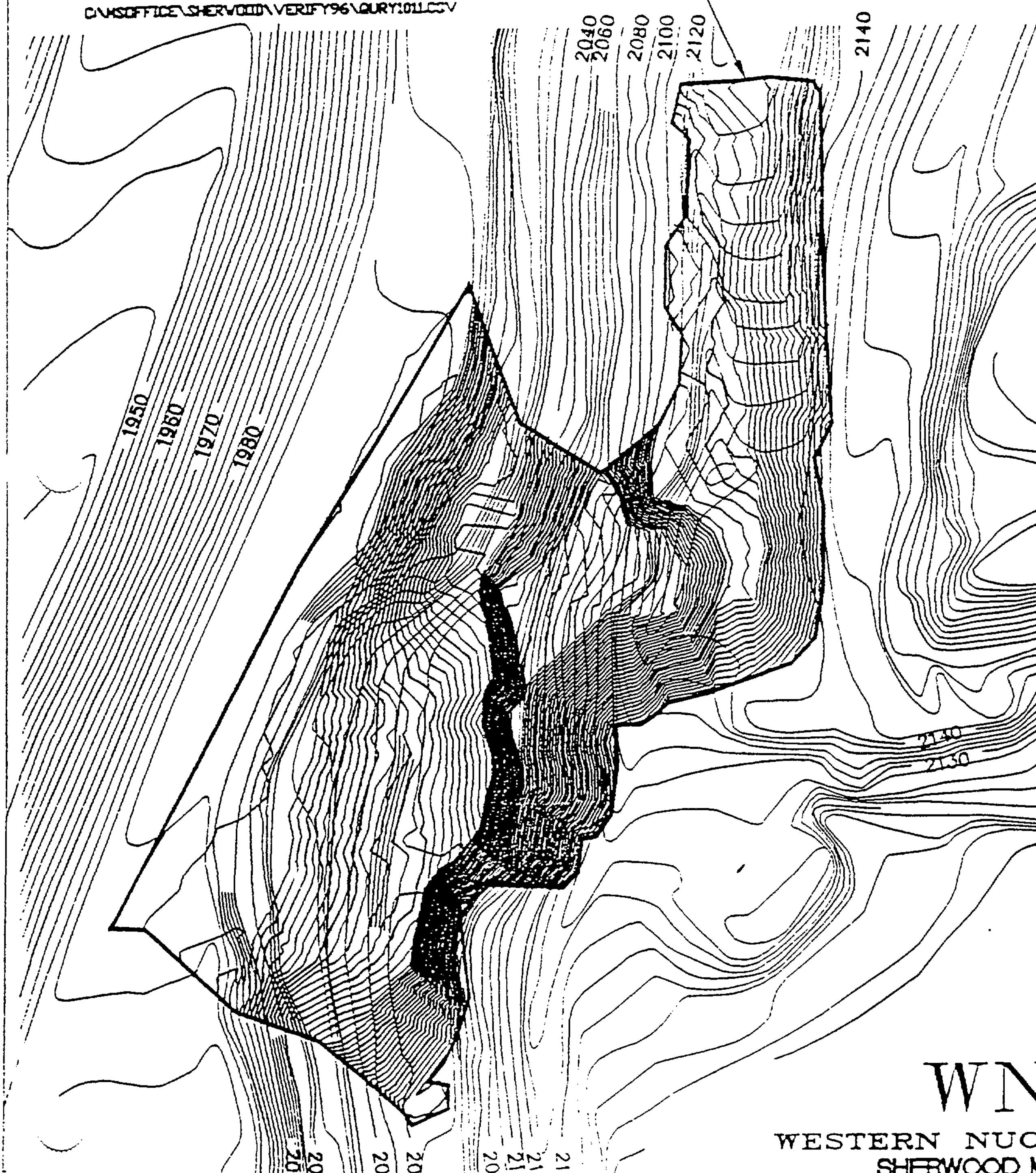
FROM THE OFFICES OF C.E. SPURLOCK JR. & ASSOC.



SCALE 1"=100'

CONTOUR INTERVAL 2'

WNI

WESTERN NUCLEAR, INC.

SHERWOOD MILLSITE

ROCK QUARRY

EXCAVATION VOLUME ESTIMATE

E173

DRAWN BY:	KWB	DATE:	10/31/96
CHECKED BY:		DRAWING NO.:	1
FILE NO.: QUARYFNL.DWG		SHEET	1 OF 1

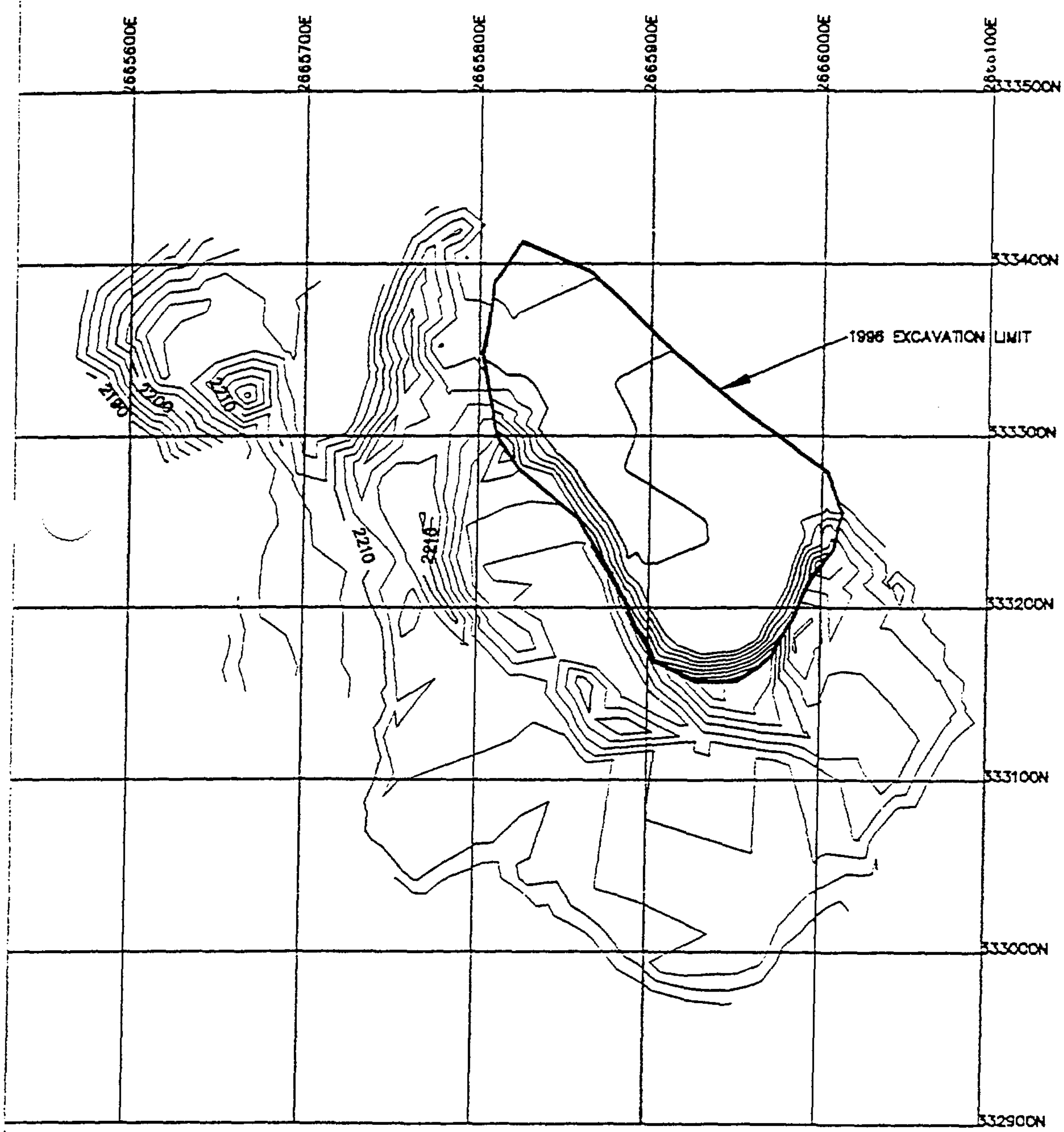
FILL QUANTITIES:

CUT VOLUME AS OF 10/11/96 = 7,626 CY

NOTE:

EXISTING GROUND ELEVATIONS BASED
ON SURVEY OF 6/23/95.
NO SHRINK FACTOR APPLIED.
ALL VOLUMES BASED ON 10 FOOT GRID
FROM DATA TAKEN ON 10/11/96.

FROM THE OFFICES OF C.E. SPURLOCK JR. & ASSOC.



SCALE 1"=100'

CONTOUR INTERVAL 2'

WNI

WESTERN NUCLEAR, INC.

SHERWOOD MILLSITE
BASALT STOCKPILE
1996 EXCAVATION VOLUME ESTIMATE

E174.

FILE:
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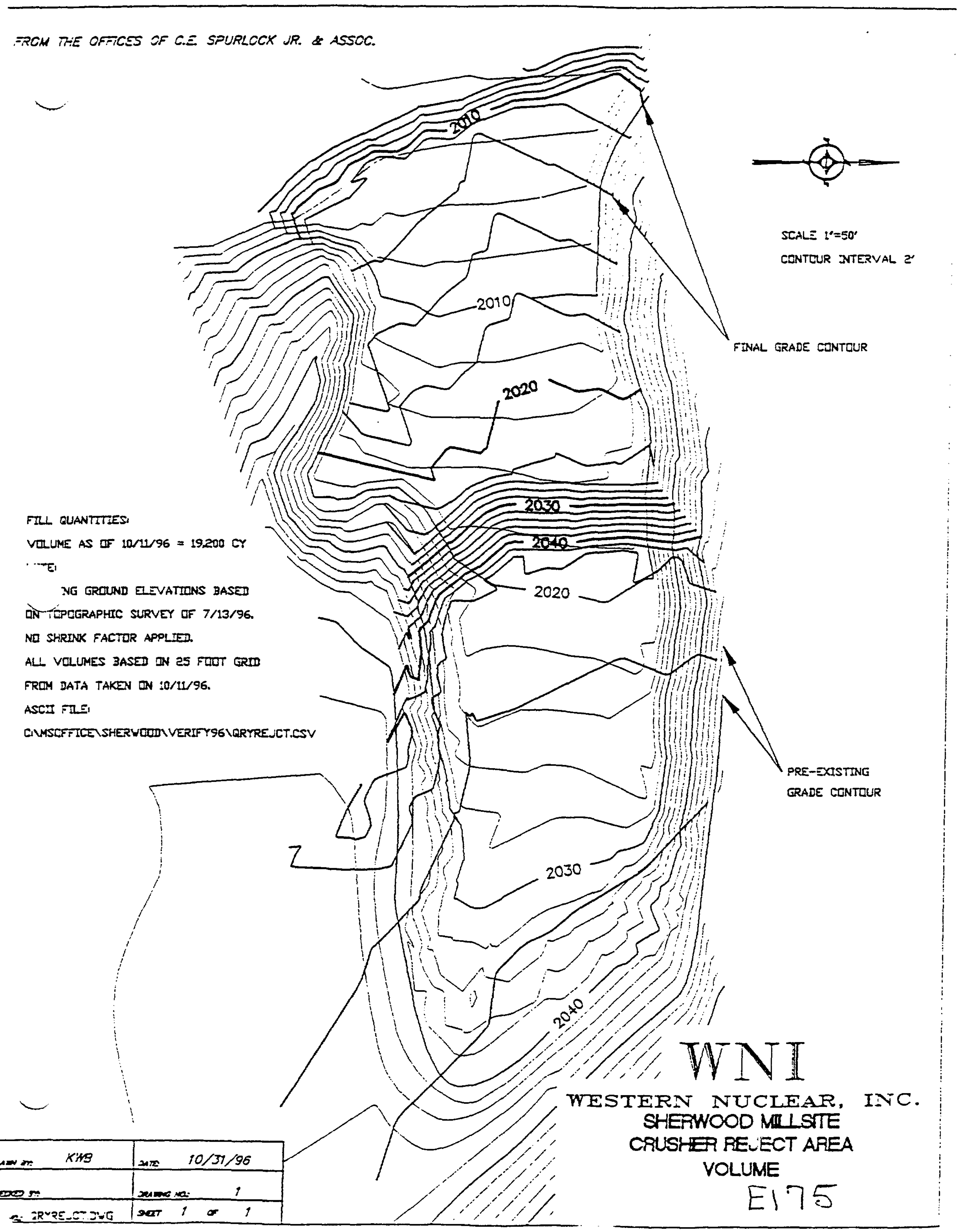
CHECKED BY:	DRAWING NO.: 1
FILE NO.: SHEROCK2.DWG	SHEET 1 OF 1


FROM THE OFFICES OF C.E. SPURLOCK JR. & ASSOC.
2010
2010
2020
2030
2040
2020
2030
2040
SCALE 1"=50'
CONTOUR INTERVAL 2'
FINAL GRADE CONTOUR
PRE-EXISTING GRADE CONTOUR
FILL QUANTITIES:
VOLUME AS OF 10/11/96 = 19,200 CY
NG GROUND ELEVATIONS BASED ON TOPOGRAPHIC SURVEY OF 7/13/96.
NO SHRINK FACTOR APPLIED.
ALL VOLUMES BASED ON 25 FOOT GRID FROM DATA TAKEN ON 10/11/96.
ASCII FILE:
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WNI
WESTERN NUCLEAR, INC.
SHERWOOD MILLSITE
CRUSHER REJECT AREA
VOLUME
E175
KWB
10/31/96
1
QRYREJCT.DWG
SHEET 1 OF 1