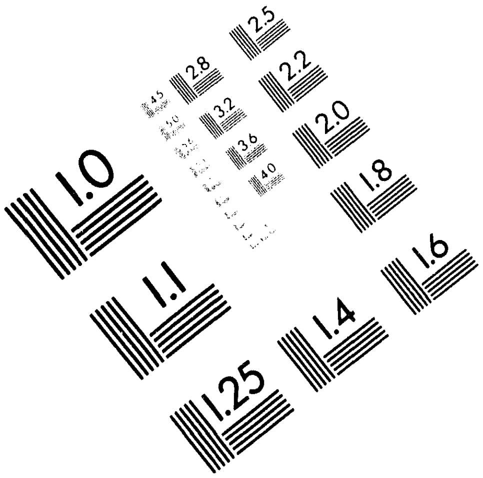

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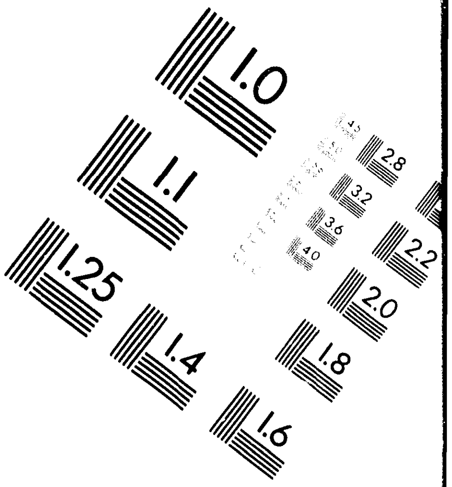

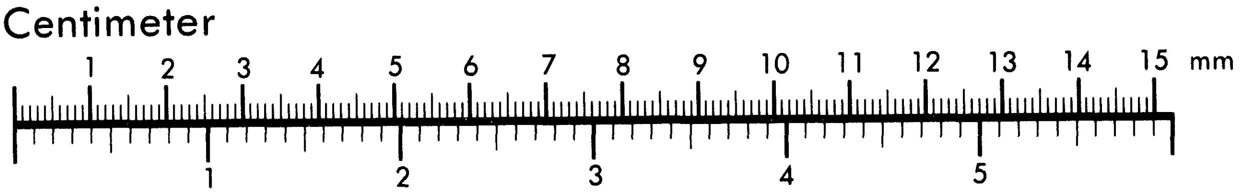

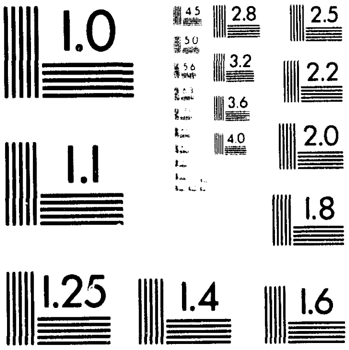

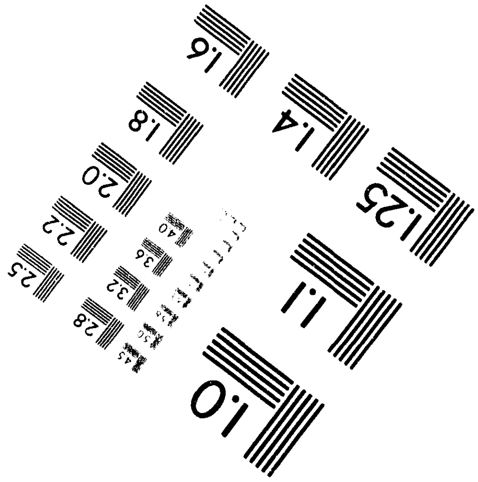

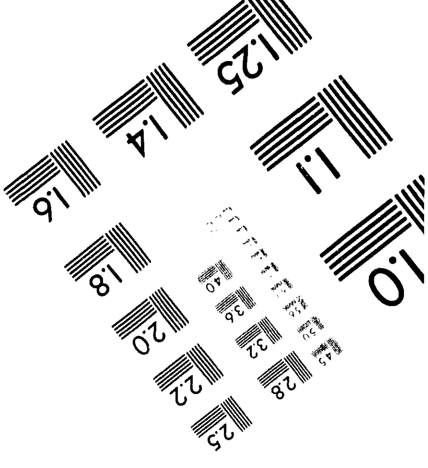

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Remediation Application Strategies for Depleted Uranium Contaminated Soils at the U.S. Army Yuma Proving Ground

D. S. Vandel
S. M. Medina
J. R. Weidner

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Idaho National Engineering Laboratory
EG&G Idaho, Inc.
Idaho Falls, ID 83415

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ABSTRACT

The U.S. Army Yuma Proving Ground (YPG), located in the southwest portion of Arizona conducts firing of projectiles into the Gunpoint (GP—20) firing range. The penetrators are composed of titanium and DU. The purpose of this project was to determine feasible cleanup technologies and disposal alternatives for the cleanup of the depleted uranium (DU) contaminated soils at YPG. The project was split up into several tasks that include (a) collecting and analyzing samples representative of the GP-20 soils, (b) evaluating the data results, (c) conducting a literature search of existing proven technologies for soil remediation, and (d) making final recommendations for implementation of this technology to the site. As a result of this study, several alternatives for the separation, treatment, and disposal procedures are identified that would result in meeting the cleanup levels defined by the Nuclear Regulatory Commission for unrestricted use of soils and would result in a significant cost savings over the life of the firing range.

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FIGURES

TABLES

ACKNOWLEDGMENTS

The authors would like to thank the following organizations for their valuable contributions to this document: The U.S. Army YPG and the EG&G Idaho, Inc. Environmental Engineering Unit, Environmental Monitoring Unit, and Engineering Graphics Unit.

ACRONYMS

ADC	Analytical Development Corporation
ADEQ	Arizona Department of Environmental Quality
AFB	Air Force Base
ASTM	American Society for Testing and Materials
B&W-NESI	Babcock and Wilcox Nuclear Environmental Services, Inc.
Ba	barium
Bergmann	Bergmann USA
BESCORP	Brice Environmental Services Corporation
Bradtec	Bradtec-U.S., Inc.
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
DNA	Defense Nuclear Agency
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
DU	depleted uranium
EcoTek	EcoTek, Inc.
Eh	Redox Potential
EPA	Environmental Protection Agency
Hg	mercury
ICP	inductively coupled plasma
INEL	Idaho National Engineering Laboratory
KOFA	King of Arizona
LANL	Los Alamos National Laboratory

LLNL	Lawrence Livermore National Laboratory
Lockheed	Lockheed Environmental Systems and Technologies Co.
MOA	methods of soil analysis
NaI	sodium iodide
NEPA	National Environmental Policy Act
NFS	Nuclear Fuel Services
NPDES	National Pollutant Discharge Elimination System
NRC	U.S. Nuclear Regulatory Commission
NRT	Nuclear Remediation Technologies
ORNL	Oak Ridge National Laboratory
Pb	lead
PCB	Polychlorinated Biphenyls
PCP	Process Control Program
RCRA	Resource Conservation and Recovery Act
RFP	Request for Proposal
SAI	Science Applications, Inc.
S. G. Frantz	S. G. Frantz Company, Inc.
SITE	superfund innovative technology evaluation
TCLP	toxicity characterization leaching procedure
Ti	titanium
TMA/Eberline	TMA/Eberline Thermo Analytical, Inc.
TRA	Test Reactor Area
TSCA	Toxic Substances Control Act
U	uranium

Westinghouse SEG	Westinghouse Scientific Ecology Group, Inc.
WWP	Warm-waste pond
YPG	Yuma Proving Ground

Remediation Application Strategies for Depleted Uranium Contaminated Soils at the U.S. Army Yuma Proving Ground

1. INTRODUCTION

1.1 Site History

This report was prepared for the U.S. Army Yuma Proving Ground (YPG) to determine the feasibility for the remediation of depleted uranium (DU) contaminated soils at YPG. The YPG is located in the Sonoran Desert in the southwestern corner of Arizona, east of the Colorado River and north of the Gila River as shown in Figure 1. YPG is composed of 870,166 acres and is situated in a "U-shaped" configuration that is surrounded by publicly owned lands, except to the south. The privately owned lands to the south are used primarily for agriculture.

Within YPG is a munitions test firing range, the King of Arizona (KOFA) range. A small portion of the KOFA range is extensively used to fire DU penetrators, a source of environmental concern when considering disposal. These penetrators vary in size and are rods manufactured of 99.25% DU and 0.75% Titanium.

The KOFA DU penetrator range is divided into 84 grid squares 1640.42 ft (500 m) on edge, each square having an area of 2,690,975 ft^2 (250,000 m^2). This represents a total area of approximately 2.26×10^8 ft^2 (2.07×10^7 m^2). The KOFA DU penetrator range is depicted in Figure 2. Figure 3 is a grid square map of the northwestern corner of the KOFA range showing the grid layout of the KOFA DU area. Centrally adjacent to grids N1 and S1 is one location of a firing site for the DU penetrators. This gun site is called Gun Position 20 (GP-20). Most projectiles originating from GP-20 impact a 1,200 × 50 ft area central to grids N9 and S9. Gun Position 17A (GP-17A), centrally located to grid squares S1B and S1C, is a new DU firing site.

Between 1984 and 1987, the heavily impacted land between grid squares N9 and S9 was cleared of approximately 3 ft of DU contaminated soil. The soil was stockpiled into three piles; commonly referred to as the North Pile, South Pile, and West Pile. The three piles are located in the vicinity of grid squares N9 and S9. The volume of these stockpiles is approximately 1,400 yd^3 (37,800 ft^3). DU contaminated soil still remains in the GP-20 target area.

In November, 1992, a sampling effort was conducted to characterize the stockpiled soil from GP-20 and provide defensible data for an evaluation of technologies for the treatment of soils.

A toxicity characterization leaching procedure (TCLP) analysis, pH analysis, bulk density, moisture retention characteristics, particle size distribution, and a total uranium (U) analysis for the YPG soils were conducted. The results of this sampling effort are presented in Appendix A.

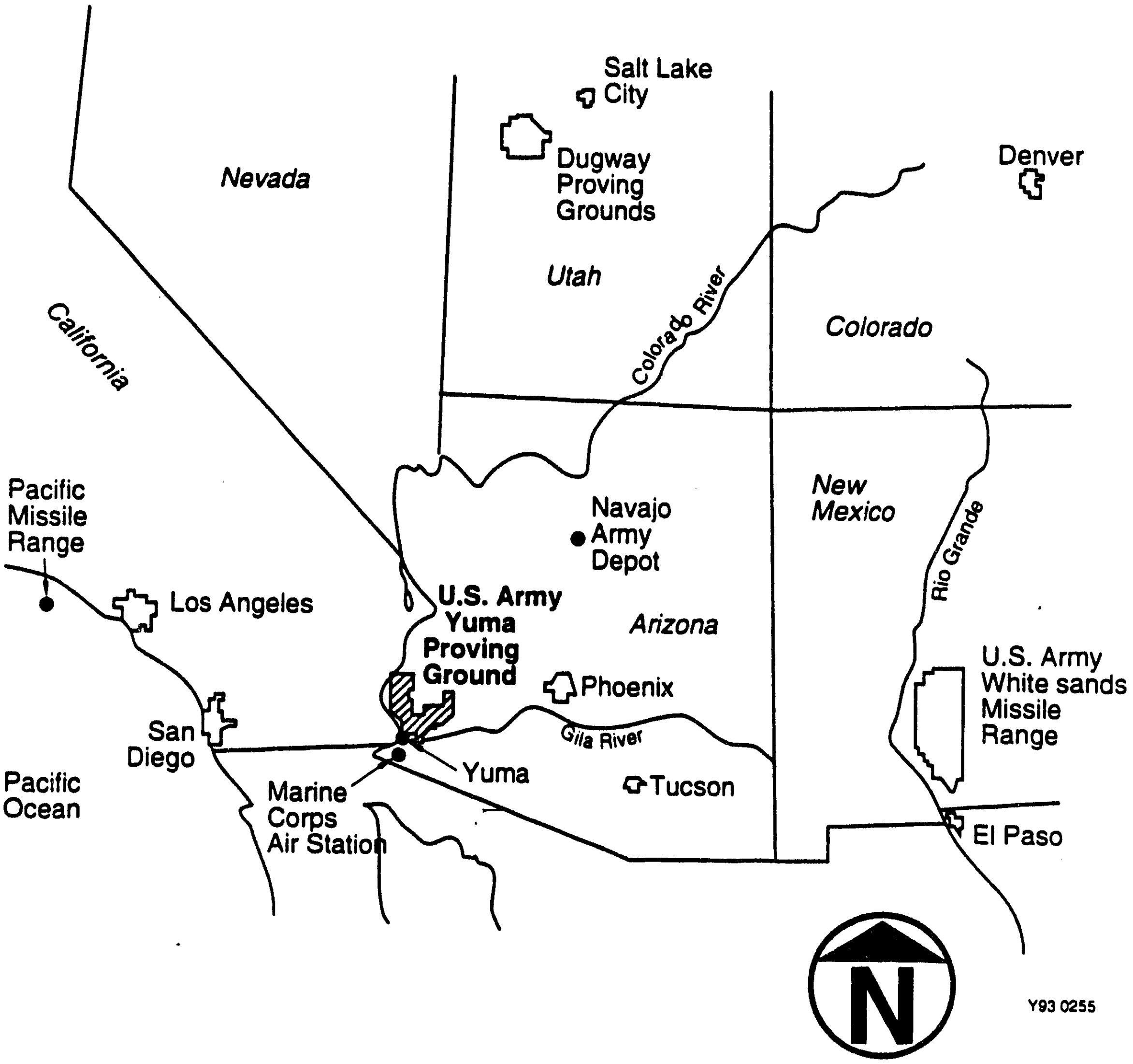


Figure 1. U.S. Army Yuma Proving Grounds location map.

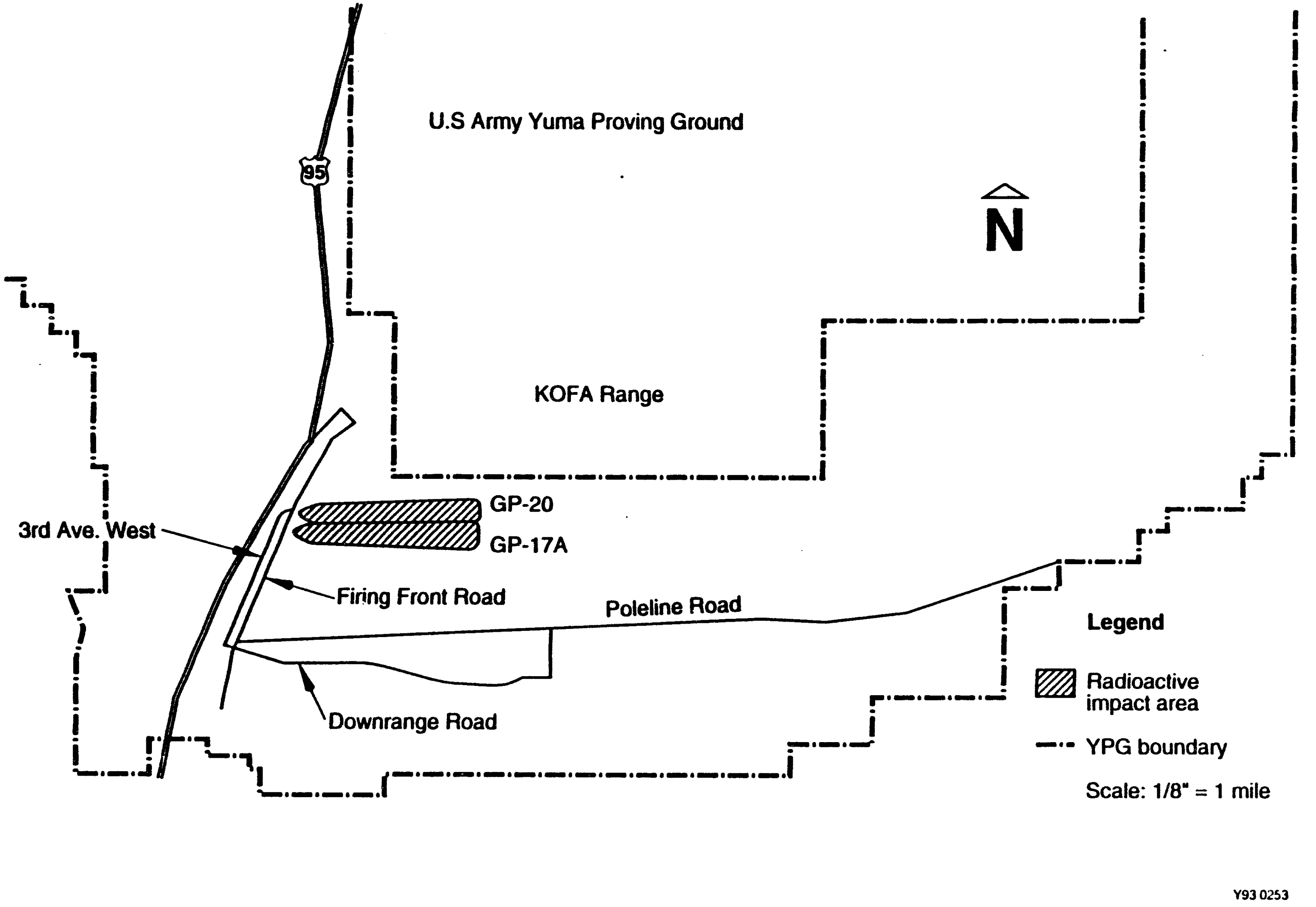


Figure 2. KOFA range.

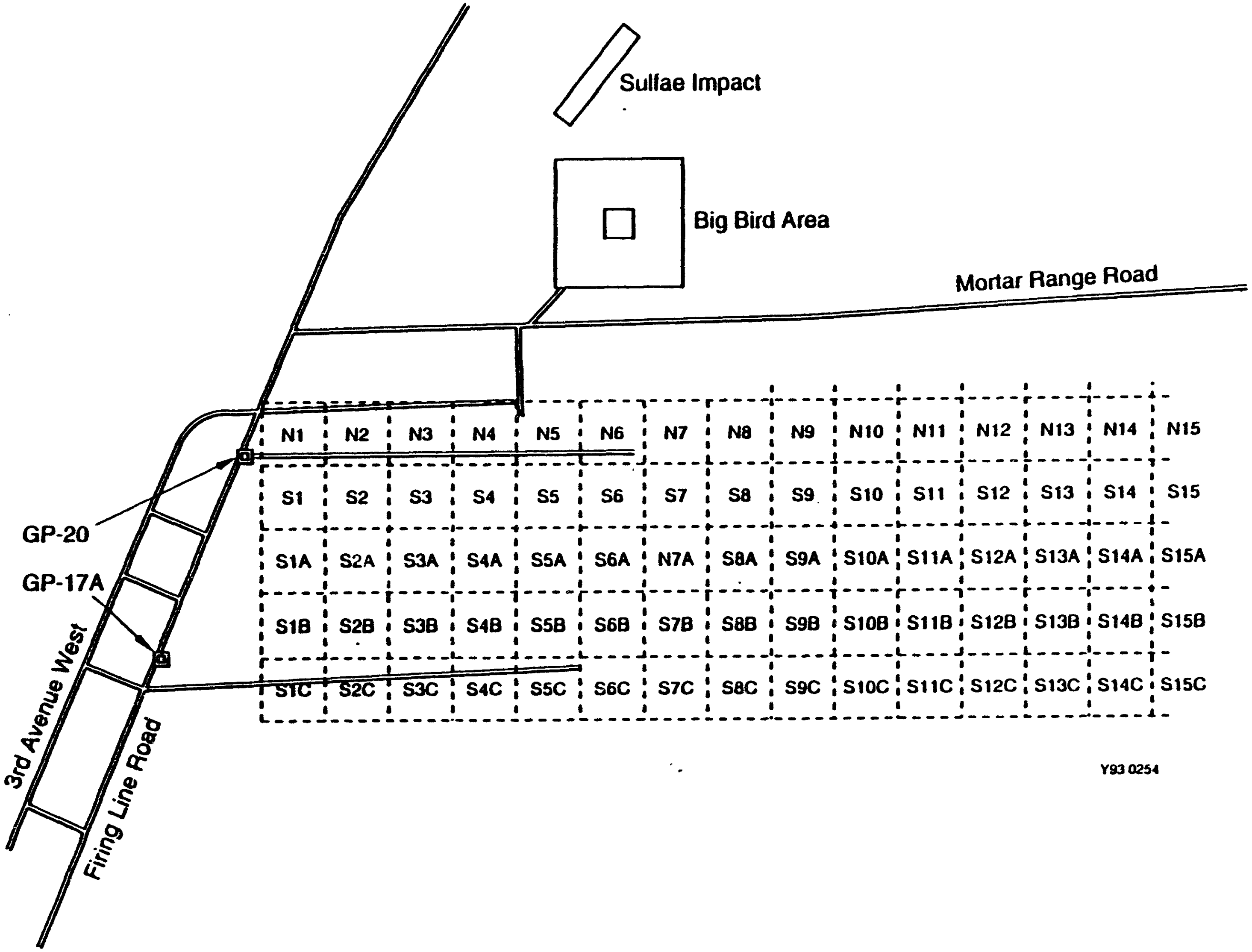


Figure 3. Grid square map of the northwest corner of the KOFA range.

1.2 Study Objective

The objective of this study is to evaluate the available methodologies for the separation of DU from the soil fractions, thus minimizing the amount of DU contaminated soil requiring disposal. The processed soil shall meet the NRC mandated level of 35 pCi/g. The methods have been evaluated to determine the technologies available for separating the size fractions on a batch or continuous scale. The methods have also been evaluated to determine the benefit of each and the potential feasibility of separating the DU from the waste pile materials. Application of the recommended technology(ies) to other contaminated sites in the future will result in the minimization of radioactive wastes in accordance with the U.S. Nuclear Regulatory Commission (NRC) License SMB-1411 and the NRC radioactive waste volume reduction policy.

1.3 Previous Study Data

Studies to evaluate methodologies for the separation of DU from soil fractions at YPG have not been conducted. However, YPG has collected analytical data within the past several years to monitor the area. In 1987, a Hydrologic and Pollution Investigation Study (Entech, Inc.) was performed to evaluate the potential of DU migrating downstream into the Colorado and Gila Rivers. This study concluded that 0.1 $in.^3$ DU particles could be displaced at a maximum of seven miles from the GP-20 target area, assuming hydraulic conditions most conductive to particle movement.

Another study performed by the Lawrence Livermore National Laboratory (LLNL) (Shinn et al. 1988) was to determine the potential environmental effects of testing surface-burst artillery projectiles containing amounts of beryllium (Be) and DU. The testing involved groundburst detonations that resulted in the dispersion and deposition of Be and DU. Science Applications Inc. (SAI) was contracted to characterize detonation on the range. This was done by collecting soil and air samples. The data indicated that:

- The amount of respirable and nonrespirable toxic material leaving the boundary of the KOFA range is below the accepted threshold limit values

- The water quality is not affected

- All significant contamination occurs within 500 m of the blast.

The report prepared by LLNL evaluated the conclusions made by SAI and also conducted an alternative study to determine the overall environmental effects that DU and Be have on the YPG firing range. To ensure the insignificance of potential effects by DU and Be to the environment, LLNL made recommendations in the report for environmental management and mitigation strategies for the remediation of YPG soils.

The information derived from these reports confirms the need to remediate the YPG DU contaminated soils. Hence, this report has been prepared to determine the applicable treatment technologies.

2. DATA COLLECTION

2.1 Data Collection Objectives

The objectives of the KOFA DU Firing Range Restoration Project are to collect data to support (a) evaluation of technologies for the separation of radioactive components and (b) application of the selected remediation technology at other sites contaminated with DU or similar contaminants. The goal of the data gathering effort is to sufficiently characterize the concentration and distribution of DU to best support further investigative studies. Characterization of the soil piles for the evaluation study includes TCLP analysis, pH analysis, bulk density, moisture content, particle size distribution, and a total U analysis.

The results of the analysis will be used in several ways. The TCLP analysis will determine if toxic metals are present in concentrations that exceed the regulatory limit established for TCLP metals by RCRA. The soil pH measurements are useful for estimating some soil mineral species, possible uranium speciation, and also the applicability of some chemical treatments for cleaning the soils. The physical properties, such as bulk density, average particle density, soil moisture, and particle size distribution, are used to evaluate the suitability of certain physical separation procedures such as screening and gravity separation of the Yuma soils and sediments. The total U analysis will be used to quantitatively establish the level U contamination present in the Yuma soils.

The separation evaluation study will provide information pertinent to the application of a separation technology for soil remediation. The study will focus on methods of lowering the DU activity of the soil below the NRC mandated action level of 35 pCi/g for unrestricted release, hence allowing the soils treated to this level to return to the original location.

2.2 Sampling and Analysis

Sampling at the YPG occurred the week of November 2, 1992. The three piles undergoing characterization were referred to as the West Pile, the North Pile, and the South Pile (see Figures 4 through 6).

All three piles were similar in composition with one exception. The South Pile consisted of what appeared to be four different mounds with two types of soil. The northern end of the South Pile and a small portion of the middle section are gravelly in nature. This gravelly soil was placed in the area during the Spring of 1990. This portion of the pile was not sampled; according to YPG personnel, it is believed that penetrators were not shot into this section (refer to the grayed areas of Figure 6).

The three piles were gridded according to the requirements defined in Section 4.0 of the Sampling and Analysis Plan (SAP) (Medina 1992). The piles were marked and divided down the long axis and into four quadrants (see Figures 4 through 6). Within each of the four quadrants, 10 subsamples were collected and combined into a single sample. The above method produced four composite samples from each of the three piles. Collection of this number of samples from each pile will meet the precision requirements to detect a 10% difference between the mean pile

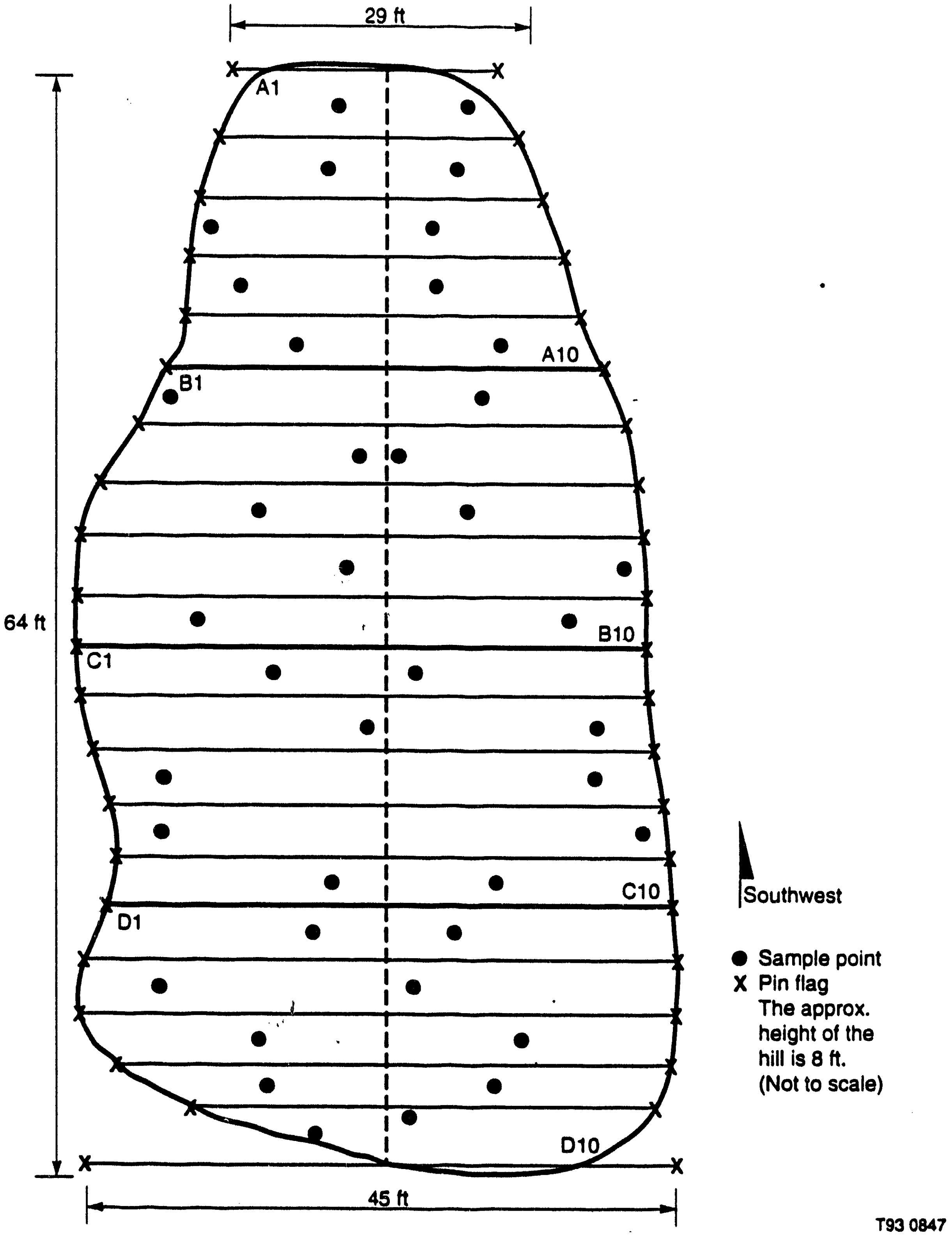


Figure 4. The collection scheme for the West Pile.

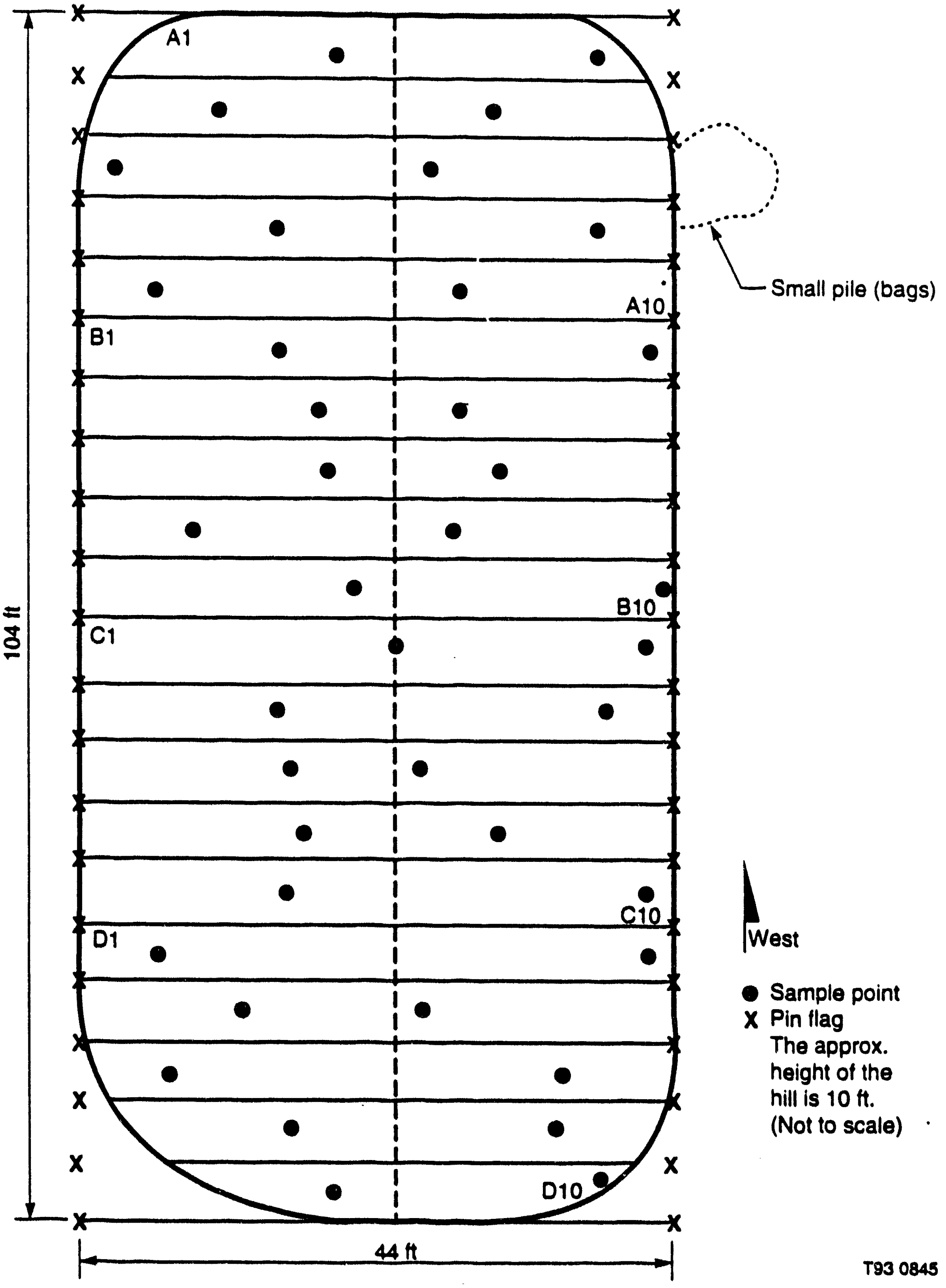


Figure 5. The collection scheme for the North Pile.

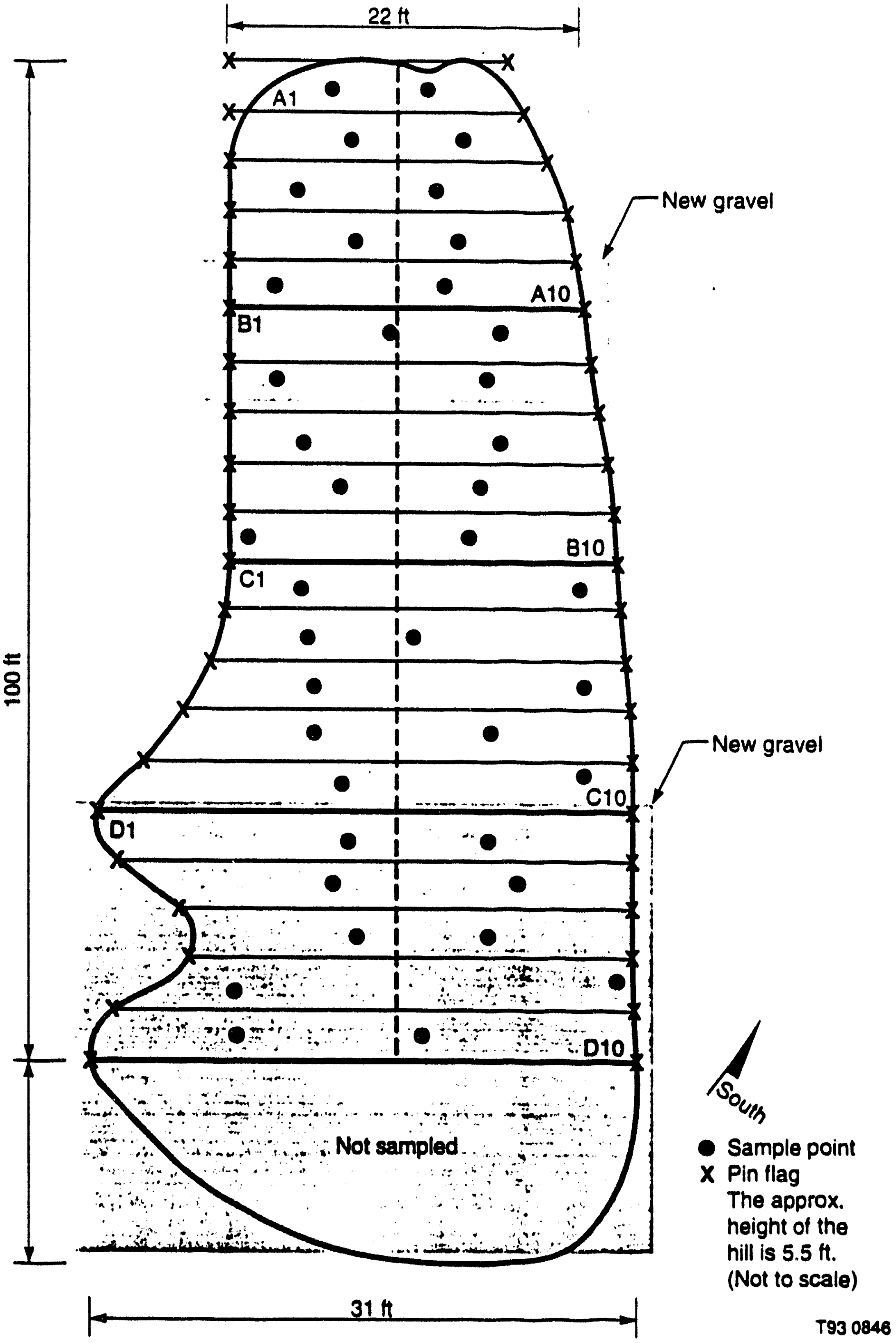


Figure 6. The collection scheme for the South Pile.

concentration with a 95% confidence level. Figures 4, 5, and 6 depict the actual collection scheme as recorded in the field logbooks during sampling of the three piles.

Sample collection consisted of collecting samples from the gridded sections as described above. A hand auger or a power auger were used to drill holes in the designated locations. One sample was collected from each grid at differing depths. All of the samples from each quadrant were then placed in a five-gallon bucket. The soil contents were thoroughly mixed to obtain an equal distribution of soil throughout the collection device. Three samples were then collected from the bucket. A TCLP (specifically for Ba, Hg, and Pb analysis) and a total U analysis were conducted on each sample. In addition, a physical properties characterization effort was included for each set of samples. At the West Pile (Section B of Figure 4), duplicate samples were collected (the first set of samples was denoted via an "a" after the sample ID and the second set with a "b" after the sample ID).

Background samples were collected from a predetermined spot at YPG. The area from which the sample was collected is approximately 1 mile northeast of the location of the piles. The sample location is by an observation tower, Tower 8.1. The soil from this location is similar in nature to the soils found at the GP-20 site. Background samples were analyzed for TCLP metals (Hg, Pb, Ba), total U (a duplicate sample was collected for this analysis), and physical properties. The samples were then taken to the laboratory to be spiked. Quality Assurance/Quality Control requirements as defined in the SAP were followed by the sampling team and the laboratories.

The samples were labeled, sealed with parafilm, and placed into a cooler with ice. Chain-of-custody forms were filled out to ensure proper custodial management of the samples.

The samples were then shipped to Aspen Laboratory for the TCLP analysis. The U used to spike the sample was analyzed via the Los Alamos National Laboratory (LANL).

2.3 Sampling Results

Twelve samples, four from each of the designated piles, were analyzed for the physical properties of the soil, TCLP analysis of Ba, Hg, and Pb, and a total U analysis. As mentioned in the previous section, a duplicate sample was collected from the West Pile.

2.3.1 Physical Properties Analysis

The physical properties analysis included bulk density (MOA, Part I and II), and moisture content (ASTM D2216-90), pH (MOA, Part I and II) analysis, particle density (MOA, Part I and II), and the particle size distribution (ASTM D422). Table 1 lists the results of the physical properties analysis specific to each pile (includes pH). Refer to Appendix A for the raw data.

Table 1. Pile samples for the physical properties analysis.

Pile	Bulk density (lb/ft^3)	Particle density (lb/ft^3)	Moisture content (%)	pH
South	98.7–106.5	169.7–171.8	1.5–3.3	7.9–8.3
North	101.9–103.0	169.6–172.0	2.6–3.0	7.9–8.1
West	96.9–99.3	170.6–171.5	2.4–2.6	7.7–7.8

The average results for the physical properties at the 95% confidence interval are as follows:

Bulk Density = 101.0 ± 1.8 lb/ft^3

Particle Density = 170.8 ± 0.5 lb/ft^3

Moisture = 2.5 ± 0.3%

pH = 8.0 ± 0.1

The samples for each pile range as listed in Table 1.

For the particle size distribution analysis, the range of the soil passing and the particle size sieve are listed in Table 2.

Table A-1 in Appendix A contains a list of the data results specific to each pile.

2.3.2 Total Uranium Analysis

The analysis of soils for U was performed by the Material Analysis Section (YPG Laboratory) with the Leaman Labs Inductively Coupled Plasma (ICP) Spectrophotometer. Water samples were analyzed with a ChemChek Kinetic Phosphorescence Analyzer.

A background sample and a duplicate sample for total U were collected. One of these samples was spiked by David L. Pond, the YPG Laboratory Chemist. The results of the spike are listed in Table 3.

True background is approximately 2 μg DU/g of soil (refer to Pond 1992) or 0.72 pCi/g. One sample was collected for background, the data results were reported as -5.39 μg/g. The sample that was to be used for the background level is below the detection limit of the ICP method used.

As can be noted by the analytical results presented in Table 3, the contaminants range from 17.79 pCi/g to a high of 155.51 pCi/g, exceeding the 35 pCi/g NRC unrestricted release limit (refer to Appendix A for the raw data results and Appendix B for the conversion factor).

Table 2. Average values of the soil passing by % and the particle size sieve for the particle size distribution analysis.

Gravel	Sand	Silt and clay
19.0 mm = 99.8 ± 0.3%	2.0 mm = 66.7 ± 3.7%	0.075 mm = 23.7 ± 5.2%
12.5 mm = 96.3 ± 1.4%	0.850 mm = 54.4 ± 5.1%	0.050 mm = 20.5 ± 4.8%
9.5 mm = 92.1 ± 2.1%	0.425 mm = 46.8 ± 6.2%	0.020 mm = 14.3 ± 3.6%
6.3 mm = 86.0 ± 2.7%	0.250 mm = 41.3 ± 6.8%	0.005 mm = 6.9 ± 2.0%
	0.106 mm = 30.1 ± 6.2%	0.001 mm = 1.3 ± 0.5%

Table 3. Results from the total U analysis.

Pile	Range of results Uranium concentration (μg/g)	Range of results Uranium concentration (pCi/g)
South	49.41-133.53	17.79–48.07
North	201.23–431.97	72.44–155.51
West	101.47-398.65	36.53–143.51
Spiked Sample[a]	61.00–66.45	21.96–23.92

a. Duplicate analysis of spiked sample.

2.3.3 Toxicity Characterization Leaching Procedure Results

A TCLP analysis for Ba, Pb, and Hg was conducted by Aspen Environmental Laboratory on the soil and water samples. The raw analytical data results are presented in Appendix A. All of the samples were below the 100 mg/L Resource Conservation and Recovery Act (RCRA) regulatory limit for Ba. Pb for the soil samples ranged between 0.05 mg/L (detection limit) to 0.79 mg/kg and for the water samples were all <0.2 mg/L. The regulatory limit for Pb is 5 mg/L. All of the results were well below this value. The RCRA TCLP limit for Hg is 0.2 mg/L. All of the samples were less than the 0.001 mg/L detection limit for this contaminant. Based on these analytical results, toxic metals are below the regulatory limit established by RCRA for TCLP metals.

2.3.4 Application of Analytical Results to Soil Treatment Technologies

Application of a treatment technology for the DU contaminated soils at YPG is dependent upon a number of factors. These include the mineralogy and particle size distribution of the soils, moisture content, the type of contaminant present at the site, the pH and buffering capacity of the soils, Eh or redox potential of the soil, the presence and nature of chemical ligands, and other such key elements. This section discusses the application of different treatment technologies to the soils. Section 3 will use the information presented in this section to determine what identified treatment technologies are feasible.

2.3.4.1 Uranium Chemistry Information and Analysis. This subsection provides information pertinent to the chemistry of U and an analysis of the data results obtained from the sampling effort.

Penetrators are composed of U metal alloyed with 0.75 wt% Ti. U metal in such an alloy is unstable at the earth's surface and will react to form oxides, oxyhydroxides, hydroxides, and other chemical compounds when in contact with soil, air, and water. Some data are available that show the oxidation of U metals when in contact with dry air, moist air, water vapor, and carbon dioxide at temperatures less than 100°C (Ritchie 1981; Tyzack and Cowne 1976).

In general, the first product of U metal oxidation is UO_2 (uraninite). As oxidation proceeds, hyperstoichiometric U oxides of the form UO_{2+x}, where $0 < x < 0.4$ are produced. These include such forms as U_4O_9, U_3O_7, and U_3O_8, all of which are mixtures of U^{+4} and U^{+6} and have the fluorite structure of UO_2. These compounds are generally green-black in color. Generalized reactions illustrating possible oxidation processes include:

$$U + [(2 + x)/2]\, 0_2 = UO_{2+x}$$

$$U + (2 + x)H_2O = UO_{2x} + (2 + x)H_2$$

$$U + 2CO_2 = UO_2 + 2CO.$$

Further oxidation and reaction with water and carbon dioxides may produce several hydrated and carbonated compounds such as UO_3, $U_3O_8 \bullet H_2O$, $(UO_3)_7 \bullet 11(H_2O)$, $(UO_2(OH)_2 \bullet H_2O)$ and complex uranyl carbonates. This group of minerals is typically yellow in color and is referred to as "yellow cake." Minor amounts of uranyl sulphate and phosphate minerals may also be present. There are more than 70 naturally occurring minerals in which U is an essential constituent and many more in which U is a minor or trace constituent; thus, the possible forms in which U could be found are quite extensive.

U in groundwater (i.e., aqueous solutions) occurs in two primary oxidation states, U^{+4} and U^{+6}. Redox conditions (Eh), pH and soil/water composition control the solubility of U in natural waters and the precipitation of solids. U in the +4 valence states will complex in natural water with several ligands that includes hydroxide, carbonate, sulfate, chloride, and phosphate as well as fluoride at pH levels less than 4.0. The dissolved U^{+6} species, the uranyl ion (UO^{+2}), will also complex with hydroxide, carbonate, fluoride, sulfate, and phosphate ions. The uranyl ion is generally complexed primarily by fluoride that is at a pH less than 4. Complexation of the U is largely dependent upon the pH, Eh and the ligand concentrations of the soil pore water. In general, the uranus form (4+ oxidation state) is less soluble than the uranyl form (6+ oxidation state).

According to studies conducted by the YPG, the background concentration of DU is approximately 0.72 pCi/g. The composition of DU from the analytical results indicates that the DU ranges between 17.79 pCi/g to approximately 155.51 pCi/g. The DU at YPG is expected to vary in the state of oxidation from metallic U with traces of Ti to UO_2, UO_3, and their derivatives. The penetrators in contact with soil water at a pH of 8 will probably produce oxidized hydroxides and carbonates of U in the 6+ oxidation state. One form of DU at the site has been noted to be yellow in color. The oxidized U is typical of oxides, hydroxides, and carbonates or U in the +6 oxidation state. A sample was collected in a study conducted by LANL (Ebinger et al. 1990) where yellow cake was visible. According to the study, the yellow material was later identified by x-ray diffraction as schoepite ($UO_2(OH)_2 \bullet H_2O$). This secondary solid material as well as other species are produced by the precipitation of dissolved U. This is more prevalent in environments of high oxidation potentials (high Eh). Low Eh and/or increased microbial activities in soils may prevent significant dissolution of U (Ebinger et al. 1990). If the DU is concentrated at the bottom of the soil piles or has not been exposed to air it may be in the metallic or in the relatively insoluble +4 state.

The LANL study also determined the U-235/U-238 ratio from samples collected at the YPG site. This ratio gives information on the source of U in the sample. U is from natural sources (UO_2, etc.) when the ratio is >0.0065, whereas U from DU penetrators has a ratio less than 0.0065. Samples collected from the YPG impact area show that the ratio ranges between 0.0023 to 0.0071. Therefore, the source of the U is both from natural sources and from penetrators.

2.3.4.2 Soil Particle Analysis. The predominant soil type in the firing range is characterized mainly as mixed alluvium of gravels, sand, silt, and clay (LLNL) and is relatively coarse textured. The average particle size distribution determined from the ASTM method was presented in Section 2.3.1. The information presented in this section are the average results for the particle size analysis for the three piles. Approximately 36.6% of the soil is made up of sand sized particles, having a particle size between 2 mm and 0.106 mm. About one third of the soil is gravelly in nature and 14% has a particle size larger than 6.3 mm (USDA soil size nomenclature).

2.3.4.3 Uranium Analysis per Particle Size Fractions. An analysis of total U for each particle size fraction was not conducted for the sampling effort employed for this particular report. However in the fall of 1991, three soil samples were collected from each of the three GP-20 piles. Each sample is a composite sample consisting of five locations on the pile to a depth of 6 in. The soil was wet sieved and a total U analysis was conducted using a GM fluorometer. The test results obtained from this analysis are listed in Table 4.

The data in Table 4 indicate that only about 0.4% of the DU is found in the greater than 4.75 mm size fraction, a fraction that makes up more than 13.5% of the soil and that would have a U concentration of less than 2 ppm. This suggests that a simple screening procedure would achieve a volume reduction of 13.5% or better. The data are not sufficiently precise to distinguish further size versus U concentration relationships, if present. However, at Tyndall Air Force Base, Florida, DU penetrators were fired into sand butts within a building. The DU particle sizes were bimodally distributed; 80% of the DU was in the greater than +10 mesh (0.1 in.) and -60 mesh (0.0167 in.) size fractions combined. The +10 mesh material was mainly metal and the -60 mesh was probably U oxides produced by pyrophoric combustion (Wichner et al. 1989). DU test penetrators were also fired into sand butts within a building at Eglin Air Force Base, Florida. A formal particle size distribution analysis of the contaminated sand was not performed, but it was noted that more than 60% of the DU was recovered as metal by screening using a 0.5 in. (#2 mesh) sieve. These observations suggest that the U contamination may also be bimodally distributed at YPG with U metal probably being concentrated in the coarser particle size fractions and the U compounds being concentrated in the fine particle size fractions.

Table 4. Test results from the uranium analysis.

Particle size (microns)	Particle size (mm)	West Pile % Uranium	East Pile % Uranium	North Pile % Uranium
≥ 19,050	19.050	0.1	0.1	0.1
19,049-4750	19.049-4.75	0.2	0.4	0.5
4749-2000	4.749-2.000	16.3	26.6	23.4
1999-840	1.999-0.84	15.0	18.6	14.7
839-600	0.839-0.600	4.1	2.9	2.8
599-300	0.599-0.300	13.1	6.8	6.3
299-145	0.299-0.145	13.6	7.0	15.3
144-75	0.144-0.075	10.7	13.2	8.1
<75	0.075	26.9	24.4	28.8

The above % of total U readings are all +/-20% of the listed value.

According to the study by ORNL (Wichner et al. 1989) on the DU contaminated soils, 51.2% of the DU particles are concentrated in the coarser or gravelly material (1.68 mm or greater) and 11.6% are in the finer fractions (0.037 mm). The particle size analysis from the YPG results indicate that approximately 14.3% of the soils are less than 0.063 mm in size and 33.3% of the soils are greater than 1.68 mm. This yields a total of 47.6% of the soils having a high probability of containing concentrated levels of DU.

According to a study conducted by LLNL (Wichner et al. 1989), the predominant soils in the YPG range are characterized as mixed alluvium of gravels, sand, silt, and clay. The data results confirm the presence of this type of soil composition.

2.3.4.4 Other Soil Parameters. The particle density of the YPG soils is roughly 169.7 to 172.0 lb/ft^3. The bulk density ranges from 96.9 to 106.5 lb/ft^3. The pH of the soils tends to be somewhat alkaline in nature, ranging between 7.7 to 8.3, values typical of desert soils that usually contain calichie (calcium carbonate). The moisture content of the soil is between 1.5 to 3.3%, which is fairly low. The data results obtained from this analysis are confirmed by a U.S. Army Study (1978), in which it was determined that the YPG soils are moderately permeable, have a moderate to low water-holding capacity, and have a pH between 7.9 and 9.4.

2.3.4.5 TCLP Analysis. The RCRA TCLP analysis indicates that all of the metals are well below the established regulatory limit (see data in Appendix A). Therefore, the site does not contain hazardous waste or mixed waste contaminants.

2.3.5 Application of Data Results to Treatment Technologies

The information described in previous sections indicates that the DU waste materials have the following properties:

- The U probably occurs in several physical states to include metal, uraninite (UO_2 and its derivatives), and yellow cake (uranyl oxides and hydroxides).
- The soil pH is alkaline, approximately 8, and suggests the presence of calcite ($CaCO_3$), a common mineral in desert environments.
- The relation of radioactivity to grain size suggests that U, perhaps as the metal, concentrated in the coarse size fraction (0.84 mm to 4.75 mm) and also in the fine size fraction (0.037 mm and less), probably as chemical compounds. The U in the fine size fraction may be present as individual fine grains, as coatings on other grains, adsorbed on other minerals, ion exchanged with other elements in minerals such as the clay minerals, or some complex combination of two or more of these possibilities. It is not found in significant amounts in the regular coarse fractions (>4.75 mm). If so, the U is most likely pieces of metal or adhered to large cobbles.

These properties will distinguish the types of treatment technologies that feasibly have the capabilities of cleaning the DU contaminated soils to the NRC mandated levels of 35 pCi/g.

2.3.6 Application of Data to Treatment Technologies

Assuming that several competing soil treatment systems can achieve the desired cleanup goals, the following guidelines are useful for choosing among the soil treatment candidates. In general, physical methods, such as gravity separation, magnetic separation, screening, and/or classifying, are preferred. The least desirable methods for removing DU are dissolution techniques using acids or bases followed by recovery using ion exchange, solvent extraction, or similar methods. This is so because of the undesirable nature and volume of the secondary waste streams generated by these processes and the severe chemical alteration of the cleaned soils that are to be returned to the environment. Froth flotation is a border-line case between physical and chemical approaches.

The complex nature of the U contamination at YPG indicates that the successful soil treatment system will combine several different techniques. This conclusion is supported by a review of different studies by LANL and ORNL for U.S. Department of Defense (DOD) sites contaminated with DU. The studies indicated that a successful approach would apply a blend of a wet separation method, size reduction, possibly magnetic separation, and the addition of a chelating agent or an acid to remove U rich coatings or adsorbed or ion exchanged U. Some of the proposed methods for soil cleanup for U contaminated soils encompass both dry and wet separation tests (includes chemical separation processes or a blend of these technologies). Dry separation methods include dry magnetic separation and electrostatic separation. Wet separation treatment technologies include several varieties of acid and base leach and dissolution reagents together with several methods for treating the liquid wastestreams. Wet physical separation methods include wet screening, wet magnetic separation, jigging, shaking table, static belt separation, moving belt separation, and a rotating spiral concentrator.

2.3.6.1 Summary of DU Contamination Properties and Possible Treatment Methods. The information described in previous sections is again summarized here together with possible treatment methods and philosophies. It should be understood that the ideas presented here are hypothetical and are to be used only as guides. Additional sample characterization and bench testing will be necessary to test the ideas presented here.

- The U probably occurs in several physical states to include metal, uraninite (UO_2 and its derivatives); and yellow cake (uranyl oxides and hydroxides). This suggests that the successful separation will be robust and capable of treating U in several chemical forms. It will probably consist of a combination of several separation methods.

- The soil pH is alkaline, approximately 8, and suggests the presence of calcite ($CaCO_3$). Calcite greatly increases the buffering capacity of the soils and will tend to buffer soil washing solutions to this value and neutralize acids used for leaching, thus decreasing their effectiveness. The optimum soil treatment system should be unaffected by the alkaline soils.

- The relation of radioactivity to grain size suggests that U is concentrated in the size fraction less than 4.75 mm. Separation of this size fraction would provide an initial overall reduction of approximately 13.5% of the DU contaminated material from the YPG soils. If, as seems likely, the DU in the coarser fraction (but less than 4.75 mm) is in the form of metal fragments from the penetrators, a simple gravity, or magnetic separator could be effectively used to further separate it from this size fraction. The situation with the fine size fraction is more complex. The DU in the fine fraction is probably a complex mixture of oxides, hydroxides, and possibly carbonate or other minerals. It probably occurs as both very fine individual particles and as coatings on other mineral grains and possibly as adsorbed on or ion exchanged into other minerals such as the clay minerals. If the U compounds in the fine material are predominantly present as individual grains, physical separation methods such as density separation, magnetic, etc., are probably applicable. If the compounds are present predominantly as coatings, adsorbed, or ion exchanged with host minerals, then chemical methods such as froth flotation, ion exchange, leach or dissolution techniques will probably be necessary to remove them from the fine size soil fraction. Although they might be separable using simple physical techniques such as gravity separation, it is likely that more sophisticated methods, such as soil washing, will be necessary to separate the DU from the soil particles in the fine fraction.

Given the complexities of the physical and chemical properties of the materials to be treated and the observation that soil treatments are very site and contaminant specific, it is clear that bench-scale testing will be required to establish the preferred soil treatment procedures.

3. TREATMENT TECHNOLOGIES

An evaluation of existing cleanup technologies for DU contaminated soils are presented in this section. Eight companies or organizations were selected for inclusion in this report as the most likely to have a technology applicable to YPG. The companies (vendors) were located from contacts at the West Valley Nuclear Service Co. Inc., Fernald Environmental Restoration Management Corporation, EG&G Idaho, Inc.'s Environmental Restoration and Waste Management Department and from information derived from the EPA's Superfund Innovative Technology Evaluation Program and the EPA's Vendor Information System for Innovative Treatment Technologies Program. The eight technologies listed in this report are not in any particular order. The information compiled in this section was directly derived from the vendors.

Economic information obtained from vendors was given in ranges versus specific costs because data results, a statement of work, soil characteristics, etc., were not provided to the vendors. A more accurate cost can be determined from the bench-scale testing. Costs for a full-scale operation are dependent upon the bench-scale results. Most vendors will require a bench-scale operation to fully determine the final costs for cleanup. Because of the lack of site-specific information, the vendors were reluctant to provide costs until a statement of work has been issued. The substantial deviations in the ranges quoted in this report were a best guess, based on not having a defined scope of work.

A set of criteria was established to determine the capability of each group as follows:

- Previous experience
- Cleanup process
- NRC Laboratory availability
- Previous cleanup levels and volume reduction achieved
- Portability of equipment
- Economics
- Radiation controls and measurements incorporated in soil monitoring
- Additional wastestreams generated
- Permits required on previous sites
- References.

The information specified by the established criteria for each technology is presented in the following sections.

3.1 TMA/Eberline Thermo Analytical Inc.

Thermo Analytical, Inc. (TMA/Eberline) is located in Albuquerque, New Mexico. The treatment technology developed by this company is referred to as the TMA/Eberline modified Johnston Atoll Plutonium (Pu) Cleanup Plant. This technology was originally designed to separate Pu and americium (Am) from a coral soil matrix. The following section provides 10 examples of relevant information as to how the criteria above are met by the technology.

1. Previous Experience

In August, 1990, TMA/Eberline was awarded a prime contract with the Defense Nuclear Agency (DNA) to make extensive modifications and improvements to a prior contractor's soil cleanup demonstration plant on Johnston Atoll. Johnston Atoll soil was contaminated with Pu-239 and Am-241 particles from nuclear weapons-effects testing conducted in the 1960's. Approximately 100,000 yd^3 of coral soil matrix containing low and intermediate levels of contamination remain inside a controlled access area and is being processed. This work is expected to be completed in the next 12 to 18 months.

2. Cleanup Process

The modified Johnston Atoll Pu Cleanup Plant is an assembly of standard sand-and-gravel handling equipment coupled with advanced instrumentation for monitoring nuclear radiation (see Figure 7). This plant was designed to process 1,000 yd^3 of soil per week. The soil remediation system uses an array of sensitive radiation detectors and software designed by Eberline Instrument Corporation. The software controls the Segmented Gate System for diverting contaminated material from soil as it moves along conveyor belts beneath an array of 15 overlapping NaI detectors. Each detector reports to a microprocessor/computer. The computer directs the diversion of contaminated material through the segmented gates and logs the radioactivity of both contaminated soil and uncontaminated soil to document the process. Clean soil is automatically diverted in one direction and contaminated soil in another. A metal drum collects hot particles while a supplemental soil washing process removes dispersed contamination. Washed soil then passes beneath a second array of radiation detectors to verify that release criteria have been met.

3. NRC Licensed Laboratory

TMA/Eberline has several licensed facilities that could be used for bench-scale testing.

4. Previous Cleanup Levels Achieved

TMA/Eberline's modified Johnston Atoll Pu Cleanup Plant was able to meet DNA's release requirements of 500 Bq/kg (13.5 pCi/g) for alpha activity from Pu and Am, and 5000 Bq/kg (135 pCi/g) for all radioactive particles. A 98% volume reduction has been achieved with this process at Johnston Atoll to date.

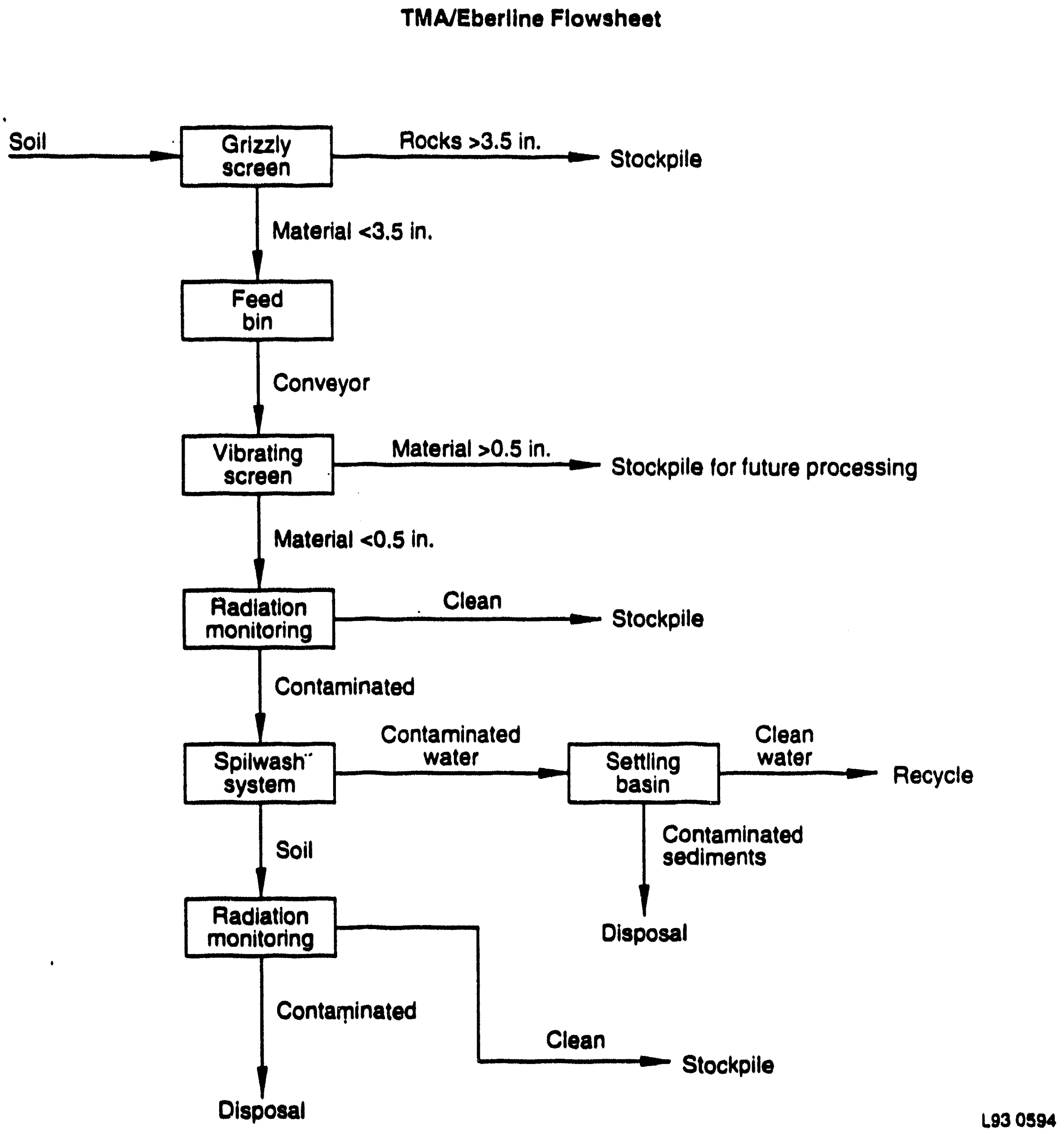


Figure 7. TMA/Eberline flowchart.

5. Portability of Equipment

The modified Johnston Atoll Pu Cleanup Plant is owned by the DNA. TMA/Eberline has completed the design of a smaller-scaled version of this plant, which is more mobile and capable of processing 200 to 300 yd^3 per week.

6. Economics

The approximate cost/yd^3 of soil ranges from $100.00 to $200.00 depending upon site conditions. TMA/Eberline is currently researching the feasibility of conducting this type of work strictly on the basis of percent cost liability savings, in other words, TMA/Eberline would receive reimbursement based entirely on the volume reduction achieved. With either option, a bench-scale or feasibility study would be required. The cost range for a bench-scale or feasibility study is $25 to $50K.

7. Radiological Soil Process Monitoring

TMA/Eberline's modified Johnston Atoll Pu Cleanup Plant utilizes an array of 15 overlapping NaI detectors. The 15 NaI detectors in each monitoring unit are arranged in two overlapping rows of 7 and 8 detectors, respectively. Each detector has an active area measuring 100 × 100 mm and is encased in an aluminum housing with a thin end window. The second row of 7 detectors is offset from the first row to prevent hot particles from passing undetected between adjacent detectors. Each detector reports to an individual microprocessor board that calculates amounts of radioactivity and determines whether a hot particle has been detected. Each detector microprocessor board then electronically reports to a master controller board that collects data, determines whether dispersed radioactivity has been detected, and selects and actuates one of the eight diversion chutes of the segmented gate system as required.

When hot particles or distributed contamination above release criteria are detected, one or more of the eight segmented gates located at the end of the sorter conveyor is electronically directed by the master controller board to divert the contaminated material. The minimum amount of diverted material is approximately 36 $in.^3$ (about 1 pint).

8. Additional Wastestreams Generated

The soil with dispersed contamination is washed with water in a spiral classifier. The wash water containing the contamination is then placed in a lined settling basin where the water may be recycled or evaporated. The sediments in the settling basin will be packaged for disposal.

9. Permits Required on Previous Sites

No permits for this process were required on Johnston Atoll.

10. References

Dr. Edward Bramlitt
Technical Director
Defense Nuclear Agency, Field Command
(505) 846-8568

Company Contact:

Nels R. Johnson, President
TMA/Eberline
(505) 345-9931

3.2 Bradtec—U.S. Inc.

Bradtec—U.S., Inc. (Bradtec) is located in Atlanta, Georgia. The treatment technology developed by this company is referred to as the ACT*DE*CON process (patent pending). This technology was developed to separate radiological contaminants from soil at Department of Energy (DOE) facilities. The following provides relevant information as to how the criteria in Section 3, "Treatment Technologies," are met by the technology.

1. Previous Experience

The Bradtec process (the ACT*DE*CON process, patent pending) has been tested at the bench-scale with various types of soil and with various contaminants, including U, Pu, Am, and Pb (see Figure 8). This process is currently scheduled to be used on a pilot-scale at two DOE facilities during 1993 and on a full-scale at a DOE facility during 1994. Chemical Waste Management, Inc. is licensed to use the Bradtec process.

2. Cleanup Process

The Bradtec process combines dissolution with dilute selective solvents, contaminant recovery, and solvent regeneration to provide a continuous recirculating treatment process for the treatment of soils to remove Sr, Cs, Tc, Ra, actinides (U and transuranics), Ba and Pb. The treatment process utilizes countercurrent extraction to dissolve and recover the contaminants. The solvent typically used is composed of hydrogen peroxide, sodium carbonate, sodium bicarbonate, 8-hydroxyquinoline, and ethylenediaminetetraacetic acid. Soil is fed to the first extractor, which provides for solvent contact and contaminant dissolution. The soil is then fed from the first extractor to the second extractor where partially treated soil and fresh solvent are mixed, resulting in further dissolution. The number of extraction stages and the contact time in the extractors is determined by the contamination level, the physical and chemical characteristics of the soil, and the level to which the soil must be treated. The treated material that exits the final extractor is then filtered to recover the treated soil. The filter cake is flushed with clean water prior to discharge. The solvent (with contaminants) is treated by either selective ion exchange or evaporation. The solvent can then be analyzed and chemically adjusted before recycling.

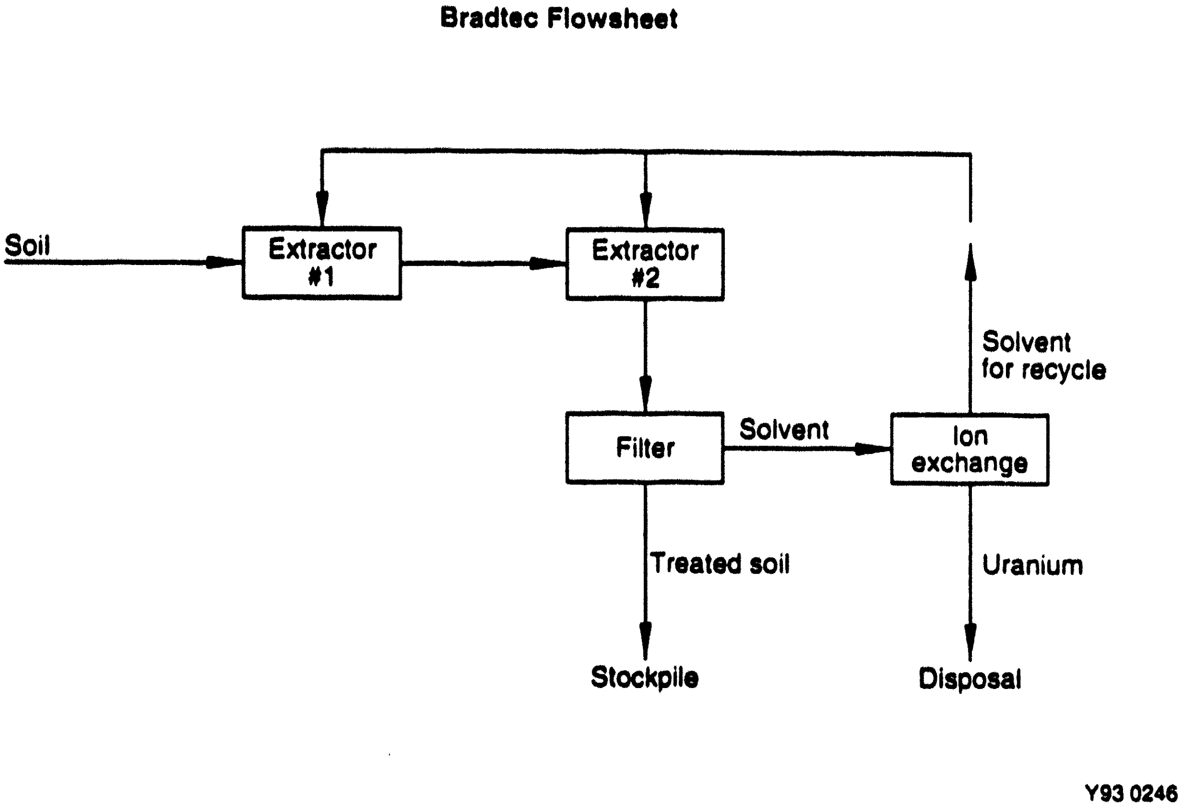


Figure 8. The Bradtec process flowchart.

3. NRC Licensed Laboratory

Bradtec—U.S. Inc. has access to Chemical Waste Management, Inc. licensed laboratories, which could be used for bench-scale testing.

4. Previous Cleanup Levels Achieved

Bench-scale testing was conducted on soils with a 87% silt fraction and a 5% clay fraction with U concentrations of 406.8, 1.167, and 1,009 pCi/g. The clean soil after testing contained 13.6, 22.6, and 34.0 pCi/g of U, respectively.

5. Portability of Equipment

Chemical Waste Management, Inc. has trailer mounted systems available.

6. Economics

The approximate cost/yd^3 of soil ranges from $50.00 to $100.00 depending upon site conditions. The cost range for a bench-scale test is $12,000 to $13,000.

7. Radiological Soil Process Monitoring

With the Bradtec process, periodic sampling of the processed soil is performed to ensure cleanup levels are satisfied.

8. Additional Wastestreams Generated

The solvent used in this process is continuously recycled. Upon completion of processing the solvent would be either evaporated or concentrated to reduce the volume requiring disposal.

9. Permits Required on Previous Sites

Bradtec personnel are not aware of any permits required for their process.

10. References

Don Johnson
Argonne National Laboratory
(708) 252-3392

Company Contact:

Mike Dunn, President
Bradtec-U.S., Inc.
(404) 640-9305

3.3 B&W Nuclear Environmental Services, Inc.

Babcock and Wilcox Nuclear Environmental Services, Inc. (B&W-NESI) is located in Lynchburg, Virginia. The treatment technology developed by this company is referred to as the B&W-NESI Soil Washing Technology. The technology was originally designed to separate clean soils from contaminated fines at a DOE site. The following section provides relevant information as to how the criteria in Section 3 are met by the technology.

1. Previous Experience

B&W-NESI developed a soil washing system for the cleanup of approximately 500,000 ft^3 of U contaminated soils from the Apollo Facility located 35 miles northeast of Pittsburgh, Pennsylvania. This facility is scheduled for decontamination and decommissioning. The U at this facility is in the form of U-234, -235, and -238. Soil contamination ranged from zero to 2,000 pCi/g. B&W-NESI developed a bench-scale model of this soil washing technology and treated approximately 1000 lbs of contaminated soil. The system never reached the pilot-plant level because it was agreed upon that it would be politically and economically more advantageous for DOE to ship all of the soil offsite to Envirocare, a disposal facility in Utah.

2. Cleanup Process

The soil washing system is composed of separating contaminated soils into a coarse size fraction and a fine size fraction, which represents the clean and contaminated portions, respectively (see Figure 9). The process comprises two screening and washing steps and two dewatering steps. Coarse screening and washing of the plus 1-in. material is achieved in a trommel (rotating screen). Fine screening and washing is achieved over a horizontal vibrating screen. The coarse fractions of the soil are dewatered mechanically in a vibrating basket-type centrifuge. The fine fractions of the soil are dewatered by a classifying cyclone dewatering screen and thickener/belt press process circuitry. The cyclone requires about 750 gpm of slurry to operate properly; therefore, a portion of the overflow is recycled for water conservation.

The discharge stream feeding the thickener from the head tank is chemically treated with flocculants (cationic or anionic type, or both) for coagulating the fine solids into large groups or particles to increase settling rates in the high capacity thickener. The thickener underflow is treated with flocculating-type chemicals and is further mechanically dewatered in a belt process. The thickener overflow is collected in the clarified water sump and is chemically treated with a wetting agent. Acid and makeup water are added as required. Two pumps split the clarified water sump to the belt press, vibrating screen, and trommel. Excess water is bled from the system and stored onsite in a storage tank.

3. NRC Licensed Laboratory

B&W-NESI has onsite laboratories capable of performing the radiological analysis.

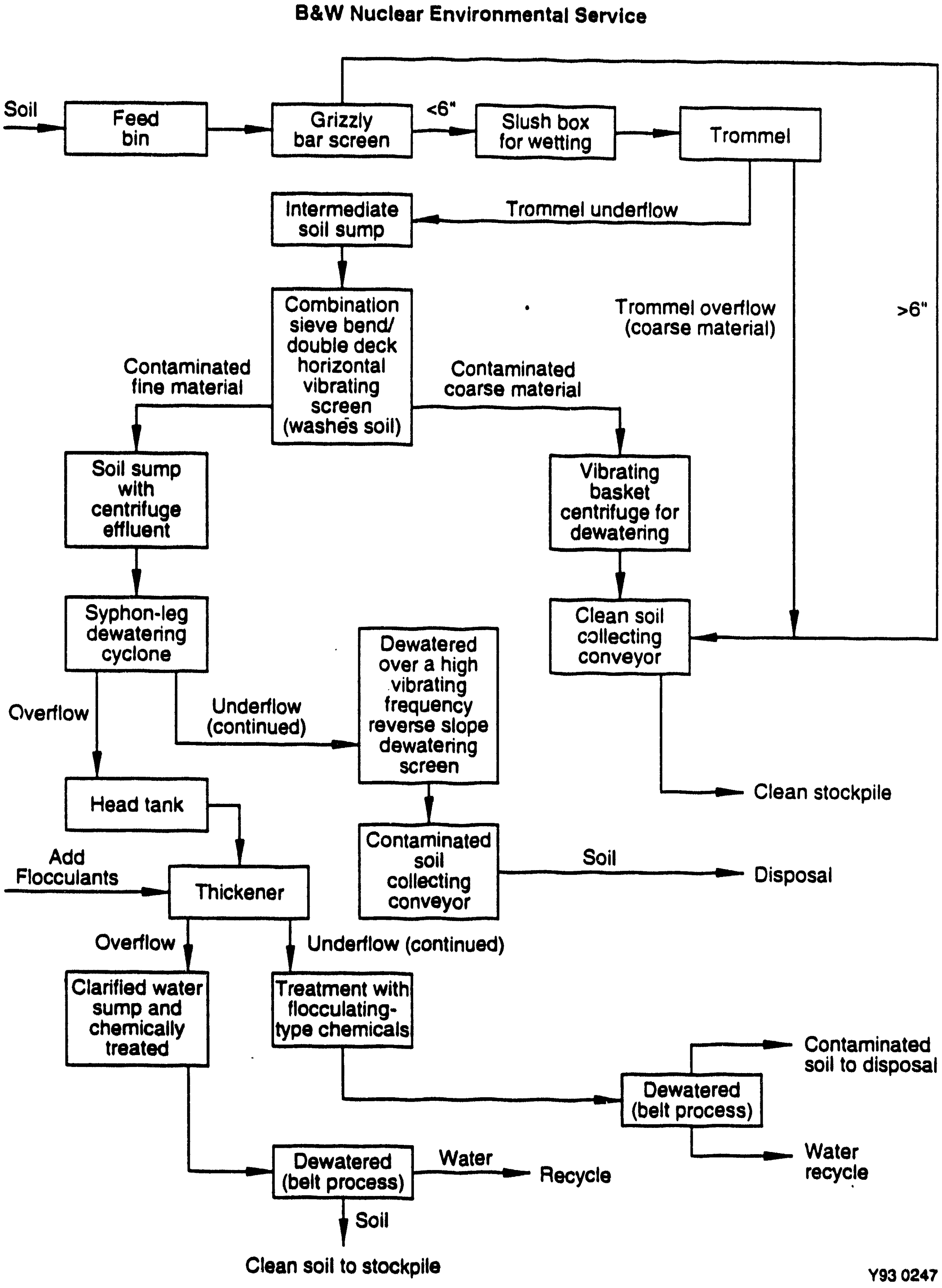


Figure 9. The B&W-NESI process flowchart.

4. Previous Cleanup Levels Achieved

The bench-scale model was able to achieve a cleanup level of 30 pCi/g for U. An 85% volume reduction was also achieved with this process. A worse case scenario for the system was that of a 50% volume reduction. The soils at Lynchburg, Virginia consist mainly of loams and clays. The absorption tendencies of clays are significant, therefore the level of difficulty for removal of U from the soils is far more difficult than from those soils found at the U.S. Army YPG.

5. Portability of Equipment

B&W-NESI can move equipment from location to location. The timeframe for a complete setup for the system ranges from 1 to 2 months.

6. Economics

The approximate cost for cleanup per yd^3 of soil ranges from $3.00 to $5.00 depending upon the site conditions. This is only for a purely consumable cost and for affiliated working labor-hours (costs do not include equipment). Bench-scale costs range from $30,000 to $70,000. This includes sample collection, data analysis, etc.

7. Radiological Soil Process Monitoring

The B&W-NESI soil washing system does not utilize direct inprocess radiological measuring controls, rather grab samples of the soil are collected randomly by built-in samplers throughout the process. The samples are collected from the up front system (input feed location), the process sampler (output feed), in process, and from the clean-fractions pile. Samples are immediately analyzed onsite for U content.

8. Additional Waste Streams Generated

Wastestreams generated other than the remaining 15% contaminated soil include wastewater. The process utilized by the plant operators is to monitor the water involved in cleanup to ensure it does not exceed the sewage system discharge limitations for the contaminant. In other words, the water is changed frequently.

9. Permits Required on Previous Site

This was a bench-scale process; therefore, permits for this system were not required.

10. References

Dr. Richard Carleson
B&W-Nuclear Environmental Services, Inc.
Lynchburg, VA 24506
(804) 948-4840

Company Contact:

Lynn D. Staten
Senior Principal Engineer
B&W Nuclear Environmental Services, Inc.
2200 Langhorne Place
Lynchburg, VA 24501
(804) 948-4606

3.4 Westinghouse Scientific Ecology Group, Inc.

Westinghouse Scientific Ecology Group, Inc. (SEG) is located in Pittsburgh, Pennsylvania. The treatment technology developed by this company is referred to as the SEG Soil Washing System. This technology was developed to separate organics, polychlorinated biphenyls (PCBs), heavy metals, and radioactive contaminants from soils. The following provides relevant information as to how the criteria in Section 3 are met by the technology.

1. Previous Experience

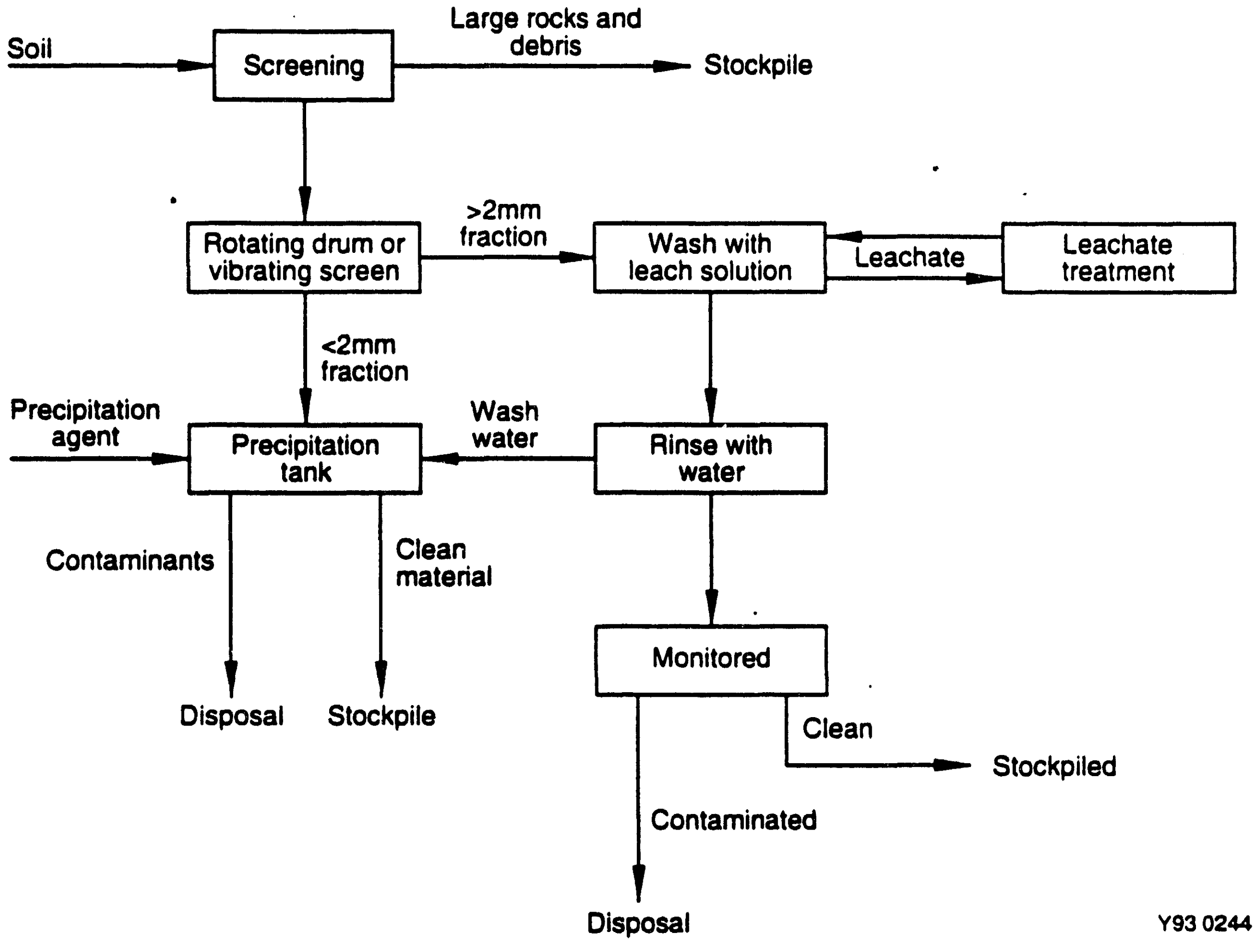
Westinghouse SEG has recently completed using their full-scale mobile soil washing system to remediate a site in Bruni, TX. The site was formerly used for the solution mining of U. The contamination of approximately 22,500 yd^3 of soil, primarily of U and Ra, was a result of well drilling material and solution spills (including resins) that occurred during the course of operations at this site. On a bench and pilot-scale basis, the SEG Soil Washing Process has been used to decontaminate soil contaminated with a mixture of grease, Polychlorinated Biphenyls (PCBs) and U at ORNL. At the same site, the SEG Soil Washing Process was used to remove U and Hg from the soil, at the bench and pilot-scale level.

2. Cleanup Process

With the SEG Mobile Soil Washing System, soil is initially screened to remove large rocks and debris. The soil is then processed in a rotating drum or vibrating screen devise to sort and prewash the soil. Large (>2 mm) pieces of soil are washed with leach solution, rinsed with water, monitored and returned to the site (see Figure 10). The remaining contaminated soil is then processed using mining processing equipment where soils are contacted with the leach solution and the fines are separated. The washed soils are rinsed, monitored, and returned to the site. The fines and wash water go to the precipitation tank. A precipitation agent is then added to precipitate the dissolved contaminates. The clean leachate is then further treated and sent to the leachate makeup tanks. The highly contaminated fines are then placed in containers for disposal.

3. NRC Licensed Laboratory

The Westinghouse Science and Technology Center Analytical Laboratory, which is licensed and permitted to conduct experiments with RCRA, TSCA, and radioactive materials, could be used for bench-scale testing.



Westinghouse Scientific Ecology Group, Inc.
Flowsheet

Figure 10. Westinghouse SEG flowchart.

4. Previous Cleanup Levels Achieved

The soil remediation objective at the Bruni site, established by the Texas Department of Health, was 42 ppm above background (1 ppm) for U in the soil. This corresponds to 30 pCi/g in the soil. The untreated soil contained 70 ppm (50 pCi/g) of U. The processed soil contained 22.5 ppm (16 pCi/g). Better than 99% of the feed soil at the Bruni site was returned to the site as clean after processing.

5. Portability of Equipment

The SEG Mobile Soil Washing System is trailer-mounted and requires approximately two weeks to setup.

6. Economics

The approximate cost/yd^3 of soil ranges from $100.00 to $1,000.00 depending upon site conditions. SEG personnel recommend conducting an initial feasibility test to determine the feasibility of using their process. The cost range for this test is $10,000 to $30,000. If the feasibility test shows positive results, work would then proceed on a detailed bench-scale test. The cost range for a detailed bench-scale test is $30,000 to $100,000.

7. Radiological Soil Process Monitoring

Online system to monitor the radioactivity of the processed soil leaving the system is available, but has not been implemented to date. Currently, SEG uses (a) continuous air monitoring to measure radioactivity levels around the system, and (b) composite soil samples of untreated and treated soil.

8. Additional Waste Streams Generated

With the SEG Mobile Soil Washing System, the leachate is stripped in an ion exchange column and recycled. This process would create an additional waste stream. But the quantity of this stream cannot be estimated until bench-scale testing is completed. This waste stream would be minimized by concentration.

9. Permits Required on Previous Sites

Air permits were required for this process by the State of Texas. However, the process used existing permits for the Bruni site.

10. References

E. J. (Gene) Miles
Director of Fuel Cycle Materials and Services Department
Westinghouse Scientific Ecology Group, Inc.
(412) 374-2580

Company Contact:

Al Dietrich
Westinghouse Scientific Ecology Group, Inc.
(412) 247-6258

3.5 S. G. Frantz Company, Inc.

The S. G. Frantz Company, Inc. (S. G. Frantz) is located in Lawrence Township, New Jersey. The treatment technology developed by this company is referred to as the Frantz Magnetic Barrier Technology. This technology was originally developed to separate and concentrate particles according to magnetic susceptibility on a laboratory scale. The following provides relevant information as to how the criteria in Section 3 are met by the technology.

1. Previous Experience

The Frantz Magnetic Barrier Technology has been tested at the bench and pilot-scales with various types of radioactive wastes, including Pu and DU. A full-scale version of this process is currently in the planning and design stages.

2. Cleanup Process

The Frantz Magnetic Barrier Technology separates and concentrates particles according to magnetic susceptibility (see Figure 11). The technology employs magnetic energy gradient (HdH/dX) transverse to field direction, or roughly perpendicular to the path of flux, to deflect particles of selected susceptibility from the paths they would follow under the influence of opposed nonmagnetic force. Because most soils are diamagnetic and most radioactive substances are paramagnetic, by concentrating the diamagnetic compounds of soils this technology can separate grains that are nonmagnetic by reason of stains or inclusions of radioactive substances. Solids from about 2 mm to a few micrometers can be processed by this technology. Pretreatment by sizing, drying, and reducing electrostatic charges, while not essential, tends to improve separation.

The pilot-scale magnetic barrier system comprises equipment of conditioning (grinding, degreasing, washing, drying, etc.) and sizing material, for feeding it to and moving it through the separator, for collecting the separated fractions, and for examining them to determine the effectiveness of the separations. Means are provided for varying field intensity and magnetic energy gradient, opposed nonmagnetic force, rate of feed, and rate of travel through the field, vibration of the feed means and conduit surfaces. The pilot-scale process is capable of processing 0.5 to 10 kg/hr while it is anticipated that the full-scale process would be capable of processing 450 to 1,800 kg/hr.

3. NRC Licensed Laboratory

S. G. Frantz does not have access to a licensed facility to do bench-scale testing. They would prefer that the customer purchase the bench-scale unit and conduct their own testing. S. G. Frantz would provide assistance with this testing.

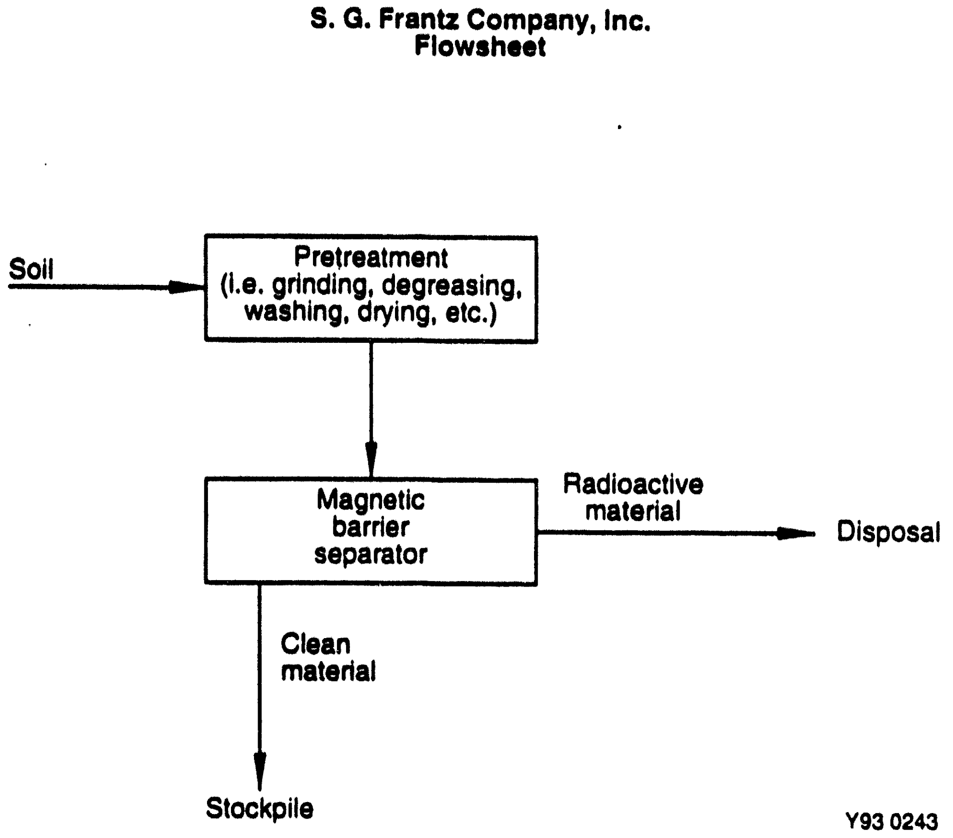


Figure 11. The S. G. Frantz process flowchart.

4. Previous Cleanup Levels Achieved

Bench-scale testing was conducted at LANL with a Magnetic Barrier Laboratory Separator. The waste consisted of sized sand, slag, and crucible residues (>45 m) from Pu production. The initial concentration of Pu ranged from 21,600 to 26,900 mg/kg (3.77×10^{11} pCi/g to 4.70×10^{11} pCi/g). The final concentration of Pu was 900 to 6500 mg/kg (1.57×10^{10} pCi/g to 1.14×10^{11} pCi/g), after treatment.

Additional bench-scale testing was conducted by LANL on sized bomb reduction sand (>90 microns) and fine sand. The initial concentration of Pu ranged from 15,500 to 15,700 mg/kg (2.71×10^{11} pCi/g to 2.74×10^{11} pCi/g). The final concentration of Pu was 5,100 to 8,600 mg/kg (8.91×10^{10} pCi/g to 1.50×10^{11} pCi/g), after treatment.

Bench-scale testing was also conducted by ORNL using a predecessor of the magnetic barrier separator, the Frantz Isodynamic Separator, a laboratory instrument used to separate individual minerals or similar substances from powdered rock or similar materials for detailed characterization. The waste consisted of DU fragments from gun test catchments and fine sand. The initial concentration of the DU ranged from 1,000 to 3,000 ppm (360 pCi/g to 1,080 pCi/g). The final concentration of DU was 10 to 200 ppm (3.6 pCi/g to 72.0 pCi/g), after treatment.

The pilot-scale process is currently being patented. Pilot-scale testing has been conducted at the S. G. Frantz facility on the separation of almandite from magnesium oxide and cupric oxide from magnesium oxide. Cupric oxide has similar magnetic properties to that of Pu. Greater than 98% separation has been achieved with a single pass. The pilot-scale can process approximately 100 g/min.

5. Portability of Equipment

The full-scale system is planned to be fully transportable.

6. Economics

The approximate cost/yd^3 of soil ranges with the full-scale system ranges from $6.00 to $6,000.00 depending upon site conditions. The purchase cost of the bench-scale equipment would be $12,000 to $15,000.

7. Radiological Soil Process Monitoring

No radiation controls or measurements have been incorporated with the Frantz Magnetic Barrier Technology.

8. Additional Waste Streams Generated

The actual magnetic barrier separator generates no additional waste streams. However, the preparation of the feed material (i.e., soil washing) would generate at least one additional waste stream, which is water.

9. Permits Required on Previous Sites

A full-scale system has not yet been constructed; therefore, no permits have been required.

10. References

Dr. Larry R. Avens, Scientist
Los Alamos National Laboratory
Los Alamos, New Mexico
(505) 667-2320

Company Contact:

Thomas Wellington, President
S. G. Frantz Co., Inc.
(609) 882-7100

3.6 EcoTek, Inc./Brice Environmental Services Corp

EcoTek Inc. (EcoTek)/Brice Environmental Services Corp. (BESCORP) is a joint venture to provide soil treatment services. EcoTek is located in Springdale, Ohio, and BESCORP is located in Fairbanks, Alaska. The treatment technology developed by these companies is referred to as the EcoTek/BESCORP Soil Washing Process. This technology was originally designed to separate hazardous, radioactive, and mixed waste contaminants from soil. The following provides relevant information as to how the criteria of Section 3, "Treatment Technologies," are met by the technology.

1. Previous Experience

EcoTek and BESCORP have formed a joint venture to provide turn-key soil treatment services for characterization through closure. The EcoTek/BESCORP team offers an integrated soil washing process for hazardous, radioactive, and mixed waste soil designated to produce clean soil by isolating and concentrating hazardous and radioactive species in a smaller volume of the original soil.

In 1992, BESCORP used the soil washing process to remediate approximately 100 yd^3 of Pb contaminated soil at the Alaskan Battery Enterprises Superfund Site, in Fairbanks, Alaska, as part of the Superfund Innovative Technologies Evaluation (SITE) Program.

In November 1992, EcoTek and BESCORP conducted a soil washing feasibility test on a representative cross-section of soil samples contaminated with Ra-226 from Tinker Air Force Base (AFB). Tinker AFB is currently seeking funding to perform a formal pilot-scale demonstration.

Feasibility tests and informal demonstrations of the soil washing system were conducted at the Hanford Site in 1991 for Westinghouse, Battelle, and Ebasco Environmental personnel. In 1992, EcoTek and BESCORP responded to a Request for Proposal (RFP) for the remediation of 1,000,000 yd^3 of mixed heavy metal and radioactive contaminated soil at Hanford. Based on stipulations of the RFP and nature of the contaminants, a processing cost of under \$20 per yd^3 was submitted. Best-and-final negotiations are currently underway.

2. Cleanup Process

In the EcoTek/BESCORP Soil Washing Process, the contaminated soil is initially screened for removal of large rocks and debris (see Figure 12). Water is added to the screened soil in a high-attrition trommel for deagglomeration of material. Oversize materials (>0.25 in.) are rinsed with a high-pressure wash, dewatered, and redeposited on site.

The slurry containing particles <0.25 in. is processed in the patented hydraulic separation chamber, which removes preselected contaminated fine soil fractions. The separation chambers can be adjusted for precisely separating contaminated fine soil fractions from the -0.25 in. material. The fine contaminated material is discharged into a clarifier for removal from the wash solution. A coagulant is added to the contaminated soil fines, which are containerized as a slurry composed of approximately 60% solids, or further dewatered with a filter press resulting in a slurry cake containing 80–90% solids. Noncontaminated -0.25 in. materials are removed from the separation chambers, washed with a high-pressure rinse, dewatered, and discharged from the plant. The -0.25 in. material is further monitored and recombined with the oversize (>0.25 in.) material to be placed back on site.

3. NRC Licensed Laboratory

On June 2, 1992, EcoTek Inc. was granted a broad scope materials license (No. 41-25193-01) by the NRC, Region II (Atlanta, GA). This license, unique in the nuclear industry, allows EcoTek to conduct a broad range of operations involving Byproduct, Source and Special Nuclear Material, incident to any of the following activities:

- Site characterization
- Environmental remediation
- Decontamination of facilities, equipment, and containers
- Treatment of soil, water, and other wastes by solidification, chemical treatment, resource recovery, or other similar operations
- Packaging for transport
- Transport, in packages or containers, for transfer to another licensee authorized to receive the material, in accordance with the terms of licenses issued by the NRC or Agreement States.

EcoTek's materials license authorizes work at temporary job sites anywhere in the United States where the NRC maintains jurisdiction. A similar license or license authority can generally be granted by Agreement States, with prior planning and notification, through the process of reciprocity.

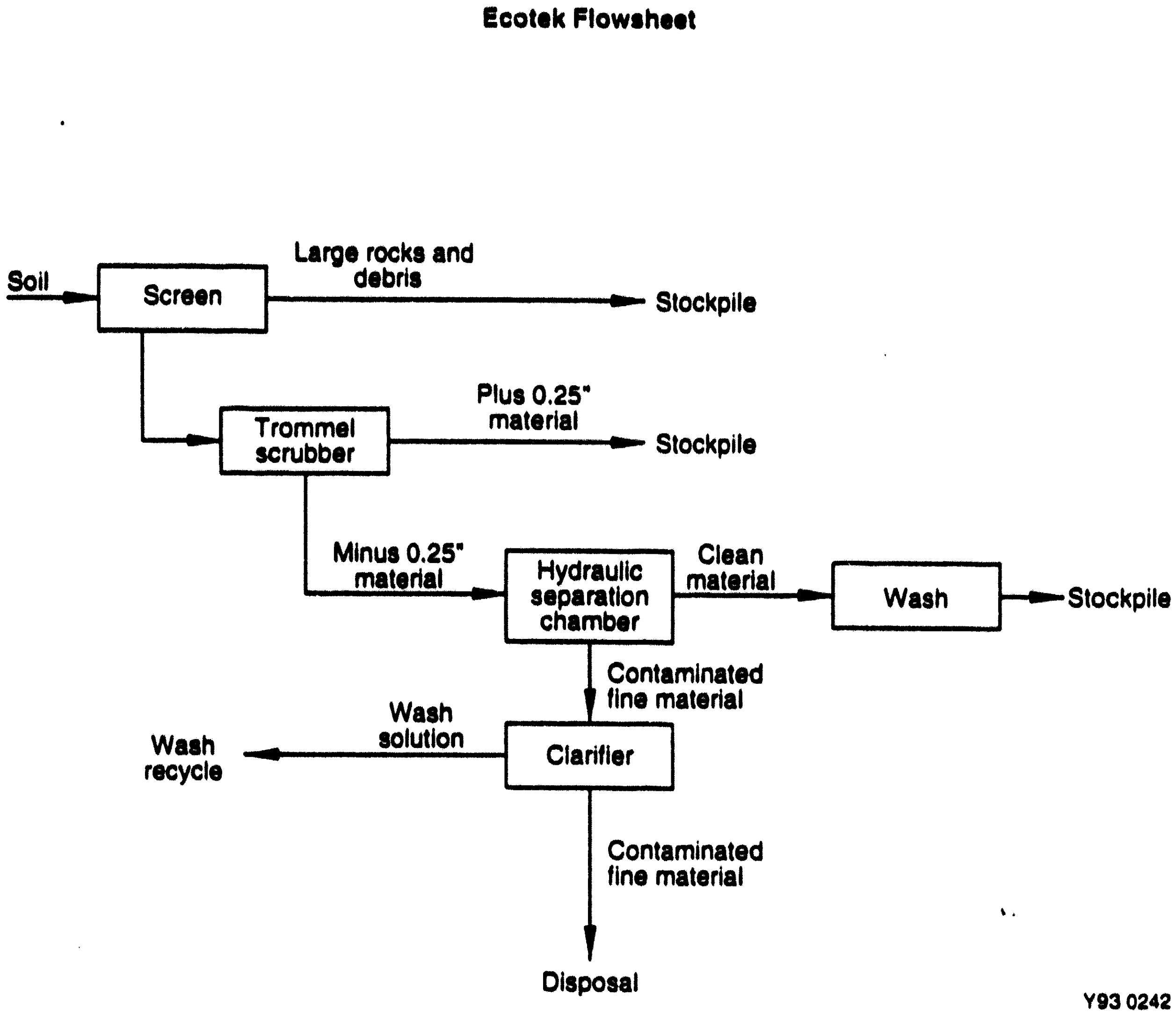


Figure 12. The EcoTek/BESCORP process flowchart.

EcoTek can use the master license to take possession of radioactive materials that are not currently under the conditions of an existing facility license. Essentially, EcoTek can take control of a site that either has no license or an inadequate license for the possession of the material or contaminant in concern.

In addition to this license, EcoTek's parent company, Nuclear Fuel Services, Inc. (NFS), has licensed facilities for the possession and use of large quantities of radioactive materials such as highly enriched U, DU, Th, and Pu. NFS is the sole supplier of nuclear fuel to the U.S. Navy and the supplier of advanced DOE fuels.

4. Previous Cleanup Levels Achieved

At the Alaskan Battery Enterprises Superfund Site, Pb contamination ranged as high as 40,000 ppm. The treated soil met the criteria of <1,000 ppm total Pb and <5 mg/L Pb. A 90% overall volume reduction was achieved.

At Tinker AFB Ra-226 levels ranged from 15 to 2,000 pCi/g. The soil washing feasibility testing showed levels could be reduced to <15 pCi/g with a 70 to 80% volume reduction.

At the Hanford site soils are contaminated with mixed toxic metal (Hg, Cr, Cd, Pb, Ni, Ag, and Cu) and radioactive contamination. Radioactive contamination ranges from 58 to 1,440 pCi/g for beta activity and from 40 to 1,430 pCi/g for alpha activity. Contamination levels for toxic metals, such as Cr and Cu, range from 7 to 546 μg/g and from 394 to 11,900 μg/g, respectively. Initial testing on these soils indicate that contamination levels can be reduced to background levels with a 95% volume reduction.

5. Portability of Equipment

The EcoTek/BESCORP 20 ton/hr processing plant is highly mobile and mounted on two 10 × 40 ft trailers. A 20 to 50 ton/hr plant is presently being fabricated for a munitions site clean up in Minnesota. All soil treatment plants are fabricated by Goldstream Manufacturing, Inc. outside Fairbanks, Alaska.

6. Economics

EcoTek/BESCORP provided the price ranges for the remediation of radioactive contamination from various soils in Table 5. This only considers the processing of the soil and does not include any support services such as excavation.

Table 5. Price ranges for the remediation of radioactive contamination from various soils.

Soil type	Volume (yd^3)	Cost in dollars (yd^3)	Cost in dollars (ft^3)
Sandy	1,000,000	20.00	0.74
Semi-sandy	18,000	120.00	4.45
Clay	1,000	625.00	23.00

A treatability test would be designed to demonstrate feasibility, define process parameters, and establish full-scale performance (i.e., volume reduction) and treatment costs. A treatability test program meeting these conditions would cost approximately $20,000. These costs can usually be deducted from the cost for full-scale treatment.

7. Radiological Soil Process Monitoring

During the soil decontamination process, sampling of all material streams released from the treatment unit will ensure process controls are operating within the specification prescribed for the project. The operating controls would be specified in a project Process Control Program (PCP).

In addition to the PCP requirements of full-scale operation, EcoTek has several inline, real-time detection system choices that can be used to ensure that the processed material released back into the environment is indeed below the desired limits. The type of system and system efficiencies are dependent upon the requirements of the site specific soil condition, radionuclide, and regulatory requirements. The following is a description of the radiation monitoring equipment proposed for the soil washing operation at the DOE Hanford site.

Cleaned and dewatered soil is continuously monitored for total activity (beta/gamma) upon discharge from the trommel and spiral classifier onto the conveyor belt. The online monitoring installation consists of a large area polyvinyl toluene plastic scintillation detector and an associated controller.

The detector, nominally 48.5 in. × 16 in. × 6 in., is mounted in a shielded enclosure above the conveyor in a 2 pi geometry, down-looking orientation. The amount of shielding in the detector enclosure, based upon engineering constraints, optimizes system detection limits to achieve detection of any radioactivity above the background of indigenous clean soil or other preset limits.

The detectors are mounted on integral stands that straddle the conveyor belt for the clean fractions of soil removed by the process. The Pb shielding is mounted on the stand and at the sides of the detector and underneath the conveyor.

The controller provides data display and storage and alarm functions and facilitates control and operation of the monitoring system. Under normal operating conditions, activity levels are continuously monitored and displayed locally at the controller. In the event that preset activity levels were exceeded, a local alarm would be activated and the reading would be both displayed on the controller and stored in memory for future retrieval. This method of data handling provides real-time operational feedback on soil washing efficiency, as well as historical information for data reporting.

8. Additional Waste Streams Generated

The soil washing system employs a closed-loop water treatment system that features the continual reuse of all water utilized in the process; hence, makeup water requirements are minimal. Depending upon the contamination type(s), water treatment may include precipitation/flocculation, clarification, ion exchange, and carbon adsorption.

The total water inventory required for the soil washing system is approximately 2,000 gal for a 20 ton/hr plant for initial startup with a minimal amount of makeup water added to the system during operation.

9. Permits Required on Previous Sites

An Environmental Protection Agency (EPA) NPDES discharge permit is required at the end of the project for the discharge of water. If a permit is not available, the water may be sent for off-site treatment and disposal.

10. References

Foster Wheeler
EPA SITE Program
Mr. Roger Gaire
(908) 906-6821

Company Contact:

Daniel R. Dilday, Business Development
EcoTek
(513) 825-8030

3.7 Lockheed Environmental Systems and Technologies Co.

Lockheed Environmental Systems & Technologies Co. (Lockheed) is located in Las Vegas, Nevada. The treatment technology developed by this company is referred to as the TRUclean process. This technology was originally developed to separate Pu and Am from a coral soil matrix. The technology was later modified to separate DU from firing range soils. The following provides relevant information as to how the criteria in Section 3 are met by the technology.

1. Previous Experience

The Lockheed TRUclean process was initially tested in a nonlaboratory setting in connection with a DNA pilot project on Johnston Atoll in the South Pacific in late 1985. The first production-size system was assembled on Johnston Atoll in November of 1988. Approximately 1,000 yd^3 of the 100,000 yd^3 of contaminated soil at Johnston Atoll was processed with the TRUclean process. This processing plant has a 15 yd^3/hr capacity and a minimum sensitivity on the order of 5 pCi/g of Pu-239.

The TRUclean process is currently in use at the China Lake Naval Weapons Center in southern California. At this site the process, which has been modified, is being used to separate DU from soil fractions at a firing range. A total volume of 6,600 yd^3 of contaminated soil is scheduled to be processed. Work at this site is expected to be completed in the summer of 1993.

2. Cleanup Process

With the Lockheed TRUclean process, contaminated soil is first placed in a feed hopper (see Figure 13). The soil is sorted by size, and the larger pieces are directed to a crusher. The crusher is optional, depending upon soil and contaminant type. When the crusher is used, crushed soil is fed back into the feed hopper. The soil is then transported to the sorter section conveyor, where it is leveled and spread to a depth of approximately 2 in. before passing beneath an array of radiation detectors. Signals from the detectors are computer processed to determine if the soil's contamination level exceeds the defined action level. When activity exceeds the action level, a gate directs soil to the decontamination section of the system. When activity does not exceed the action level, a gate directs soil to the clean stockpile where it is sampled and released for unrestricted use.

Contaminated soil is mixed with water and forms a slurry as it enters the decontamination section. The slurry flows into the gravimetric separator and is subjected to a pulsed pressure wave generated by a diaphragm. Continued agitation causes the radioactive materials to separate from the lower specific gravity soil particles. After being dewatered, decontaminated soil particles are delivered to a conveyor where the radiation detectors again monitor for radioactivity. Signals from the detectors drive a gate to direct soil to either the clean soils pile or divert it for further processing. Clean soil is sampled and certified to be nonradioactive before release to unrestricted use.

Soil diverted for further processing then enters the chemical leach system where chemicals, such as sulfuric acid, are added to the soil. The chemicals leach the U from the soil particles. This is required because U contamination commonly adheres to soil particles. The chemical leaching system consists of a series of ten 5,000-gal tanks. After the chemical leaching system, the slurry enters a countercurrent ion exchange system where the U is removed from the slurry. The slurry then goes to a filter press where the leaching solution is removed from the clean soil. The leaching solution may then be chemically adjusted and recycled.

3. NRC Licensed Laboratory

Lockheed has NRC licensed facilities available for conducting bench-scale testing.

4. Previous Cleanup Levels Achieved

Initial DU contamination levels at China Lake ranged from 4,000 to 5,000 pCi/g for material in the catchment box and 40 to 500 pCi/g for soils surrounding the catchment box. Cleanup levels achieved to date at China Lake are below 35 pCi/g with a 92% overall volume reduction.

5. Portability of Equipment

The Lockheed TRUclean system is trailer-mounted and completely transportable. The TRUclean system requires 1 to 6 months for setup depending on site conditions and required equipment.

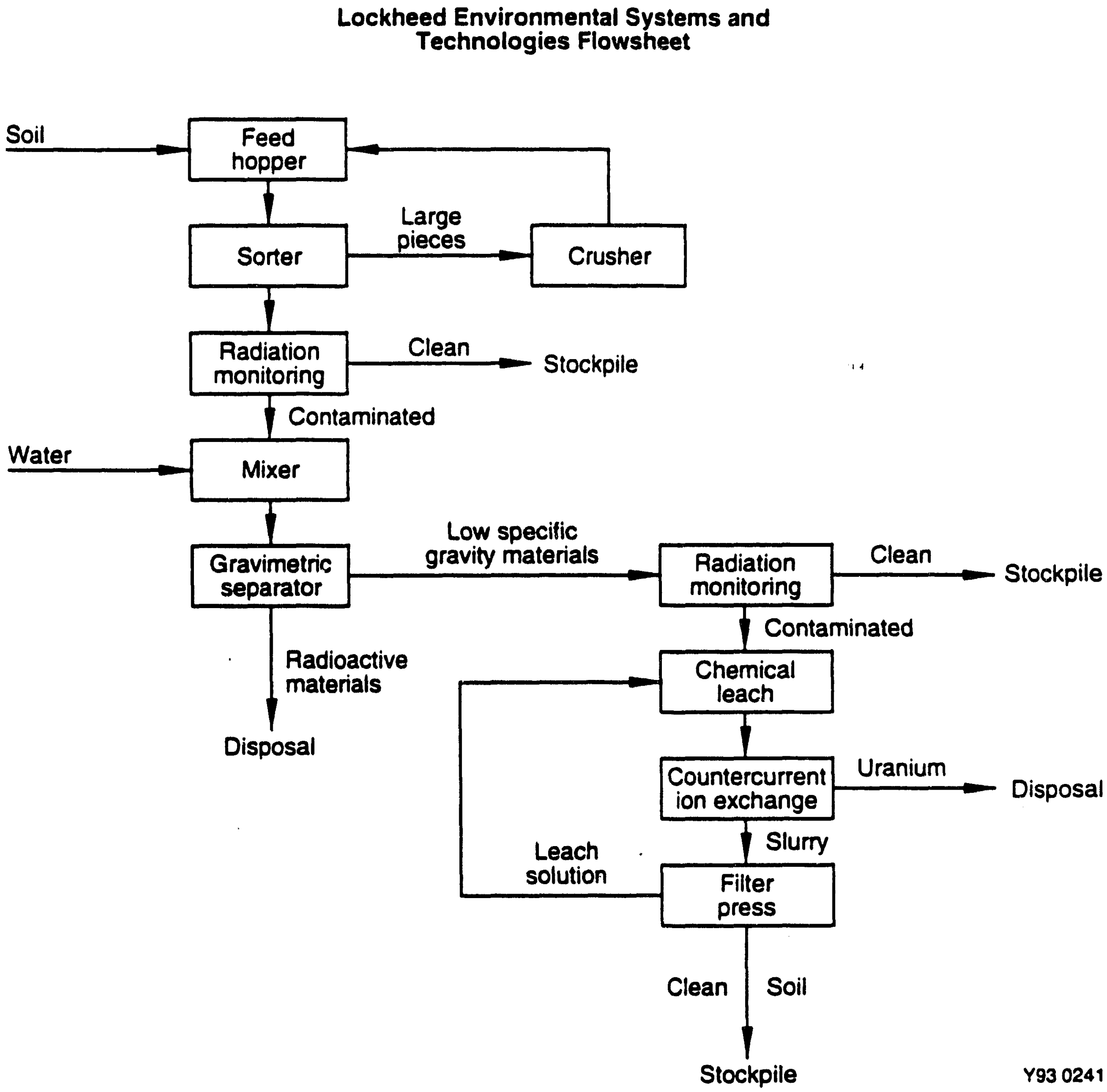

Lockheed Environmental Systems and Technologies Flowsheet

Figure 13. The Lockheed TRUclean process flowchart.

6. Economics

The approximate cost/yd^3 of soil ranges from $100.00 to $2,000.00 depending upon site conditions. The cost range for a bench-scale is $200,000.00 to $250,000.00. This includes soil characterization, developing a treatment approach, and testing the treatment approach.

7. Radiological Soil Process Monitoring

In the Lockheed TRUclean process, soil is leveled and spread to a depth of approximately 2 in. on a conveyor belt. The soil then passes beneath two rows of gamma radiation detectors. Signals from the detectors are computer processed to determine if the soil's contamination level exceeds the defined action level. When activity exceeds the action level, a gate directs the soil to the decontamination section of the system. When activity does not exceed the action level, a gate directs the soil to the clean stockpile where it is sampled and released for unrestricted use. After the decontamination section, the soil passes beneath a similar array of detectors where soil is once again separated according to activity level. All soil released for unrestricted use is thoroughly sampled to verify the activity level is below 35 pCi/g.

8. Additional Waste Streams Generated

The only additional waste stream generated by this process is water. After the water has been used in the system, it is placed in a lined settling basin where the water may be recycled or evaporated. The sediments in the settling basin will be packaged for disposal. The chemicals used in leaching systems are continuously recycled.

9. Permits Required on Previous Sites

At China Lake, a water usage/discharge permit was required by the State of California.

10. References

Dr. Edward Bramlitt
Technical Director
Defense Nuclear Agency, Field Command
(505) 846-8568

3.8 Nuclear Remediation Technologies

Nuclear Remediation Technologies (NRT), a division of General Atomics, is located in San Diego, California. The treatment technology developed by this company is referred to as the NRT soil washing/chemical extraction system. This technology was developed for the removal of radioactive contaminants from soils. The following section provides relevant information as to how the criteria in Section 3 are met by the technology.

1. Previous Experience

Nuclear Remediation Technologies (NRT), a Division of General Atomics, recommends soil washing combined with chemical extraction to separate DU from soil. NRT works with Bergmann USA (Bergmann), the applied environmental technologies group of Bergmann/Linatex, for supply of soil washing technology. Bergmann/Linatex has designed and built 18 soil washing plants operating on hazardous waste contaminated soil and sediment in Holland, Belgium, and Germany. The soil washing plants range in size from 5 to 75 tons/hr and are removing hazardous metals and organics by physical and chemical separation methods. For providing full-scale chemical extraction equipment, NRT would work with a chemical equipment manufacturer to construct a plant suitable for removal of DU contaminants from the finer fraction of soil.

2. Cleanup Process

NRT, under contract to Canonie Environmental Services, performed centrifugal concentration/soil washing bench-scale tests on DU contaminated soils from a firing range owned by Olin Ordinance (see Figure 14). A Knelson centrifugal concentrator was successfully used to clean the soil to 15 pCi/g from a starting contaminant of 150 pCi/g. DU contamination was present in the form of metallic particles (4 x 325 mesh) and fused silica particles containing U oxide from pyrophoric ignition of projectiles.

In 1992, NRT, under contract to Advanced Sciences, Inc., conducted bench-scale treatability tests with a combination of soil washing and chemical extraction techniques for removal of Cs (Cs^{137}) at the Test Reactor Area (TRA) Warm-Waste Ponds (WWP) at the INEL. Tests results indicated that by combining selected process steps, more than 90% of the WWP sediment could be reduced to the required Cs-137 concentration of 690 pCi/g or less.

Also in 1992, NRT, under contract to Barge, Waggoner, Sumner & Cannon, conducted bench-scale soil washing and chemical leaching tests on Pu and Th contaminated soils at the DOE Mound Site. Testing showed that the initial activity of 1,950 pCi/g could be reduced to 148 pCi/g with a 92% volume reduction.

The soil washing/chemical extraction system NRT recommends for YPG would be similar to the system proposed to EG&G Idaho, Inc. for the Pit 9 remediation of Pu contaminated soil, with some significant modifications. This system has only been tested at the bench-scale. With this system, soil is fed onto a grizzly bar screen where oversize material will slide off the grizzly onto a conveyor belt where it will be transferred to the Oversize Material Processing Area. Should this coarse material be characterized as contaminated, it will be sent on to further processing. Undersize material (nominal <2 in.) will pass the grizzly bars and fall into a hopper. Here it will await discharge via a belt feeder.

The belt feeder then transports the material to a trommel scrubber. The purpose of the trommel scrubber is to thoroughly mix the <2 in. dry feed with water creating a slurry, breaking up lumps of debris and soil, and deagglomerating contaminated finer soil particles (<0.25 in.) from larger debris. The slurried and thoroughly mixed waste material will exit the trommel and drop onto a flat deck vibrating screen with 0.25 in. openings. The <0.25 in. material will pass

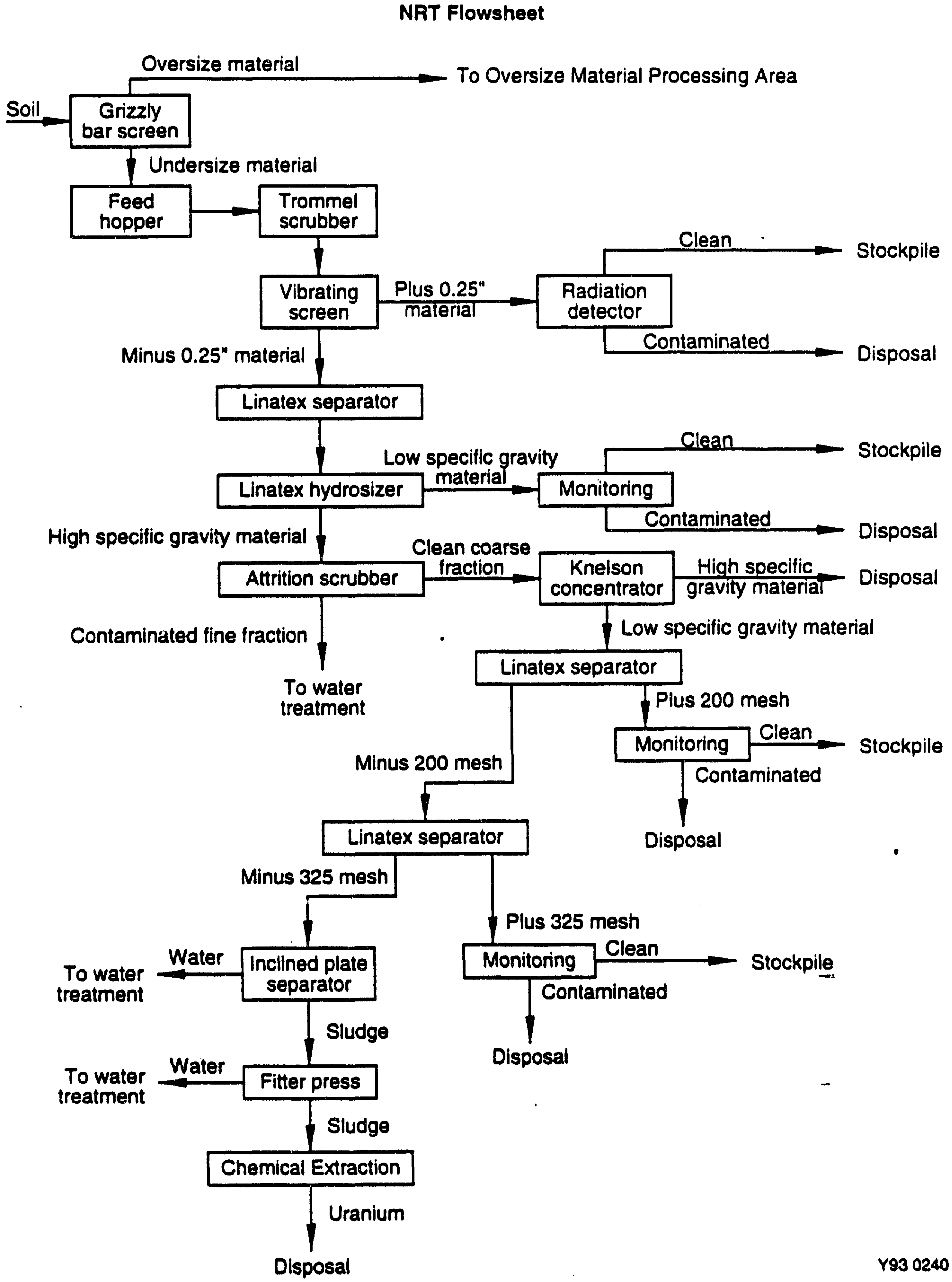


Figure 14. The NRT process flowchart.

through the screen for further processing downstream. The <2 in. plus 0.25 in. material will spread out and move along the top of the screen deck, where it will be thoroughly cleaned by high pressure (2,000 psi) fan water sprays.

The <2 in. plus 0.25 in. material will then pass under alpha, beta, and gamma radiation detectors. If clean, it will be directed to clean material dumpsters where it will await final characterization to verify <35 pCi/g. If the material is not clean (>35 pCi/g), it will be placed into containers for disposal.

The <0.25 in. material from the underflow of the flat deck screen would then be pumped to a Linatex Separator. The Linatex Separator is a high-efficiency hydrocyclone designed to provide a consistently dense underflow (coarse) product regardless of fluctuations in feed percent solids. The separation action within the separator is produced by the rotation of the fluid as it flows through the unit. This rotation develops high centrifugal forces, which tend to move both the larger and denser particles to the wall where they flow down to the underflow. Finer and less dense particles remain near the center of the cyclone and are carried out to the overflow along with most of the water associated with the feed. As a result, the underflow contains the coarser and denser particles at a solids concentration on the order of 70% by weight. The primary purpose of this specific hydrocyclone is to control the pulp density of the <0.25 in. material passing from the underflow and into the Linatex Hydrosizer.

The Linatex Hydrosizer is a dense media separator. As feed enters the top of the hydrosizer, the particles of solids are met by an upward rising current of water. Lighter gravity particles (e.g., less than 1.6 in gravity) cannot penetrate this bed and are floated from the top of the hydrosizer. Heavier and coarser sand particles do penetrate this dense bed and are removed from the unit by means of a pneumatically operated underflow valve.

The low specific gravity material will be monitored and either returned to the site or packaged for disposal after dewatering. The high-specific gravity material will pass out the underflow discharge valve of the hydrosizer by gravity and into the Attrition Scrubber.

The Attrition Scrubber is a high energy, high shear, multistage mixer. The purpose of this unit is to thoroughly abrade or scrub the <0.25 in. material. This results in a clean coarse fraction and a contaminated fine slurry fraction. The contaminated fine slurry fraction is transferred with the process waste waster for treatment and the clean coarse fraction passes on to a Knelson Concentrator.

The Knelson Concentrator is a high speed fluidized bed centrifuge. The purpose of this device is to capture high specific gravity metals and metal oxides and remove them from the <0.25 in. material. The high specific gravity concentrate will, by definition, contain a high contaminant level. This material will be packaged for disposal. The <0.25 in. lower specific gravity material from the overflow of this unit will flow to yet another Linatex Separator.

This second Linatex Concentrator will be configured to make a sand and silt split at 200 mesh. The plus 200 mesh will flow to a horizontal belt filter for final dewatering and then be placed in dumpsters, while analytically verifying that it is <35 pCi/g. The <200 mesh material will flow to another Linatex Separator configured to make a silt and clay split at 325 mesh. The <200 plus 325 mesh material will then be dewatered and placed in dumpsters, while analytically verifying that it is <35 pCi/g. The <325 mesh material will flow to an inclined plate clarifier to collect and settle the material. The sludge from the clarifier will then be placed in a filter press for dewatering before chemical extraction.

The Chemical Extraction will be used to extract the U from the <325 mesh material and all other fractions not meeting the <35 pCi/g criteria.

3. NRC Licensed Laboratory

NRT's San Diego facility is licensed by the NRC and the State of California to handle a variety of radioactive materials. This facility could be used to conduct bench-scale treatability studies to establish the soil characteristics, contaminant distribution characteristics, and the behavior of the various soil fractions when subjected to specific physical and chemical separation treatments.

4. Previous Cleanup Levels Achieved

In bench-scale centrifugal concentration/soil washing tests on DU contaminated soils from a firing range owned by Olin Ordinance. A Knelson centrifugal concentrator was successfully used to clean the soil to 15 pCi/g from a starting contaminant of 150 pCi/g.

In bench-scale soil wash and chemical extraction tests conducted for removal of Cs-137 at the TRA WWP at the INEL, tests results indicated that by combining selected process steps, more than 90% of the WWP sediment could be reduced to the required Cs-137 concentration of 690 pCi/g or less.

In bench-scale soil washing and chemical leaching tests on Pu and Th contaminated soils at the DOE Mound Site. Testing showed that the initial activity of 1950 pCi/g could be reduced to 148 pCi/g with a 92% volume reduction.

5. Portability of Equipment

Soil cleaning plants can be provided in a range of sizes from small, truck-mounted pilot plants capable of processing several hundred pounds per hour up to large, modular plants capable of 75 tons/hr. All plants are constructed in modular fashion to facilitate rapid assembly and disassembly.

6. Economics

The approximate cost/yd^3 of soil ranges from $540.00 to $1350.00 depending on site conditions. The cost range for comprehensive bench-scale testing ranges from $200,000.00 to $300,000.00, and includes a preliminary design for a full-scale system.

7. Radiological Soil Process Monitoring

Characterization in the soil washing process will be accomplished using alpha, beta, and gamma detectors. These detectors will be used to analyze all input and output stream and intermediate process conditions.

8. Additional Waste Streams Generated

The modular Bergmann Waste Water Treatment System is used as the primary water treatment system for the soil washing system to clean and recycle the process water. This system uses standard flocculation and sedimentation technology enhanced by polyelectrolytes to precipitate and remove, via inclined plate clarifier, <325 suspended particles. Dissolved solids, (including heavy metals) that are precipitated by pH adjustment causing the formation of metal hydroxide salts, are then removed by dissolved air flotation.

Solids from the inclined plate clarifier and dissolved air flotation system are then dewatered via a belt filter press. The resultant filter cake is then sent for solidification and stabilization. The clarified process water, if sufficiently cleaned of U, is returned to the soil washing system. If not sufficiently cleaned of U to prevent cross-contamination, it will pass to the iron ferrate water treatment module.

The Analytical Development Corporation (ADC) will supply the potassium ferrate (K_2FeO_4) for the ferrate precipitation system. This technology was developed by the LANL and acquired by ADC for exclusive use by ADC. The ferrate has been shown to be very effective in the reduction of gross alpha and beta radioactivity from a variety of radioactive elements. Ferrate also produces only 1/4 to 1/3 of the volume of sludges produced by other conventional flocculants and precipitants.

9. Permits Required on Previous Sites

Because a full-scale system has not yet been constructed, no permits have been required.

10. References

Yusuf Noorani
Advanced Sciences, Inc.
(208) 529-2002

Kirby Burton
Barge, Waggoner, Sumner & Cannon
(513) 438-0378

3.9 Alternative Options for Management of DU Contaminated Soils

Another alternative is to excavate the DU contaminated soil and dispose of it at a facility licensed to receive DU contaminated soil. Envirocare, a facility located in Utah, has obtained an

NRC license to receive low-level waste (also specific RCRA hazardous wastes and mixed wastes), including DU contaminated soils. The maximum concentration of DU acceptable for disposable at the facility is 1.1×10^5 pCi/g.

The costs affiliated with analysis required by Envirocare, excavation, packaging, and shipment of DU contaminated soil from YPG presented in this report are estimates based on information derived directly from Envirocare.

Disposal costs for disposal of DU contaminated soils at the Envirocare facility range from \$24.00 to \$30.00/ft^3. Shipment costs depend greatly upon the type of shipping containers, etc. that the soil will be shipped in. The most cost effective containerization is shipping via bulk lined railcars. The cost for this depends upon the mileage, weight of soil per car, and the potential volume. Union Pacific works closely with Envirocare in the shipment of soils to their facility. An approximate cost of \$51.50/net ton on 170,000 lb minimum weight was quoted to the INEL for railcar shipment [Charlie Black, Union Pacific Railroad (402) 271-5204.]

3.10 Partial Volumetric Reduction/Disposal of DU Contaminated Soils

An additional alternative is to utilize an existing gravitational separation device, screen or both, to reduce the volume of DU contaminated soil to approximately 50% as discussed in Section 2 and dispose of the remaining contaminated soil at a disposal facility. This can be done by a combination of processes that include treatment technologies described in Section 3.0 of this report. The remainder of the soil that has not achieved the 35 pCi/g cleanup level can be disposed of at the Envirocare facility in Utah.

This will require obtaining a cost breakdown for the gravitational separating device and having the actual excavation, packaging, shipping, and costs invoked by Envirocare. This should cost less, and wastestreams generated by a soil washing, or other type of process, would not be generated.

4. SELECTION BASIS

Each treatment technology described in Section 3 has some basis for the feasibility of remediating DU-contaminated soils. This section will provide a tabular summary of each technology, screening application of the technology, and a final recommendation in Table 6.

4.1 Summary of Treatment Technologies

The treatment technologies presented in Section 3 are summarized in tabular form in this section. The specific areas that are emphasized are listed at the head of each column, with the technology listed at the left hand side of Table 6.

As shown in Table 6, all of the identified technologies have had some experience in the area of either a bench-scale/pilot plant or full-scale remediation application for contaminated soils. The contaminants range from heavy metals, radiological, to DU contaminated soils. The following section will present an overall review of the treatment technologies and a discussion of each treatment technology to determine the feasibility of the technology for the YPG DU contaminated soils. A high, medium, or low ranking shall be assigned to each treatment technology based on the discussion. Some pilot-scale or bench-scale testing will be required for the selected treatment process. Each process must be tailored to the soil and its conditions as well as the contaminant structure.

4.2 Screening Criteria

This section of the report discusses each treatment technology to determine which technology(ies) presumably will achieve the required cleanup levels for YPG. The discussion will center around the capability of the treatment technology to (a) clean DU contaminated soils, and reach the specified release limit of 35 pCi/g, (b) actual field experience in conducting a full-scale treatment, and the (c) feasibility of cleaning the DU contaminated soils based on the geochemical analysis. If the treatment technologies do not attain a high or medium ranking based on the evaluation, then the treatment technology will be screened out.

The ranking is based on the following rating system:

High	This technology has a very high probability of separating the DU contamination from the soils at YPG based upon the past use of this technology and the applicability of the technology to the conditions at YPG. The high ranking is based on whether the technology has had experience with radioactive/DU/U contaminants, has undergone a full-scale remediation, and has been successful in applying the treatment technology to the contaminated site.
Medium	This technology has a good to fair probability of separating the DU contamination from the soils at YPG based upon the past use of this technology and the applicability of the technology to the conditions at YPG. The medium ranking is

Table 6. Tabular summary of each treatment technology.

Technology	Previous Experience	NRC licensed lab.	Previous cleanup levels achieved	Volume reduction (%)	Portability of equipment	Economics ($)	Radiation soil monitoring process	Additional wastestreams generated	Permits required
TMA/Eberline	Full-scale for Pu-239 & Am-241	Yes	13.5 pCi/g for Pu-239/Am-241 and 135 pCi/g for all radioactive particles	98	Yes	100.00–200.00/yd^3 Bench-scale = 25-50K	Array of 15 overlapping NaI detectors	Washwater, sediments	None
Bradtec	Bench-scale for U, Pu, Am, and Pb[a]	Yes	U contaminated soils ranging from 406 to 1009 pCi/g were cleaned to 12 - 30 mg/kg	—	Trailer mounted systems	50.00–100.00/yd^3 Bench-scale=12–13K	Periodic sampling	Solvent	None
B&W-NES	BS for U-234, -235, -238	Yes	30 pCi/g for U	85 (worst case would be 50)	Yes	3.00–5.00/yd^3	Grab sampling	Wastewater	None
Westinghouse SEG	Full-scale for U and Bench-scale/pilot-scale for Ra	Yes	16 pCi/g	99	Trailer mounted system	100.00-1000.00/yd^3 Feasibility Test = 10,000–30,000 Detailed Bench-scale = 30,000–100,000	Continuous air monitoring to measure radioact. levels around the system and composite sampling	Ion exchange, process waste	Air permits
S. G. Frantz	Bench-scale/pilot-scale for Pu and DU	No	For DU, Bench-scale testing cleaned soil to 10 to 200 ppm	98	Yes	6.00–6,000/yd^3 Bench-scale = 12,000–15,000	No radiation monitoring	None	None
EcoTek II BESCORP	-Feasibility test at Tinker AFB for Ra-226; -Feasibility Tests for mixed heavy metals and radioactive contaminated soils at the Hanford Site	Yes	Tinker AFB-Ra-226 was reduced to <15 pCi/g; Hanford Site - to background levels	Tinker AFB—70 to 80; Hanford Site—95	Trailer mounted	Sandy soil cost is 20.00/yd^3; Semi-sandy soil is 120.00/yd^3;	In line real time detection systems. Soil samples are also collected from the system during processing.	Dependent upon the water treatment employed	NPDES

Table 6. (continued).

Technology	Previous Experience	NRC licensed lab.	Previous cleanup levels achieved	Volume reduction (%)	Portability of equipment	Economics ($)	Radiation soil monitoring process	Additional wastestreams generated	Permits required
Lockheed	Full-scale for DU at the China Lake Naval Weapons Center	Yes	Below 35 pCi/g	92	Trailer-mounted	100.00–2,000.00 Bench-scale=200,000–250,000	On-line gamma radiation detectors	Water sediments	Water usage/ discharge
NRT	Bench-scale for DU contaminated soils for a firing range owned by Olin Ordinance	Yes	15 pCi/g	90–92	Modular plants	540.00–1350.00 per cubic yard; Bench-scale=200,000–300,000	Use of alpha, beta, and gamma detectors	Sludge water solids	None

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a. This process is currently scheduled to be used on a pilot-scale at two DOE facilities during 1993 and on a full-scale at a DOE facility during 1994.

based on the fact that the technology has had only limited experience with radioactive/DU/U contaminants, has only undergone a BS/PP study, and has had limited success in application of the treatment technology to the contaminated site.

Low	This technology has a poor probability of separating the DU contamination from the soils at YPG based upon the past use of this technology and the applicability of the technology to the conditions at YPG. This technology may have the ability to treat the contaminated coarse or fine soil fraction, but not both. The low ranking is based on the fact that the technology has had little or no experience with radioactive/DU/U contaminants, had undergone only a BS/PS study, and has had little or no success in application of the treatment technology to the contaminated soils.

After the treatment technologies have been screened out, each remaining treatment technology will be evaluated against the following:

- Volume reduction
- Cost for bench-scale/pilot plant.

4.2.1 Application of Treatment Process to YPG Soils

This section will discuss the ranking assigned to each treatment technology and its application to YPG DU contaminated soils.

4.2.1.1 Discussion of TMA Eberline Treatment Technology. Operational details of the soil washing system are not available, particularly the segmented gate system. However, it appears to be based on physical separation systems, probably screening apparatus, density separators, and particle classifiers. In principal, this system should work well with the Yuma U contaminated materials. The individual particles of U minerals and metal should respond well to both the size and density separation procedures because the U appears to be concentrated in the coarse and fine size fractions and the U particles have a much higher density than the matrix material. Adsorbed or ion exchanged U will probably require chemical extraction methods for removal. Like all physical systems, it has minimum secondary waste streams and minimum chemical alteration of the cleaned soil.

TMA/Eberline's experience with radiological contamination at Johnston Atoll and previous work is excellent, however, their experience with soil washing is somewhat limited. Therefore, TMA/Eberline is rated as medium as their technology applies to YPG.

4.2.1.2 Discussion of Bradtec Treatment Technology. This system is a chemical treatment system and probably would not be appropriate for treating all the YPG DU waste. However, combined with other methods, it might be very effective, particularly for treating the U concentrated in the fine particle size fraction. If it is present as coatings, chemical dissolution methods are possible removal methods, but the calcium carbonate in the Yuma soils would decrease the effectiveness of methods using acids or any other chemical system that requires a pH other than about 8 to be effective.

Bradtec's chemical treatment technology may have considerable difficulty removing the U from the coarse soil fraction. This along with the fact that the Bradtec process has not been demonstrated on a full-scale result in a low rating as their technology applies to YPG.

4.2.1.3 Discussion of B&W Nuclear Services, Inc. Treatment Technology. The system is based primarily on a combination of wet physical separation methods. In principle, the system would be appropriate for the treatment of the YPG contaminated materials. However, the system has not progressed beyond the initial bench-scale tests. Extensive development work would be expected before it could be put into production at YPG.

B&W's soil washing technology would be well suited to remediate the Yuma Proving Ground soils. However, because this technology has not been demonstrated on a full scale, it is rated as "Medium" as it applies to YPG.

4.2.1.4 Discussion of Westinghouse Scientific Ecology Group, Inc. Treatment Technology. This method is based primarily on chemical leaching and would be appropriate for the fine soil fraction, provided that the U in the coarse fraction of the soil was removed before the chemical treatment (assuming that the U is in fact present as metal or another form that can be removed by a simple physical process as previously discussed in Section 3.4. The nature of the leachate is not known, but for greatest effectiveness it should be stable in pH 8 solutions.

The Westinghouse SEG Soil Washing System has demonstrated its ability to successfully remediate soils contaminated with U. With this experience and a proven technology, it is rated as high as it applies to YPG.

4.2.1.5 Discussion of S. G. Frantz Company, Inc. Treatment Technology. The S. G. Frantz magnetic system is probably not appropriate for processing all of the YPG U waste because the DU is present in several different forms. However, the magnetic method could be very effective if combined with other separation methods. For example, it could be very difficult to separate individual particles of U metal or a particular U compound if these are present as individual grains. The system is in the development stage and probably requires significant additional work before production is achieved.

The S. G. Frantz technology would have considerable difficulty in treating both the fine and coarse soil fractions. This along with the fact that this technology has not been demonstrated on a full-scale result in a low rating as their technology applies to YPG.

4.2.1.6 Discussion of EcoTek, Inc./Brice Environmental Services Corp Treatment Technology. This system uses a series of wet physical separation procedures based on size and density differences among the materials present in the contaminated soil. In principle, this approach may be very effective when applied to the YPG soils. The individual particles of U minerals and metal should respond well to both the size and density separation procedures because the U appears to be concentrated in the less than 4.25 mm size fraction and the U particles have a much higher density than the matrix material. Adsorbed or ion exchanged U will probably require chemical extraction methods for removal. As is true of all potential remediation methods, the final design parameters would only be determined following detailed characterization of YPG contaminated soil, and bench and pilot testing using YPG materials. The selection of components depends on specific site conditions and nature of contaminants. Because of the myriad of contaminant types and soil conditions, bench-scale testing is required to determine the optimal approach.

EcoTek and BESCORP have extensive experience with radiological contaminants and soil washing. Based on their past experience and proven technology, it is rated as high as it applies to YPG.

4.2.1.7 Discussion of Lockheed Environmental Systems & Technologies, Inc. Treatment Technology. This system is based on a combination pH physical separation methods, mainly gravity separation and chemical leach techniques, including acid leach. Physical methods, particularly density separation, are appropriate for separating the metallic U from the coarse soil size fraction and individual U mineral particles from the fine soil size fraction. Chemical dissolution methods might be useful for removing U coating adsorbed material and ion exchanged material. However, it should be noted that the calcium carbonate (calcite probably present) in the YPG soils will cause acid leaching to be less effective than at other locations.

Lockheed has demonstrated their ability to remediate DU contaminated soils on a full-scale. With some modifications, their system has a very high probability of being able to remediate the YPG soils. This technology is rated as high as it applies to YPG.

4.2.1.8 Discussion of Nuclear Remediation Technologies. The NRT soil cleaning approach is based primarily on physical separation methods, mainly screening, together with sophisticated density and size separation apparati. Unspecified chemical extraction methods are suggested by NRT for the less than 0.003 in. size fraction. In principal, this system should work well with the YPG DU contaminated soils. The individual particles of U minerals and metal should respond well to both the size and density separation procedures because the U appears to be concentrated in the coarse and fine size fractions and the U particles have a much higher density than the matrix material. Adsorbed or ion exchanged U will probably require chemical extraction methods for removal. The NRT system is a modular design and can be easily modified to meet the requirements of a specific site. As is true of all potential remediation methods, the final design parameters would only be determined following detailed YPG contaminated soil characterization and bench-scale testing using YPG contaminated soils.

NRT's soil cleaning technology would be well suited to remediate the YPG soils. However, because this technology has not been demonstrated on a full-scale, it is rated as medium as it applies to YPG.

4.3 Recommended Treatment Technologies

Table 7 summarizes the treatment technologies, the assigned ranking, the volume reduction, and the bench-scale costs. Westinghouse SEG, EcoTek/BESCORP, and Lockheed were all assigned a "high" ranking based on the criterion assigned above.

Table 7. A summary of the assigned ranking, the volume reductions, and the bench-scale costs of the treatment technologies.

Treatment technology	Ranking	Bench-scale cost ($)	Volume reduction (%)	Cost/yd^3 ($)
TMA/Eberline	Medium	25,000-50,000	98	100–200
Bradtec-U.S., Inc.	Low	12,000–13,000	—	50–100
B&W-NESI	Medium	30,000–70,000	85	3–5
Westinghouse SEG	High	30,000–100,000	99	100–1,000
S. G. Frantz	Low	12,000–15,000	—	6–6,000
EcoTek/BESCORP	High		70–95	20–625
Lockheed Environmental Systems & Technologies Co.	High	200,000–250,000	92	100–200
NRT	Medium	200,000–300,000	—	540–1,350

5. CONCLUSIONS

The information provided in this report closely follows the guidelines established by the EPA for the remediation of a Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) site. Although the YPG is not regulated as a superfund site, it was determined that the mechanism designed by the EPA to determine the feasibility of a treatment technology for remediation of a site can be implemented here. The following sections describe a CERCLA treatability study, a review of regulatory requirements that may be applicable for the remediation of the site, and a final recommendation.

5.1 Treatability Studies

Although the YPG site is not a CERCLA site, the treatability study process defined by the EPA streamlines the mechanism in which a remedy is selected for cleanup of the site and its implementation. A treatability study, as defined under CERCLA, is a set of laboratory or field tests that are "designed to define critical data needed to evaluate and, ultimately, to implement one or more technologies." A treatability study generally involves characterizing a site and evaluating the performance of a treatment technology for remediation of the site. Three tiers are defined in a treatability study, these are (1) laboratory screening, (2) bench-scale testing, and (3) pilot-scale testing. The first two of which will be discussed here.

Laboratory screening is used to yield data to define the technology's potential to meet the remediation goal. It also serves to identify parameters for investigation during bench- or pilot-scale testing. This laboratory screening was used in this phase of the project to determine the feasibility of remediation of the YPG soils by the specified treatment technologies.

The second phase is to implement a bench-scale testing. This phase is intended to determine the technology's performance for the site. A bench-scale testing will verify that the technology can meet the expected remediation level of 35 pCi/g. The study will also serve to provide cost and design information relative to the specified treatment technologies.

5.2 Regulatory Requirements

Instituting remediation at a site will require an evaluation of regulatory requirements or applicable or relevant and appropriate requirements. This should be done concurrently while the treatability study is planned.

Installation of a treatment system utilizing a soil separation device and/or a soil washing system plus some additional treatment methods discussed in the above sections of this report would require a review of existing NRC, EPA, Arizona Department of Environmental Quality (ADEQ), and U.S. Army YPG regulations and requirements.

In remediation of the site, there is a high probability that YPG may be required to excavate the soil and move it to another location for treatment. If this is the case, YPG must ensure the staging location is covered under the existing NEPA documentation and NRC license.

Air. The existing ADEQ requirements for utilizing a soil separation/washing system would require a review of Arizona Air Regulations for fugitive dust emissions resulting from the separation and/or crushing activity.

Water Discharge Permit. Water that is used during the soil washing process may require an evaporation pond of sorts. YPG currently has an evaporation pond. It may benefit YPG to utilize an open storage tank versus an evaporation pond. This would not a require a water discharge permit. Consideration must ensure wildlife does not have access to the water.

National Environmental Policy Act. The DOD and the DOE require documentation ensuring that a negative impact to the environment does not occur from the treatment process. A review of the process should be done and an environmental checklist prepared to determine if this process falls under a categorical exclusion.

Solid Waste Disposal Requirements. The disposal of the remaining percent of soil containing elevated concentrations of DU will require disposal at a facility licensed to receive this material. If the material exceeds a 2,000 pCi/g level of U, disposal to the Utah Envirocare facility is not an acceptable alternative.

Department of Transportation. Soils contaminated with DU must adhere to the DOT shipping requirements for LLW. In addition to this, additional transportation regulations may be required by the specific state for which the shipment is being transported through. This set of regulations must be researched before commencing with this activity.

5.3 Final Recommendations

It is recommended that the U.S. Army YPG proceed to initiate bench-scale testing with the three treatment technologies that were rated as high. This bench-scale testing is further defined in Section 5.1. The bench-scale testing would serve to further evaluate each of the three technologies and ensure the best technology will be utilized for the conditions at YPG.

6. REFERENCES

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Appendix A

Data

STEYP-MT-TL-MP 30 Dec 92

MEMORANDUM FOR STEYP-ES (Dunfrund)

SUBJECT: Review of Laboratory data for INEL

1. Thank you for getting me a copy of the data from TSSI and Aspen Laboratories for review. As you had noted to me there were several items in both reports that needed clarification or change. I looked deeper and found additional errors. I went to the COR for the contracts and with his blessing have had the corrections made. I will go over the items I had changed on an individual basis.

2. Technical Support Services, Inc. (TSSI) data on uranium analysis: Corrected sheets attached.

On the data sheet "Analysis Results for Unknowns" the column labeled "Result ug/ml" should read "Results ug/g." At your request on the next page of the report I had a final note added "Calculations: ICP results (ug/ml) X dilution (ml) / soil (g) = results (ug/g)."

On the data sheet "Results for Standards and Spikes" the two headers "Expected ug/ml" and "Obtained ug/ml" should read "Expected ug/g" and "Obtained ug/g". Also under "Expected ug/g" the number "200" should be "401.23" and the number "300" should be "422.92".

A missing portion of the report "Environmental Monitoring, Chain of Custody Forms" were located and are included. These forms can be used to cross reference the Laboratory sample numbers to the INEL sample numbers, but to make it clearer I had them print out a cross reference sheet that can be attached.

A missing portion of the report "Idaho National Laboratory Uranium Study, Cover Letter and QA Release" and "Storage and Shipping Requirements" were located and are included.

3. Aspen Environmental Laboratory TCLP analysis. Corrected sheets attached.

Your initial concern was that none of the results for Lead meet the regulatory limits. I looked into how Aspen arrived at their results and found several problems. There initial report listed the units for lead as mg/L. These are the units that the EPA uses for the regulatory limit. In the "Federal Register/ Vol. 55, No. 61/ Thursday, March 29, 1990/ Rules and Regulations" page 11804, for EPA Hazardous waste No. D008 Lead, CAS NO. 7439-92-1 the Regulatory level is 5.0 mg/L and the Chronic Toxicity reference level is 0.05 mg/L. Looking at their raw data indicates that is not what they reported. They calculated and the number they reported is the amount of lead in the soil as ug/g of soil, but with the incorrect units of ug/L. The TCLP procedure is very specific. In the above referenced Federal Register on page 11873 Paragraph 8.15 it reads, "Compare the contaminant concentrations in the <u>TCLP extract</u> (my underline) with the thresholds identified in the appropriate regulations." On there raw data and calculation sheet they should have reported the value under "Actual ppm". This value is what is in the TCLP extract and is about 20 times lower than what is in the soil. In talking to Aspen laboratories I also found several other labeling errors on their raw data and calculation sheet and other data sheets. They refer to "Final Volume" when it should be "Extract Weight" as TCLP requires you to add a weight of extraction fluid that is 20 times the solid sample weight. I talked to Aspen about this and they confirmed that in fact this column is a weight. If this is true then the final calculated value of lead in the soil in ug/g needs to be corrected for the density of the TCLP extract, which they do not do. All of these extra calculations are not of importance to us as the value we need is the concentration in the TCLP extract. I asked Aspen to verify what I was telling them and they called the EPA Regional office in San Francisco and verified that it is the concentration in the TCLP extract that is to be compared against the regulatory limit. Using these numbers, all of the samples taken are below the regulatory limit. Aspen is putting out an amended report that shows the amount in the TCLP extract which reads "Reported in mg/L." If it were me I would label it Reported in mg/L of extract. They also are putting out the data labeled "Reported in mg/Kg". If it were me I would label it Reported in mg/Kg of Soil, and would correct the answer for the density of the extract. Since we do not need the concentration in the soil you could also eliminate the page.

4. I hope this clears up the questions concerning the data to be sent to INEL. If you have any further questions feel free to call.

David L. Pond

DAVID L. POND
CHEMIST
MATERIAL ANALYSIS LABORATORY

ENVIRONMENTAL RADIATION MONITORING

YUMA PROVING GROUND

ANALYSIS OF URINE AND WATER FOR URANIUM

The analysis of urine and water samples for uranium are performed by the Material Analysis Section under the following guidelines. The instrumentation used is a ChemChek KPA-10 Kinetic Phosphorescence Analyzer. The procedures used for the sample preparation of urine samples are adapted from those suggested by ChemChek Instruments, Inc., of Richland, Washington in their Operation and Service Manual for the KPA-10.

The following procedure is applicable to both water and urine samples. However, throughout the text we refer only to urine samples since they are the more difficult of the two to analyze. Using the methods described below, we have found that reliable quantitation is obtained down to about 0.00017 ug/ml.

I. Reagents, Standards, and Supplies

Deionized Water: referred to as "di water"; preferably 10 megohms or better.

The term "n:n nitric:di water" refers to a volume/volume solution of concentrated nitric acid and deionized water.

Uraplex: A proprietary uranium complexing reagent sold by ChemChek specifically for use with the KPA. The Uraplex must be filtered daily through a 0.45 um pore size filter and stored in the refrigerator when not being used.

Uranium Stock Standard; A 1000 ug/ml solution available from Leeman Labs. Dilutions of this standard are made using 1:19 nitric:di water.

Acid Dispenser: Eppendorf multipipettor, adjustable to deliver 1·to 5 ml.

Liquid Scintillation Vials, 20 ml: For analyses below ~0.2 ug/l, vials must be leached in 4M nitric acid at 60 deg C for two or more days to remove leachable uranium. As an alternative, soak the vials in 1:1 nitric:di water for 2-3 weeks at room temperature. Rinse well with di water.

Hot Plate: Used with or without optional heating block designed to hold scintillation vials.

Muffle Furnace: optional

II. Sample Preparation

Raw urine cannot be analyzed without pretreatment except at levels well above 0.020 ug/ml. The reason for this is that the organic constituents phosphoresce, complex uranium, and along with chloride, quench uranyl phosphorescence. Therefore, wet-ashing becomes increasingly important as the desired detection is lowered. Good ashing technique is essential to obtaining high precision.

A. Add 5 ml of sample to a 20 ml vial.
NOTE: Samples with solids must be homogenized (vigorously stirred), because uranium concentrates in solids.

B. Add 3 ml of 16 M nitric acid with swirling and 0.5 ml of 30% hydrogen peroxide.

C. Place vials on hot plate at moderate heat and NEAR boiling for several hours. After partially cooling the samples, hydrogen peroxide may be effectively added at this time.

D. Increase heat to boil dry. If needed, replenish oxidants 2-3 times until the residue is pale yellow to white. Use 1 ml of 16M nitric acid and 0.25 ml of hydrogen peroxide each time.

OPTIONAL: When the vials are dry, place in muffle furnace at 500-550 degrees C for at least 1/2 hour.

NOTE: WET-ASHING MUST BE COMPLETE TO AVOID RESIDUAL ORGANICS. FURNACE TREATMENT WILL NOT COMPENSATE FOR POOR WET-ASHING.

The presence of carbon black after the furnace step indicates incomplete wet-ashing. For less than 0.2 ug/l samples, the ashing should be restarted with a fresh aliquot.

E. When cool, dissolve the urine salts in 2 ml of 1:1 nitric:di water with warming. Dilute to 10 ml with di water. Swirl to mix. Final volume may be determined by weight.

F. For low level samples, it is beneficial to let solutions sit overnight to let micro-particulates settle out. Centrifuging is an alternative.

G. Analyze resulting solutions with the KPA as described in the next section. Avoid picking up solids with the sample aliquot.

III. Analysis of Samples

The ChemChek KPA-10 Analyzer is too complex for us to write a detailed description of the operating procedure. The following is a general outline of the analysis process. Before an operator can be expected to produce good data with this instrument, it is expected that he/she will be trained by an experienced operator and will have spent time studying the Operators Manual.

A. Preparation of Spiking Standards

These solutions are made by making serial dilutions of a 1000 ug/ml uranium solution, available from Leeman Labs, with 1:19 nitric:di water. If low levels of uranium are anticipated for the samples, the dilutions should be prepared down to the 0.01 ug/ml level.

B. Preparation of Calibration Standards

From the above spiking standard solutions the following calibration standards need to be made; 0.0001, 0.0005, 0.001, 0.005, .01, and .05 ug/ml for the low range and 0.05, and 0.1, .5, 1.0, and 2.0 ug/ml for the high range. These calibration standards are made with the 5% nitric acid solution and spiked with the appropriate amount of the spiking solution.

NOTE: Concentrations selected for standards will vary with the concentration range of the samples being analyzed.

C. Quality Control

To ensure that the analytical processes used are effective and accurate, each batch of urine samples will include spiked samples of the operator's urine. Three samples will be spiked as described below, and then carried through the same sample preparation procedures as the rest of the urine samples. The three samples can also be unknown's, sample duplicates, or other QC checks, as long as there is sufficient checks made to validize the data.

QC Standard 1: To 5 ml of urine in a 20 ml scintillation vial, add 50 ul of the 0.1 ug/ml spiking standard. This will yield a sample with a concentration of 0.001 ug/ml.

QC Standard 2: Prepare like QC standard 1, using 50 ul of the 1.0 ug/ml spiking standard. This will yield a sample with a concentration of 0.01 ug/ml.

QC Standard 3: Prepare like QC standard 1, using 50 ul of 10.0 ug.ml spiking standard. This will yield a sample with a concentration of 0.1 ug/ml.

The spike recovery of each QC Standard should be within 20% of its actual concentration. If not, the sample batch (with additional QC standards) should be analyzed again after a procedural review by the On-site Chemist and/or the On-site Manager.

D. Final Preparation for Calibration and Analysis

Filter the Uraplex through a millipore filtration system with a 0.45 um pore size. Turn on the ChemChek and computer systems and then place the calibration standards in rack 1, the samples in rack 2 and the QC Standards in rack 3.

E. Calibration Procedure

1. Enter the calibration portion of the software through the Main menu and, using 1:19 nitric:di water, make background measurements for both the low and high ranges.

2. Next, place the calibration standards in the rack and put the mixing tubes into their corresponding positions. Make sure to check the linearity, intensities and lifetimes of the calibration standards to see if they are within their limits before going to the next one. When both of the ranges are calibrated, go to the Main menu and select the Analyze menu.

F. Analysis Procedure

From the Analyze menu go into Data Entry and list the samples by name and location in the racks. It is also a good idea to run the calibration standards against themselves as a secondary check. Enter the theoretical concentrations and dilution factors of the calibration standards and the quality control samples so that the computer will automatically calculate their % recoveries. Analyze the batch of samples, turn off the system and refrigerate the Uraplex.

Idaho National Laboratories Uranium Study

Rinse Water Results

Laboratory Personnel:

Manager/Chief Chemist; Stephen Maurer, MS Chemistry
QC Manager; Ranell Caiazzo, BS Biology, 8 years experience at YPG laboratory
Analyst; Daron Hargadine, BA Chemistry

Analytical Method:

Data for the analysis of the water samples was obtained through the use of a developmental procedure titled "Environmental Radiation Monitoring, Yuma Proving Grounds - Analysis of Urine and Water for Uranium". This method has not been submitted for Nuclear Regulatory Commission approval. The method will be submitted in the near future.

Deviations from Written Procedure:

Due to the low concentrations of uranium in the samples 100.0 ml aliquots were evaporated down to 10.0 ml. Then 6.0 ml of concentrated nitric acid and 1.0ml of 30% hydrogen peroxide were added to the sample vials. The samples were evaporated to dryness and cooled. 2.0ml of concentrated nitric acid and 0.5 ml of 30% hydrogen peroxide were added and the samples were evaporated to dryness again. This step was repeated four times. The samples were then placed in a muffle oven for 30 minutes at 550 C and brought back up to 10.0ml with 5% nitric acid. The samples were capped and left over night to insure that all the uranium was redissolved in the liquid. Then they were analyzed on the Chemchek KPA-10 Kinetic Phosphorescence Analyzer. All the samples were analyzed using this deviation from the written procedure.

Laboratory Sample Log Number/INEL Sample Number Correlation
All samples were analyzed on 7 Dec 92 at the time given.

Sample ID# LAB#	INEL#	Analysis Time
DI WATER		11:12
DI WATER PRE		11:17
DI WATER POST		11:37
92-4569	YPG-110392-SP-00-ER	14:15
92-4569B-1	YPG-110392-SP-00-ER	14:18
92-4569B-2	YPG-110392-SP-00-ER	14:20
92-4570 1	YPG-110392-SP-00-FB	14:23
92-4570 2	YPG-110392-SP-00-FB	14:25
92-4585 1	YPG-110492-NP-00-ER	14:28
92-4585 2	YPG-110492-NP-00-ER	14:34
92-4586 1	YPG-110492-NP-00-FB	14:38
92-4586 2	YPG-110492-NP-00-FB	14:40
92-4669	YPG-110592-WP-00-ER	12:09
92-4669 W/S	YPG-110592-WP-00-ER	12:19
92-4670A-1	YPG-110592-WP-00-FB	14:44
92-4670A-2	YPG-110592-WP-00-FB	14:53
92-4670A-3	YPG-110592-WP-00-FB	15:09
92-4670B-1	YPG-110592-WP-00-FB	14:58
92-4670B-2	YPG-110592-WP-00-FB	15:00
92-4670BB-1	YPG-110592-WP-00-FB	15:03
92-4670BB-2	YPG-110592-WP-00-FB	15:05
UNKNOWN		12:44

Laboratory Sample Log Number/INEL Sample Number Correlation (cont.)

SAMPLE ID#	INEL#	ANALYSIS TIME
11-6-92 1		13:33
11-6-92 2		13:38
11-9-92 1		13:42
11-9-92 2		13:48
11-10-92 1		13:50
11-10-92 2		13:55
11-12-92 1		13:59
11-12-92 2		14:01
11-13-92 1		14:03
11-13-92 2		14:06
11-16-92 1		14:09
11-16-92 2		14:11

Note:

The samples beginning with #11-6-92 1 were laboratory rinse water gathered while cleaning our equipment.

Results from Analysis

SAMPLE # LAB ID#	SPIKE ADDED (ppm)	MEASURED CONC. (ppm)	%DIFF (1/2*100)	% RECOVERY
DI Water		6.29E-6		
DI Water Pre	0.00500	4.53E-3		90.47
DI Water Post	0.00500	4.93E-3		98.47
92-4569*		9.95E-5		
92-4569B-1		2.66E-4		
92-4569B-2		2.57E-4	103.50	
92-4570 1		1.62E-5		
92-4570 2		1.47E-5	110.20	
92-4585 1		9.60E-4		
92-4585 2		1.01E-3	95.05	
92-4586 1		1.30E-5		
92-4586 2		1.19E-5	109.24	
92-4669		3.09E-6		
92-4669 W/S	0.00500	4.42E-3		88.34
92-4670A-1		9.34E-6		
92-4670A-2		7.41E-6	126.04	
92-4670A-3		9.67E-6	96.59 (1/3)	
92-4670B-1*		9.00E-6		
92-4670B-2*		6.55E-6	137.40	
92-4670BB-1		9.27E-6		
92-4670BB-2		1.04E-5	89.13	
UNKNOWN	0.007500	7.26E-3		96.80

Results cont.				
RINSE WATER SAMPLES	SPIKE ADDED	MEASURED CONC.	% DIFF (1\2*100)	% RECOVERY
11-6-92 1		1.21E-3		
11-6-92 2		9.95E-4	121.61	
11-9-92 1		2.69E-3		
11-9-92 2		2.85E-3	94.39	
11-10-92 1		2.42E-3		
11-10-92 2		2.64E-3	91.67	
11-12-92 1		4.50E-4		
11-12-92 2		4.42E-4	101.81	
11-13-92 1		2.05E-3		
11-13-92 2		2.04E-3	100.49	
11-16-92 1		1.23E-3		
11-16-92 2		1.15E-3	106.95	

Notes:

Samples (92-4569* and 92-4670B*) experienced loss during the wet ashing. Both samples were started over from scratch and analyzed with the other samples.

The unknown sample was prepared by a chemist other than the analyst. The concentration was unknown to the analyst until the results had been obtain. The calibration standards were run after the samples to make sure that the calibration curve was still valid.

Most of the samples were run more than once, this corresponds to the Lab ID#s ending with a 1 or 2. Duplicate samples were also prepared i.e. 92-4670A and 92-4670BB. The % difference between 92-4670A's average and 92-4670BB's average was 89.54%.

Calibration Check Results

Sample Id	Theoretical Conc.	Measured Conc.	% Recovery	
1:19	blank	0.000144		
.0001 cs	0.000100	0.000182	182.27	
.0005 cs	0.000500	0.000549	109.79	
.001 cs	0.00100	0.00106	105.59	
.005 cs	0.00500	0.00543	108.51	
.01 cs	0.0100	0.0108	107.93	
.05 cs	0.0500	0.0494	98.88	low range
.05 cs	0.0500	0.0488	97.60	high range
.1 cs	0.100	0.106	105.81	
.5 cs	0.500	0.498	99.58	
1.0 cs	01.00	1.02	102.00	
2.0 cs	02.00	1.90	95.00	

From this data, it appears that the detection limit is around 0.0005 ppm.

Analyst Certification:

The preceding results are truthfully reported and were obtained as indicated.

Daron Hargadine
Analyst
Daron Hargadine
12-16-92

QC Manager Verification:

The preceding data has been reviewed as prescribed in paragraph 7.2.1.1. of the Sampling and Analysis Plan for the Yuma Proving Ground Firing Range Restoration Project.

Ranell Caiazzo
12 16 92
Ranell Caiazzo
QC Manager

ENVIRONMENTAL RADIATION MONITORING

YUMA PROVING GROUND

ANALYSIS OF SOILS FOR URANIUM AND BERYLLIUM

The analyses of soils for uranium and beryllium are performed by the Material Analysis Section under the following guidelines.

Uranium analysis for all samples will first be done with the Leeman Labs Inductively Coupled Plasma Spectrophotometer (ICP). Samples with concentrations less than ~100 ug/g as determined by the ICP will be analyzed using the ChemChek Kinetic Phosphorescence Analyzer (KPA).

Beryllium analysis for all samples will be run on the ICP or by atomic absorption spectroscopy (AA). Those with concentrations less than 0.5 ug Be/g will be analyzed by AA. All others will be analyzed by ICP.

I. Preparations

Solutions needed for analysis are as follows:

extract from a blank soil (soil # 504 wet ashed extract)
100 ug/ml uranium in 1:19 nitric:di water
10 ug/ml uranium in 1:19 nitric:di water
1 ug/ml uranium in 1:19 nitric:di water
Uraplex (KPA only)

The term "n:n nitric:di water" refers to a volume/volume solution of concentrated nitric acid and deionized water (10 megohm or better).

Uraplex is a proprietary uranium complexing reagent sold by ChemChek specifically for use with the KPA. The Uraplex must be filtered daily through a 0.45 um pore size filter prior to use.

The uranium stock standard is a 1000 ug/ml concentration available from Leeman Labs. The acid mix is a volume:volume ratio of stock concentrated nitric acid and 10 megohm (or better) di water.

The standard containing 10 ug Be/ml is prepared by serial dilutions (described in the ICP section) from a standard containing 10,000 ug Be/ml which is available from NBS. These dilutions should be made with 1:9 nitric:di water.

To compensate for the effect of the soil matrix on the analytes of interest, calibration standards are prepared by spiking an extract of Yuma soil that is not contaminated by uranium or beryllium. The soil used for the calibration standards must be certified to contain less than 1 ug U/g by neutron activation analysis, and less than 0.2 ug Be/g by atomic absorption analysis. The soil used for the development work leading to this procedure is soil # 504 from Yuma Proving Ground (YPG).

II. Microwave extraction

The microwave procedure described below is used to prepare samples for the ICP, the KPA, and the AA. It is designed to extract uranium contamination added to the soil by YPG firing programs. It does not involve a total dissolution of uranium, and any uranium locked up in the soil matrix is not accounted for by this method.

In short, uranium is extracted from a soil sample. An aliquot is removed for analysis on the ICP. When analyte concentrations below the ICP's quantitation limit are encountered, additional aliquots are removed and prepared for analysis on the KPA and/or the AA.

A. Weigh 0.50 g of finely ground soil (particle size <75 um) into a tared teflon microwave extraction vessel.
B. Add 8.0 ml of concentrated nitric acid and 2.0 ml of concentrated sulfuric acid using the Eppendorf multipipettor.
C. Allow each batch of 12 vessels to sit for about 10 minutes. When capping the vessels, install a pressure relief valve with the ring facing upwards. Be aware that acidic fumes are being released by the mixture and this process should be done under a hood.
D. Tighten the caps to the specified torque (the blue line on the meter) using the capping station.
E. Record the weight (to the hundredth of a gram) of each teflon vessel before installing it in the microwave carousel.
F. The carousel must always have twelve vessels in it. Use dummy samples, complete with soil and acid, to fill all twelve. Make sure that the vent tubes are securely inserted into the central collection vessel.
G. Program the microwave oven as follows:
   stage 1 - 10 minutes 90% power (590 watts)
   stage 2 - 5 minutes 70% power (450 watts)
   stage 3 - 10 minutes 60% power (390 watts)
   The microwave oven should be calibrated every six months and power settings adjusted so that specified wattages are maintained. Low recoveries on the QC samples (described later) may be indicative of a drop in power, and would suggest a calibration check of the oven.

   NOTE: The fan in the oven must be set on 8.

H. Place the carousel into the microwave and set the rotation to [on]. Begin the programmed extraction process.

I. After the program is complete, allow the vessels to stay in the oven for five to ten minutes.

J. Remove the carousel and allow the teflon vessels to cool to room temperature (at least 30 minutes).

K. Weigh each of the teflon vessels and compare to the previously recorded weight. If more than 0.5 grams were lost from a vessel, discard the extract and repeat the extraction of that sample.

L. Use the capping station under a hood to loosen the caps on the vessels. It is not unusual for a large puff of orange fumes to be released as each cap is loosened.

M. Transfer the contents of each vessel to a 100 ml centrifuge tube. Rinse the interior walls of the vessels twice with a stream of 1:1 nitric:di water and add the rinses to the extract in the centrifuge tube. Use 1:1 nitric:di water to equalize the levels in each of the tubes to the 20 ml mark.

N. Centrifuge the samples at 2000 rpm for 8 minutes. Decant into 25 ml volumetric flasks. Add concentrated nitric to the 4 ml mark and stir the mixture with a glass rod. Centrifuge again and add to the appropriate flasks.

O. Bring the volume of each volumetric flask up to the mark with di water and mix thoroughly. Allow the flasks to cool and again fill to the mark with di water.

P. Move the extract from the volumetrics to 30 ml Nalgene bottles for transport and storage.

III. ANALYSIS OF SOILS FOR URANIUM AND BERYLLIUM BY ICP

The analysis of soils by ICP spectroscopy for uranium and beryllium is applicable to soils with uranium concentrations greater than ~100 ug U/g and beryllium concentrations greater than 0.5 ug Be/g. Procedures for soil analysis by ICP are outlined below.

A. Preparation of Standards

1. Calibration standards

a. The extract used for the ICP calibration standards is prepared as described above in the microwave extraction procedure.

b. Obtain three vials of blank soil extract and label them as Standard 1, Standard 2, and Standard 3.

c. Spike each standard as described below. Motorized digital pipets are used for metering the spikes; use a pipet that allows you to stay within its accurate range (10-100% of capacity).

(1). Standard 1: Spike with 200 ul of a standard containing 1000 ug U/ml and 200 ul of a standard containing 10 ug Be/ml. The concentrations of this standard are 9.804 ug U/ml and 0.098 ug Be/ml (calculations based on a final volume of 20.40 ml). This standard should be prepared fresh daily.

(2). Standard 2: Spike with 100 ul of a standard containing 1000 ug U/ml and 100 ul of a standard containing 10 ug Be/ml. The concentrations of this standard are 4.950 ug U/ml and 0.0495 ug Be/ml (calculations based on a final volume of 20.20 ml). This standard should be prepared fresh daily.

(3). Standard 3: Standard 3 is the blank and is not spiked.

2. Spiking standards

The standard containing 1000 ug U/ml is commercially available from Leeman Labs and used without alteration. The standard containing 10 ug Be/ml is prepared by serial dilutions (described below) of a standard containing 10,000 ug Be/ml which is available from NITS.

To prepare the beryllium standards, dilute (with 1:9 nitric:di water) 500 ul of the 10,000 ug/ml beryllium standard to 50 ml in a volumetric flask and mix thoroughly. This is now a 100 ug/ml solution. This standard should be replaced every 6 months. Dilute 1000 ul of this 100 ug/ml solution to 10 ml in a volumetric flask and mix thoroughly. This standard now contains 10 ug Be/ml. This standard should be replaced every 3 months.

B. Quality Control

The following quality control procedures will be implemented in order to insure that (a) each extraction batch is subject to conditions rigorous enough to fully extract the analytes of interest, and (b) the ICP (or KPA) analyses are accurate over the full range of expected concentrations. Three QC samples (as described below) will be part of each digestion batch.

1. Each extraction batch should contain one soil sample with a known uranium concentration (verified by neutron activation analysis) in the 500 to 1000 ug/g range. (Currently available soils are # 542 at 670 +/- 70 ug U/g and # 573 at 760 +/- 70 ug U/g.)

   QC Sample 1--Use 0.5 g of the soil labeled "QC Sample 1 - ICP". This soil was prepared by milling 100.0 g of soil #573 with 0.0015 g of BeO. ICP analysis of this sample should yield 5.2 ug Be/g +/- 10% and 760 ug U/g +/- 10%.

2. Each extraction batch should contain two vessels of the uncontaminated soil (#504) used for calibration standards that have been spiked with uranium and beryllium as described below.

   a. QC Sample 2--spike 0.5 g of the calibration soil with 500 ul of the 1000 ug/ml uranium standard and 100 ul of the 10 ug/ml beryllium standard. ICP analysis of this sample should yield 1000 ug U/g +/- 10% and 2 ug Be/g +/- 10%.

   b. QC Sample 3--spike 0.5 g of the calibration soil with 50 ul of a 10 ug/ml uranium standard and 25 ul of the 10 ug/ml beryllium standard. ICP analysis of this sample should yield 0.5 ug Be/g +/- 10%, but the U concentration will be too low to accurately quantitate. KPA analysis of this sample should yield 1.0 ug U/ml +/- 10%.

C. ICP Analysis

Since the ICP spectrometer is too complex to be operated as a "black box", a detailed operational procedure will not be attempted here. A very detailed operator's manual and tutorial has been provided by the manufacturer. Intensive one-on-one training must be provided to anyone expected to provide consistent, high quality data with this instrument. The procedures described below contain an outline of the tasks to be performed, the basic operating parameters used for the analysis of uranium and beryllium, and tips for optimizing precision and accuracy.

1. Turn on the monitor (the computer is left on continuously), and go to the main menu and get the ERM protocol. Create and open a folder (usually identified by the date). Select element lines U1, Be1, and Mn1 (used for peaking). Turn "on" all three lines, and set integration times at 3 for Mn1 and 6 for U1 and Be1. Leave gains at default of 3. Set values as follows:

number of integrations	3
uptake time	60 seconds
scan integration time	1
weight	N
dilution	N
interelement correction	N
peaking line	Mn1
Bkgd integration = peak	Y

2. From the main menu go to ICP:Operation and enter the following values:

power	1.0
coolant	13
nebulizer	35
auxiliary	0.5
pump rate	1.0
autostart coolant	11

Turn on the argon and the power to the ICP (green button). Turn on the coolant, the nebulizer and the auxiliary and allow the system to purge for 5 minutes. This is especially important if argon cylinders have been replaced, allowing air to enter the line. Be sure to use a cylinder with enough argon to prevent having to open another cylinder in the middle of an analytical run. Air in the line will extinguish the plasma or destroy the torch if the line for that cylinder has not been purged. Turn off the coolant and the auxiliary and turn on the pump. Using di water, observe the nebulizer spray pattern and adjust it to a fine spray with no "spitting".

Turn on the water recirculator, and use Autostart to ignite the plasma. **Do not** run the water recirculator for extended periods of time prior to starting the plasma: it may cause condensation on the coil which will damage the unit when attempting to light the plasma.

NOTE: The red button shuts off power to the ICP and should be used any time unusual sputtering sounds are emitted from the plasma compartment. Quick action can save an expensive torch.

3. Prepare a solution that is approximately 50 ug/ml in each of U, Be, and Mn. This will be used for the peaking routines. After 30 minutes of warmup, go through the Peak x, y routine on the ICP-Operation screen, making final adjustments of the nebulizer pressure and pump rate. Then go through the Peak Wavelengths routine in the Utility section of the main menu. [Use a mixture of nitric acid, sulfuric acid, and di water that is similar in viscosity and density to the samples (240 ml concentrated nitric acid, 40 ml concentrated sulfuric acid, and 220 ml di water) for preparing the peaking solution.]

NOTE: After peaking, it is essential that none of the parameters related to sample introduction or the plasma flame be changed until calibration and analysis is complete. Changing any of these parameters (power, nebulizer pressure, roller pressure on the pump tubing, pump rate, auxiliary, coolant) will invalidate the data collected and will require recalibration and a repeat analysis.

4. Scan at least 5 samples (allow 45 sec of uptake time for each sample) and use the results to set background correction points for each analyte.
5. Reset the calibration coefficients, enter the concentrations of the calibration standards, and recalibrate.

NOTE: It is important to rinse the sample uptake tube with 50% nitric acid for at least 5 minutes after peaking with the 50 ppm solutions. It is also necessary to rinse the sample uptake tube for at least 15 seconds between standards and/or samples. When running standards, the chances for cross contamination can be minimized by running them in order of increasing concentration.

6. Check the calibration curve generated for each analyte, and accept it if appropriate. If linearity is poor, recalibrate using new standards if necessary.
7. Analyze the samples. Run a standard after every tenth sample (or after the last sample if there are fewer than 10) to check

for stability. The analysis of the standard should be within 10% of its known concentration.

8. When analysis is complete, rinse sample uptake tube with 50% nitric acid, followed by di water. Extinguish the plasma and turn off the argon at the cylinder. Turn the auxiliary, the nebulizer, and the coolant back on until the argon interlock light comes on (this bleeds the line). Release the pressure on the pump tubing, and turn off the water recirculator. Turn off the power to the ICP (red button). Exit the ICP program and turn off the monitor.

IV. ANALYSIS OF SOILS BY KINETIC PHOSPHORIMETRY

The analysis of soils by kinetic phosphorimetry for uranium is applicable to soils with original concentrations of less than ~250 ug/g. Procedures for soil analysis by the ChemChek Kinetic Phosphorescence Analyzer (KPA-10 or KPA) are outlined below. Quality control for the KPA is covered in Section III B.

A. Preparation of Reference Solution and Calibration Standards

The reference solution is prepared in the reference cell cuvette) and not replaced until it responds with a lifetime of less than approximately 150 us or a coefficient of linearity less than 0.992.

The KPA measures samples in one of two ranges. The low range is applicable for final concentration levels from the detection limit of 0.0004 ug/ml up to approximately 0.25 ug/ml, while the high range is applicable for concentrations from approximately 0.1 ug/ml to 2.0 ug/ml. Sample linearity is lost beyond 2.0 ug/ml concentration.

The KPA utilizes a background measurement and correction for each range. Up to three calibration standards may be used for each range. In practice, one standard for the low range and one standard for the high range have been shown to give acceptable results.

The concentrations of the calibration standards are 0.01 ug/ml for the low range and 0.2 ug/ml for the high range.

1. Reference Solution

The reference solution is contained in a quartz sample cuvette. The surfaces of the cuvette are optical surfaces and should be treated with care. Do not touch the cuvette with anything but lint-free tissues.

a. Remove the reference cuvette from the sample excitation chamber. Note that the flat surfaces of the cell are optical elements and care should be taken when handling the cell.

b. Use a transfer pipet to remove the reference solution from the cell.

c. Fill the cell halfway with methanol and replace the cap. Invert several times to clean the interior walls of the cell. Use a transfer pipet to remove the methanol.
d. Rinse well with di water several times.
e. Using the 100 ul motorized pipet, add 30 ul of 1 ug U/ml and 3.0 ml Uraplex to the cell.
f. Cap and invert to mix the solution.
g. Use methanol and lint-free tissues to clean the outside surfaces of the cell. Small fibers will be seen suspended in the solution. This should be minimized but is a normal occurrence.
h. Replace the reference cell in the sample chamber of the KPA.

2. Calibration Standards

a. Label and date four scintillation vials as "soil blank", ".01 soil", "0.2 soil", and "2.0 soil".
b. Add 10 ml of blank soil (#504) wet ashed extract to all vials.
c. To the ".01 soil" vial, add 0.010 ml of 10 ug/ml U.
d. To the ".2 soil" vial, add 0.204 ml of 10 ug/ml U.
e. Cap and invert to mix.

NOTE: Alternatively, the calibration standards could be made with straight soil extract and wet ashed on the hotplate along with the samples, although good results are obtained with the post-wet ash spiking.

B. Sample Preparation

1. Transfer a 2.0 ml aliquot from the microwave extract of each sample into 20 ml scintillation vials and evaporate to dryness on a hotplate. This generally takes 4 to 5 hours with the hotplate set on 3.5 to 4.1.
2. After cooling the sample slightly to avoid any spattering, add 1.0 ml of 1:1 nitric:di water to each vial and evaporate to dryness.
3. Again add 1.0 ml of 1:1 nitric:di water to each vial and evaporate to dryness. Allow the vials to cool to room temperature.
4. Add 0.8 ml of 1:1 nitric:di water to the samples. Swirl and allow to sit for 25 minutes on a warm plate (lowest setting).
5. Add 3.2 ml nitric:di water to each vial. Swirl and allow to sit for an additional 25 minutes.
6. Add 6.0 ml di water and allow the sample to sit for about 5 minutes before analyzing.

NOTE: Dilution factor at this point is 250.

C. KPA Operation

1. System Startup

Before running the KPA, an ample supply of filtered Uraplex must be available. The Uraplex must be filtered daily through a 0.45 um pore size filter prior to use.

Using an acid washed 250 ml graduated cylinder, dilute the contents of the Uraplex bottle (30 ml Nalgene) to a total of 500 ml with >10 megohm di water.

Turn on all components of the system. At this time all components are plugged in together behind the main unit and are energized with the switch on the power strip.

If a new reference solution was prepared, go to the configuration menu and change the date of the reference solution before continuing with the calibration.

2. KPA Calibration

Below is a quick overview of calibration and operation; the unit is too complex to be run from a strict set of directions. Time must be spent with the manuals and/or a knowledgeable operator before independent operation of the unit should be attempted.

The KPA must be calibrated before use each day. The unit is equipped with an automatic sampler that is controlled from the computer. Limited control is accessible from the various menus.

Each calibration point is independent from the others. If two or more calibration points exist for a range, only one will be in use at any one time. The KPA will only switch calibration points (or ranges) when the current point yields grossly improper data, such as when the sample yields results more than 10 times smaller or 20 times larger than the calibration point. For this reason, usually only one point in a range is set, and any samples that fall outside that range, but within the limits of the unit, must be analyzed again.

a. Go to the calibration menu and choose to measure the background for both the low and high ranges. This will also reset the previous calibration points.
b. Press [F10] to rinse the sample cell.
c. Place the scintillation vials in the 1, 2, and 3 positions on the left-most rack in the following order: blank, .01, and .2 ug/ml.
d. Place culture tubes in the 1, 2, and 3 positions of the rack on the right.
e. Make sure that the toggle switch on the front of the main unit is in the down position. Set the printer on the beginning of a new page. Measure the background for the low range and print the graphs of the background and the reference data on the sheet in that order.

f. Advance the paper in the printer to the next page and set the toggle switch to the up position. Measure the background for the high range and print the graphs of the background and reference data. Note that the KPA measured the same material twice without using the autosampler between the runs.

g. Advance the paper in the printer again and set the toggle to the down position. Measure the low calibration standard and print the graphs.

h. Advance the paper in the printer and set the toggle back to the up position. Measure the high calibration standard and print the graphs.

i. Rinse the cell and return the toggle switch to the down position.

NOTE: The toggle switch serves the following functions. During calibration it sets the light entrance aperture from low to high for each standard. During sample analysis it relinquishes control of the aperture to the computer in the down position, and in the up position it forces the aperture to the high setting. In the high setting during sample analysis most of the light from middle to low concentration samples will not reach the photomultiplier tube and results of 0.00E+00 will be given.

3. Analysis of Samples

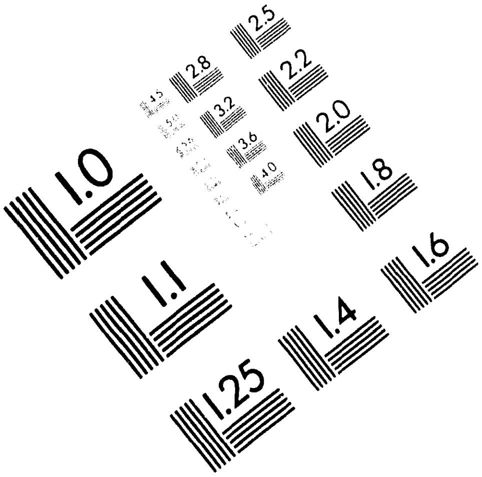
Once the samples have been prepared and the instrument calibrated, analysis is a simple operation. Make sure the matrices are identical for samples and calibration standards. Always load a di water-filled scintillation vial as the last sample. This helps to keep the inside of the sample cuvette relatively clean.

a. Load the scintillation vials in racks 1 through 4 and load the matching culture tubes in rack 5. Blank slots are not a concern as the KPA will only sample slots that have data assigned to them from the data input menu.

b. Go to the analyze menu from the main menu and enter the sample description for each sample. Dilution factors and standard additions are also possible from the data input table.

c. Return to the Analyze menu and start the sample analysis from any rack and vial that is convenient.

After the analysis is finished, put the Uraplex into the refrigerator and cap the samples. Uraplex must be kept cool when not in use, and capping the samples prevents contamination and evaporation.



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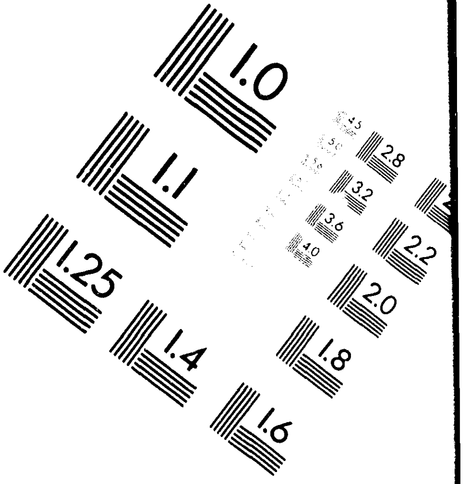

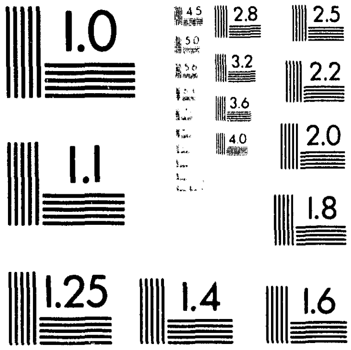

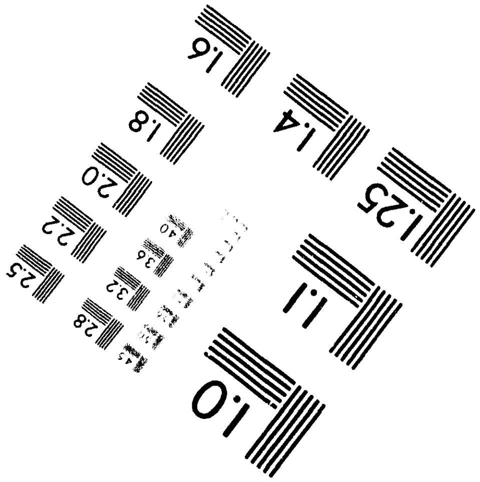

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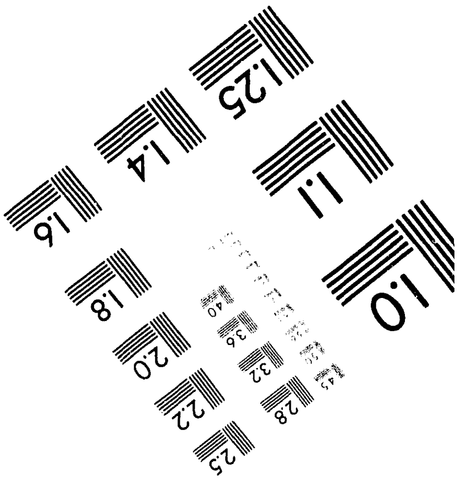


2 of 3

MATERIAL TEST DIRECTORATE
YUMA PROVING GROUND
YUMA, ARIZONA

LABORATORY SERVICES BRANCH TEST REPORT

Item: Field Matrix spike with DU Date: 9 Nov 92

Project Engineer: Sylvia M Medina

Comments: This report is a special report for the use of INEL in their QA/QC documentation of the Sampling and Analysis Plan for the Yuma Proving Ground Firing Range Restoration Project.

In this report the term Depleted Uranium (DU) is used as it is the material that has contaminated the firing range. To avoid confusion in the reports the term DU is always used. The Laboratory does not analyze for only DU but all of the isotopes of Uranium which is a Total Uranium Analysis that is labeled DU.

Test Results

In the setting up of the sampling and analysis plan for the analysis of Depleted Uranium (DU) by the laboratory at Yuma Proving Ground (YPG) a double blind field matrix spike was desired. To make the spike as close to an actual field sample as possible it would be desirable to have the DU spike media be the same as the DU in the actual samples taken from the range. To accomplish this the following method was used.

1. Take two background samples from the range at YPG. Label one as Bk-01-DU and the other as Bk-02-DU.

2. Have one of these samples analyzed as a true background sample. This should give a DU value of around 2 micrograms of DU per gram of soil (ug/g). We know this from past samples from this location.

3. Spike the second sample with a portion of soil mixed with DU. The portion of soil used for this spike is an actual soil sample (YPG sample number 573) from the area under analysis (Hill and Berm Area) for this project that has been ground to a powder of less than 75 microns and analyzed by an outside laboratory. The analysis on this soil was done by Los Alamos National Laboratory. See the attached letter from Los Alamos.

4. To make the mixture, 1034.9 grams of the background soil was mixed with 83.4 grams of sample number 573. The sample was then shaken and submitted to the laboratory as a background sample.

5. The value for sample number 573 is listed at 760 +/- 70 ug/g. To get the value range for the spiked sample that was produced at YPG we have to make a low and high calculation

using 690 ug/g as the low value and 830 ug/g as the high value.

$$\frac{((83.4g\times690ug/g)+(1034.9g\times2ug/g))}{(1034.9g+83.4g)}=53.3ug/g$$

$$\frac{((83.4g\times830ug/g)+(1034.9g\times2ug/g))}{(1034.9g+83.4g)}=63.8ug/g$$

6. The value reported by the laboratory for this spiked background sample should be between these two values for DU. I hope that this sample is what you had in mind for your matrix spike. I would have liked the value to have been higher, but the dilution killed us.

7. POC: David L. Pond, 602-328-6246.

A copy of this report is on a 3.5 inch HD disk included in this data package. This report is a WordPerfect file which is in the subdirectory WP under its file name DU-SPIKE. This is a protected file with the code being INPP.

INSPECTED BY: ________________________
DAVID L. POND
Chemist
Material Analysis Laboratory

Los Alamos
Los Alamos National Laboratory
Los Alamos, New Mexico 87545

DATE: September 11, 1989
IN REPLY REFER TO: HSE-9/89-446
MAIL STOP: K484
TELEPHONE: (505)667-6028
(FTS)667-6028

Mr. Dave Ponds
MT-MP
Yuma Proving Grounds
Yuma, AZ 85365

Dear Dave:

Enclosed are two reprints on some of our nuclear methods for determining total uranium in samples that contain uranium that is depleted in U-235. We have also run the three comparison samples that you provided us during our May 1989 visit by instrumental epithermal neutron activation analysis:

Yuma Sample #	U (ug/g)
504	< 1
542	670 +/- 70
573	760 +/- 70

Quality assurance was provided by the concurrent analysis of Canadian Certified Reference Materials Project BL-4 (uranium ore):

U (ug/g)	
HSE-9	CCRMP Certified Value
1620 +/- 100	1730 +/- 40

I hope these data and reprints will be of assistance. Thank you again for all your help during our May visit. I certainly hope that we will be spending more time at Yuma next year.

Warmest regards,

Ernest S. Gladney
Health and Environmental Chemistry

ESG/mr
(wp\esg\ponds)

Enc.a/s

Cy: HSE-DO, MS-K491
CRM-4, (2) MS-A150
HSE-9 file

Idaho National Laboratories Uranium Study

Soil Results

Laboratory Name: United States Army Yuma Proving Ground
Technical Support Services, Inc., Laboratory
Contractor

Laboratory Personnel:
Manager/Chief Chemist; Stephen Maurer, MS Chemistry
QC manager; Daron Hargadine, BA Chemistry
Analyst; Ranell Caiazzo, BS Biology, 8 years experience at YPG laboratory

Analytical Method:

Lab personnel followed a developmental procedure titled "Analysis of Soils for Uranium and Beryllium". The microwave extraction procedure (Section II) and ICP Analysis (Section III) are the specific sections used. The procedure is used for determination of Uranium at high levels. The actual lower detection limit has not been verified. Preliminary studies indicate 50 ppm as this point. This method has not been approved for use by the Nuclear Regulatory Commission. It will be submitted for approval in the near future.

All soil samples analyzed for Uranium were analyzed by this method.

Equipment Used:

	Brand	Model	Serial Number
Microwave	CEM	MDS-81D	6148888
ICP	Leeman Labs	PS1000	1125

Laboratory Sample Log Number/INEL Sample Number Correlation

Sample Number	INEL Number	Analysis date
4558	YPG110392 SP01 DU	11/30/92
4558d	YPG110392 SP01 DU	11/30/92
4561	YPG110392 SP02 DU	11/30/92
4564	YPG110392 SP03 DU	11/30/92
4567	YPG110392 SP04 DU	11/30/92
4574	YPG110492 NP01 DU	11/30/92
4574s	YPG110492 NP01 DU	11/30/92
4577	YPG110492 NP02 DU	11/30/92
4580	YPG110492 NP03 DU	11/30/92
4583	YPG110492 NP04 DU	11/30/92
4658	YPG110592 WP01 DU	11/30/92
4661	YPG110592 WP02 DUa	11/30/92
4664a	YPG110592 WP02 DUb	11/30/92
4664b	YPG110592 WP02 DU	11/30/92
4664db	YPG110592 WP02 DU	11/30/92
4667	YPG110592 WP03 DU	11/30/92
4667s	YPG110592 WP03 DU	11/30/92
4672	YPG110592 BK01 DU	11/30/92
4673	YPG110592 BK02 DU	11/30/92
4676	YPG110592 WP04 DU	11/30/92
Can III		11/30/92
Can II		11/30/92
Std "A"		11/30/92
"A" Pre		11/30/92
"A" Post		11/30/92
Blank		11/30/92
B spike		11/30/92

Analysis Results for Unknowns

Sample Number	ICP Results ug/ml	Soil(g) dilution factor(ml)		Result ug/g	Analysis time	
4558	1.230	.52	25	59.13	11:35	
4558d	1.357	.54	25	62.82	12:11	
4561	1.057	.52	25	50.82	11:39	
4564	2.724	.51	25	133.53	11:44	
4567	1.008	.51	25	49.41	11:52	
4574	4.105	.51	25	201.23	11:56	
4574s	8.985	.52	25	431.97	10:22	
4577	6.674	.51	25	327.16	11:59	
4580	5.008	.52	25	240.77	12:03	
4583	7.921	.50	25	396.05	12:07	
4658	3.685	.52	25	177.16	10:17	
4661	5.865	.50	25	293.25	12:22	
4664a	8.292	.52	25	398.65	10:45	
4664b	6.521	.51	25	319.66	9:26	
4664db1	7.645	.51	25	374.75	9:39	duplicate
4664db2	7.698	.51	25	377.35	12:32	scan
4667	2.606	.53	25	122.92	9:59	
4667s	8.052	.50	25	402.60	9:55	
4672	-.1078	.50	25	-5.39	10:14	
4673	1.220	.50	25	61.00	10:03	duplicate
4673	1.329	.50	25	66.45	11:47	scan
4676	2.070	.51	25	101.47	12:27	
Can III	14.00	.50	25	700.00	10:33	
Can II	5.327	.53	25	251.27	10:08	
Std "A"	-.0178	.53	25	-0.84	9:51	
"A" Pre	7.158	.52	25	344.13	12:43	
"A" Post	6.730	.53	25	317.45	12:36	
Blank	-.1010		25	-2.53	10:39	
B spike	7.195		25	179.88	10:26	

Notes:

Sample number 4664 was used for two systems checks. It was first split as a preparation check, then [illegible](b) was split as a digestion check.

Samples designated with a "d" after the number are duplicates, those with an "s" are spikes.

Calculations:

ICP results (ug/ml) x dilution (ml) / soil (g) = results (ug/g)

Results for Standards and Spikes

Standard	Expected ug/g	Obtained ug/g	% Recovery
4574		201.23	
4574 spike	401.23	431.87	115
4667		122.92	
4667 spike	422.92	402.60	93
Blank	0.0	ND	
Blank Spike	150	179.88	120
Can III	630/650	700.00	111/108
Can II	280/290	251.27	90/87
Internal A	0.0	ND	
A Preprep	300	344.13	115
A Postprep	300	317.45	106
			RPD
4664 dup.scan		374.75/377.35	0.69
4673 dup scan		61.00/66.45	7.87

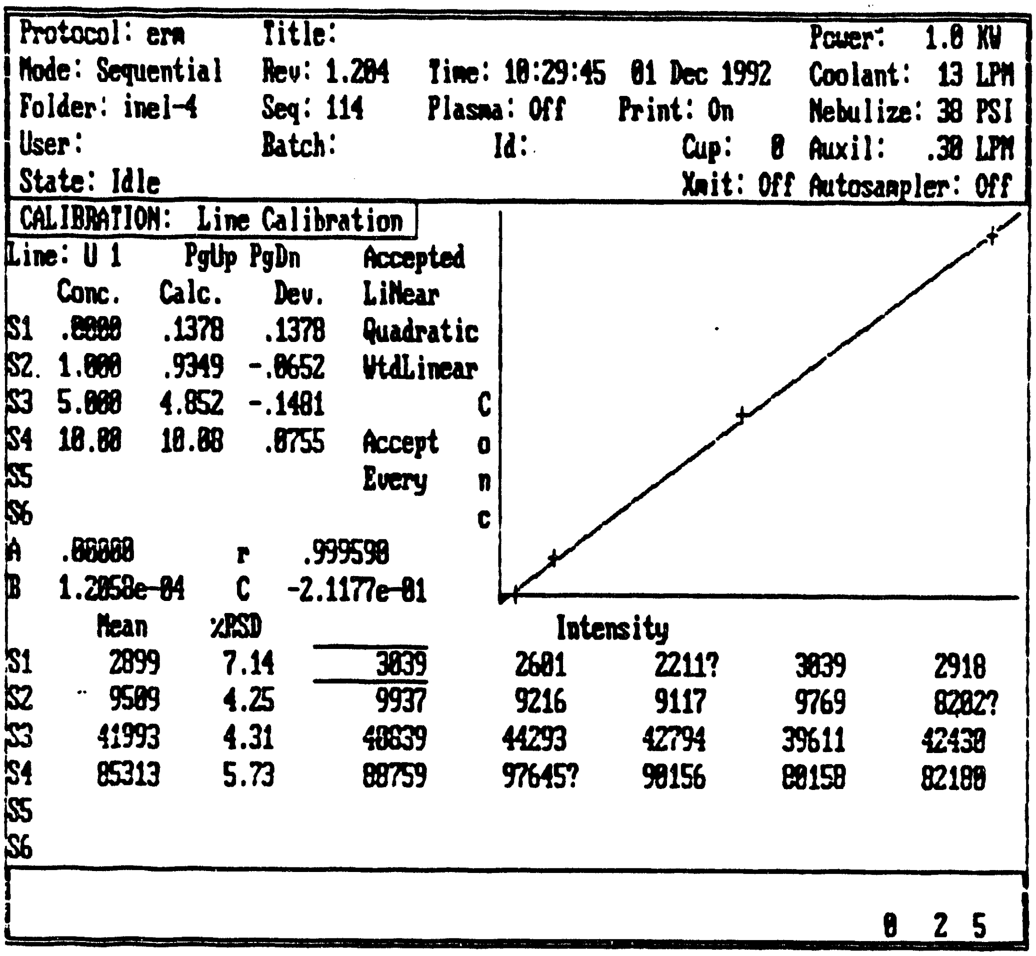
Notes:

Background selection on the ICP is the operators choice, based on scans of several samples. The most common intersection of the scan lines is selected, if the sample does not fit this point exactly it may cause high or low readings. There is not enough historical data at this time to aid in selection of the proper point.

Calibration standards 1 ppm and 5 ppm were checked as samples midway through sample analysis. The results showed both standards were higher; 1 ppm at 1.237 ppm and 5 ppm at 5.349 ppm. At this time the the instrument was recalibrated.

Standards labeled Can II and III were obtained from the Canada Centre for Mineral and Energy Technology. They were analyzed by the Canadian officials and by Los Alamos National Laboratory. (See attached reports: CANMET 79-35 and LA-8770-MS.) In the expected column, the figure on the left is the Los Alamos figure and on the right the Canadian figure.

Raw Data - U analysis. Includes calibration.



```
Protocol: erm      Title:                                            Power:    1.0 KW
Mode: Sequential   Rev: 1.204   Time: 10:29:45  01 Dec 1992         Coolant:  13 LPM
Folder: inel-4     Seq: 114     Plasma: Off     Print: On           Nebulize: 30 PSI
User:              Batch:             Id:           Cup:   0        Auxil:   .30 LPM
State: Idle                                         Xmit: Off       Autosampler: Off
CALIBRATION:  Line Calibration
Line: U 1      PgUp PgDn      Accepted
    Conc.    Calc.    Dev.    LiNear
S1  .0000    .1378    .1378   Quadratic
S2. 1.000    .9349   -.0652   WtdLinear
S3  5.000    4.852   -.1401            C
S4  10.00    10.08    .0755   Accept   o
S5                            Every    n
S6                                     c
A   .00000         r    .999590
B   1.2058e-04     C   -2.1177e-01
         Mean     %RSD                        Intensity
S1       2899     7.14       3039      2601      2211?      3039      2918
S2       9509     4.25       9937      9216      9117       9769      8202?
S3      41993     4.31      40639     44293     42794      39611     42430
S4      85313     5.73      88759     97645?    90156      80158     82100
S5
S6

                                                                     0  2  5
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 YUMA PROVING GROUND           Folder:   inel-4                        Page 1
08:26:10 30 Nov 1992           Protocol: erm

Line  Wave.   Conc.  Units     SD/RSD       1         2         3         4         5
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*** Standard: 1 Rep: 1                 Seq:  8       08:26:10 30 Nov 1992

U 1  385.958  .0000  UG/ML        -28374    -28404    -28208
                       Ave. Int. =    -28329 S. D. =       106

*** Standard: 1 Rep: 2                 Seq:  9       08:27:14 30 Nov 1992

U 1  385.958  .0000  UG/ML        -28474    -29765    -29080
                       Ave. Int. =    -29106 S. D. =       646

*** Standard: 1 Rep: 3                 Seq:  10      08:28:02 30 Nov 1992

U 1  385.958  .0000  UG/ML        -29514    -29286    -28980
                       Ave. Int. =    -29260 S. D. =       268

*** Standard: 1 Rep: 4                 Seq:  11      08:28:49 30 Nov 1992

U 1  385.958  .0000  UG/ML        -29510    -28820    -28314
                       Ave. Int. =    -28881 S. D. =       600

*** Standard: 1 Rep: 5                 Seq:  12      08:29:37 30 Nov 1992

U 1  385.958  .0000  UG/ML        -29433    -28959    -29070
                       Ave. Int. =    -29154 S. D. =       248

*** Standard: 2 Rep: 1                 Seq:  13      08:34:12 30 Nov 1992

U 1  385.958  1.000  UG/ML        -17197    -17380    -16892
                       Ave. Int. =    -17156 S. D. =       247

*** Standard: 2 Rep: 2                 Seq:  14      08:35:00 30 Nov 1992

U 1  385.958  1.000  UG/ML        -17787    -16913    -17328
                       Ave. Int. =    -17343 S. D. =       437

*** Standard: 2 Rep: 3                 Seq:  15      08:35:48 30 Nov 1992

U 1  385.958  1.000  UG/ML        -16912    -16848    -16443
                       Ave. Int. =    -16734 S. D. =       254

*** Standard: 2 Rep: 4                 Seq:  16      08:36:35 30 Nov 1992

U 1  385.958  1.000  UG/ML        -16961    -16016    -16818
                       Ave. Int. =    -16598 S. D. =       509
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 YUMA PROVING GROUND              Folder:   inel-4                     Page 2
08:37:23 30 Nov 1992              Protocol: erm

Line  Wave.   Conc.  Units      SD/RSD      1        2        3        4        5
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*** Standard: 2 Rep: 5                Seq:  17      08:37:23 30 Nov 1992

U 1   385.958  1.000  UG/ML          -17105   -17275   -16783
                         Ave. Int. =    -17054 S. D. =      250

*** Standard: 3 Rep: 1                Seq:  19      08:41:40 30 Nov 1992

U 1   385.958  5.000  UG/ML           28798    28494    26696
                         Ave. Int. =     27996 S. D. =     1136

*** Standard: 3 Rep: 2                Seq:  20      08:42:28 30 Nov 1992

U 1   385.958  5.000  UG/ML           30020    28781    29346
                         Ave. Int. =     29382 S. D. =      620

*** Standard: 3 Rep: 3                Seq:  21      08:43:15 30 Nov 1992

U 1   385.958  5.000  UG/ML           26127    26375    28564
                         Ave. Int. =     27022 S. D. =     1341

*** Standard: 3 Rep: 4                Seq:  22      08:44:03 30 Nov 1992

U 1   385.958  5.000  UG/ML           27995    29272    29206
                         Ave. Int. =     28824 S. D. =      719

*** Standard: 3 Rep: 5                Seq:  23      08:44:50 30 Nov 1992

U 1   385.958  5.000  UG/ML           27584    28709    29108
                         Ave. Int. =     28467 S. D. =      790

*** Standard: 1 Rep: 1                Seq:  24      08:51:27 30 Nov 1992

U 1   385.958  .0000  UG/ML            -168      -70     -248
                         Ave. Int. =      -169 S. D. =       91

*** Standard: 1 Rep: 2                Seq:  25      08:52:15 30 Nov 1992

U 1   385.958  .0000  UG/ML            1803      997       47
                         Ave. Int. =       949 S. D. =      879

*** Standard: 1 Rep: 3                Seq:  26      08:53:03 30 Nov 1992

U 1   385.958  .0000  UG/ML             -51    -1092      285
                         Ave. Int. =      -286 S. D. =      718
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 YUMA PROVING GROUND            Folder:   inel-4                         Page 3
08:53:52 30 Nov 1992            Protocol: erm

Line  Wave.    Conc.  Units     SD/RSD      1        2        3        4        5
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*** Standard: 1 Rep: 4               Seq:  27      08:53:52 30 Nov 1992

U 1  385.958  .0000  UG/ML          -573     -599     -505
                      Ave. Int. =      -559 S. D. =       49

*** Standard: 1 Rep: 5               Seq:  28      08:54:40 30 Nov 1992

U 1  385.958  .0000  UG/ML         -1506      -14      -58
                      Ave. Int. =      -526 S. D. =      849

*** Standard: 2 Rep: 1               Seq:  29      08:58:08 30 Nov 1992

U 1  385.958  1.000  UG/ML          7192     7851     7881
                      Ave. Int. =      7641 S. D. =      389

*** Standard: 2 Rep: 2               Seq:  30      08:58:56 30 Nov 1992

U 1  385.958  1.000  UG/ML          7153     8876     8656
                      Ave. Int. =      8228 S. D. =      938

*** Standard: 2 Rep: 3               Seq:  31      08:59:44 30 Nov 1992

U 1  385.958  1.000  UG/ML          9346    10264     8246
                      Ave. Int. =      9285 S. D. =     1010

*** Standard: 2 Rep: 4               Seq:  32      09:00:33 30 Nov 1992

U 1  385.958  1.000  UG/ML          9678     8727     9748
                      Ave. Int. =      9384 S. D. =      570

*** Standard: 2 Rep: 5               Seq:  33      09:01:21 30 Nov 1992

U 1  385.958  1.000  UG/ML          9624    10204     8492
                      Ave. Int. =      9440 S. D. =      871

*** Standard: 3 Rep: 1               Seq:  35      09:08:37 30 Nov 1992

U 1  385.958  5.000  UG/ML         44996    37131    36571
                      Ave. Int. =     39566 S. D. =     4711

*** Standard: 3 Rep: 2               Seq:  36      09:09:25 30 Nov 1992

U 1  385.958  5.000  UG/ML         47343    44304    34071
                      Ave. Int. =     41906 S. D. =     6953
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Line  Wave.    Conc.  Units      SD/RSD     1         2         3         4         5
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*** Standard: 3 Rep: 3               Seq:  37      09:10:13 30 Nov 1992

U 1  385.958  5.000  UG/ML         38769     46451     45459
                      Ave. Int. =     43560 S. D. =     4178

*** Standard: 3 Rep: 4               Seq:  38      09:11:01 30 Nov 1992

U 1  385.958  5.000  UG/ML         48789     32015     36419
                      Ave. Int. =     39074 S. D. =     8697

*** Standard: 3 Rep: 5               Seq:  39      09:11:49 30 Nov 1992

U 1  385.958  5.000  UG/ML         45690     38962     37233
                      Ave. Int. =     40628 S. D. =     4468

*** Standard: 4 Rep: 1               Seq:  40      09:17:57 30 Nov 1992

U 1  385.958  10.00  UG/ML         85343     88934     91650
                      Ave. Int. =     88642 S. D. =     3164

*** Standard: 4 Rep: 2               Seq:  41      09:18:45 30 Nov 1992

U 1  385.958  10.00  UG/ML         70236     74006     73239
                      Ave. Int. =     72494 S. D. =     1992

*** Standard: 4 Rep: 3               Seq:  42      09:19:34 30 Nov 1992

U 1  385.958  10.00  UG/ML         80333     71409     72804
                      Ave. Int. =     74849 S. D. =     4801

*** Standard: 4 Rep: 4               Seq:  43      09:20:22 30 Nov 1992

U 1  385.958  10.00  UG/ML         68669     80970     73056
                      Ave. Int. =     74232 S. D. =     6234

*** Standard: 4 Rep: 5               Seq:  44      09:21:10 30 Nov 1992

U 1  385.958  10.00  UG/ML         80052     76807     73242
                      Ave. Int. =     76700 S. D. =     3406
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Line  Wave.    Conc.  Units     SD/RSD     1        2        3        4        5
--------------------------------------------------------------------------------
                4664-6
*** Sample ID: 4664-g               Seq:  45      09:26:06 30 Nov 1992

U 1  385.958  6.521  UG/ML       44925    52175    56090

*** Sample ID: ~~blank II~~                 Seq:  47      09:29:17 30 Nov 1992

U 1  385.958  .4716  UG/ML        5192     4552     3250

*** Sample ID: ~~blank~~                Seq:  48      09:31:56 30 Nov 1992

U 1  385.958  .2484  UG/ML        2637     2224     2962

*** Sample ID: 4667                 Seq:  49      09:35:29 30 Nov 1992

U 1  385.958  1.655  UG/ML       14090     9965    16368
                4664d-d
*** Sample ID: 4664d-h              Seq:  50      09:39:26 30 Nov 1992

U 1  385.958  7.645  UG/ML       59713    59736    59788

*** Sample ID: ~~4661-b~~               Seq:  51      09:46:14 30 Nov 1992

U 1  385.958  4.469  UG/ML       33393    36325    35910

Std *** Sample ID: ~~[illegible]~~ Std        Seq:  53      09:51:43 30 Nov 1992

U 1  385.958 -.0178  UG/ML         234     1377       42

*** Sample ID: 4667s-I-2            Seq:  54      09:55:14 30 Nov 1992

U 1  385.958  8.052  UG/ML       54067    64703    69888

*** Sample ID: 4667-c               Seq:  55      09:59:05 30 Nov 1992

U 1  385.958  2.606  UG/ML       22022    20017    20427

*** Sample ID: 4673-e               Seq:  56      10:03:10 30 Nov 1992

U 1  385.958  1.220  UG/ML       10094    10237    10000

*** Sample ID: canII                Seq:  57      10:08:01 30 Nov 1992

U 1  385.958  5.327  UG/ML       44659    38827    42043

*** Sample ID: 4672-d               Seq:  59      10:14:15 30 Nov 1992

U 1  385.958 -.1078  UG/ML        1564    -1516     -480
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 YUMA PROVING GROUND           Folder:   inel-4                    Page 6
10:17:28 30 Nov 1992           Protocol: erm

Line  Wave.   Conc.  Units     SD/RSD       1       2        3        4        5
---------------------------------------------------------------------------------

*** Sample ID: 4658-a                 Seq:  60     10:17:28 30 Nov 1992

U 1  385.958  3.685  UG/ML        30147     29166     28160

*** Sample ID: 4574s-10               Seq:  61     10:22:21 30 Nov 1992

U 1  385.958  8.985  UG/ML        69278     70424     70593

*** Sample ID: blankspike             Seq:  62     10:26:27 30 Nov 1992

U 1  385.958  7.195  UG/ML        57113     56600     55100

*** Sample ID: canIII-12              Seq:  63     10:33:21 30 Nov 1992

U 1  385.958  14.00  UG/ML       113646    113880     98920

*** Sample ID: ~~4561-11~~ blank       Seq:  65     10:39:18 30 Nov 1992

U 1  385.958 -.1010  UG/ML         -545       590      -321
                4664-A
*** Sample ID: 4664-g                 Seq:  66     10:45:13 30 Nov 1992

U 1  385.958  8.292  UG/ML        64030     60832     69372

*** Sample ID: 5ppm check             Seq:  67     10:49:59 30 Nov 1992

U 1  385.958  6.262  UG/ML        48694     48650     49844

*** Sample ID: 5ppm check             Seq:  68     10:52:48 30 Nov 1992

U 1  385.958  5.349  UG/ML        43508     43550     38979

*** Sample ID: 1ppm check             Seq:  71     11:02:06 30 Nov 1992

recal U 1  385.958  1.237  UG/ML         8803      9492     12444

*** Standard: 1 Rep: 1               Seq:  72     11:06:00 30 Nov 1992

U 1  385.958  .0000  UG/ML         2636      2983      3497
                     Ave. Int. =     3039 S. D. =      433

*** Standard: 1 Rep: 2               Seq:  73     11:06:48 30 Nov 1992

U 1  385.958  .0000  UG/ML         2350      2818      2636
                     Ave. Int. =     2601 S. D. =      236
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 YUMA PROVING GROUND          Folder:   inel-4                        Page /
11:07:37 30 Nov 1992          Protocol: ers

Line  Wave.   Conc.  Units     SD/RSD     1       2       3       4       5
-------------------------------------------------------------------------------

*** Standard: 1 Rep: 3              Seq:  74      11:07:37 30 Nov 1992

U 1  385.958  .0000  UG/ML            3166     1124      2343
                     Ave. Int. =        2211 S. D. =     1027

*** Standard: 1 Rep: 4              Seq:  75      11:08:25 30 Nov 1992

U 1  385.958  .0000  UG/ML            1942     3240      3934
                     Ave. Int. =        3039 S. D. =     1011

*** Standard: 1 Rep: 5              Seq:  76      11:09:13 30 Nov 1992

U 1  385.958  .0000  UG/ML            2894     2361      3500
                     Ave. Int. =        2918 S. D. =      570

*** Standard: 2 Rep: 1              Seq:  77      11:11:48 30 Nov 1992

U 1  385.958  1.000  UG/ML           10566     8620     10624
                     Ave. Int. =        9937 S. D. =     1141

*** Standard: 2 Rep: 2              Seq:  78      11:12:36 30 Nov 1992

U 1  385.958  1.000  UG/ML            9032     9265      9352
                     Ave. Int. =        9216 S. D. =      165

*** Standard: 2 Rep: 3              Seq:  79      11:13:24 30 Nov 1992

U 1  385.958  1.000  UG/ML            9094     9805      8452
                     Ave. Int. =        9117 S. D. =      677

*** Standard: 2 Rep: 4              Seq:  80      11:14:12 30 Nov 1992

U 1  385.958  1.000  UG/ML            7828    11931      9547
                     Ave. Int. =        9769 S. D. =     2060

*** Standard: 2 Rep: 5              Seq:  81      11:15:01 30 Nov 1992

U 1  385.958  1.000  UG/ML            7078     8129      9398
                     Ave. Int. =        8202 S. D. =     1162

*** Standard: 3 Rep: 1              Seq:  82      11:18:47 30 Nov 1992

U 1  385.958  5.000  UG/ML           42105    40390     40021
                     Ave. Int. =       40839 S. D. =     1112
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Line  Wave.    Conc.   Units     SD/RSD      1        2        3        4        5
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*** Standard: 3 Rep: 2              Seq:  83      11:19:35 30 Nov 1992

U 1   385.958  5.000  UG/ML        45892    42855    44132
                      Ave. Int. =    44293 S. D. =    1525

*** Standard: 3 Rep: 3              Seq:  84      11:20:23 30 Nov 1992

U 1   385.958  5.000  UG/ML        42009    41497    44875
                      Ave. Int. =    42794 S. D. =    1821

*** Standard: 3 Rep: 4              Seq:  85      11:21:11 30 Nov 1992

U 1   385.958  5.000  UG/ML        41873    38031    38930
                      Ave. Int. =    39611 S. D. =    2010

*** Standard: 3 Rep: 5              Seq:  86      11:22:00 30 Nov 1992

U 1   385.958  5.000  UG/ML        44252    41362    41677
                      Ave. Int. =    42430 S. D. =    1585

*** Standard: 4 Rep: 1              Seq:  88      11:26:59 30 Nov 1992

U 1   385.958  10.00  UG/ML        86212    96900    83166
                      Ave. Int. =    88759 S. D. =    7213

*** Standard: 4 Rep: 2              Seq:  89      11:27:47 30 Nov 1992

U 1   385.958  10.00  UG/ML        96715    100039   96180
                      Ave. Int. =    97645 S. D. =    2091

*** Standard: 4 Rep: 3              Seq:  90      11:28:35 30 Nov 1992

U 1   385.958  10.00  UG/ML        94868    88029    87571
                      Ave. Int. =    90156 S. D. =    4087

*** Standard: 4 Rep: 4              Seq:  91      11:29:23 30 Nov 1992

U 1   385.956  10.00  UG/ML        75223    85630    79622
                      Ave. Int. =    80158 S. D. =    5224

*** Standard: 4 Rep: 5              Seq:  92      11:30:11 30 Nov 1992

U 1   385.958  10.00  UG/ML        76750    87424    82365
                      Ave. Int. =    82180 S. D. =    5339

*** Sample ID: 4558-1                 Seq:  93      11:35:31 30 Nov 1992

U 1   385.958  1.230  UG/ML        11900    11706    12267
```

```
Line  Wave.    Conc.  Units     SD/RSD      1        2        3        4        5
----------------------------------------------------------------------------------

*** Sample ID: 4561-2               Seq:  94     11:39:33 30 Nov 1992

U 1  385.958  1.057  UG/ML         9714     10483     11360

*** Sample ID: 4564-3               Seq:  95     11:44:15 30 Nov 1992

U 1  385.958  2.724  UG/ML        24000     25016     24014

*** Sample ID: 4673-e-2             Seq:  97     11:47:56 30 Nov 1992

U 1  385.958  1.329  UG/ML        12832     12718     12794

*** Sample ID: 4567-4               Seq:  98     11:52:04 30 Nov 1992

U 1  385.958  1.008  UG/ML         9312      9372     11668

*** Sample ID: 4574-5               Seq:  99     11:56:16 30 Nov 1992

U 1  385.958  4.105  UG/ML        35381     35644     36383

*** Sample ID: 4577-6               Seq:  100    11:59:58 30 Nov 1992

U 1  385.958  6.674  UG/ML        58123     56286     56903

*** Sample ID: 4580-7               Seq:  101    12:03:33 30 Nov 1992

U 1  385.958  5.008  UG/ML        41707     43723     44435

*** Sample ID: 4583-8               Seq:  102    12:07:23 30 Nov 1992

U 1  385.958  7.921  UG/ML        69459     66494     66373

*** Sample ID: 4558d-9              Seq:  104    12:11:32 30 Nov 1992

U 1  385.958  1.357  UG/ML        12572     13304     13146

*** Sample ID: canI-1               Seq:  105    12:15:03 30 Nov 1992

U 1  385.958  .2565  UG/ML         4405      3320      3926

*** Sample ID: canI-1-2             Seq:  106    12:18:17 30 Nov 1992

U 1  385.958  .3057  UG/ML         4071      4664      4139

*** Sample ID: 4661-b               Seq:  107    12:22:33 30 Nov 1992

U 1  385.958  5.865  UG/ML        50208     51075     49904
```

```
 YUMA PROVING GROUND              Folder:   inel-4                     Page 10
12:27:49 30 Nov 1992              Protocol: erm

Line  Wave.   Conc.  Units     SD/RSD     1          2          3          4          5
----------------------------------------------------------------------------------------

*** Sample ID: 4676-f                 Seq:  108    12:27:49 30 Nov 1992

U 1   385.958  2.070  UG/ML        19039     19148     18573
                4664762
*** Sample ID: 4664d-h                Seq:  109    12:32:00 30 Nov 1992

U 1   385.958  7.698  UG/ML        63421     67299     66077

*** Sample ID: stdA-post              Seq:  111    12:36:43 30 Nov 1992

U 1   385.958  6.730  UG/ML        60312     56069     56321

*** Sample ID: stdA-pre               Seq:  112    12:43:21 30 Nov 1992

U 1   385.958  7.158  UG/ML        61659     60485     61219

*** Sample ID: ~~canII-2~~            Seq:  113    12:47:37 30 Nov 1992

U 1   385.958  4.824  UG/ML        38026     44357     42910
```

Laboratory Sample Log Number/INEL Sample Number Correlation

Sample Number	INEL Number	Analysis date
4557	YPG110392 SP01 TC	11/24/92
4560	YPG110392 SP02 TC	11/24/92
4563	YPG110392 SP03 TC	11/24/92
4566	YPG110392 SP04 TC	11/24/92
4566b	YPG110392 SP04 TC	11/24/92
4573	YPG110492 NP01 TC	11/24/92
4576	YPG110492 NP02 TC	11/24/92
4579	YPG110492 NP03 TC	11/24/92
4582	YPG110492 NP04 TC	11/24/92
4657	YPG110592 WP01 TC	11/24/92
4660	YPG110592 WP02 TCa	11/24/92
4663	YPG110592 WP02 TCb	11/24/92
4666	YPG110592 WP03 TC	11/24/92
4671	YPG110592 BK01 TC	11/24/92
4677	YPG110592 WP04 TC	11/24/92
4569	YPG110392 SP00 ER	11/24/92
4570	YPG110392 SP00 FB	11/24/92
4585	YPG110492 NP00 ER	11/24/92
4586	YPG110492 NP00 FB	11/24/92
4669	YPG110592 WP01 ER	11/24/92
4670	YPG110592 WP00 FB	11/24/92

Aspen Environmental Laboratory
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LABORATORY QA/QC REPORT

Client: T.S.S.I.
U.S. Army Yuma Proving Ground
STEYP-MT-TL-MP, Bldg. 2060
Yuma, AZ 85366

For: YPG GP-20

SOIL/WATER SAMPLES

Project Number N/A
Sample ID Listed Below
Lab ID 111092-08 thru 20
Sampling Date 11/03/92, 11/04/92, & 11/05/92
Date Received 11/10/92
Date of Analysis 11/24/92
Date of Report 12/28/92

LABORATORY CONTROL SUMMARY

	Barium	Lead	Mercury
Limit of Detection (mg/L) (leachate)	0.5	0.05	0.001
Limit of Detection (mg/Kg) (weight basis)	10	1	0.02
Calibration Check Standard (% Recovery)	100.4	103.1	109.9
Acceptance Criteria	90 - 110	90 - 110	90 - 110
Method Blank (mg/L)	<MDL	<MDL	<MDL
Method Blank Spike (% Recovery)	108.6	99.7	108.9
Acceptance Criteria	80 - 120	80 - 120	80 - 120
Laboratory Control (% Recovery)	98.4	106.5	85.9
Aspen Acceptance Criteria	72.6 - 120	68.9 - 133	65.5 - 121

Lab Notes/Comments:

MDL = Method Detection Limit

Amended Report

Analyzed By:

12-29-92
Date

Reviewed By:

12/29/92
Laboratory Director **Date**

Aspen Environmental Laboratory
4730 N. Oracle Rd., Suite 212 • Tucson, AZ 85705 • (602) 887-1975 • Fax (602) 887-2352

LABORATORY REPORT OF CHEMICAL ANALYSIS

Client:
T.S.S.I.
U.S. Army Yuma Proving Ground
STEYP-MT-TL-MP, Bldg. 2060
Yuma, AZ 85366

For:
YPG GP-20

SOIL & WATER SAMPLES

Project Number	N/A
Sample ID	Listed Below
Lab ID	111092- 14~19, 08~13, 21~23
Sampling Date	11/03/92, 11/04/92, 11/05/92
Date Received	11/10/92
Date of Analysis	11/24/92
Date of Report	12/28/92

TCLP - Priority Metals

Parameter	Arsenic	Barium	Cadmium	Chromium	Lead	Mercury	Selenium	Silver
Limit of Detection (ppm)		0.5			0.05	0.001		
92-4557		<0.5			0.66	<0.001		
92-4560		<0.5			0.42	<0.001		
92-4563		<0.5			0.79	<0.001		
92-4566		<0.5			0.25	<0.001		
*92-4566		<0.5			0.25	<0.001		
92-4569		<0.5			<0.05	<0.001		
92-4570		<0.5			<0.05	<0.001		
92-4573		<0.5			0.19	<0.001		
92-4576		<0.5			0.19	<0.001		
92-4579		<0.5			0.66	<0.001		
92-4582		<0.5			0.79	<0.001		
92-4585		<0.5			<0.05	<0.001		
92-4586		<0.5			<0.05	<0.001		
92-4657		<0.5			0.79	<0.001		
92-4660		<0.5			0.59	<0.001		
92-4663		<0.5			0.42	<0.001		

Reported in mg/L

Lab Notes/Comments:

Amended Report.

*Duplicate extraction performed.

Analyzed By:

12-28-92
Date

Reviewed By:
Timothy Kennedy
Laboratory Director

12/28/92
Date

Aspen Environmental Laboratory
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LABORATORY REPORT OF CHEMICAL ANALYSIS

Client:
T.S.S.I.
U.S. Army Yuma Proving Ground
STEYP-MT-TL-MP, Bldg. 2060
Yuma, AZ 85366

For:
YPG GP-20

SOIL & WATER SAMPLES

Project Number N/A
Sample ID Listed Below
Lab ID 111092- 24~27, & 20
Sampling Date 11/05/92
Date Received 11/10/92
Date of Analysis 11/24/92
Date of Report 12/28/92

TCLP - Priority Metals

Parameter	Arsenic	Barium	Cadmium	Chromium	Lead	Mercury	Selenium	Silver
Limit of Detection (ppm)		0.5			0.05	0.001		
92-4666		<0.5			0.73	<0.001		
92-4669		<0.5			<0.05	<0.001		
92-4670		<0.5			<0.05	<0.001		
92-4671		<0.5			0.35	<0.001		
92-4677		<0.5			0.35	<0.001		

Reported in mg/L

Lab Notes/Comments:
Amended Report.

Analyzed By:
12-28-92
Date

Reviewed By:
Janelle Kennedy
12/28/92
Laboratory Director
Date

Aspen Environmental Laboratory
4730 N. Oracle Rd., Suite 212 • Tucson, AZ 85705 • (602) 887-1975 • Fax (602) 887-2352

LABORATORY REPORT OF CHEMICAL ANALYSIS

Client:
T.S.S.I.
U.S. Army Yuma Proving Ground
STEYP-MT-TL-MP, Bldg. 2060
Yuma, AZ 85366

For:
YPG GP-20

SOIL SAMPLES

Project Number	N/A
Sample ID	Listed Below
Lab ID	111092-14~17, 08~11, 21~24, 27, 20
Sampling Date	11/03/92, 11/04/92
Date Received	11/10/92
Date of Analysis	11/24/92
Date of Report	12/28/92

TCLP - Priority Metals

Parameter	Arsenic	Barium	Cadmium	Chromium	Lead	Mercury	Selenium	Silver
Limit of Detection (ppm)		10			1	0.02		
92-4557		<10			12.9	<0.02		
92-4560		<10			8.27	<0.02		
92-4563		<10			15.2	<0.02		
92-4566		<10			4.98	<0.02		
*92-4566		<10			5.02	<0.02		
92-4573		<10			3.65	<0.02		
92-4576		<10			3.62	<0.02		
92-4579		<10			13.0	<0.02		
92-4582		<10			15.6	<0.02		
92-4657		<10			15.6	<0.02		
92-4660		<10			11.7	<0.02		
92-4663		<10			8.19	<0.02		
92-4666		<10			14.4	<0.02		
92-4671		<10			6.98	<0.02		
92-4677		<10			7.02	<0.02		

Reported in mg/Kg

Lab Notes/Comments:
Amended Report.
*Duplicate extraction performed.

Analyzed By: Julie Morris 12-28-92
Date

Reviewed By: Janelle Kennedy 12/28/92
Laboratory Director **Date**

INEL COPY

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LABORATORY REPORT OF CHEMICAL ANALYSIS

Client:
T.S.S.I.
U.S. Army Yuma Proving Ground
STEYP-MT-TL-MP, Bldg. 2060
Yuma, AZ 85366

For:
YPG GP-20

SOIL SAMPLES

Project Number N/A
Sample ID Listed Below
Lab ID 111092-14~17, 08~11, 21~24, 27, 20
Sampling Date 11/03/92, 11/04/92
Date Received 11/10/92
Date of Analysis 11/24/92
Date of Report 11/30/92

TCLP - Priority Metals

Parameter	Arsenic	Barium	Cadmium	Chromium	Lead	Mercury	Selenium	Silver
Limit of Detection (ppm)		10			1	0.02		
92-4557		<10			12.95	<0.02		
92-4560		<10			8.27	<0.02		
92-4563		<10			15.19	<0.02		
92-4566		<10			4.98	<0.02		
*92-4566		<10			5.02	<0.02		
92-4573		<10			3.65	<0.02		
92-4576		<10			3.62	<0.02		
92-4579		<10			13.03	<0.02		
92-4582		<10			15.63	<0.02		
92-4657		<10			15.61	<0.02		
92-4660		<10			11.69	<0.02		
92-4663		<10			8.19	<0.02		
92-4666		<10			14.44	<0.02		
92-4671		<10			6.98	<0.02		
92-4677		<10			7.02	<0.02		

Reported in mg/L

Lab Notes/Comments:
*Duplicate extraction performed.

Analyzed By:
12-09-92
Date

Reviewed By:
[illegible]
Laboratory Director
Date

Aspen Environmental Laboratory
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LABORATORY REPORT OF CHEMICAL ANALYSIS

Client:
T.S.S.I.
U.S. Army Yuma Proving Ground
STEYP-MT-TL-MP, Bldg. 2060
Yuma, AZ 85366

For:
YPG GP-20

WATER SAMPLES

Project Number	N/A
Sample ID	Listed Below
Lab ID	111092-18, 19, 12, 13, 25, 26
Sampling Date	11/03/92, 11/04/92, 11/05/92
Date Received	11/10/92
Date of Analysis	11/24/92
Date of Report	11/30/92

TCLP - Priority Metals

Parameter	Arsenic	Barium	Cadmium	Chromium	Lead	Mercury	Selenium	Silver
Limit of Detection (ppm)		0.5			0.2	0.001		
92-4569		<0.5			<0.2	<0.001		
92-4570		<0.5			<0.2	<0.001		
92-4585		<0.5			<0.2	<0.001		
92-4586		<0.5			<0.2	<0.001		
92-4669		<0.5			<0.2	<0.001		
92-4670		<0.5			<0.2	<0.001		

Reported in mg/L

Lab Notes/Comments:

Analyzed By:

12-09-92
Date

Reviewed By:

Laboratory Director

[illegible]
Date

Aspen Environmental Laboratory
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LABORATORY QA/QC REPORT

Client: T.S.S.I.
U.S. Army Yuma Proving Ground
STEYP-MT-TL-MP, Bldg. 2060
Yuma, AZ 85366

For: YPG GP-20

SOIL/WATER SAMPLES

Project Number N/A
Sample ID Listed Below
Lab ID 111092-08 thru 20
Sampling Date 11/03/92, 11/04/92, & 11/05/92
Date Received 11/10/92
Date of Analysis 11/24/92
Date of Report 12/08/92

LABORATORY CONTROL SUMMARY

	Barium	Lead	Mercury
Limit of Detection (mg/L) (water)	0.5	0.2	0.001
Limit of Detection (mg/Kg) (soil)	10	1	0.02
Calibration Check Standard (% Recovery)	100.4	103.1	109.9
Acceptance Criteria	90 - 110	90 - 110	90 - 110
Method Blank (mg/L)	<MDL	<MDL	<MDL
Method Blank Spike (% Recovery)	108.6	99.7	108.9
Acceptance Criteria	80 - 120	80 - 120	80 - 120
Laboratory Control (% Recovery)	98.4	106.5	85.9
Aspen Acceptance Criteria	72.6 - 120	68.9 - 133	65.5 - 121

Lab Notes/Comments:
MDL = Method Detection Limit

Analyzed By:
12-10-92
Date

Reviewed By:
12/10/92
Laboratory Director **Date**

Aspen Environmental Laboratory
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LABORATORY QA/QC REPORT

Client: T.S.S.I.
U.S. Army Yuma Proving Ground
STEYP-MT-TL-MP, Bldg. 2060
Yuma, AZ 85366

For: YPG GP-20

SOIL/WATER SAMPLES

Project Number	N/A
Sample ID	Listed Below
Lab ID	111092-08 thru 20
Sampling Date	11/03/92, 11/04/92, & 11/05/92
Date Received	11/10/92
Date of Analysis	11/24/92
Date of Report	12/08/92

LABORATORY DUPLICATE & SPIKE SUMMARY

	Sample ID	Matrix	Barium	Lead	Mercury
***Laboratory Duplicate (% Difference)**	92-4566	SOIL	0	0.84	0
Laboratory Duplicate (% Difference)	92-4569	WATER	0	0	-
	92-4570	WATER	-	-	0
	92-4566	SOIL	-	-	0
	92-4573	SOIL	0	-	-
	92-4576	SOIL	-	30.9	-
	92-4666	SOIL	0	8.91	-
Matrix Spike (% Recovery)	92-4586	WATER	-	-	120.2
	92-4669	WATER	92.4	111.4	-
	92-4573	SOIL	-	101.5	-
	92-4576	SOIL	90.7	-	-
	92-4579	SOIL	-	-	116.5
	92-4666	SOIL	-	-	132.9
	92-4671	SOIL	109.5	94.8	-
Aspen Acceptance Criteria			60.0 - 133.3	71.7 - 114.7	69.4 - 153.7

Lab Notes/Comments:

*Duplicate Extraction

Analyzed By:

12-10-92

Date

Reviewed By:

12/10/92

Laboratory Director

Date

EG&G Idaho, Inc.

EG&G Idaho, Inc.
P O Box 1625 MS 8102
Idaho Falls, Idaho
(208) 526-8075 (208) 526-9535
Environmental Monitoring Team

ENVIRONMENTAL MONITORING
CHAIN OF CUSTODY FORM

01535

SAMPLER: *(Signature)*

PROJECT NAME: YPG GP-20

SAMPLE NO. FIELD	SAMPLE NO. LAB	SAMPLING DATE	SAMPLING TIME	COMP.	GRAB	SAMPLE LOCATION	AQUEOUS	SOLID	OTHER	REMARKS	RECEIVED BY ANALYST	DATE/TIME DATE/TIME
YPG-110492-NP01-TC	✓ 92 4573 A	11/04/92	0845	X		North Pile		X		TCLP METALS (Hg, Ba, Pb) 111092-08		
YPG-110492-NP-01-DU	✓ 92 4574 Y	↓	↓	X		↓		X		TOTAl URANIUM		
YPG-110492-NP-01-PP	✓ 92 4575 Y			X				X		Physical Properties		
YPG-110492-NP02-TC	✓ 92 4576 A		1016	X				X		TCLP METAls (Hg, Ba, Pb) 111092-09		
YPG-110492-NP-02-DU	✓ 92 4577 Y		1016	X				X		TOTAl URANIUM		
YPG-110492-NP-02-PP	✓ 92 4578 Y		1016	X				X		Physical Properties		
YPG-110492-NP-03 TC	✓ 92 4579 A		1134	X				X		TCLP METAls (Hg, Ba, Pb) 111092-10		
YPG-110492-NP-03-DU	✓ 92 4580 Y		1134	X				X		TOTAl URANIUM		
YPG-110492-NP-03-PP	✓ 92 4581 Y		1134	X				X		Physical Properties		
YPG-110492-NP-04-TC	✓ 92 4582 A		1420	X				X		TCLP METAls (Hg, Pb, Ba) 111092-11		
YPG-110492-NP-04-DU	✓ 92 4583 Y		1420	X				X		TOTAl URANIUM		
YPG-110492-NP-04-PP	✓ 92 4584 Y		1420	X				X		Physical Properties		
YPG-110492-NP-00-ER	✓ 92 4585 A/Y		1430		X		X			TCLP METALS (Hg, Pb, Ba) 111092-12 TOTAl URANIUM Physical Properties		
YPG-110492-NP-00-FB	✓ 92 4586 A/Y	↓	1440		X	↓	X			TCLP Metals (Hg, Pb, Ba) 111092-13 TOTAl uranium Physical Properties		
						JAY 11/92						

Relinquished by: *(Signature)*	Date/Time	Received by: *(Signature)*	Relinquished by: *(Signature)*	Date/Time	Received by: *(Signature)*
	11/04/92 1520	Ranell Carazzo	Ranell Carazzo	11/9 330	Jill L. Nawcek 2:00 11/10/92
Relinquished by: *(Signature)*	Date/Time	Received by: *(Signature)*	Relinquished by: *(Signature)*	Date/Time	Received by: *(Signature)*

DISTRIBUTION Original and Pink copies accompany sample shipment to laboratory Original copy retained by custodian Pink copy retained by laboratory Yellow copy retained by samplers

EG&G Idaho, Inc.
P O Box 1625 MS 8102
Idaho Falls, Idaho
(208) 526-8075 (208) 526-9535
Environmental Monitoring Team

ENVIRONMENTAL MONITORING CHAIN OF CUSTODY FORM

01534

SAMPLER: *(Signature)*

PROJECT NAME: YPG GP-20

SAMPLE NO. FIELD	SAMPLE NO. LAB	SAMPLING DATE	SAMPLING TIME	COMP.	GRAB	SAMPLE LOCATION	AQUEOUS	SOLID	OTHER	REMARKS	RECEIVED BY ANALYST	DATE/TIME
YPG-110392-SP-01-TC	✓ 92-4557	11/03/92	0908	X		Aspen 11-9		X		TCLP METALS (Hg, Pb, Ba) 111092-14		
YPG-110392-SP-01-DU	✓ 92-4558		0908	X		YPG		X		TOTAL URANIUM		
YPG-110392-SP-01-PP	✓ 92-4559		0908	X		YPG		X		Physical Properties		
YPG-110392-SP-02-TC	✓ 92-4560		1030	X		Aspen		X		TCLP METALS (Hg, Pb, Ba) 111092-15		
YPG-110392-SP-02-DU	✓ 92-4561		1030	X		YPG		X		TOTAL URANIUM		
YPG-110392-SP-02-PP	✓ 92-4562		1030	X		YPG		X		Physical Properties		
YBG-110392-SP-03TC	✓ 92-4563		1341	X		Aspen		X		TCLP METALS (Hg, Pb, Ba) 111092-16		
YPG-110392-SP-03-DU	✓ 92-4564		1341	X		YPG		X		TOTAL URANIUM		
YPG-110392-SP-03-PP	✓ 92-4565		1341	X		YPG		X		Physical Properties		
YPG-110392-SP-04-TC	✓ 92-4566		1420	X		Aspen		X		TCLP Metals (Hg, Pb, Ba) 111092-17		
YPG-110392-SP-04-DU	✓ 92-4567		1420	X		YPG		X		TOTAL URANIUM		
YPG-110392-SP-04-PP	✓ 92-4568		1420	X		YPG		X		Physical Properties		
YPG-110392-SP-00-ER	✓ 92-4569		1443	X		Aspen/YPG	X			TCLP Metals (Hg, Pb, Ba) Total Uranium Physical Properties 111092-18		
YPG-110392-SP-00-FB	✓ 92-4570		1450		X	Aspen/YPG	X			TCLP Metals (Hg, Pb, Ba) Total Uranium Physical Properties 111092-19		
						JAY	4/92					

Relinquished by: *(Signature)*	Date/Time 11/13/92 | 1523	Received by: *(Signature)* Ranell Carozzo	Relinquished by: *(Signature)* Ranell Carozzo	Date/Time 11/9 | 730	Received by: *(Signature)* 2:00 11/10/92 Jill L. Hawlek
Relinquished by: *(Signature)*	Date/Time	Received by: *(Signature)*	Relinquished by: *(Signature)*	Date/Time	Received by: *(Signature)*

DISTRIBUTION Original and Pink copies accompany sample shipment to laboratory Original copy retained by custodian Pink copy retained by laboratory Yello

EG&G Idaho, Inc

EG&G Idaho, Inc.
P O Box 1625 MS 8102
Idaho Falls, Idaho
(208) 526-8075 (208) 526-9535
Environmental Monitoring Team

ENVIRONMENTAL MONITORING
CHAIN OF CUSTODY FORM

01538

SAMPLER: *(Signature)* Steve Davis

PROJECT NAME: YPG-CP-20

SAMPLE NO. FIELD	SAMPLE NO. LAB	SAMPLING DATE	SAMPLING TIME	COMP.	GRAB	SAMPLE LOCATION	AQUEOUS	SOLID	OTHER	REMARKS	RECEIVED BY ANALYST	DATE/TIME
YPG-110592-WP-04-PP ✓	924675 Y	11/5/92	1149	✓		WEST Pile		X		Physical Properties		
YPG-110592-WP-04-DU ✓	924676 Y	↓	1149	✓		↓		X		TOTAL Uranium		
YPG-110592-WP-04-TC ✓	924677 A	↓	1149	✓		↓		X		TCLP metals (Hg Pb Ba) 111092-20		

SG
11-5-92

Relinquished by *(Signature)*	Date/Time	Received by: *(Signature)*	Relinquished by *(Signature)*	Date/Time	Received by: *(Signature)*
Steve Davis	11-5-92 3:25	Ranell Caiazzo	Ranell Caiazzo	11/9 3:30	Jill L. Mawek 11/10/92
Relinquished by *(Signature)*	Date/Time	Received by: *(Signature)*	Relinquished by *(Signature)*	Date/Time	Received by: *(Signature)*

DISTRIBUTION Original and Pink copies accompany sample shipment to laboratory Original copy retained by custodian Pink copy retained by laboratory Yellow copy retained by samplers

EG&G Idaho, Inc.
EG&G Idaho, Inc
P.O. Box 1625 MS 8102
Idaho Falls, Idaho
(208) 526-8075 (208) 526-9535
Environmental Monitoring Team

ENVIRONMENTAL MONITORING CHAIN OF CUSTODY FORM

01536

SAMPLER (Signature)

PROJECT NAME: YPG GP-20

SAMPLE NO. FIELD	SAMPLE NO. LAB	SAMPLING DATE	SAMPLING TIME	COMP	GRAB	SAMPLE LOCATION	AQUEOUS	SOLID	OTHER	REMARKS	RECEIVED BY ANALYST	DATE/TIME
YPG-110592-WP-01-TC	✓ 924657 A	11/05/92	0825	X		WEST PILE		X		TCLP METALS (Hg, Pb, Ba) 111092-21		
YPG-110592-WP-01-DU	✓ 924658 Y		0825	X				X		TOTAL URANIUM		
YPG-110592-WP-01-PP	✓ 924659 Y		0825	X				X		Physical Properties		
YPG-110592-WP-02-TC(a)	✓ 924660 A		0943	X				X		TCLP METALS (Hg, Pb, Ba) 111092-22		
YPG-110592-WP-02-DU(a)	✓ 924661 Y		0943	X				X		TOTAL URANIUM		
YPG-110592-WP-02-PP(a)	✓ 924662 Y		0943	X				X		Physical Properties		
YPG-110592-WP-02-TC(b)	✓ 924663 A		0943	X				X		TCLP METALS (Hg, Pb, Ba) 111092-23		
YPG-110592-WP-02-DU(b)	✓ 924664 Y		0943	X				X		TOTAL URANIUM		
YPG-110592-WP-02-PP(b)	✓ 924665 Y		0943	X				X		Physical Properties		
YPG-110592-WP-03-TC	✓ 924666 A		1043	X				X		TCLP Metals (Hg, Pb, Ba) 111092-24		
YPG-110592-WP-03-DU	✓ 924667 Y		1043	X				X		TOTAL URANIUM		
YPG-110592-WP-03-PP	✓ 924668 Y		1043	X				X		Physicals Properties		
YPG-110592-WP-00-ER	✓ 924669 A/Y		1210		X		X			TCLP METALS (HG, PB, BA) TOTAL URANIUM Physical Properties 111092-25		
YPG-110592-WP-00-FB	✓ 924670 A/Y		1215		X		X			TCLP METALS (HG, PB, BA) TOTAL Uranium Physical Properties 111092-26		
YPG-110592-BK-01-TC	✓ 924671 A		1257		X	TOWER 8.9		X		TCLP METALS (Hg, Pb, Ba) 111092-27		
YPG-110592-BK-01-DU	✓ 924672 Y		1257		X			X		TOTAL URANIUM		

Relinquished by (Signature)	Date/Time	Received by (Signature)	Relinquished by (Signature)	Date/Time	Received by (Signature)
	11/5/92 1525	Ranell Caiazzo	Ranell Caiazzo	11/9 3:30	2:00 11/09 Jill L. Nawrek

Relinquished by (Signature)	Date/Time	Received by (Signature)	Relinquished by (Signature)	Date/Time	Received by (Signature)

DISTRIBUTION: Original and Pink copies accompany sample shipment to laboratory. Original copy retained by custodian. Pink copy retained by laboratory. Yellow copy retained by samplers.

J.K.

Effective: 10/13/92
Supercedes: 02/13/92

Aspen Environmental Laboratory

TCLP EXTRACTION LOG BOOK

Date	Lab ID	Weight (grams)	pH / pH 3.5 ml 1N HCL	Extract Liquid (1 or 2)	Volume (ml)	Start Time	Stop Time	Initials
11/15/92	111092-08	101.11	8.98/2.38	1	2000	14:00	8:04	JM
	111092-09	102.08	8.64/4.45	1	2000	14:00	8:04	
	111092-10	101.09	8.47/5.12	2	2000	14:00	8:04	
	1110.92-11	101 57	8.46/5.29	2	2000	14 00	8:04	
11/16/92	1110 92-14	101.72	7.86/5.12	2	2000	16:10	8:40	JM
	1110.92-15	101.98	8.26/1.99	1	2000	16:10	8:40	
	1110.92-16	104.55	8.52/5.10	2	2000	16:10	8:40	
	1110.92-17	101.93	8.70/2.05	1	2000	16:00	8:40	
11/17/92	1110 92-20	100.89	8.69/1.94	1	2000	17:05	9:57	JM
	1110 92-21	101.70	8.56/5.11	2	2000	17:05	9:57	
	1110 92-22	101.066	8.39/2.23	1	2000	17:05	9:57	
	1110 92-23	102.90	8.59/2.27	1	2000	17:05	9:57	
11/18/92	1110 92-24	100.61	8.47/5.88	2	2000	16:43	10:00	JM
	1110 92-27	101.44	8.47/2.99	1	2000	16:43	10:00	
	Blank	0		1	2000	16:43	10:00	
11/18/92	1110.92-17 DUP	100.48	8.70/2.05	1	2000	16:43	10:00	
12-08-92	111292-01	101.41	8.54/1.61	1	2000	14 50		JM

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Aspen Environmental Laboratory

METALS DIGESTION LOG

Lead Based Paint and EPA Methods 3010A, 3020A, 3050A, 7060A, 7740A, 7470A, & 7471A

Date	Laboratory ID	Method Sample Type	Beginning ml or gram	Ending Volume	Spikes/Notes	Initials
1-10-92	Std 1	2455	100	100	10ul of 100 ppm Hg	JM
	Std 2				50 " " " "	
	Std 3				75 " " " "	
	Std 4				200 " " " "	
	Control 1				400ul of 250ppm Hg	
	Control 2				" " "	
-12-92	110492-02	Pb-Paint	6.284 gm	50		
1-20-92	111092-08	3010	100	50		
	111092-08spk				5ml of 10 ppm Pb	
	111092-09					
	111092-09spk				5ml of 30 ppm Be	
	-10					
	-11					
	-14					
	-15					
	-16					
	-17					
	-17ex 2				EXTRACT #2	
	-20					
	-21					
	-22					
	-23					
	111092 -24					

REVIEWED BY:

Tuelle Kennedy
Laboratory Director

12/10/92
Date

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Aspen Environmental Laboratory

METALS DIGESTION LOG

Lead Based Paint and EPA Methods 3010A, 3020A, 3050A, 7060A, 7740A, 7470A, & 7471A

Date	Laboratory ID	Method Sample Type	Beginning ml or gram	Ending Volume	Spikes/Notes	Initials
11-20-92	111092-24a	3010	100	50		JM
	-27		100			
	-27spk		100		5ml of 10ppm Pb 5ml of 30 ppm Ba	
	Blank TCLP a		100			
	111092-12					
	-13					
	-18					
	-18d					
	-19					
	-25					
↓	111092 25spk	↓	↓	↓	5ml of 10 ppm Pb 5ml of 30 ppm Ba	↓
11-23-92	111992-15	Pb-Paint	10.728	50		JM
	-16		11.855			
↓	-17	↓	12.850	↓		
11-23-92	111092-23	3010	100	50		
	Control	3010	100		Cd, (25ul) Be, Cu, Cr, Zn, Pb, Ni (100ul)	
	Control	3010	100		Ba (5ml)	
	111192-15	3010	100			
	111992-13	3010	100			
	111392-02	3050	2.262			
	111392-02d		2.105			
	111392-03		2.164			
	111192-03spk	↓	2.209	↓	5ml of 3ppm Cd, 10ppm Cu, Ni, Zn, Cr, Pb 5ml of 5ppm As, 50ppm (Sb) Tl)	↓

√(?)

REVIEWED BY:

Laboratory Director

12/11/95
Date

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Aspen Environmental Laboratory

METALS DIGESTION LOG

Lead Based Paint and EPA Methods 3010A, 3020A, 3050A, 7060A, 7740A, 7470A, & 7471A

Date	Laboratory ID	Method Sample Type	Beginning ml or gram	Ending Volume	Spikes/Notes	Initials
11-24-92	Blank	7470A	100			JM
	Std 1				10ul of 10ppm Hg	
	Std 2				50ul " "	
	Std 3				100 " "	
	Std 4				400 " "	
	Control 1				400ul of 5ppm Hg	
	TCLP Blank					
	111092-08					
	111092-09					
	111092-09spk				100ul of 10ppm Hg	
	111092-10					
	111092-11					
	111092-14					
	111092-15					
	111092-16					
	111092-17					
	111092-17d					
	111092-17[illegible]					
	111092-20					
	111092-21					
	111092-22					
	Control 2				400 ul of 5ppm Hg	

REVIEWED BY:

Laboratory Director

12/10/92
Date

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Aspen Environmental Laboratory

METALS DIGESTION LOG

Lead Based Paint and EPA Methods 3010A, 3020A, 3050A, 7060A, 7740A, 7470A, & 7471A

Date	Laboratory ID	Method Sample Type	Beginning [✓ ml] or gram	Ending Volume	Spikes/Notes	Initials
11-25-92	Std 1	7470A	100	100	10 ul 10ppm Hg	JM
	Std 2				50 ul 10ppm Hg	
	Std 3				100 ul 10ppm Hg	
	Std 4				400 ul 10ppm Hg	
	Control 1				400 ul 5ppm Hg PE 3/93	
	Control 2				400 ul 5ppm Hg PE 3/93	
	Blank				0 ul Hg	
	TCLP Blank				0.0 ul Hg	
	111092-12					
	111092-13					
	111092-13 spk				100 ul of 10ppm Hg	
	111092-18					
	111092-19					
	111092-19 dup					
	111092-23					
	111092-24					
	111092-24 spk				100 ul of 10.0ppm Hg	
	111092-25					
	111092-26					
	111092-27					

REVIEWED BY:

Tanelle Kennedy
Laboratory Director

12/10/92
Date

Aspen Environmental Laboratory

Date	Parameter									QC Check
11/24/92	Lead									
Standards (ppm)	Absorbance									
0.1	0.002									
1	0.016									
5	0.078									
10	0.148									
Σ [x(i)^2]	Σ [y(i)^2]	Σ x(i)y(i)								
126.01	0.028248	1.8862								
Numerator	Denominator		Corr. Coeff.							
3.6164	3.617683303		0.99965							ck
Linest(slope)	y-intercept	x-intercept								
0.014771066	0.001546461	-0.10469528								
				Wt of						
Laboratory ID	Absorbance	Dilution	Actual ppm	Solids grams	Final Volume	Adjusted ppm	% Difference	% Recovery		
Cal. Check Std. 2.0ppm	0.032	1	2.062					103.09		ck
Digested Blank	0	0.5	Out of Range							—
TCLP Blank	0	0.5	Out of Range							✓
111092-08	0.007	0.5	0.185	101.1100	2.0000	3.652				—
111092-08 spk 1	0.022	0.5	0.692	101.1100	2.0000	13.695		101.55		ck
111092-09	0.007	0.5	0.185	102.0800	2.0000	3.617				✓
111092-09 dup	0.009	0.5	0.252	102.0800	2.0000	4.943	30.991			?
111092-10	0.021	0.5	0.659	101.0900	2.0000	13.028				✓
111092-11	0.025	0.5	0.794	101.5700	2.0000	15.633				✓
111092-12	0	0.5	Out of Range							✓
111092-13	0	0.5	Out of Range							✓
111092-14	0.021	0.5	0.659	101.7200	2.0000	12.947				✓
Spiked Blank 2.0ppm	0.031	1	1.994					99.70		ck
111092-15	0.014	0.5	0.422	101.9800	2.0000	8.267				✓
111092-16	0.025	0.5	0.794	104.5500	2.0000	15.187				✓
111092-17	0.009	0.5	0.252	101.3300	2.0000	4.980				✓
111092-17 ext. 2	0.009	0.5	0,252	100.4800	2.0000	5.022				✓
111092-18	0.001	0.5	Out of Range							✓
111092-18 dup	0.001	0.5	Out of Range				#VALUE!			ck ✓
111092-19	0	0.5	Out of Range							✓
111092-20	0.012	0.5	0.354	100.8900	2.0000	7.015				✓
111092-21	0.025	0.5	0.794	101.7000	2.0000	15.613				✓
Spiked Blank 2.0ppm	0.03	1	1.926					96.32		ck
111092-22	0.019	0.5	0.591	101.0660	2.0000	11.691				✓
111092-23	0.014	0.5	0.422	102.9000	2.0000	8.193				—
111092-24	0.023	0.5	0.726	100.61	2	14.436				✓
111092-24 dup	0.025	0.5	0.794	100.61	2	15.782	8.907			ck
111092-25	0.002	0.5	<Standard							—
111092-25 spk 1	0.018	0.5	0.557					111.39		ck

Analyzed by

Reviewed by

111092-26	0.002	0.5	<Standard						✓
111092-27	0.012	0.5	0.354	101.44	2	6.977			✓
111092-27 spk 1	0.026	0.5	0.828	101.44	2	16.320		94.78	ok
TCLP Ext.1	0	1	Out of Range						✓
TCLP Ext.2	-0.002	1	Out of Range						✓
Dig. Control 2.0ppm	0.033	1	2.129					106.47	ok.

Analyzed by

Reviewed by

Aspen Environmental Laboratory

AA - Calculation Sheet

Date: 11-24-92
Element: Pb
Energy: 55
Acetylene: 22
Oxidizer: 40
Lamp MA: 14
Standards:
Control: PE 3/93
Slit (nm): H 0.7

Standards (ppm)	Absorbance
0.1	0.002
1.0	0.016
5.0	0.078
10.0	0.148
Detection Limit ppm	

Wavelength (nm): 217

Correlation Coefficient:

Slope:

y-intercept:

Sensitivity:

Lab ID#	Absorbance	Dilution	Matrix
Cal. check std 2.0	0.032	1	
Blank	0.000		
TCLP Blank	0.000		
111092-08	0.007		
-08spk	0.022		
-09	0.007		
-09dup	0.009		
-10	0.021		
-11	0.025		
-12	0.000		
-13	0.020		
-14	0.021		
-15	0.014		
Dig. control 2.0	0.031	↓	

Comments, Notes, Etc.:

Analyzed by,

Reviewed by,

2 of 3

Aspen Environmental Laboratory

AA - Calculation Sheet

Date: 11-24-92 Element: Pb Energy: 55

Acetylene: 22 Oxidizer: 40 Lamp MA: 14

Standards: Control: Slit (nm): #0.7

Standards (ppm)	Absorbance
Detection Limit ppm	

Same as pg 1

Wavelength (nm): 217

Correlation Coefficient:

Slope:

y-intercept:

Sensitivity:

Lab ID#	Absorbance	Dilution	Matrix
Cal. check std 2.0	0.031	1	
Blank	0.001		
TCLP Blank	0.001		
111092-16	0.026		
-17	0.009		
-17 ext 2	0.009		
-18	0.001		
-18 dup	0.001		
-19	0.000		
-20	0.012		
-21	0.029		
-22	0.012		
-23	0.014		
Dig. control 2.0	0.030		

Comments, Notes, Etc.:

Analyzed by, Julie Moran

Reviewed by, J.K

3 of 3

Aspen Environmental Laboratory

AA - Calculation Sheet

Date: 11-24-92 Element: Pb Energy: 55

Acetylene: 22 Oxidizer: 40 Lamp MA: 14

Standards: Control: Slit (nm): 4 0.7

Standards (ppm)	Absorbance
See pg 1	See pg 1
Detection Limit ppm	

Wavelength (nm): 217

Correlation Coefficient:

Slope:

y-intercept:

Sensitivity:

Lab ID#	Absorbance	Dilution	Matrix
Cal. check std 2.0	0.031	1	
Blank	0.001		
TCLP Blank	0.001		
111092-24	0.023		
-24d	0.025		
-25	0.002		
-25spk	0.018		
-26	0.002		
-27	0.012		
-27spk	0.026		
Dig. control 2.0	0.033		

Comments, Notes, Etc.:

Analyzed by, Moran

Reviewed by, J.A

Aspen Environmental Laboratory

Date	Parameter								QC Check
11/24/92	Lead								
Standards (ppm)	Absorbance								
0.1	0.002								
1	0.016								
5	0.078								
10	0.148								
Σ [x(i)^2]	Σ [y(i)^2]	Σ x(i)y(i)							
126.01	0.028248	1.8862							
Numerator	Denominator		Corr. Coeff.						
3.6164	3.617683303		0.99965						
Linest(slope)	y-intercept	x-intercept							
0.014771066	0.001546461	-0.10469528							
				Wt of					
Laboratory ID	Absorbance	Dilution	Actual ppm	Solids grams	Final Volume	Adjusted ppm	% Difference	% Recovery	
Cal. Check Std. 2.0ppm	0.032	1	2.062					103.09	
Digested Blank	0	0.5	Out of Range						
TCLP Blank	0.007	0.5	0.185						
* 111092-08 ✓	0.014	0.5	0.422						
* 111092-08 spk 1	0.029	0.5	0.929					101.55	
* 111092-09 ✓	0.014	0.5	0.422						
111092-09 dup	0.016	0.5	0.489				14.866		
111092-10	0.021	0.5	0.659						
111092-11	0.025	0.5	0.794						
111092-12	0	0.5	Out of Range						
111092-13	0	0.5	Out of Range						
111092-14	0.021 ✓	0.5	0.659						
Dig. Control 2.0ppm	0.031	1	1.994					99.70	
* 111092-15	0.021	0.5	0.659						
111092-16	0.025	0.5	0.794						
* 111092-17	0.016 ✓	0.5	0.489						
111092-17 ext. 2	0.016 ✓	0.5	0.489						
111092-18	0.001	0.5	Out of Range						
111092-18 dup	0.001	0.5	Out of Range				#VALUE!		
111092-19	0	0.5	Out of Range						
111092-20	0.019 ✓	0.5	0.591						
111092-21	0.025	0.5	0.794						
Dig. Control 2.0ppm	0.03	1	1.926					96.32	
* 111092-22	0.019 ✓	0.5	0.591						
111092-23	0.014	0.5	0.422						
111092-24	0.023	0.5	0.726						
111092-24 dup	0.025	0.5	0.794				8.907		
111092-25	0.002	0.5	<Standard						
111092-25 spk 1	0.018	0.5	0.557					111.39	

* The TCLP Blank absorbance reading will be subtracted from these sample(s) absorbancies since they were extracted with extract 1.

Analyzed by

Reviewed by J.K.

111092-26	0.002	0.5	<Standard						
* 111092-27	0.019 ✓	0.5	0.591						
* 111092-27 spk 1	0.033	0.5	1.065					94.78	ok
TCLP Ext.1	0.004	1	0.166						
TCLP Ext.2	-0.002	1	Out of Range						
Dig. Control 2.0ppm	0.033	1	2.129					106.47	ok

Analyzed by

Reviewed by J.K.

①

Aspen Environmental Laboratory

AA - Calculation Sheet

Date: 11-24-92
Element: Pb
Energy: 55
Acetylene: 22
Oxidizer: 40
Lamp MA: 14
Standards:
Control: 0E3/93
Slit (nm): H 0.7

Standards (ppm)	Absorbance
0.1	0.002
1.0	0.016
5.0	0.078
10.0	0.148
20.0	0.271
Detection Limit ppm	

Wavelength (nm): 217
Correlation Coefficient:
Slope:
y-intercept:
Sensitivity:

Lab ID#	Absorbance	Dilution	Matrix
Cal. check std 20	0.032		
Blank	0.000		
TCLP Blank ext1	0.007		
111092-08	0.014		
-08 spk	0.029		
-09	0.044		
-09d	0.016		
-10	0.021		
-11	0.025		
-12	0.000		
-13	0.000		
-14	0.021		
-15	0.011		
Dig. control 20	0.037		

Comments, Notes, Etc.:

Analyzed by,

Reviewed by,

Aspen Environmental Laboratory

AA - Calculation Sheet

Date: 11-24-92 Element: Pb Energy:

Acetylene: 22 Oxidizer: Lamp MA:

Standards: Control: Slit (nm):

Standards (ppm)	Absorbance
Detection Limit ppm	

Wavelength (nm):

Correlation Coefficient:

Slope:

y-intercept:

Sensitivity:

Lab ID#	Absorbance	Dilution	Matrix
Cal. check std	0.032		
Blank	0.001		
TCLP Blank	0.008		
111092-16	0.025		
-17	0.016		
-17ext2	0.016		
-18	0.001		
-18d	0.001		
-19	0.000		
-20	0.019		
-21	0.025		
-22	0.019		
-23	0.014		
Dig. control 20	0.030		

Comments, Notes, Etc.:

Analyzed by,

Reviewed by,

3 of 3

Aspen Environmental Laboratory

AA - Calculation Sheet

Date: 11-24-92
Element: Pb
Energy:
Acetylene: 22
Oxidizer: 40
Lamp MA: 14
Standards:
Control: PE 3/93
Slit (nm): H 0.7

Standards (ppm)	Absorbance
Detection Limit ppm	

Wavelength (nm): 217

Correlation Coefficient:

Slope:

y-intercept:

Sensitivity:

Lab ID#	Absorbance	Dilution	Matrix
Cal. check std 20	0.031		
Blank	0.001		
TCLP Blank	0.008		
111092-24	0.023		
-24 d	0.025		
- 25	0.002		
-25 spk	0.018		
-26	0.002		
-27	0.019		
-27 spk	0,033		
EXTRACT #1	0.004		
EXTRACT # 2	-0.002		
Dig. control 20	0.033		

Comments, Notes, Etc.:

Analyzed by,

Reviewed by,

Aspen Environmental Laboratory

Date	Parameter								QC Check
11/25/92	Barium								
Standards (ppm)	Absorbance								
1	0.01								
5	0.05								
10	0.103								
30	0.294								
Σ [x(i)^2]	Σ [y(i)^2]	Σ x(i)y(i)							
1026	0.099645	10.11							
Numerator	Denominator		Corr. Coeff.						
19.418	19.42125712		0.999832291						✓
Linest(slope)	y-intercept	x-intercept							
0.009767606	0.001922535	-0.19682769							
Laboratory ID	Absorbance	Dilution	Actual ppm	Wt of Solids grams	Final Volume	Adjusted ppm	% Difference	% Recovery	
Cal.Check Std. 10ppm	0.1	1	10.041					100.411	ok
Digt. TCLP Blank	0	1	Out of Range						✓
Method Blank	0	1	Out of Range						✓
111092-08	-0.007	0.5	Out of Range						✓
111092-08 dup	-0.008	0.5	Out of Range				#VALUE!		✓
111092-09	-0.001	0.5	Out of Range						✓
111092-09 spk 3	0.0285	0.5	1.360					90.699	ok
111092-10	-0.005	0.5	Out of Range						✓
111092-11	0	0.5	Out of Range						✓
111092-12	0	0.5	Out of Range						✓
111092-13	0	0.5	Out of Range						✓
111092-14	-0.007	0.5	Out of Range						✓
111092-15	-0.002	0.5	Out of Range						✓
Spiked Blank 10ppm	0.108	1	10.860					108.601	ok
111092-16	-0.0017	0.5	Out of Range						✓
111092-17	-0.001	0.5	Out of Range						✓
111092-17 ext.2	-0.002	0.5	Out of Range						✓
111092-18	0.001	0.5	Out of Range						✓
111092-18 dup	0.001	0.5	Out of Range				#VALUE!		✓
111092-19	0.001	0.5	<Standard						✓
111092-20	0	0.5	Out of Range						✓
111092-21	0.006	0.5	Out of Range						✓
111092-22	-0.006	0.5	Out of Range						✓
111092-23	-0.007	0.5	Out of Range						✓
111092-24	-0.0013	0.5	Out of Range						✓
Spiked Blank 10ppm	0.097	1	9.734					97.340	ok

Analyzed by

Reviewed by

172

Aspen Environmental Laboratory

AA - Calculation Sheet

Date: 11/24/92
Element: Ba
Energy: 69
Acetylene: 26
~~Oxidizer~~ N2O: 36
Lamp MA: 25
Standards:
Control:
Slit (nm): H 0.4

Standards (ppm)	Absorbance
1	0.010
5	0.050
10	0.103
30	0.294
Detection Limit ppm	

Wavelength (nm): 553.6

Correlation Coefficient:

Slope:

y-intercept:

Sensitivity:

Lab ID#	Absorbance	Dilution	Matrix
Cal. check std/10	0.100		
Blank	0.000		
TCLP Blank	0.000		
111092-08	-0.007	0.5	
-08d	-0.008	↓	
-09	-0.004		
-09spk	0.028/29		
-10	-0.005		
-11	0.000		
-12	0.000		
-13	0.000		
-14	-0.007		
-15	-0.002	↓	
Dig. control/10	0.108	1	
-16	-0.0017	0.5	
-17	-0.001	↓	
-17spk	-0.002		
-18	0.001		
-18d	0.001	↓	

Comments, Notes, Etc.:

Analyzed by,

Reviewed by,

Aspen Environmental Laboratory

Date	Parameter								QC Check
11/25/92	Barium								
Standards (ppm)	Absorbance								
1	0.01								
5	0.05								
10	0.103								
30	0.294								
Σ [x(i)^2]	Σ [y(i)^2]	Σ x(i)y(i)							
1026	0.099645	10.11							
Numerator	Denominator		Corr. Coeff.						
19.418	19.42125712		0.999832291						✓
Linest(slope)	y-intercept	x-intercept							
0.009767606	0.001922535	-0.19682769							
				Wt of					
Laboratory ID	Absorbance	Dilution	Actual ppm	Solids grams	Final Volume	Adjusted ppm	% Difference	% Recovery	
Cal. Check Std. 10ppm	0.097	1	9.734					97.340	CK
Digt. TCLP Blank		1	Out of Range						
Method Baink		1	Out of Range						
111092-24	-0.0013	0.5	Out of Range						
111092-24 dup	-0.004	0.5	Out of Range				#VALUE!		
111092-25	0.001	0.5	Out of Range						
111092-25 spk 3	0.029	0.5	1.386					92.406	✓
111092-26	0.001	0.5	Out of Range						
111092-27	0.01	0.5	<Standard						
111092-27 spk 3	0.034	0.5	1.642					109.469	✓
			Out of Range						
			Out of Range						
			Out of Range						
Control 10ppm	0.098	1	9.836					98.363	✓
			#VALUE!						
Control 10ppm		1						#VALUE!	

Analyzed by

Reviewed by

272

Aspen Environmental Laboratory

AA - Calculation Sheet

Date: 11/24/92
Element: Ba
Energy: 69
Acetylene: 26
Oxidizer: N₂O 36
Lamp MA: 25
Standards:
Control:
Slit (nm): H 0.4

Standards (ppm)	Absorbance
1	
5	
10	
30	
Detection Limit ppm	

Wavelength (nm): 553.6

Correlation Coefficient:

Slope:

y-intercept:

Sensitivity:

Lab ID#	Absorbance	Dilution	Matrix
Cal. check std 10	0.100	1	
Blank			
TCLP Blank	0.001	1	
111092-19	0.001	0.5	
-20	-0.000		
-21	0.006		
-22	-0.006		
-23	-0.007		
-24	-0.0013		
-24d	-0.004		
-25	0.001		
-25spk	0.029		
-26	0.001	↓	
Dig. control 10	0.097	10	
-27	0.010	0.5	
-27spk	0.034	↓	
Control 10	0.098	1	

Comments, Notes, Etc.:

Analyzed by

Reviewed by,

Aspen Environmental Laboratory

Date	Parameter								QC Check
11/24-25/1992	Mercury								
Standards (ppb)	Absorbance								
1	0.009								
5	0.041								
10	0.078								
40	0.227								
Σ [x(i)^2]	Σ [y(i)^2]	Σ x(i)y(i)							
1726	0.059375	10.074							
Numerator	Denominator		Corr. Coeff.						
20.416	20.49482374		0.99615						✓
Linest(slope)	y-intercept	x-intercept							
0.005418259	0.012894374	-2.37980016							
				Wt of					
Laboratory ID	Absorbance	Dilution	Actual ppm	Solids grams	Final Volume	Adjusted ppm	% Difference	% Recovery	
Cal. Check Std. 20ppb	0.132	1	21.982					109.91	✓
Method Blank	0.003	1	Out of Range						✓
TCLP Blank	0.002	1	Out of Range						✓
111092-08	0.003	1	Out of Range						✓
111092-09	0.002	1	Out of Range						✓
111092-09 spk 10	0.076	1	11.647					116.47	✓
111092-10	0.002	1	Out of Range						✓
111092-11	0.002	1	Out of Range						✓
111092-14	0.002	1	Out of Range						✓
111092-15	0.002	1	Out of Range						
111092-16	0.003	1	Out of Range						✓
111092-17	0.002	1	Out of Range						✓
Dig. Control 20ppb	0.131	1	21.798					108.99	✓
111092-17 dup	0.002	1	Out of Range				#VALUE!		✓
111092-17 ext 2	0.002	1	Out of Range						✓
111092-20	0.002	1	Out of Range						✓
111092-21	0.002	1	Out of Range					#VALUE!	✓
111092-22	0.002	1	Out of Range						✓
111092-12	0.004	1	Out of Range						✓
111092-13	0.003	1	Out of Range						✓
111092-13 spk 10	0.078	1	12.016					120.16	OK
111092-18	0.003	1	Out of Range						✓
Dig. Control 20 ppb	0.132	1	21.982						✓
111092-19	0.003	1	Out of Range						✓
111092-19 dup	0.003	1	Out of Range				#VALUE!		✓
111092-23	0.003	1	Out of Range						✓
111092-24	0.003	1	Out of Range						✓
111092-24 spk 10	0.086	1	13.492					134.92	High
111092-25	0.002	1	Out of Range						✓

Analyzed by

Reviewed by

111092-26	0.005	1	Out of Range						
111092-27	0.004	1	<Standard						
Dig. Control 20 ppb	0.106	1	17.184					85.92	ck

Analyzed by

Reviewed by

1 of 2

Aspen Environmental Laboratory

AA - Calculation Sheet

Date: 11-24-92 Element: Hg Energy: 55

Acetylene: Cold Vapor Oxidizer: Lamp MA: 6

Standards: Control: PE 3/93 Slit (nm): H 0.7

Standards (ppb)	Absorbance
1	0.009
5	0.041
10	0.078
40	0.227
Detection Limit ppm	

Wavelength (nm): 253.7

Correlation Coefficient:

Slope:

y-intercept:

Sensitivity:

Lab ID#	Absorbance	Dilution	Matrix
Cal. check std 20	0.132	1	
Blank	0.003		
TCLP Blank	0.002		
111092-08	0.003		
-09	0.002		
-09spk	0.076		
-10	0.002		
-11	0.002		
-14	0.002		
-15	0.002		
-16	0.003		
-17	0.002		
-17d	0.002		
Dig. control 20			
-17ext2	0.002		
-20	0.002		
-21	0.002		
-22	0.002		
Control 20	0.131	↓	

Comments, Notes, Etc.:

Analyzed by,

Reviewed by,

2072

Aspen Environmental Laboratory

AA - Calculation Sheet

Date: 11-26-92
Element: Hg
Energy: 55
Acetylene: Cold Vapor
Oxidizer:
Lamp MA: 6
Standards:
Control: PE3/93
Slit (nm): H 0.7

Standards (ppm)	Absorbance
1	0.009
5	0.041
10	0.078
40	0.227
Detection Limit ppm	

Wavelength (nm): 253.7

Correlation Coefficient:

Slope:

y-intercept:

Sensitivity:

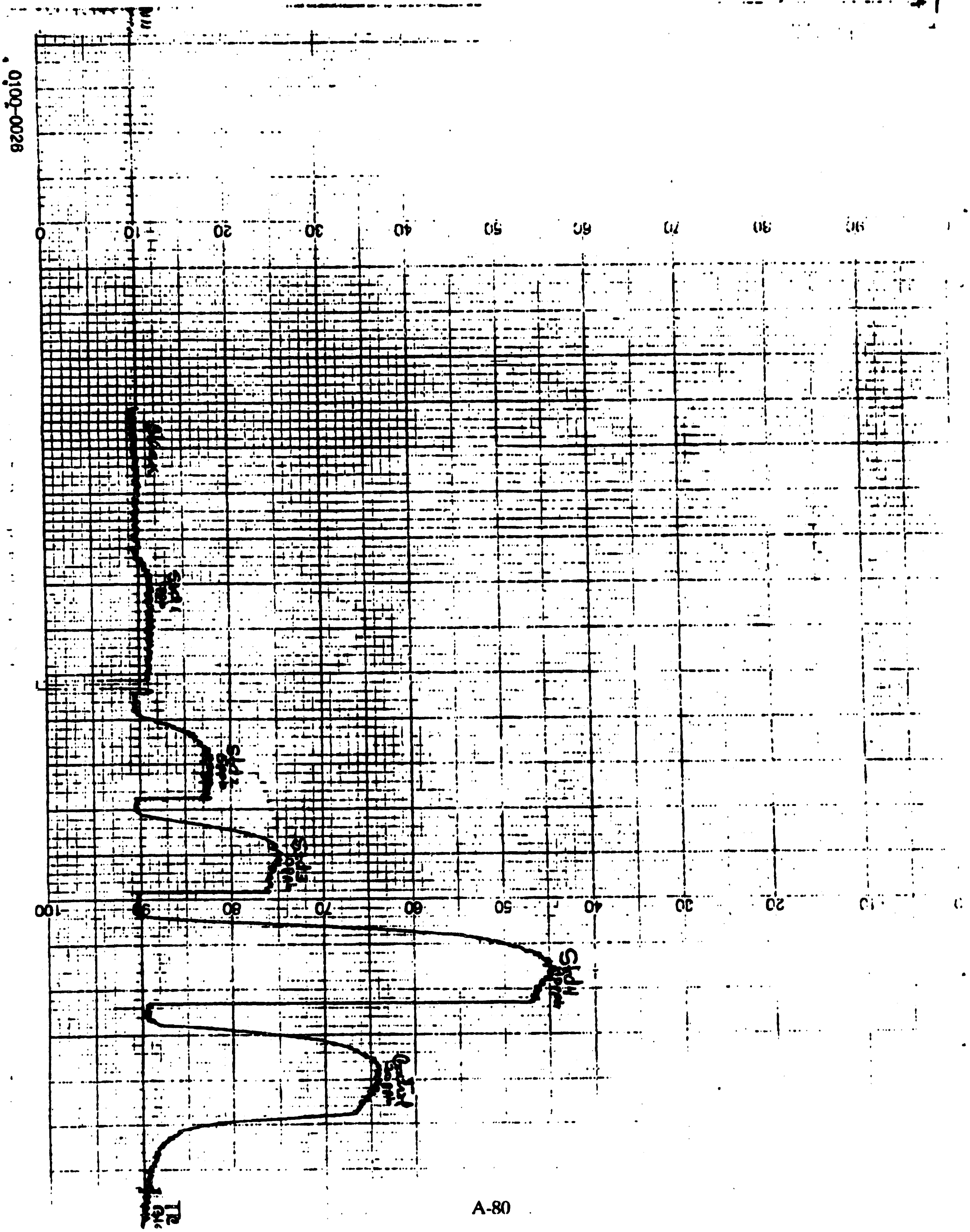
Lab ID#	Absorbance	Dilution	Matrix
Cal. check std 20	0.131	1	
Blank	0.004		
TCLP Blank	0.002		
111092-12	0.004	1	
-13	0.003		
-13spk	0.078		
-18	0.003		
-19	0.003		
-19d	0.003		
-23	0.003		
-24	0.003		
-24spk	0.086		
-25	0.002		
Dig. control 20			
-26	0.005		
-27	0.004		
Control 20	0.106		

Comments, Notes, Etc.:

Analyzed by,

Reviewed by,

#1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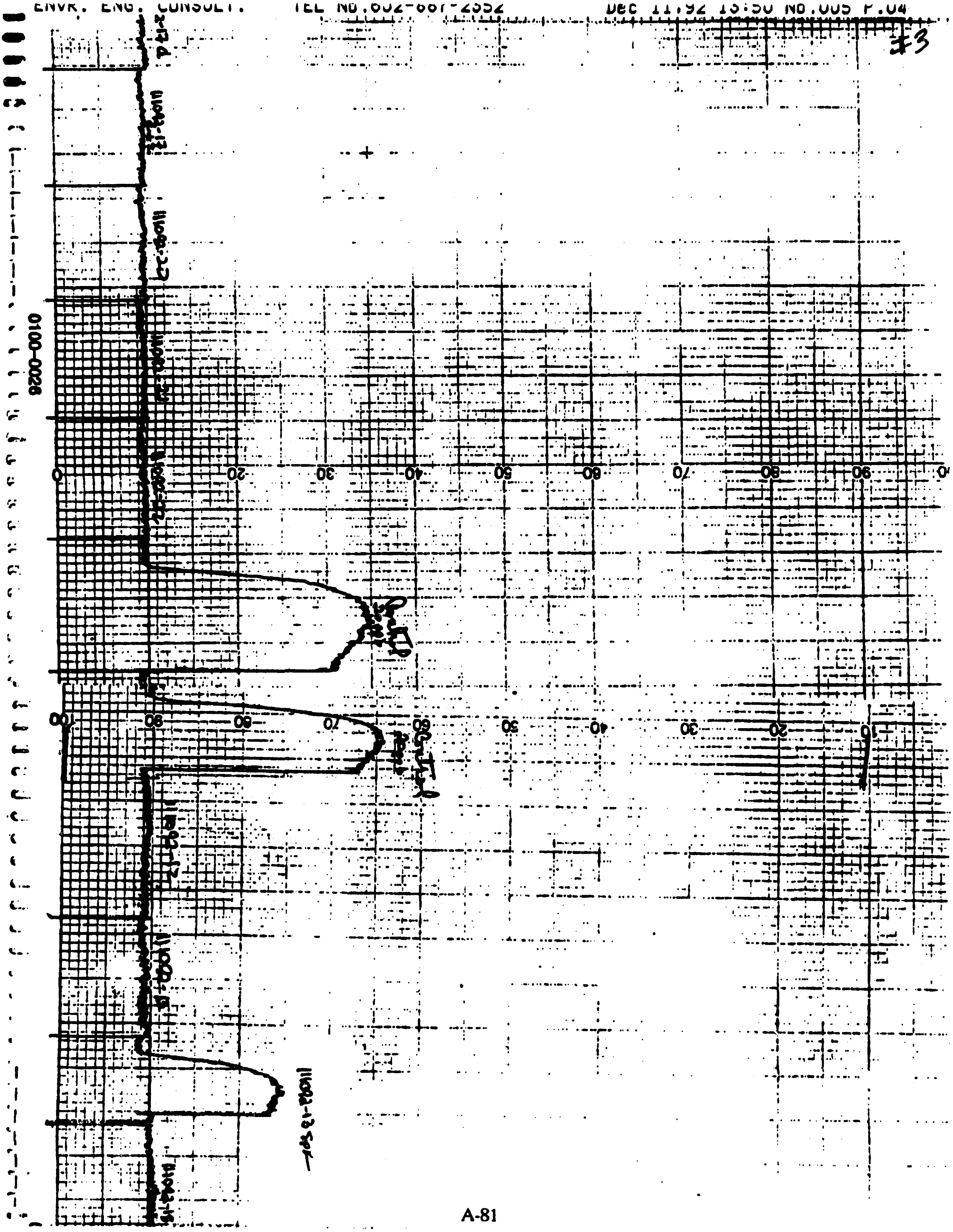
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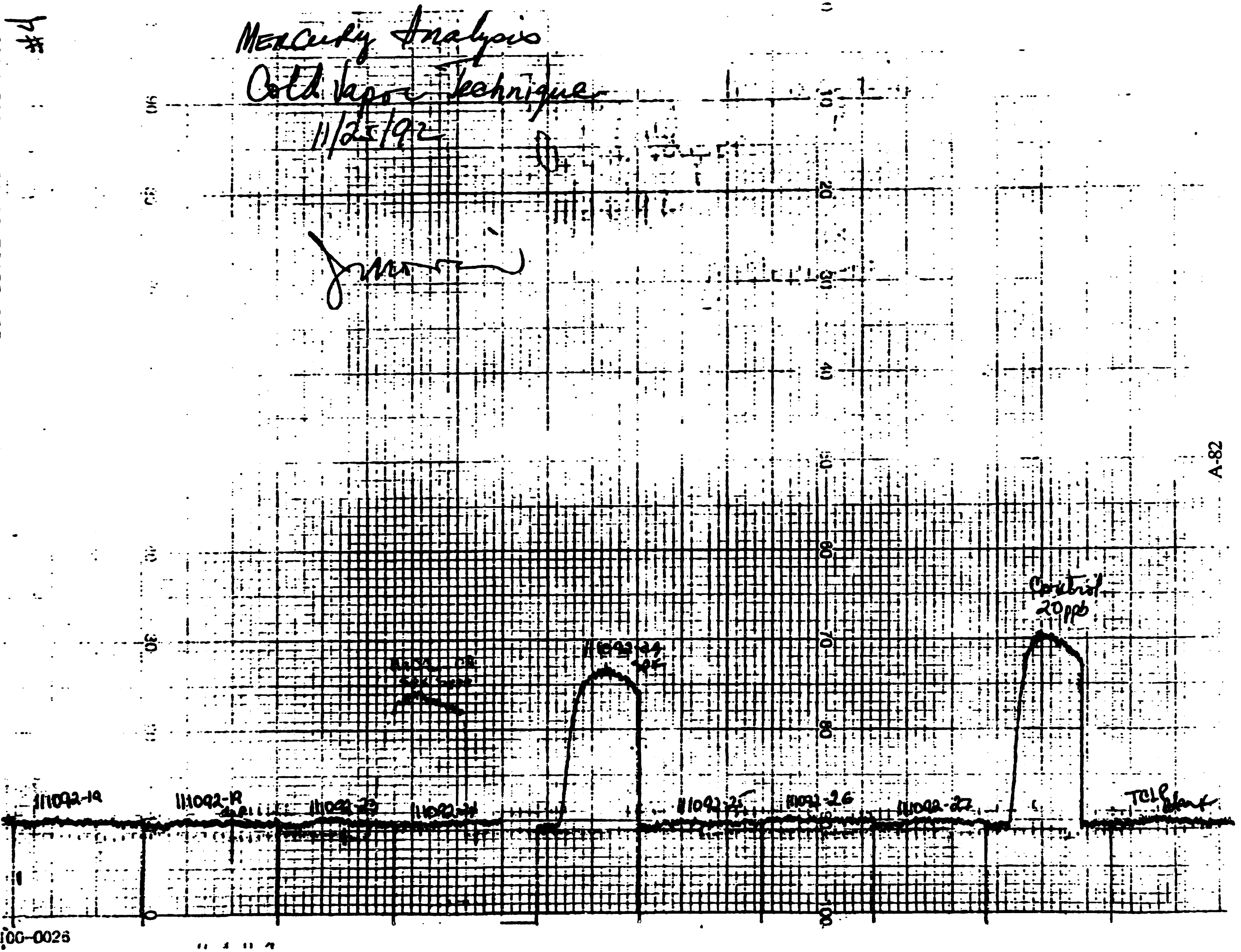
11092-13 Spk

#4



Mercury Analysis
Cold Vapor Technique
11/25/92

Idaho National Laboratory Uranium Study

Cover Letter and QA Release

The results contained within this package were obtained using developmental procedures. Consequently we have no historical data to use for QC purposes. In particular, we do not know how well our extraction procedure works except to say that recoveries from the spiked samples analyzed seem acceptable. Nevertheless, we have followed our procedures faithfully including the QC steps inherent in those procedures.

I have reviewed the contents of this package. It complies with the stipulations found in para. 7.2.1.3. except that no QC reports were generated.

16 Dec 92
Stephen M. Maurer
Chief Chemist

Storage and Shipping Requirements

Samples were stored in wide mouth glass jars with teflon liners. No holding times were exceeded.

Samples sent out for analysis were shipped on ice in a insulated container via UPS Overnight. The void space in the container was filled in with styrofoam packing "peanuts" to secure the sample jars within the shipping container.

Analyst Certification:

The preceding results are truthfully reported and were obtained by the procedure indicated.

Ranell Caiazzo
12 16 92

Ranell Caiazzo
Analyst

QC Manager Verification:

The preceding data has been reviewed as prescribed in paragraph 7.2.1.1. of the Sampling and Analysis Plan for the Yuma Proving Ground Firing Range Restoration Project.

Daron Hargadine
QC Manager

Daron Hargadine
12.16 92

MATERIAL TEST DIRECTORATE
YUMA PROVING GROUND
YUMA, ARIZONA

LABORATORY SERVICES BRANCH TEST REPORT

Item: Field QA/QC Date: 13 Nov. 1992

Project Engineer: Sylvia M. Medina

Comments: This report is the documentation of the quality of the Yuma Proving Ground (YPG) provided of equipment used in the field sampling for Sampling and analysis plan for the Yuma Proving Ground Firing Range Restoration Project. The sampling was conducted by INEL on 2 - 5 November 1992.

Test Results

Rinse Water Quality:

The water used in the field to wash and rinse the equipment was produced at Yuma Proving Grounds (YPG) by the Environmental Simulation Section at GP-1 Environmental Chambers. The water is produced using reverse osmosis and deionization. The water was produced fresh for this test, transferred to a sealed 110 gallon polyethylene tank in a pickup truck and used throughout the four days of sampling. The water was transferred in the field using a new polyethylene transfer pump inserted it the top of the tank through a sampling port.

ASTM Type II water was requested for this requirement. The water in the 110 gallon tank was checked in the field after filling for conductance. The meter used was a Digital Conductivity Meter with Automatic Temperature Compensation, by Curtin Matheson Scientific, Inc. Calibration was performed at the test site using the Calibration Plug provided by the manufacturer for the meter.

The results of the test were: 0.9 Micromho per cm which converts to 1.1 megohm per cm. This is better quality water than the requirement for electrical resistivity of ASTM Type II water.

Sample Container Quality:

The sample bottles for the TCLP, DU, Field Blanks, and Equipment blanks were 300 Series 1,000 ml HDPE Wide-Mouth Jars produced by I-Chem. The certificate of analysis is attached for the three cases used for sampling.

The sample bottles for the Physical Properties were 100 Series

500 ml HDPE Wide-Mouth Jars sold by VWR Scientific.

The 5 Gallon and 2 Gallon pails with lids used in the sample preparation were new HDPE pails with air-tight covers sold by Aldrich.

The sample scoops were new chrome plated scoops purchased at a local hardware store.

The sample transport containers were Coleman Steel Belted 40 ice chests filled with ice from the YPG ice machines used for human consumption.

A copy of this report is on a 3.5 inch HD disk included in this data package. This report is a WordPerfect file which is in the subdirectory WP under its file name DU-FIELD.

INSPECTED BY:
DAVID L. POND
Chemist
Material Analysis Laboratory

I-CHEM

CERTIFICATE OF ANALYSIS

CONTROL NO. 02[illegible]

This is your Certificate of Analysis for I-CHEM SUPERFUND-ANALYZED™ product which has been prepared in accordance with I-CHEM Performace-Based Specifications. This product meets or exceeds all analyte specifications established in the U.S. EPA "Specifications and Guidance for Obtaining Contaminant-Free Sample Containers" for use in Superfund and other hazardous waste programs. Please refer to the case label for information about the recommended application of this product.

Glass and Plastic Sample Containers
for use in the analysis of Metals and Cyanides

Analyte	Detection Limit(ug/L)	Analyte	Detection Limit(ug/L)	Analyte	Detection Limit(ug/L)
Aluminum	< 80	Cobalt	< 10	Selenium	< 2
Antimony	< 5	Copper	< 10	Silver	< 5
Arsenic	< 2	Iron	< 50	Sodium	< 5000
Barium	< 20	Lead	< 2	Sodium (HDPE)	< 100
Barium (Amber HDPE)	< 50	Magnesium	< 100	Thallium	< 5
Beryllium	< 0.5	Manganese	< 10	Vanadium	< 10
Cadmium	< 1	Mercury	< 0.2	Zinc	< 10
Calcium	< 500	Nickel	< 20	Zinc (Amber HDPE)	< 500
Calcium (HDPE)	< 100	Potassium	< 750	Cyanide	< 10
Chromium	< 10	Potassium (HDPE)	< 100		

Glass Sample Containers
for use in the analysis of Semi-Volatiles, Pesticides, and PCBs

Compound	Quantitation Limit(ug/L)	Compound	Quantitation Limit(ug/L)	Compound	Quantitation Limit(ug/L)
Acenaphthene	< 5	Acenaphthylene	< 5	Anthracene	< 5
Benzo(a)anthracene	< 5	Benzo(a)pyrene	< 5	Benzo(b)fluoranthene	< 5
Benzo(k)fluoranthene	< 5	Benzo(g,h,i)perylene	< 5	Benzoic Acid	< 20
Benzyl Alcohol	< 5	4-Bromophenyl-phenylether	< 5	Butylbenzylphthalate	< 5
4-Chloroaniline	< 5	4-Chloro-3-methylphenol	< 5	bis-(2-Chloroethoxy)methane	< 5
bis-(2-Chloroethyl)ether	< 5	bis-(2-Chloroisopropyl)ether	< 5	2-Chloronaphthalene	< 5
2-Chlorophenol	< 5	4-Chlorophenyl-phenylether	< 5	Chrysene	< 5
Di-n-butylphthalate	< 5	Di-n-octylphthalate	< 5	Dibenzo(a,h)anthracene	< 5
Dibenzofuran	< 5	1,2-Dichlorobenzene	< 5	1,4-Dichlorobenzene	< 5
1,3-Dichlorobenzene	< 5	3,3'-Dichlorobenzidine	< 5	2,4-dichlorophenol	< 5
Diethylphthalate	< 5	Dimethylphthalate	< 5	2,4-Dimethylphenol	< 5
4,6-Dinitro-2-methylphenol	< 20	2,4-Dinitrophenol	< 20	2,4-Dinitrotoluene	< 5
2,6-Dinitrotoluene	< 5	bis-(2-Ethylhexyl)phthalate	< 5	Fluoranthene	< 5
Fluorene	< 5	Hexachlorobenzene	< 5	Hexachlorobutadiene	< 5
Hexachlorocyclopentadiene	< 5	Hexachloroethane	< 5	Indeno(1,2,3-cd)pyrene	< 5
Isophorone	< 5	2-Methylnaphthalene	< 5	2-Methylphenol	< 5
4-Methylphenol	< 5	2-Nitroaniline	< 20	3-Nitroaniline	< 20
4-Nitroaniline	< 20	N-Nitroso-di-n-propylamine	< 5	N-Nitrosodimethylamine	< 5
N-Nitrosodiphenylamine	< 5	Naphthalene	< 5	Nitrobenzene	< 5
2-Nitrophenol	< 5	4-Nitrophenol	< 20	Pentachlorophenol	< 20
Phenanthrene	< 5	Phenol	< 5	Pyrene	< 5
1,2,4-Trichlorobenzene	< 5	2,4,5-Trichlorophenol	< 20	2,4,6-Trichlorophenol	< 5
1,2-Diphenylhydrazine	< 5	Carbazole	< 5	Aldrin	< 0.01
4,4'-DDD	< 0.02	Endosulfan II	< 0.02	Alpha-BHC	< 0.01
4,4'-DDE	< 0.02	Endosulfan Sulfate	< 0.02	Beta-BHC	< 0.01
4,4'-DDT	< 0.02	Endrin	< 0.02	Delta-BHC	< 0.01
Dieldrin	< 0.02	Endrin Aldehyde	< 0.02	Gamma-BHC	< 0.01
Endosulfan I	< 0.01	Heptachlor	< 0.01	Heptachlor Epoxide	< 0.01
Methoxychlor	< 0.10	Endrin Ketone	< 0.02	Alpha-Chlordane	< 0.01
Gamma-Chlordane	< 0.01	Toxaphene	< 1.0	Aroclor-1016	< 0.20
Aroclor-1221	< 0.02	Aroclor-1232	< 0.40	Aroclor-1242	< 0.20
Aroclor-1248	< 0.20	Aroclor-1254	< 0.20	Aroclor-1260	< 0.20
Aroclor-1262	< 0.20	Aroclor-1268	< 0.20		

Glass Sample Containers
for use in the analysis of Volatile Organics

Compound	Quantitation Limit(ug/L)	Compound	Quantitation Limit(ug/L)	Compound	Quantitation Limit(ug/L)
Acetone	< 5	1,3-Dichloropropane	< 1	Benzene	< 1
2,2-Dichloropropane	< 1	Bromobenzene	< 1	1,2-Dichloropropane	< 1
Bromodichloromethane	< 1	trans-1,3-Dichloropropene	< 1	Bromoform	< 1
cis-1,3-Dichloropropene	< 1	Bromomethane	< 1	1,1-Dichloropropene	< 1
2-Butanone	< 5	Ethylbenzene	< 1	tert-Butylbenzene	< 1
Hexachlorobutadiene	< 1	sec-Butylbenzene	< 1	2-Hexanone	< 5
n-Butylbenzene	< 1	Isopropylbenzene	< 1	Carbon Disulfide	< 1
p-Isopropyltoluene	< 1	Carbon Tetrachloride	< 1	4-Methyl-2-pentanone	< 5
Chlorobenzene	< 1	Methylene Chloride	< 5	Chloroethane	< 1
Naphthalene	< 1	Chloroform	< 1	n-Propylbenzene	< 1
Chloromethane	< 1	Styrene	< 1	2 & 4 Chlorotoluene	< 1
1,1,2,2-Tetrachloroethane	< 1	1,2-Dibromo-3-chloropropane	< 1	Tetrachloroethene	< 1
Dibromochloromethane	< 1	Toluene	< 1	1,2-Dibromoethane (EDB)	< 1
1,2,3-Trichlorobenzene	< 1	Dibromomethane	< 1	1,2,4-Trichlorobenzene	< 1
1,4-Dichlorobenzene	< 1	1,1,2-Trichloroethane	< 1	1,3-Dichlorobenzene	< 1
1,1,1-Trichloroethane	< 1	1,2-Dichlorobenzene	< 1	Trichloroethene	< 1
Dichlorodifluoromethane	< 1	Trichlorofluoromethane	< 1	1,2-Dichloroethane	< 1
1,2,3-Trichloropropane	< 1	1,1-Dichloroethane	< 1		
trans-1,2-Dichloroethene	< 1	1,3,5-Trimethylbenzene	< 1		
Vinyl Acetate	< 5	1,1-Dichloroethene	< 1		
Xylene (total)	< 1	1,2,4-Trimethylbenzene	< 1		
Vinyl Chloride	< 1	cis-1,2-Dichloroethene	< 1		

Please keep this certificate for your records and to facilitate any necessary correspondence. If additional information is required, contact our Technical Service Department at (800) 443-1689 or (800) 262-5006 inside California.

Randy E. Benson

Randy E. Benson
Corporate Quality Assurance Manager

I-CHEM

CERTIFICATE OF ANALYSIS

CONTROL NO. 030000

This is your Certificate of Analysis for I-CHEM SUPERFUND-ANALYZED™ product which has been prepared in accordance with I-CHEM Performace-Based Specifications. This product meets or exceeds all analyte specifications established in the U.S. EPA "Specifications and Guidance for Obtaining Contaminant-Free Sample Containers" for use in Superfund and other hazardous waste programs. Please refer to the case label for information about the recommended application of this product.

Glass and Plastic Sample Containers
for use in the analysis of Metals and Cyanides

Analyte	Detection Limit(ug/L)	Analyte	Detection Limit(ug/L)	Analyte	Detection Limit(ug/L)
Aluminum	< 80	Cobalt	< 10	Selenium	< 2
Antimony	< 5	Copper	< 10	Silver	< 5
Arsenic	< 2	Iron	< 50	Sodium	< 5000
Barium	< 20	Lead	< 2	Sodium (HDPE)	< 100
Barium (Amber HDPE)	< 50	Magnesium	< 100	Thallium	< 5
Beryllium	< 0.5	Manganese	< 10	Vanadium	< 10
Cadmium	< 1	Mercury	< 0.2	Zinc	< 10
Calcium	< 500	Nickel	< 20	Zinc (Amber HDPE)	< 500
Calcium (HDPE)	< 100	Potassium	< 750	Cyanide	< 10
Chromium	< 10	Potassium (HDPE)	< 100		

Glass Sample Containers
for use in the analysis of Semi-Volatiles, Pesticides, and PCBs

Compound	Quantitation Limit(ug/L)	Compound	Quantitation Limit(ug/L)	Compound	Quantitation Limit(ug/L)
Acenaphthene	< 5	Acenaphthylene	< 5	Anthracene	< 5
Benzo(a)anthracene	< 5	Benzo(a)pyrene	< 5	Benzo(b)fluoranthene	< 5
Benzo(k)fluoranthene	< 5	Benzo(g,h,i)perylene	< 5	Benzoic Acid	< 20
Benzyl Alcohol	< 5	4-Bromophenyl-phenylether	< 5	Butylbenzylphthalate	< 5
4-Chloroaniline	< 5	4-Chloro-3-methylphenol	< 5	bis-(2-Chloroethoxy)methane	< 5
bis-(2-Chloroethyl)ether	< 5	bis-(2-Chloroisopropyl)ether	< 5	2-Chloronaphthalene	< 5
2-Chlorophenol	< 5	4-Chlorophenyl-phenylether	< 5	Chrysene	< 5
Di-n-butylphthalate	< 5	Di-n-octylphthalate	< 5	Dibenzo(a,h)anthracene	< 5
Dibenzofuran	< 5	1,2-Dichlorobenzene	< 5	1,4-Dichlorobenzene	< 5
1,3-Dichlorobenzene	< 5	3,3'-Dichlorobenzidine	< 5	2,4-dichlorophenol	< 5
Diethylphthalate	< 5	Dimethylphthalate	< 5	2,4-Dimethylphenol	< 5
4,6-Dinitro-2-methylphenol	< 20	2,4-Dinitrophenol	< 20	2,4-Dinitrotoluene	< 5
2,6-Dinitrotoluene	< 5	bis-(2-Ethylhexyl)phthalate	< 5	Fluoranthene	< 5
Fluorene	< 5	Hexachlorobenzene	< 5	Hexachlorobutadiene	< 5
Hexachlorocyclopentadiene	< 5	Hexachloroethane	< 5	Indeno(1,2,3-cd)pyrene	< 5
Isophorone	< 5	2-Methylnaphthalene	< 5	2-Methylphenol	< 5
4-Methylphenol	< 5	2-Nitroaniline	< 20	3-Nitroaniline	< 20
4-Nitroaniline	< 20	N-Nitroso-di-n-propylamine	< 5	N-Nitrosodimethylamine	< 5
N-Nitrosodiphenylamine	< 5	Naphthalene	< 5	Nitrobenzene	< 5
2-Nitrophenol	< 5	4-Nitrophenol	< 20	Pentachlorophenol	< 20
Phenanthrene	< 5	Phenol	< 5	Pyrene	< 5
1,2,4-Trichlorobenzene	< 5	2,4,5-Trichlorophenol	< 20	2,4,6-Trichlorophenol	< 5
1,2-Diphenylhydrazine	< 5	Carbazole	< 5	Aldrin	< 0.01
4,4'-DDD	< 0.02	Endosulfan II	< 0.02	Alpha-BHC	< 0.01
4,4'-DDE	< 0.02	Endosulfan Sulfate	< 0.02	Beta-BHC	< 0.01
4,4'-DDT	< 0.02	Endrin	< 0.02	Delta-BHC	< 0.01
Dieldrin	< 0.02	Endrin Aldehyde	< 0.02	Gamma-BHC	< 0.01
Endosulfan I	< 0.01	Heptachlor	< 0.01	Heptachlor Epoxide	< 0.01
Methoxychlor	< 0.10	Endrin Ketone	< 0.02	Alpha-Chlordane	< 0.01
Gamma-Chlordane	< 0.01	Toxaphene	< 1.0	Aroclor-1016	< 0.20
Aroclor-1221	< 0.02	Aroclor-1232	< 0.40	Aroclor-1242	< 0.20
Aroclor-1248	< 0.20	Aroclor-1254	< 0.20	Aroclor-1260	< 0.20
Aroclor-1262	< 0.20	Aroclor-1268	< 0.20		

Glass Sample Containers
for use in the analysis of Volatile Organics

Compound	Quantitation Limit(ug/L)	Compound	Quantitation Limit(ug/L)	Compound	Quantitation Limit(ug/L)
Acetone	< 5	1,3-Dichloropropane	< 1	Benzene	< 1
2,2-Dichloropropane	< 1	Bromobenzene	< 1	1,2-Dichloropropane	< 1
Bromodichloromethane	< 1	trans-1,3-Dichloropropene	< 1	Bromoform	< 1
cis-1,3-Dichloropropene	< 1	Bromomethane	< 1	1,1-Dichloropropene	< 1
2-Butanone	< 5	Ethylbenzene	< 1	tert-Butylbenzene	< 1
Hexachlorobutadiene	< 1	sec-Butylbenzene	< 1	2-Hexanone	< 5
n-Butylbenzene	< 1	Isopropylbenzene	< 1	Carbon Disulfide	< 1
p-Isopropyltoluene	< 1	Carbon Tetrachloride	< 1	4-Methyl-2-pentanone	< 5
Chlorobenzene	< 1	Methylene Chloride	< 5	Chloroethane	< 1
Naphthalene	< 1	Chloroform	< 1	n-Propylbenzene	< 1
Chloromethane	< 1	Styrene	< 1	2 & 4 Chlorotoluene	< 1
1,1,2,2-Tetrachloroethane	< 1	1,2-Dibromo-3-chloropropane	< 1	Tetrachloroethene	< 1
Dibromochloromethane	< 1	Toluene	< 1	1,2-Dibromoethane (EDB)	< 1
1,2,3-Trichlorobenzene	< 1	Dibromomethane	< 1	1,2,4-Trichlorobenzene	< 1
1,4-Dichlorobenzene	< 1	1,1,2-Trichloroethane	< 1	1,3-Dichlorobenzene	< 1
1,1,1-Trichloroethane	< 1	1,2-Dichlorobenzene	< 1	Trichloroethene	< 1
Dichlorodifluoromethane	< 1	Trichlorofluoromethane	< 1	1,2-Dichloroethane	< 1
1,2,3-Trichloropropane	< 1	1,1-Dichloroethane	< 1		
trans-1,2-Dichloroethene	< 1	1,3,5-Trimethylbenzene	< 1		
Vinyl Acetate	< 5	1,1-Dichloroethene	< 1		
Xylene (total)	< 1	1,2,4-Trimethylbenzene	< 1		
Vinyl Chloride	< 1	cis-1,2-Dichloroethene	< 1		

Please keep this certificate for your records and to facilitate any necessary correspondence. If additional information is required, contact our Technical Service Department at (800) 443-1689 or (800) 262-5006 inside California.

Randy E. Benson

Randy E. Benson
Corporate Quality Assurance Manager

I-CHEM

CERTIFICATE OF ANALYSIS

CONTROL NO. 029987

This is your Certificate of Analysis for I-CHEM SUPERFUND-ANALYZED™ product which has been prepared in accordance with I-CHEM Performace-Based Specifications. This product meets or exceeds all analyte specifications established in the U.S. EPA "Specifications and Guidance for Obtaining Contaminant-Free Sample Containers" for use in Superfund and other hazardous waste programs. Please refer to the case label for information about the recommended application of this product.

Glass and Plastic Sample Containers
for use in the analysis of Metals and Cyanides

Analyte	Detection Limit(ug/L)	Analyte	Detection Limit(ug/L)	Analyte	Detection Limit(ug/L)
Aluminum	< 80	Cobalt	< 10	Selenium	< 2
Antimony	< 5	Copper	< 10	Silver	< 5
Arsenic	< 2	Iron	< 50	Sodium	< 5000
Barium	< 20	Lead	< 2	Sodium (HDPE)	< 100
Barium (Amber HDPE)	< 50	Magnesium	< 100	Thallium	< 5
Beryllium	< 0.5	Manganese	< 10	Vanadium	< 10
Cadmium	< 1	Mercury	< 0.2	Zinc	< 10
Calcium	< 500	Nickel	< 20	Zinc (Amber HDPE)	< 500
Calcium (HDPE)	< 100	Potassium	< 750	Cyanide	< 10
Chromium	< 10	Potassium (HDPE)	< 100		

Glass Sample Containers
for use in the analysis of Semi-Volatiles, Pesticides, and PCBs

Compound	Quantitation Limit(ug/L)	Compound	Quantitation Limit(ug/L)	Compound	Quantitation Limit(ug/L)
Acenaphthene	< 5	Acenaphthylene	< 5	Anthracene	< 5
Benzo(a)anthracene	< 5	Benzo(a)pyrene	< 5	Benzo(b)fluoranthene	< 5
Benzo(k)fluoranthene	< 5	Benzo(g,h,i)perylene	< 5	Benzoic Acid	< 20
Benzyl Alcohol	< 5	4-Bromophenyl-phenylether	< 5	Butylbenzylphthalate	< 5
4-Chloroaniline	< 5	4-Chloro-3-methylphenol	< 5	bis-(2-Chloroethoxy)methane	< 5
bis-(2-Chloroethyl)ether	< 5	bis-(2-Chloroisopropyl)ether	< 5	2-Chloronaphthalene	< 5
2-Chlorophenol	< 5	4-Chlorophenyl-phenylether	< 5	Chrysene	< 5
Di-n-butylphthalate	< 5	Di-n-octylphthalate	< 5	Dibenzo(a,h)anthracene	< 5
Dibenzofuran	< 5	1,2-Dichlorobenzene	< 5	1,4-Dichlorobenzene	< 5
1,3-Dichlorobenzene	< 5	3,3'-Dichlorobenzidine	< 5	2,4-dichlorophenol	< 5
Diethylphthalate	< 5	Dimethylphthalate	< 5	2,4-Dimethylphenol	< 5
4,6-Dinitro-2-methylphenol	< 20	2,4-Dinitrophenol	< 20	2,4-Dinitrotoluene	< 5
2,6-Dinitrotoluene	< 5	bis-(2-Ethylhexyl)phthalate	< 5	Fluoranthene	< 5
Fluorene	< 5	Hexachlorobenzene	< 5	Hexachlorobutadiene	< 5
Hexachlorocyclopentadiene	< 5	Hexachloroethane	< 5	Indeno(1,2,3-cd)pyrene	< 5
Isophorone	< 5	2-Methylnaphthalene	< 5	2-Methylphenol	< 5
4-Methylphenol	< 5	2-Nitroaniline	< 20	3-Nitroaniline	< 20
4-Nitroaniline	< 20	N-Nitroso-di-n-propylamine	< 5	N-Nitrosodimethylamine	< 5
N-Nitrosodiphenylamine	< 5	Naphthalene	< 5	Nitrobenzene	< 5
2-Nitrophenol	< 5	4-Nitrophenol	< 20	Pentachlorophenol	< 20
Phenanthrene	< 5	Phenol	< 5	Pyrene	< 5
1,2,4-Trichlorobenzene	< 5	2,4,5-Trichlorophenol	< 20	2,4,6-Trichlorophenol	< 5
1,2-Diphenylhydrazine	< 5	Carbazole	< 5	Aldrin	< 0.01
4,4'-DDD	< 0.02	Endosulfan II	< 0.02	Alpha-BHC	< 0.01
4,4'-DDE	< 0.02	Endosulfan Sulfate	< 0.02	Beta-BHC	< 0.01
4,4'-DDT	< 0.02	Endrin	< 0.02	Delta-BHC	< 0.01
Dieldrin	< 0.02	Endrin Aldehyde	< 0.02	Gamma-BHC	< 0.01
Endosulfan I	< 0.01	Heptachlor	< 0.01	Heptachlor Epoxide	< 0.01
Methoxychlor	< 0.10	Endrin Ketone	< 0.02	Alpha-Chlordane	< 0.01
Gamma-Chlordane	< 0.01	Toxaphene	< 1.0	Aroclor-1016	< 0.20
Aroclor-1221	< 0.02	Aroclor-1232	< 0.40	Aroclor-1242	< 0.20
Aroclor-1248	< 0.20	Aroclor-1254	< 0.20	Aroclor-1260	< 0.20
Aroclor-1262	< 0.20	Aroclor-1268	< 0.20		

Glass Sample Containers
for use in the analysis of Volatile Organics

Compound	Quantitation Limit(ug/L)	Compound	Quantitation Limit(ug/L)	Compound	Quantitation Limit(ug/L)
Acetone	< 5	1,3-Dichloropropane	< 1	Benzene	< 1
2,2-Dichloropropane	< 1	Bromobenzene	< 1	1,2-Dichloropropane	< 1
Bromodichloromethane	< 1	trans-1,3-Dichloropropene	< 1	Bromoform	< 1
cis-1,3-Dichloropropene	< 1	Bromomethane	< 1	1,1-Dichloropropene	< 1
2-Butanone	< 5	Ethylbenzene	< 1	tert-Butylbenzene	< 1
Hexachlorobutadiene	< 1	sec-Butylbenzene	< 1	2-Hexanone	< 5
n-Butylbenzene	< 1	Isopropylbenzene	< 1	Carbon Disulfide	< 1
p-Isopropyltoluene	< 1	Carbon Tetrachloride	< 1	4-Methyl-2-pentanone	< 5
Chlorobenzene	< 1	Methylene Chloride	< 5	Chloroethane	< 1
Naphthalene	< 1	Chloroform	< 1	n-Propylbenzene	< 1
Chloromethane	< 1	Styrene	< 1	2 & 4 Chlorotoluene	< 1
1,1,2,2-Tetrachloroethane	< 1	1,2-Dibromo-3-chloropropane	< 1	Tetrachloroethene	< 1
Dibromochloromethane	< 1	Toluene	< 1	1,2-Dibromoethane (EDB)	< 1
1,2,3-Trichlorobenzene	< 1	Dibromomethane	< 1	1,2,4-Trichlorobenzene	< 1
1,4-Dichlorobenzene	< 1	1,1,2-Trichloroethane	< 1	1,3-Dichlorobenzene	< 1
1,1,1-Trichloroethane	< 1	1,2-Dichlorobenzene	< 1	Trichloroethene	< 1
Dichlorodifluoromethane	< 1	Trichlorofluoromethane	< 1	1,2-Dichloroethane	< 1
1,2,3-Trichloropropane	< 1	1,1-Dichloroethane	< 1		
trans-1,2-Dichloroethene	< 1	1,3,5-Trimethylbenzene	< 1		
Vinyl Acetate	< 5	1,1-Dichloroethene	< 1		
Xylene (total)	< 1	1,2,4-Trimethylbenzene	< 1		
Vinyl Chloride	< 1	cis-1,2-Dichloroethene	< 1		

Please keep this certificate for your records and to facilitate any necessary correspondence. If additional information is required, contact our Technical Service Department at (800) 443-1689 or (800) 262-5006 inside California.

Randy E. Benson

Randy E. Benson
Corporate Quality Assurance Manager

Appendix B

Particle Size Analysis Data

Appendix B

Particle Size Analysis Data

Note that the confidence interval was established using the following formula (for a small sample):

$$X \pm t_{\alpha/2}\, s/\sqrt{n}$$

where

X = Sample mean

$t_{\alpha/2}$ = Student - t

s = standard deviation

n = sample size

URANIUM ANALYSIS

CONVERSION FACTOR

Example:

Specific Activity of DU = 0.36×10^6 pCi/g

(49.41 ug of DU/gm of soil) $\times$ (0.36×10^6 pCi/g) $\times$ (1 gm/1×10^6 ug) =

= 17.79 pCi of DU/gm of soil

MATERIAL TEST DIRECTORATE
YUMA PROVING GROUND
YUMA, ARIZONA

LABORATORY SERVICES BRANCH TEST REPORT

Item: PHYSICAL PROPERTIES DATA PACKAGE **Date:** 30 Nov. 1992

Project Engineer: Sylvia M. Medina

Comments: This data package consists of the reports for the Physical Properties tests for the <u>Sampling and Analysis Plan for the Yuma Proving Ground Firing Range Restoration Project.</u>

Test Results

The data package consists of two summary confidence interval estimate data sheets and six hard copy reports.

The two data sheets are the calculations for the confidence intervals listed in this summary cover sheet.

The first four reports are for the Physical Properties listed in Table 2 page 4-4 of the Sampling and Analysis Plan. These tests are:

1. Bulk Density and Moisture Content,
2. pH,
3. Particle Density,
4. Particle Size Distribution.

The fifth report consists of the information on the Quality of the material used in support of the INEL field sampling.

The sixth report is the information on how the Field Matrix Spike for DU was prepared at Yuma Proving Ground (YPG).

The data package also consists of one 3.5 inch HD disk. This disk contains the WordPerfect, word processing files and Lotus 1-2-3, data files used to generate this data package. The file names are included at the end of each report. The file name for this cover sheet is DU-COVER in the subdirectory of WP on the disk. The file name for the two data sheets is DU-SUM in the subdirectory of 123 on the disk.

The quality of the physical properties data in these reports is as good as the Material Analysis Laboratory could generate using the limited amount of sample available. The soil in all three piles basically came from the same geological location at YPG and can therefore be considered to be the same soil from a Physical Properties (as defined in this project) standpoint for the physical properties tests run. If the above is assumed then confidence intervals for the data can be generated using the twelve sample locations as twelve samples of the same soil. The formula for calculating the confidence interval estimate of the mean when the sample size is small is:

$$\bar{X} \pm t_{\alpha/2}\frac{s}{\sqrt{n}}$$

$$\bar{X} = Sample.Mean$$

$$t_{\alpha/2} = Student\text{-}t$$

$$s = Standard.Deviation$$

$$n = Sample.Size$$

Using the above formula and calculating the mean for the 12 sample locations we get the following for the average results for the Physical Properties at the 95% confidence interval.

Bulk Density = 101.0 +/- 1.8 lbs/cu ft
Particle Density = 170.8 +/- 0.5 lbs/cu ft
Moisture = 2.5 +/- 0.3 %
pH = 8.0 +/- 0.1

Particle Size Percent Passing
19 mm = 99.8 +/- 0.3 %
12.5 mm = 96.3 +/- 1.4 %
9.5 mm = 92.1 +/- 2.1 %
6.3 mm = 86.0 +/- 2.7 %
2.00 mm = 66.7 +/- 3.7 %
0.850 mm = 54.4 +/- 5.1 %
0.425 mm = 46.8 +/- 6.2 %
0.250 mm = 41.3 +/- 6.8 %
0.106 mm = 30.1 +/- 6.2 %
0.075 mm = 23.7 +/- 5.2 %
0.050 mm = 20.5 +/- 4.8 %
0.020 mm = 14.3 +/- 3.6 %
0.005 mm = 6.9 +/- 2.0 %
0.001 mm = 1.3 +/- 0.5 %

INSPECTED BY: ______________________
DAVID L. POND
Chemist
Material Analysis Laboratory

CONFIDENCE INTERVAL ESTIMATE AT 95%

SAMPLE NUMBER	BULK DENSITY lb/cu ft	PARTICLE DENSITY lb/cu ft	MOISTURE %	pH
110392-SP-01-PP	98.7	169.7	2.1	7.9
110392-SP-02-PP	105.2	170.7	1.5	8.3
110392-SP-03-PP	99.1	171.8	3.3	8.2
110392-SP-04-PP	106.5	170.1	2.1	8.2
110492-NP-01-PP	102.0	169.6	3.0	8.1
110492-NP-02-PP	102.9	170.9	2.8	7.9
110492-NP-03-PP	103.0	170.9	2.6	7.9
110492-NP-04-PP	101.9	172.0	3.0	8.0
110592-WP-01-PP	98.0	170.8	2.4	7.7
110592-WP-02-PP	98.9	171.0	2.6	7.7
110592-WP-03-PP	96.9	171.5	2.5	7.8
110592-WP-04-PP	99.3	170.6	2.5	7.8
MEAN	101.0	170.8	2.5	8.0
STANDARD DEVIATION	2.88	0.72	0.46	0.19
CONFIDENCE INTERVAL	1.8	0.5	0.3	0.1

Student t Factor for 95% Confidence Limit = 2.201
Sample Size = 12

CONFIDENCE INTERVAL ESTIMATE AT 95%

	PERCENT OF SOIL PASSING													
SAMPLE NUMBER	19.0 MM	12.5 MM	9.5 MM	6.3 MM	2.00 MM	0.850 MM	0.425 MM	0.250 MM	0.106 MM	0.075 MM	0.050 MM	0.020 MM	0.005 MM	0.001 MM
110392-SP-01-PP	99.9	96.8	94.2	87.1	64.7	51.6	43.6	37.5	28.2	22.1	19.3	13.9	6.2	0.9
110392-SP-02-PP	100.0	96.7	94.8	90.9	63.9	48.0	35.8	27.0	15.4	11.5	9.8	6.8	2.7	0.3
110392-SP-03-PP	99.9	96.5	88.3	81.6	64.6	50.6	42.6	36.8	26.3	20.1	17.4	12.6	6.3	1.1
110392-SP-04-PP	99.9	96.1	93.8	89.8	64.3	47.1	35.4	27.7	17.2	14.4	13.0	9.7	4.4	0.7
110492-NP-01-PP	100.0	92.0	86.1	79.7	61.2	48.2	39.7	33.7	23.1	17.8	15.3	10.6	4.8	0.6
110492-NP-02-PP	100.0	96.6	93.7	85.3	64.5	52.2	44.7	39.3	28.2	21.6	18.9	12.9	6.1	1.2
110492-NP-03-PP	100.0	93.7	88.1	80.4	61.7	49.7	43.0	38.3	27.9	21.9	19.9	14.5	7.3	1.6
110492-NP-04-PP	99.9	98.3	95.7	91.2	74.0	61.6	52.6	46.0	32.2	24.1	20.6	13.6	5.5	0.7
110592-WP-01-PP	99.9	99.1	94.7	89.2	76.3	68.6	64.6	61.0	48.5	40.4	36.6	26.8	13.6	3.0
110592-WP-02-PP	100.0	98.7	94.9	88.0	71.8	62.9	57.2	52.5	39.4	30.8	26.7	18.8	9.3	2.0
110592-WP-03-PP	100.0	98.0	92.5	88.6	75.5	67.7	63.4	59.5	46.4	37.2	32.7	22.9	12.1	2.7
110592-WP-04-PP	98.3	92.9	88.1	79.6	57.6	44.9	39.1	35.8	28.7	22.0	15.4	8.5	4.1	0.6
MEAN	99.8	96.3	92.1	86.0	66.7	54.4	46.8	41.3	30.1	23.7	20.5	14.3	6.9	1.3
STANDARD DEVIATION	0.46	2.20	3.26	4.28	5.87	8.04	9.75	10.77	9.81	8.21	7.55	5.63	3.13	0.83
CONFIDENCE INTERVAL	0.3	1.4	2.1	2.7	3.7	5.1	6.2	6.8	6.2	5.2	4.8	3.6	2.0	0.5

MATERIAL TEST DIRECTORATE
YUMA PROVING GROUND
YUMA, ARIZONA

LABORATORY SERVICES BRANCH TEST REPORT

Item: Bulk Density and Moisture of Soil Date: 13 Nov 1992

Project Engineer: Sylvia M. Medina

Comments: This report is the documentation of the Bulk Density and Moisture data for the Sampling and Analysis Plan for the Yuma Proving Ground Firing Range Restoration Project.

Test Results

The bulk density of the soil for each of the piles of soil was measured undisturbed at the sample location using a reference provided by INEL. The method was "Bulk Density" from Methods of Soil Analysis Part I and II, A. Klute ed., American Society of Agronomy, Madison, WI. From the method, section 13-5, "Radiation Methods" was used to take the readings from the 40 locations on each hill corresponding to the 40 locations used for soil sampling.

Verification of the bulk densities was made by using section 13-3 subparagraph 2.2.2 "Rubber-Balloon Method". One sample location consisting of ten readings was analyzed by both methods for comparison.

The Moisture of the soil for each of the piles was measured undisturbed at the sample location using a radiation method provided by the manufacturer of the moisture density gauge in the operators instruction manual. Readings from 40 locations on each hill corresponding to the 40 locations used for soil sampling.

Verification of the moisture was made by using a reference provided by INEL. The method was ASTM D2216-90 "Standard Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock". One sample location consisting of ten readings was analyzed by both methods for comparison.

The Moisture and density content of the soil was taken simultaneously using a Troxler Model 3411-B Surface Moisture-Density Gauge, S/N 9185. Verification of the density was made using a Soiltest CN980 Volumeasure Rubber-Balloon apparatus, Bar Code number P6170. The oven for the moisture was a Precision Scientific, Model M-C, Microwave/Convection forced air oven, S/N 10AW-12, used in the convection mode. The balance for both moisture and density analysis was a Mettler PE3600 top loading balance, S/N E32675.

Calibration of the Troxler Moisture-Density Gauge was conducted the day of the test in the field using the procedure outlined in Chapter IV of the Instruction Manual with a the provided Reference Standard. Due to the inability of being able to obtain realistic soil density and moisture check standards for the Troxler Moisture-Density Gauge, the method of verification with a second method was used. The Rubber-balloon method for density and the ASTM 2216 method for moisture were used.

Attached to this report are two data sheets. The first sheet is the raw and final data from using the Troxler Moisture-Density Gauge for the 120 readings for the twelve sample locations taken from the three hills. SD stands for standard deviation for the 10 analysis. The depth of the probe for the density measurements was set at 12 inches. Moisture measurements are always a backscatter method for this gauge. The second data sheet is the raw and final data for the verification readings using the Rubber-Balloon method and ASTM 2216.

A copy of this report is on a 3.5 inch HD disk included in this data package. This cover sheet is a WordPerfect file which is in the subdirectory WP under its file name DU-DENST. The data is a Lotus 1-2-3 file which is in the subdirectory 123 under its file mane DU-DENSI.

INSPECTED BY:
DAVID L. POND
Chemist
Material Analysis Laboratory

DENSITY AND MOISTURE DATA FOR FIRING RANGE RESTORATION PROJECT
DENSITY IN POUNDS PER CUBIC FOOT AND MOISTURE IN PERCENT

GRID	WEST PILE		SOUTH PILE		NORTH PILE	
LOCATION	DENSITY	MOISTURE	DENSITY	MOISTURE	DENSITY	MOISTURE
A1	97.9	2.4	96.1	1.8	102.4	3.4
A2	92.4	2.0	95.7	2.0	104.6	2.6
A3	96.0	2.1	95.1	2.6	104.3	3.0
A4	92.3	1.9	99.1	2.5	96.5	2.5
A5	95.3	2.5	104.7	1.0	103.9	2.1
A6	97.5	3.0	97.4	1.9	101.2	3.2
A7	103.2	2.6	92.8	2.3	103.8	3.3
A8	100.4	3.5	102.0	2.4	100.8	3.3
A9	102.1	1.9	98.4	2.6	103.7	2.9
A10	103.2	2.2	105.3	1.7	98.4	4.1
AVERAGE	98.0	2.4	98.7	2.1	102.0	3.0
SD	3.9	0.5	3.9	0.5	2.6	0.5
B1	93.6	2.8	105.6	1.1	104.3	2.1
B2	89.7	2.8	104.9	1.1	100.4	2.6
B3	99.3	2.4	104.4	0.9	104.7	2.2
B4	96.4	2.9	108.5	1.0	108.0	2.4
B5	101.5	2.3	99.3	2.8	105.0	2.4
B6	101.3	2.4	108.4	1.0	100.2	3.3
B7	102.0	2.5	106.0	1.0	106.4	3.2
B8	101.4	2.7	107.7	0.9	105.6	2.5
B9	101.3	3.2	110.0	2.0	93.6	4.2
B10	102.9	2.2	96.7	3.6	101.1	3.5
AVERAGE	98.9	2.6	105.2	1.5	102.9	2.8
SD	4.1	0.3	4.0	0.9	4.0	0.6
C1	98.3	2.1	98.4	3.5	106.3	2.1
C2	96.5	2.0	98.1	3.3	105.4	2.4
C3	93.9	2.6	100.8	3.3	103.1	2.7
C4	98.2	2.0	100.5	2.9	96.6	3.0
C5	97.5	2.0	99.3	3.0	100.7	2.8
C6	98.9	2.5	96.3	3.5	103.9	2.6
C7	97.6	2.6	99.9	3.2	94.4	3.6
C8	91.6	3.4	102.2	2.9	106.5	2.7
C9	99.2	2.9	100.9	3.5	104.2	2.4
C10	96.8	2.9	94.7	3.6	109.2	2.1
AVERAGE	96.9	2.5	99.1	3.3	103.0	2.6
SD	2.3	0.5	2.2	0.2	4.4	0.4
D1	97.3	2.2	102.9	3.4	105.2	2.2
D2	99.0	2.3	108.8	2.1	100.6	2.5
D3	96.7	2.9	111.3	3.4	104.1	2.2
D4	99.5	3.1	110.7	1.2	102.1	3.2
D5	103.7	2.1	110.7	1.2	100.8	3.3
D6	98.5	2.8	98.1	4.1	101.0	3.0
D7	102.6	2.7	99.7	3.2	99.3	3.5
D8	91.0	2.8	106.7	0.9	95.0	4.2
D9	101.8	2.1	109.6	0.8	103.0	3.3
D10	103.0	2.3	106.8	0.6	108.1	2.8
AVERAGE	99.3	2.5	106.5	2.1	101.9	3.0
SD	3.6	0.3	4.5	1.2	3.4	0.6

DENSITY AND MOISTURE DATA FOR FIRING RANGE RESTORATION PROJECT
DENSITY IN POUNDS PER CUBIC FOOT AND MOISTURE IN PERCENT

GRID LOCATION	RADIATION METHOD NORTH PILE		RUBBER-BALLOON METHOD NORTH PILE	
	DENSITY	MOISTURE	DENSITY	MOISTURE
C1	106.3	2.1	106.0	1.3
C2	105.4	2.4	100.3	2.0
C3	103.1	2.7	102.1	3.2
C4	96.6	3.0	94.7	2.6
C5	100.7	2.8	105.0	1.6
C6	103.9	2.6	107.8	2.9
C7	94.4	3.6	92.9	2.9
C8	106.5	2.7	115.0	2.4
C9	104.2	2.4	91.9	2.9
C10	109.2	2.1	108.9	2.0
AVERAGE	103.0	2.6	102.5	2.4
SD	4.4	0.4	7.2	0.6

MATERIAL TEST DIRECTORATE
YUMA PROVING GROUND
YUMA, ARIZONA

LABORATORY SERVICES BRANCH TEST REPORT

Item: pH of Soils **Date: 16 Nov 1992**

Project Engineer: Sylvia M. Medina

Comments: This report is the documentation of the Soil pH for the Sampling and Analysis Plan for the Yuma Proving Ground Firing Range Restoration Project.

Test Results

The Soil pH was measured using the soil from the 14 samples taken by INEL on 2 - 5 November 1992 and submitted to the Material Analysis Laboratory labeled PP for physical properties. The method used for the pH measurement was "Soil pH (Hydrogen Ion Activity): Intensity Factor of Soil Acidity" From Methods of Soil Analysis Part I and II, A. Klute ed., American Society of Agronomy, Madison, WI. From the method, section 12-2.6 "Glass Electrode-Calomel Electrode pH Meter Method" was used to take the readings from the 14 samples.

To the method the following modifications were made:

1. Buffer solutions of pH 7 and 10 were used rather than the recommended pH 7 and 4. The reason for this is that the desert soil at YPG is alkali in nature normally having a pH of about 8. By using buffers of pH 7 and 10 the area that the unknown samples are suspected to being in is bracketed.

2. The soil and water were both weighed rather than the water being pipetted. This method was more convenient and will give identical results.

3. 10 grams of soil and 10 grams of deionized water were used rather than the recommended 5 grams of soil and 5 ml of water. The doubling of the amounts was done so that total immersion of the electrode tips could be achieved.

4. Mechanical stirring was used.

The pH analyzer used was a Fisher Accument Selective Ion Analyzer with Automatic Temp. Compensation, Model 750, S/N 1313. The electrode was an Orion Combination Gel-Filled pH, Model 91-05. The two buffers were VWR, Blue Borate Buffer Solution pH10 (10.00+/-0.01 @ 25 Deg. C), traceable to National Institute of Standards and Technology SRM 191 and 192, and VWR Yellow Phosphate Buffer Solution pH7 (7.00+/-0.01 @ 25 Deg. C) traceable to National Institute of Standards and Technology SRM 186 I and II.

SOIL pH RESULTS
All pH values are +/-0.1

LAB NO.	INEL NO.	pH	TIME
92-4559	YPG-110392-SP-01-PP	7.9	12:05
92-4562	YPG-110392-SP-02-PP	8.3	12:06
92-4565	YPG-110392-SP-03-PP	8.2	12:07
92-4568	YPG-110392-SP-04-PP	8.2	12:08
92-4575	YPG-110492-NP-01-PP	8.1	12:09
92-4578	YPG-110492-NP-02-PP	7.9	12:09
92-4581	YPG-110492-NP-03-PP	7.9	12:10
92-4584	YPG-110492-NP-04-PP	8.0	12:11
92-4659	YPG-110592-WP-01-PP	7.7	12:12
92-4662	YPG-110592-WP-02-PP	7.7	12:12
92-4665	YPG-110592-WP-02-PP(b)	7.7	12:13
92-4668	YPG-110592-WP-03-PP	7.8	12:14
92-4674	YPG-110592-BK-01-PP	7.8	12:15
92-4675	YPG-110592-WP-04-PP	7.8	12:15
	LABORATORY DUPLICATE SAMPLES		
92-4562	YPG-110392-SP-02-PP	8.3	12:18
92-4662	YPG-110592-WP-02-PP(b)	7.8	12:19

INSPECTED BY: ______________________

DAVID L. POND
Chemist
Material Analysis Laboratory

MATERIAL TEST DIRECTORATE
YUMA PROVING GROUND
YUMA, ARIZONA

LABORATORY SERVICES BRANCH TEST REPORT

Item: Particle Density of Soil **Date:** 24 Nov 1992

Project Engineer: Sylvia M. Medina

Comments: This report is the documentation of the Particle Density data for the Sampling and Analysis Plan for the Yuma Proving Ground Firing Range Restoration Project.

Test Results

The particle density was measured using the soil from the 14 samples taken by INEL on 2 - 5 November 1992 and submitted to the Material Analysis Laboratory, labeled for physical properties. The method used for the particle density was "Particle Density" From Methods of soil Analysis Part I and II, A. Klute ed., American Society of Agronomy, Madison, WI. From the method, section 14-3 "Pycnometer Method" was used to take the data for the 14 samples.

To the method the following modifications were made:

1. Rather than using air dry soil and subtracting out the moisture, oven dry soil was used.

The balance used for all measurements was a Mettler PE3600 top loading balance, S/N E32675. The pycnometers were 100-mL volumetric flasks. The water was 17.7 megohm water.

A copy of this report is on a 3.5 inch HD disk included in this data package. This cover sheet is a WordPerfect file which is in the subdirectory WP under its file name DU-PARTI. The data is a Lotus 1-2-3 file which is in the subdirectory 123 under its file name DU-PART.

INSPECTED BY: ______________________
DAVID L. POND
Chemist
Material Analysis Laboratory

PARTICLE DENSITY DATA FOR FIRING RANGE RESTORATION PROJECT
DENSITY IN GRAMS PER CUBIC CENTIMETER AND WEIGHTS IN GRAMS

SAMPLE NUMBER	FLASK Wa	FLASK SOIL Ws	FLASK SOIL WATER Wsw	TEMP C	FLASK WATER Ww	PARTICLE DENSITY g/cm3	PARTICLE DENSITY lb/cu ft
92-4559	69.51	119.03	207.75	23	176.40	2.7	169.7
92-4562	69.35	119.44	208.24	23	176.42	2.7	170.7
92-4565	69.06	119.56	208.89	23	176.70	2.8	171.8
92-4568	70.29	120.33	208.72	23	177.00	2.7	170.1
92-4575	68.72	117.90	205.94	23	174.82	2.7	169.6
92-4578	70.56	119.07	206.56	23	175.73	2.7	170.9
92-4581	69.72	119.10	208.05	23	176.66	2.7	170.9
92-4584	67.97	121.71	208.69	23	174.41	2.8	172.0
92-4659	71.39	121.36	209.17	23	177.42	2.7	170.8
92-4662	69.78	119.23	208.69	23	177.25	2.7	171.0
92-4665	69.84	119.01	207.67	23	176.49	2.7	170.2
92-4668	71.18	120.95	208.34	23	176.64	2.7	171.5
92-4674	59.82	107.95	194.95	23	164.53	2.7	169.2
92-4675	70.49	120.75	208.41	23	176.50	2.7	170.6
		LABORATORY DUPLICATE SAMPLES					
92-4659	69.90	116.74	206.89	23	177.19	2.7	170.2
92-4584	59.20	106.64	200.60	23	170.48	2.7	170.6

DENSITY OF WATER AT 23 DEG C =0.997534

MATERIAL TEST DIRECTORATE
YUMA PROVING GROUND
YUMA, ARIZONA

LABORATORY SERVICES BRANCH TEST REPORT

Item: Particle Size of Soils **Date: 23 Nov 1992**

Project Engineer: Sylvia M. Medina

Comments: This report is the documentation of the Soil Particle Size for the Sampling and Analysis Plan for the Yuma Proving Ground Firing Range Restoration Project.

Test Results

The particle size was measured using the soil from the 14 samples taken by INEL on 2 - 5 November 1992 and submitted to the Material Analysis Laboratory, labeled for physical properties. The method used for the particle size analysis was ASTM D421 "Dry Preparation of Soil Samples for Particle-size Analysis and Determination of Soil Constants" and ASTM D422 "Standard Test Method for Particle-size Analysis of Soils".

To the method the following modifications were made:

1. The entire sample bottle of soil was used for the sieving. This gave only about 50% of the required 500 grams of soil that should be retained on the No. 10 sieve which is used for the course fraction.

2. The less than 75 micron fraction was analyzed in water using a Malvern, MasterSizer IP laser ensemble light scattering particle size analyzer S/N 8019.It was used rather than the listed hydrometer method because of its superior speed and quality or results. The analyzer was calibrated using AC fine dust from AC Spark Plug Division of General Motors Corp. The Material Analysis Laboratory Operating Procedure used is tilled "Particle Size Analysis on the Melvern".

3. Through past experience it is known that the fine sieving procedure in D422 will not work on most soils at YPG. The soil will cake upon drying and not pass through the sieves. The procedure that will give repeatable results is as follows.

   A. Dry sieve the 100 grams of fines through the sieve set on a sieve shaker for 10 minutes.

   B. Wash each sieve with water through the lower sieves until the wash water is clear. Save the Wash water, dry, weigh, and run on the Malvern.

C. Dry the sieves in an oven at 105 Deg. C.

D. Sieve on a sieve shaker for 5 minutes.

E. Weigh the sieves.

The sieves used were U.S. Standard Testing Sieves with a Certificate of Compliance to specifications of ASTM Specification E-11-81. The balance was a Sartorius Model 3876 MP8-2 top loading balance, S/N 37030063.

All calculations were made using a Lotus 1-2-3 Spreadsheet program. A copy of each data file is included in this data package on a 3.5 inch HD disk. The files are in a subdirectory called 123 with the files listed as DU-xxxx where xxxx is the YPG sample number. Example: YPG-110392-SP-02-PP which is YPG No. 92-4562 is filed under DU-4562. The data and graph were printed from the 1-2-3 file. This cover sheet is a WordPerfect file which is in the subdirectory WP under its file name DU-SIEVE.

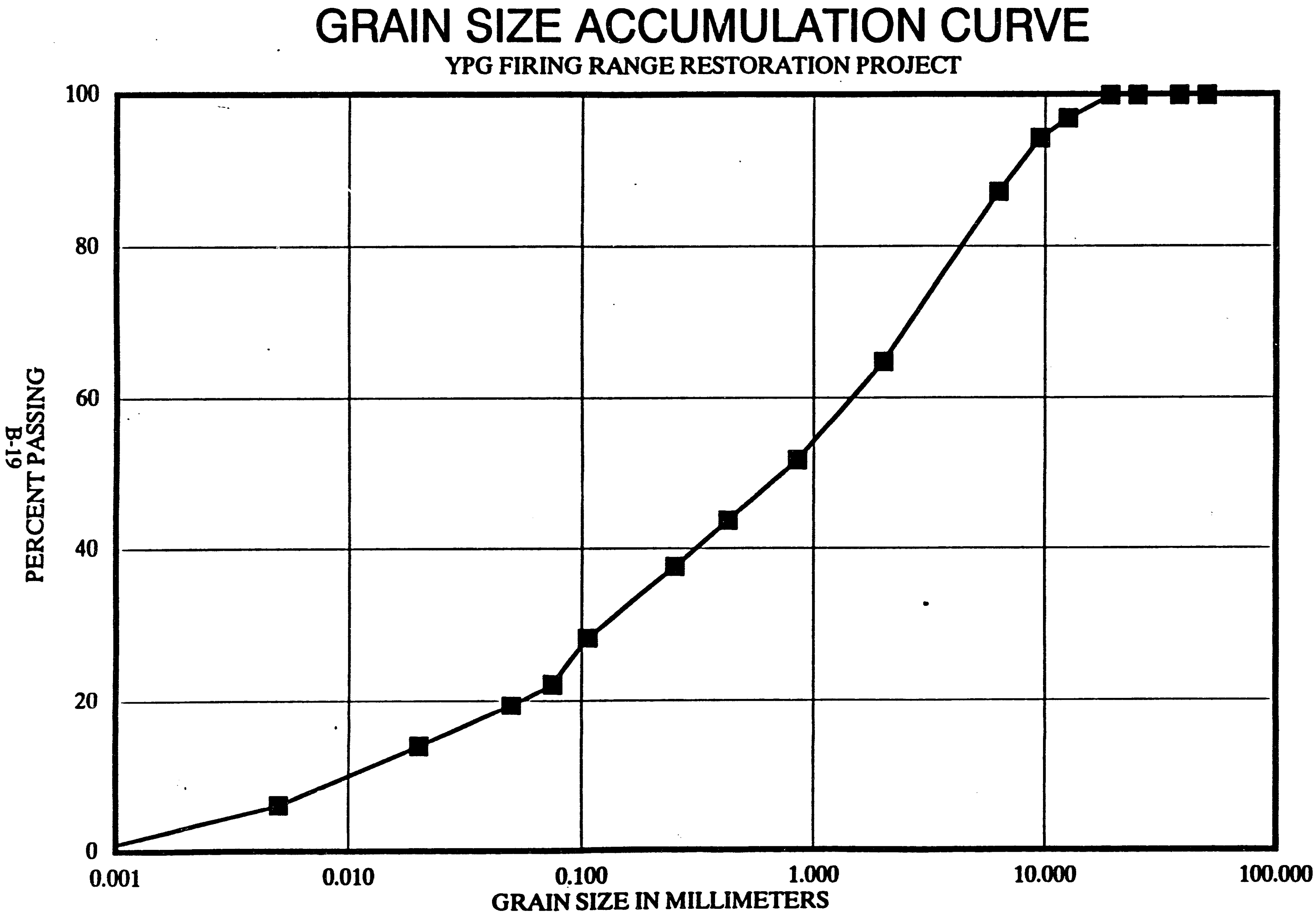
INSPECTED BY: ________________________
DAVID L. POND
Chemist
Material Analysis Laboratory

```
              SAMPLE NUMBER  =   YPG-110392-SP-01-PP (92-4559)
                                 ALL WEIGHTS ARE IN GRAMS
    SAMPLE PREP ASTM D421
                                 TARE WT.  FULL WT.   NET WT.  % TOTAL % PASSING
           STARTING SOIL WEIGHT   1105.9    1817.9     712.0  RETAINED
                #10 SIEVE WEIGHT   502.8     761.8     259.0
    COURSE TOTAL SOIL WEIGHT                           251.1      35.3
                PAN SIEVE WEIGHT   368.3     797.6     429.3
            WASH WATER SOIL WT     383.7     406.4      22.7
       FINES TOTAL SOIL WEIGHT                         459.9      64.7
    SUM COURSE & FINE WEIGHTS                          711.0     100.0
                            LOSS                         1.0
                PERCENT RECOVERY                        99.9

    COURSE SIEVE ASTM D422
              SIEVE SIZE          TARE WT.  FULL WT.  NET WT.
         50.0 MM   2.000 INCH      778.1     778.1      0.0        0.0       99.9
         38.1 MM   1.500 INCH      793.4     793.4      0.0        0.0       99.9
         25.0 MM   1.000 INCH      844.8     844.8      0.0        0.0       99.9
         19.0 MM   0.750 INCH      773.8     773.8      0.0        0.0       99.9
         12.5 MM   0.500 INCH      793.2     814.8     21.6        3.0       96.8
          9.5 MM   0.375 INCH      840.9     859.4     18.5        2.6       94.2
          6.3 MM   0.250 INCH      808.3     858.9     50.6        7.1       87.1
         2.00 MM          #10      457.7     617.1    159.4       22.4       64.7
                          PAN      372.4     380.3      7.9        1.1
                        TOTAL                         258.0
                         LOSS                           1.0
             PERCENT RECOVERY                          99.6
    ADJUSTED TOTAL REMOVE PAN WEIGHT <#10 SIEVE       250.1       35.2

    FINES SIEVE ASTM D422
                                  TARE WT.  FULL WT.  NET WT.
            FINES SOIL WEIGHT      176.5     278.1    101.6       64.7
       PERCENT OF TOTAL FINES                          22.1
              SIEVE SIZE
                0.850 MM  #20      416.3     436.4     20.1       13.1       51.6
                0.425 MM  #40      378.6     391.0     12.4        8.1       43.6
                0.250 MM  #60      358.7     368.0      9.3        6.0       37.5
                0.106 MM #140      353.1     367.5     14.4        9.4       28.2
                0.075 MM #200      351.8     361.2      9.4        6.1       22.1
                          PAN      770.5     804.5     34.0       22.1
                    SUB TOTAL                          99.6       64.7
                         LOSS                           2.0
             PERCENT RECOVERY                          98.0

    LASER PARTICLE SIZING           %         %     % PASSING
        MICROM BRACKET RANGE      53.4      48.7
                    0.050 MM      89.1      86.9      87.5        2.8       19.3
        MICRON BRACKET RANGE      21.0      19.1
                    0.020 MM      64.4      61.8      63.0        5.4       13.9
        MICRON BRACKET RANGE       5.2       4.7
                    0.005 MM      28.9      26.9      28.2        7.7        6.2
        MICRON BRACKET RANGE       1.1       1.0
                    0.001 MM       4.6       3.9       4.2        5.3        0.9
         LESS THAN 0.001 MM                                       0.9
                   SUB TOTAL                                     22.1
```



YPG-110392-SP-01-PP
92-4559

```
[illegible] Instruments [illegible]

Dispersant   : None
Additives    : [illegible]
Ultrasound   : None
Pump speed   : [illegible]
Stir speed   : [illegible]
Notes        :
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```
High  Under |High  Under |High  Under |High  Under |High  Under |High  Under || Span
Size    %   |Size    %   |Size    %   |Size    %   |Size    %   |Size    %   ||  4.[illegible]
---------------------------------------------------------------------------------------
[illegible]  [illegible] |54.[illegible] [illegible] |[illegible] [illegible] |8.[illegible] [illegible] |[illegible] [illegible] |[illegible] [illegible] || [illegible]
154   99.[illegible] |[illegible] [illegible] |[illegible]  24.4 |7.[illegible] [illegible] |[illegible] [illegible] |[illegible] [illegible] ||  22.2[illegible]um
136   [illegible].4 |[illegible] [illegible] |[illegible]  2[illegible].5 |[illegible] [illegible] |[illegible] [illegible] |[illegible] [illegible] || D[illegible]
124   99.[illegible] |[illegible]  24.5 |15.[illegible] [illegible].7 |5.57  [illegible] |[illegible] [illegible] |[illegible] [illegible] ||  4.50um
112   99.[illegible] |[illegible] [illegible] |[illegible] [illegible] |5.[illegible]7 [illegible] |[illegible] [illegible] |[illegible] [illegible] || [illegible]
103   98.0 |[illegible] [illegible] |[illegible] [illegible] |4.7[illegible] [illegible] |[illegible] [illegible] |[illegible] [illegible] ||  53.58um
[illegible]  97.3 |[illegible] [illegible] |[illegible]  4[illegible].3 |4.2[illegible] [illegible] |[illegible] [illegible] |[illegible] [illegible] || D(v,0.1)
[illegible] [illegible] |[illegible] [illegible] |[illegible] [illegible] |[illegible] [illegible] |[illegible] [illegible] |[illegible] [illegible] ||  1.76um
77.[illegible] [illegible] |[illegible] [illegible] |[illegible] [illegible] |3.5[illegible] 21.2 |[illegible] [illegible] |
70.7  [illegible] |[illegible] [illegible] |[illegible] [illegible] |3.2[illegible] 19.[illegible] |[illegible] [illegible] |
---------------------------------------------------------------------------------------
Source =      Sample   Beam length =  2.4 mm  Model indp                   || D(v,0.5)
                       Residual    =  [illegible] %                        ||  12.03um
Focal length =  100 mm Obscuration = 0.2[illegible]  Volume Conc. = 0.[illegible]%
Presentation = [illegible]  Volume distribution  Sp.S.A [illegible] m²/cc.
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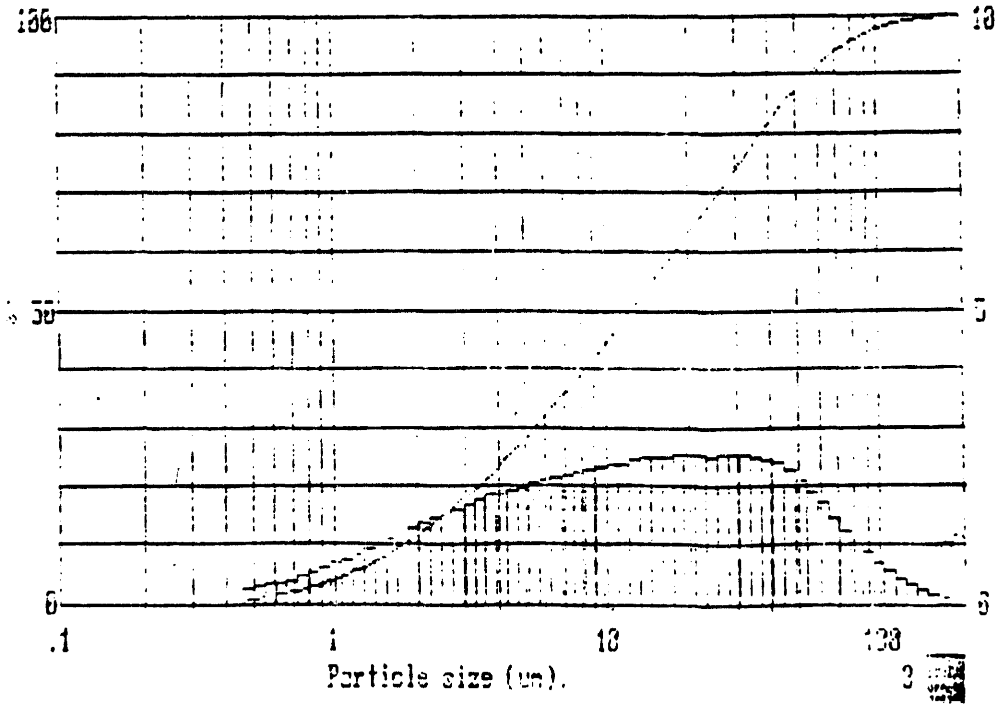


YUMA PROVING GROUND

```
        SAMPLE NUMBER  =    YPG-110392-SP-02-PP (92-4562)
                            ALL WEIGHTS ARE IN GRAMS
SAMPLE PREP ASTM D421
                            TARE WT. FULL WT.  NET WT.  % TOTAL % PASSING
     STARTING SOIL WEIGHT    1196.3   1953.5    757.2 RETAINED
         #10 SIEVE WEIGHT     592.4    872.7    280.3
COURSE TOTAL SOIL WEIGHT                        272.4     36.1
        PAN SIEVE WEIGHT      368.2    835.1    466.9
       WASH WATER SOIL WT     374.7    382.6      7.9
  FINES TOTAL SOIL WEIGHT                       482.7     63.9
SUM COURSE & FINE WEIGHTS                       755.1    100.0
                     LOSS                         2.1
         PERCENT RECOVERY                        99.7

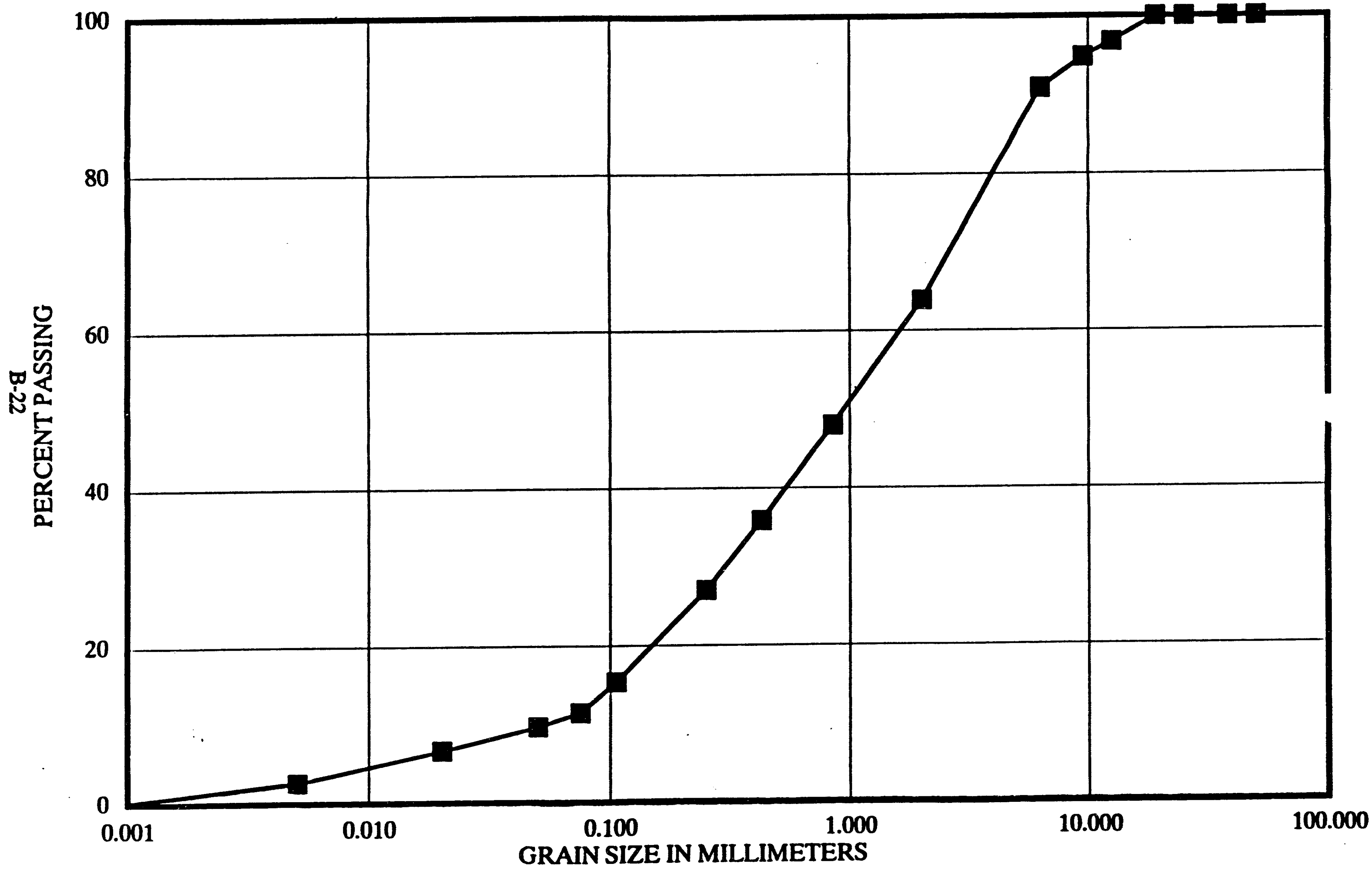
COURSE SIEVE ASTM D422
        SIEVE SIZE          TARE WT. FULL WT.  NET WT.
     50.0 MM   2.000 INCH     778.1    778.1      0.0      0.0     100.0
     38.1 MM   1.500 INCH     793.4    793.4      0.0      0.0     100.0
     25.0 MM   1.000 INCH     844.8    844.8      0.0      0.0     100.0
     19.0 MM   0.750 INCH     773.8    773.8      0.0      0.0     100.0
     12.5 MM   0.500 INCH     793.3    817.7     24.4      3.2      96.7
      9.5 MM   0.375 INCH     840.5    855.4     14.9      2.0      94.8
      6.3 MM   0.250 INCH     808.2    837.2     29.0      3.8      90.9
     2.00 MM          #10     457.7    661.6    203.9     27.0      63.9
                      PAN     372.4    380.3      7.9      1.0
                    TOTAL                       280.1
                     LOSS                         0.2
         PERCENT RECOVERY                        99.9
ADJUSTED TOTAL REMOVE PAN WEIGHT <#10 SIEVE     272.2     36.0

FINES SIEVE ASTM D422
                            TARE WT. FULL WT.  NET WT.
        FINES SOIL WEIGHT     144.1    244.4    100.3     63.9
    PERCENT OF TOTAL FINES                       20.8
        SIEVE SIZE
           0.850 MM   #20     416.2    441.0     24.8     15.9      48.0
           0.425 MM   #40     378.4    397.3     18.9     12.2      35.8
           0.250 MM   #60     359.0    372.7     13.7      8.8      27.0
           0.106 MM  #140     353.1    371.2     18.1     11.6      15.4
           0.075 MM  #200     351.7    357.7      6.0      3.9      11.5
                      PAN     751.2    769.1     17.9     11.5
                SUB TOTAL                        99.4     63.9
                     LOSS                         0.9
         PERCENT RECOVERY                        99.1

LASER PARTICLE SIZING           %        %    % PASSING
     MICROM BRACKET RANGE      53.4     48.7
                 0.050 MM      86.7     84.1     84.8      1.7       9.8
     MICRON BRACKET RANGE      21.0     19.1
                 0.020 MM      60.5     58.0     59.2      3.0       6.8
     MICRON BRACKET RANGE       5.2      4.7
                 0.005 MM      24.5     22.5     23.8      4.1       2.7
     MICRON BRACKET RANGE       1.1      1.0
                 0.001 MM       2.6      2.1      2.3      2.5       0.3
       LESS THAN 0.001 MM                                 0.3
                SUB TOTAL                                11.5
```

GRAIN SIZE ACCUMULATION CURVE

YPG FIRING RANGE RESTORATION PROJECT



YPG–110392–SP–02–PP
92–4562

[illegible] Instruments [illegible]

[illegible]

[illegible]	: [illegible]
[illegible]	: [illegible]
[illegible]	: [illegible]
[illegible] speed	: [illegible]
[illegible] speed	: [illegible]
[illegible]	:

[illegible] stnd [illegible]

High Size	Under %	High Size	Under %	High Size	Under %	High Size	Under %	High Size	Under %	High Size	Under %	[illegible]
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Model [illegible]

Residual = [illegible]

Focal length = 100 mm

Obscuration = [illegible]

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Volume distribution

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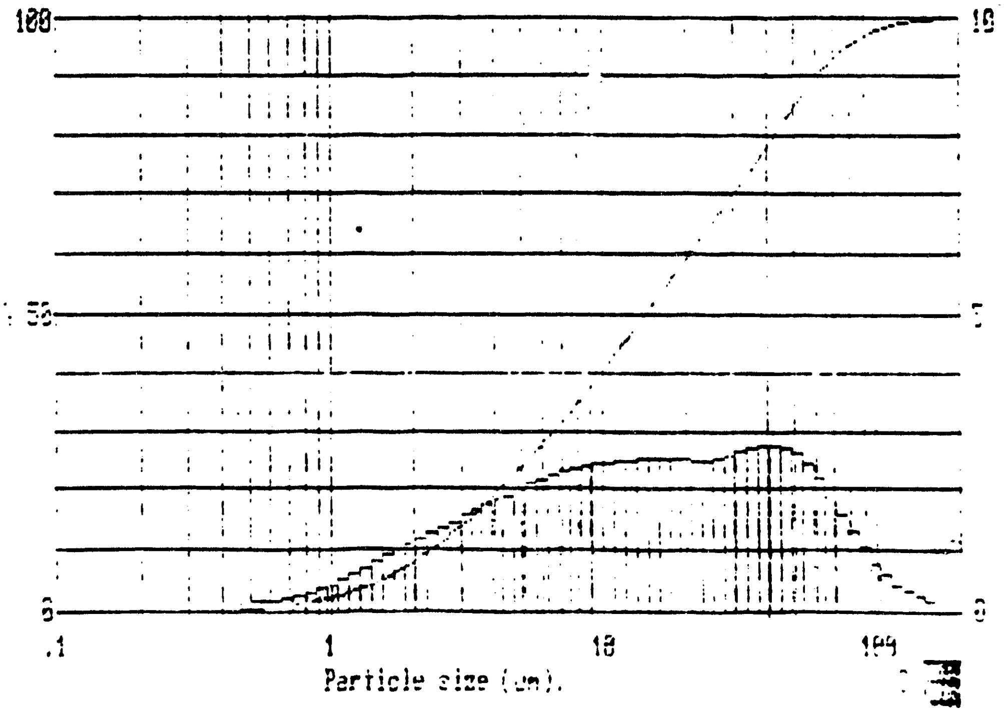

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           SAMPLE NUMBER   =   YPG-110392-SP-03-PP (92-4565)
                               ALL WEIGHTS ARE IN GRAMS
SAMPLE PREP ASTM D421
                               TARE WT. FULL WT.  NET WT.  % TOTAL % PASSING
      STARTING SOIL WEIGHT      1109.3   1758.0    648.7 RETAINED
          #10 SIEVE WEIGHT       503.1    743.8    240.7
COURSE TOTAL SOIL WEIGHT                           227.9     35.4
          PAN SIEVE WEIGHT       368.3    753.4    385.1
        WASH WATER SOIL WT       412.8    430.4     17.6
   FINES TOTAL SOIL WEIGHT                         415.5     64.6
SUM COURSE & FINE WEIGHTS                          643.4    100.0
                      LOSS                           5.3
          PERCENT RECOVERY                          99.2

COURSE SIEVE ASTM D422
        SIEVE SIZE             TARE WT.  FULL WT.  NET WT.
     50.0 MM    2.000 INCH       778.1    778.1      0.0       0.0       99.9
     38.1 MM    1.500 INCH       793.4    793.4      0.0       0.0       99.9
     25.0 MM    1.000 INCH       844.8    844.8      0.0       0.0       99.9
     19.0 MM    0.750 INCH       773.8    773.8      0.0       0.0       99.9
     12.5 MM    0.500 INCH       793.3    815.2     21.9       3.4       96.5
      9.5 MM    0.375 INCH       840.6    893.2     52.6       8.2       88.3
      6.3 MM    0.250 INCH       808.3    851.9     43.6       6.8       81.6
     2.00 MM           #10       457.6    566.9    109.3      17.0       64.6
                       PAN       372.2    385.0     12.8       2.0
                     TOTAL                         240.2
                      LOSS                           0.5
          PERCENT RECOVERY                          99.8
ADJUSTED TOTAL REMOVE PAN WEIGHT <#10 SIEVE        227.4      35.3

FINES SIEVE ASTM D422
                               TARE WT.  FULL WT.  NET WT.
        FINES SOIL WEIGHT        144.1    245.0    100.9      64.6
   PERCENT OF TOTAL FINES                           24.3
        SIEVE SIZE
           0.850 MM    #20       415.8    436.9     21.1      13.9       50.6
           0.425 MM    #40       378.4    390.6     12.2       8.1       42.6
           0.250 MM    #60       358.9    367.6      8.7       5.7       36.8
           0.106 MM   #140       353.1    369.0     15.9      10.5       26.3
           0.075 MM   #200       351.7    361.1      9.4       6.2       20.1
                       PAN       793.4    823.9     30.5      20.1
                 SUB TOTAL                          97.8      64.6
                      LOSS                           3.1
          PERCENT RECOVERY                          96.9

LASER PARTICLE SIZING             %         %     % PASSING
     MICROM BRACKET RANGE      53.4      48.7
                0.050 MM       87.9      85.6       86.2       2.8       17.4
     MICRON BRACKET RANGE      21.0      19.1
                0.020 MM       63.6      61.3       62.4       4.8       12.6
     MICRON BRACKET RANGE       5.2       4.7
                0.005 MM       32.1      30.1       31.4       6.2        6.3
     MICRON BRACKET RANGE       1.1       1.0
                0.001 MM        6.1       5.2        5.6       5.2        1.1
       LESS THAN 0.001 MM                                      1.1
                SUB TOTAL                                     20.1
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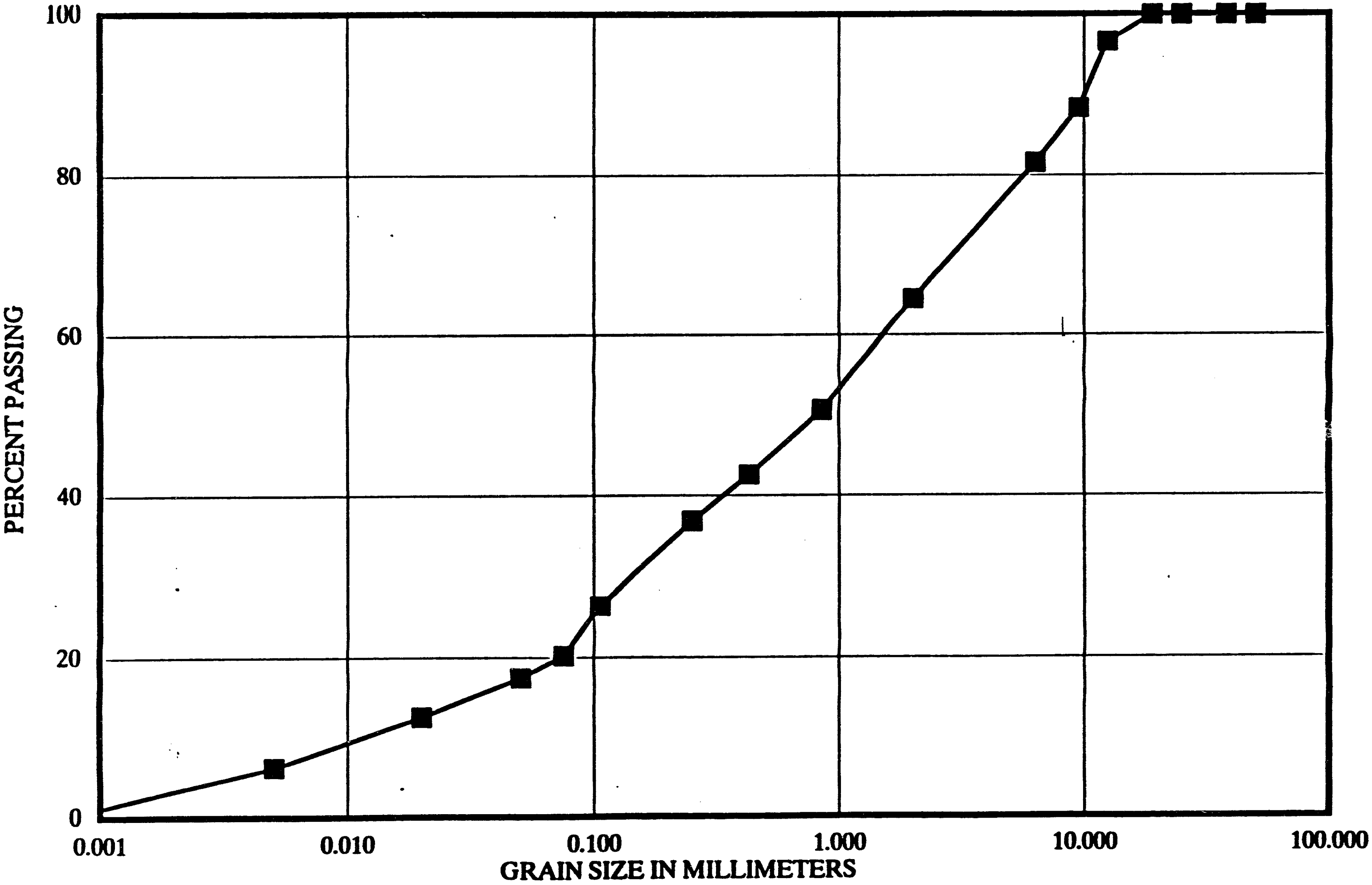
GRAIN SIZE ACCUMULATION CURVE

YPG FIRING RANGE RESTORATION PROJECT



YPG–110392–SP–03–PP
92–4565

MALVERN Instruments [illegible]

[illegible]

High Size	Under %	High Size	Under %	High Size	Under %	High Size	Under %	High Size	Under %	High Size	Under %	Span
188	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	42.1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
164	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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128	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.23	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5.57	34.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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103	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	30.1	1.69	[illegible]	[illegible]	[illegible]	[illegible]
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[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	25.4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
70.5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.27	[illegible]			[illegible]
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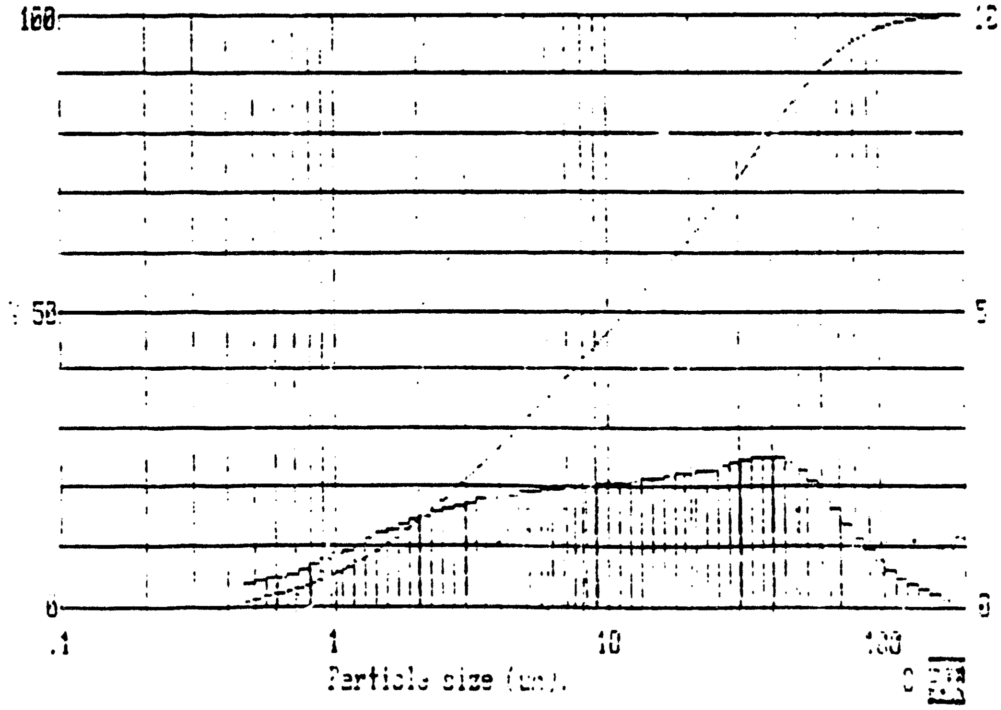
Presentation = [illegible]
Volume distribution
Model indp
Volume Conc. = [illegible]
Sp.S.A [illegible] m²/cc.



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       SAMPLE NUMBER  =   YPG-110392-SP-04-PP (92-4568)
                          ALL WEIGHTS ARE IN GRAMS
SAMPLE PREP ASTM D421
                          TARE WT. FULL WT.  NET WT.  % TOTAL % PASSING
     STARTING SOIL WEIGHT  1199.1   1903.3    704.2 RETAINED
         #10 SIEVE WEIGHT   592.4    855.2    262.8
COURSE TOTAL SOIL WEIGHT                      250.8     35.7
         PAN SIEVE WEIGHT   368.2    796.4    428.2
       WASH WATER SOIL WT   395.5    406.1     10.6
   FINES TOTAL SOIL WEIGHT                    450.8     64.3
SUM COURSE & FINE WEIGHTS                     701.6    100.0
                     LOSS                       2.6
         PERCENT RECOVERY                      99.6

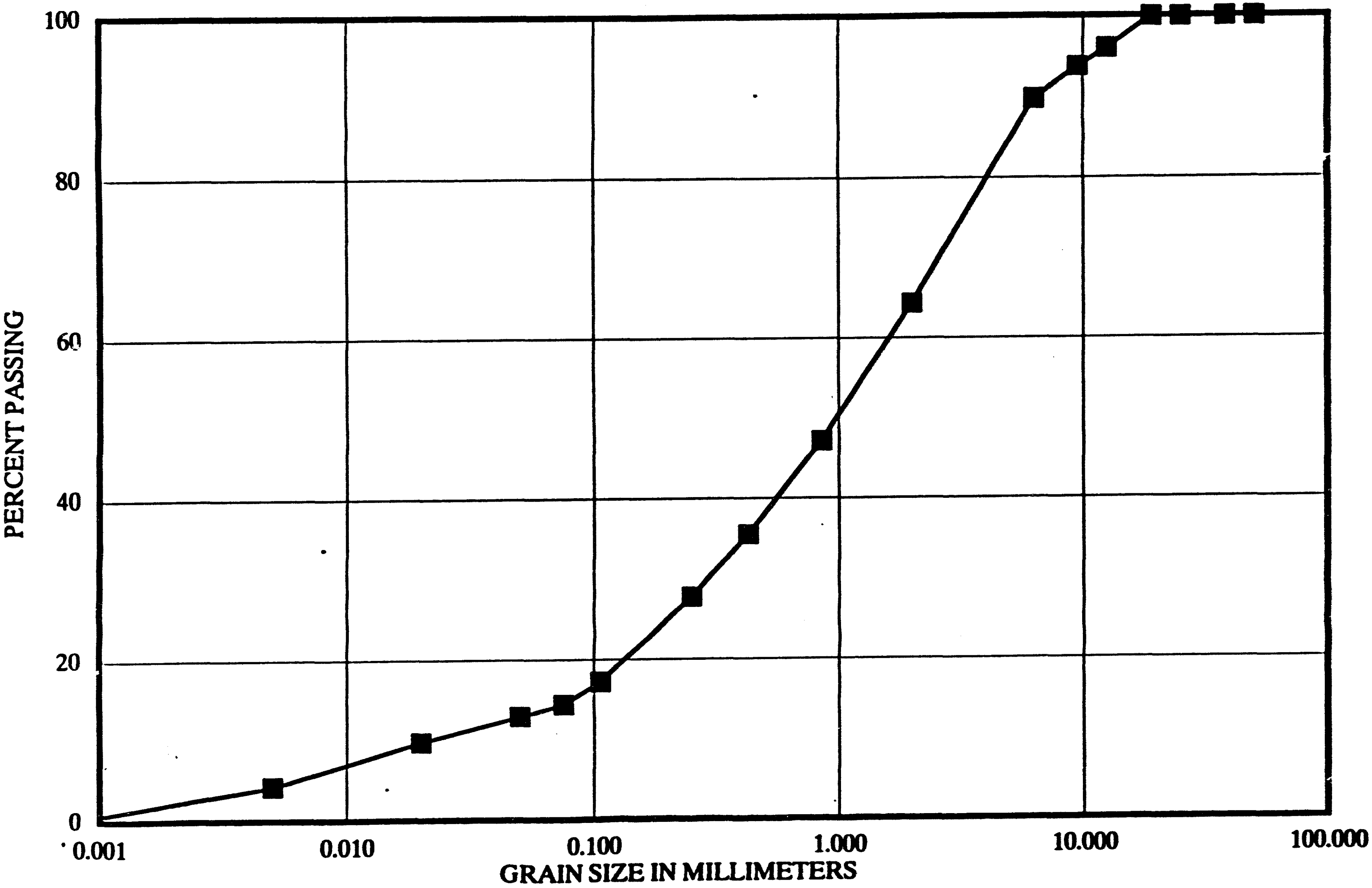
COURSE SIEVE ASTM D422
        SIEVE SIZE        TARE WT. FULL WT.  NET WT.
     50.0 MM   2.000 INCH   778.1    778.1      0.0      0.0      99.9
     38.1 MM   1.500 INCH   793.4    793.4      0.0      0.0      99.9
     25.0 MM   1.000 INCH   844.8    844.8      0.0      0.0      99.9
     19.0 MM   0.750 INCH   773.8    773.8      0.0      0.0      99.9
     12.5 MM   0.500 INCH   793.1    820.1     27.0      3.8      96.1
      9.5 MM   0.375 INCH   840.6    856.7     16.1      2.3      93.8
      6.3 MM   0.250 INCH   808.3    836.5     28.2      4.0      89.8
     2.00 MM          #10   458.0    637.0    179.0     25.5      64.3
                      PAN   372.6    384.6     12.0      1.7
                    TOTAL                     262.3
                     LOSS                       0.5
         PERCENT RECOVERY                      99.8
ADJUSTED TOTAL REMOVE PAN WEIGHT <#10 SIEVE   250.3     35.7

FINES SIEVE ASTM D422
                          TARE WT. FULL WT.  NET WT.
        FINES SOIL WEIGHT   144.1    247.4    103.3     64.3
    PERCENT OF TOTAL FINES                     22.9
        SIEVE SIZE
           0.850 MM   #20   416.2    443.3     27.1     17.1      47.1
           0.425 MM   #40   378.3    396.8     18.5     11.7      35.4
           0.250 MM   #60   358.8    371.0     12.2      7.7      27.7
           0.106 MM  #140   353.0    369.6     16.6     10.5      17.2
           0.075 MM  #200   351.7    356.1      4.4      2.8      14.4
                      PAN   779.2    802.0     22.8     14.4
                SUB TOTAL                     101.6     64.3
                     LOSS                       1.7
         PERCENT RECOVERY                      98.4

LASER PARTICLE SIZING          %        %   % PASSING
     MICROM BRACKET RANGE    53.4     48.7
              0.050 MM       91.2     89.4     89.9      1.5      13.0
     MICRON BRACKET RANGE    21.0     19.1
              0.020 MM       68.9     66.4     67.6      3.2       9.7
     MICRON BRACKET RANGE     5.2      4.7
              0.005 MM       31.4     29.2     30.6      5.3       4.4
     MICRON BRACKET RANGE     1.1      1.0
              0.001 MM        5.5      4.8      5.1      3.7       0.7
       LESS THAN 0.001 MM                                0.7
                SUB TOTAL                               14.4
```

GRAIN SIZE ACCUMULATION CURVE

YPG FIRING RANGE RESTORATION PROJECT



YPG–110392–SP–04–PP
92–4568

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Additives   : [illegible]
Literature  : [illegible]
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[illegible]
Notes       :

[illegible]

| High Under| High Under| High Under| High Under| High Under| High Under|  Span
| Size    % | Size    % | Size    % | Size    % | Size    % | Size    % |  [illegible]
|[illegible]|[illegible]|23.0  71.4 | 8.25  [illegible]|[illegible]|[illegible]|
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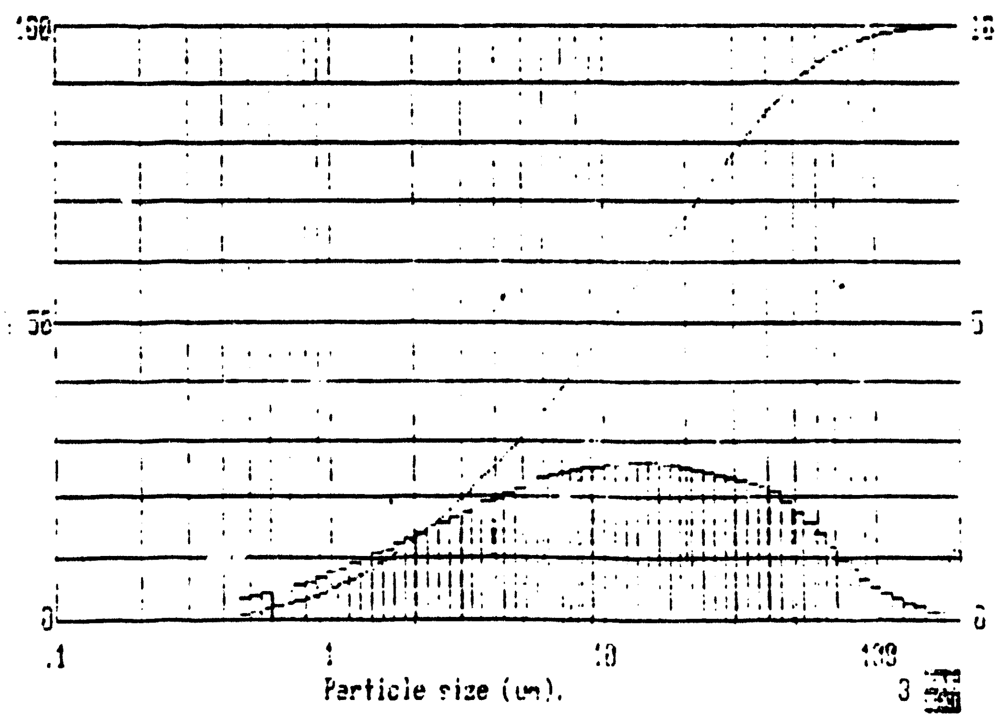

SAMPLE NUMBER = YPG-110492-NP-01-PP (92-4575)
ALL WEIGHTS ARE IN GRAMS

SAMPLE PREP ASTM D421

	TARE WT.	FULL WT.	NET WT.	% TOTAL RETAINED	% PASSING
STARTING SOIL WEIGHT	1109.7	1832.9	723.2		
#10 SIEVE WEIGHT	502.7	804.2	301.5		
COURSE TOTAL SOIL WEIGHT			279.0	38.8	
PAN SIEVE WEIGHT	368.3	770.5	402.2		
WASH WATER SOIL WT	415.3	431.0	15.7		
FINES TOTAL SOIL WEIGHT			440.4	61.2	
SUM COURSE & FINE WEIGHTS			719.4	100.0	
LOSS			3.8		
PERCENT RECOVERY			99.5		

COURSE SIEVE ASTM D422

SIEVE SIZE		TARE WT.	FULL WT.	NET WT.		
50.0 MM	2.000 INCH	778.1	778.1	0.0	0.0	100.0
38.1 MM	1.500 INCH	793.4	793.4	0.0	0.0	100.0
25.0 MM	1.000 INCH	844.8	844.8	0.0	0.0	100.0
19.0 MM	0.750 INCH	773.8	773.8	0.0	0.0	100.0
12.5 MM	0.500 INCH	793.2	851.0	57.8	8.0	92.0
9.5 MM	0.375 INCH	840.5	883.2	42.7	5.9	86.1
6.3 MM	0.250 INCH	808.2	854.2	46.0	6.4	79.7
2.00 MM	#10	457.8	590.6	132.8	18.5	61.2
	PAN	372.3	394.8	22.5	3.1	
	TOTAL			301.8		
	LOSS			-0.3		
	PERCENT RECOVERY			100.1		
ADJUSTED TOTAL REMOVE PAN WEIGHT <#10 SIEVE				279.3	38.8	

FINES SIEVE ASTM D422

		TARE WT.	FULL WT.	NET WT.		
FINES SOIL WEIGHT		144.1	244.9	100.8	61.2	
PERCENT OF TOTAL FINES				22.9		
SIEVE SIZE						
0.850 MM	#20	416.2	436.8	20.6	13.0	48.2
0.425 MM	#40	378.3	391.9	13.6	8.6	39.7
0.250 MM	#60	358.8	368.2	9.4	5.9	33.7
0.106 MM	#140	353.2	370.0	16.8	10.6	23.1
0.075 MM	#200	351.7	360.2	8.5	5.4	17.8
	PAN	789.8	818.0	28.2	17.8	
	SUB TOTAL			97.1	61.2	
	LOSS			3.7		
	PERCENT RECOVERY			96.3		

LASER PARTICLE SIZING	%	%	% PASSING		
MICROM BRACKET RANGE	53.4	48.7			
0.050 MM	87.7	85.2	85.9	2.5	15.3
MICRON BRACKET RANGE	21.0	19.1			
0.020 MM	61.0	58.5	59.7	4.7	10.6
MICRON BRACKET RANGE	5.2	4.7			
0.005 MM	27.7	25.8	27.0	5.8	4.8
MICRON BRACKET RANGE	1.1	1.0			
0.001 MM	4.0	3.4	3.6	4.2	0.6
LESS THAN 0.001 MM				0.6	
SUB TOTAL				17.8	

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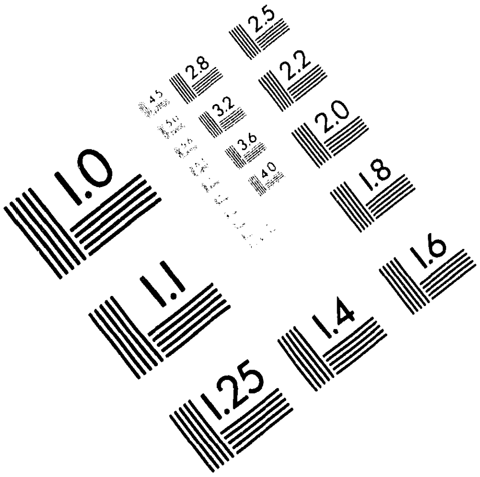

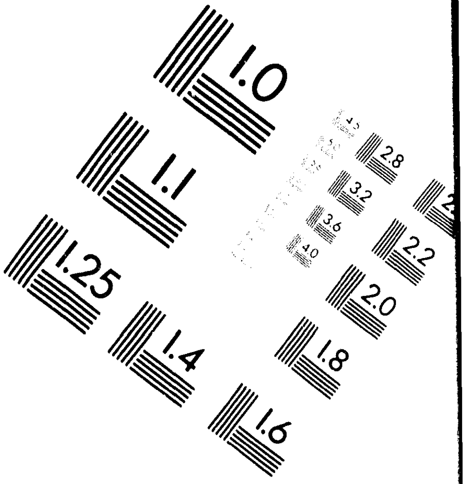

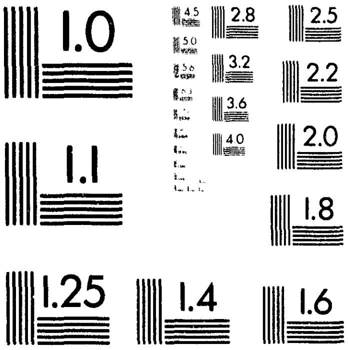

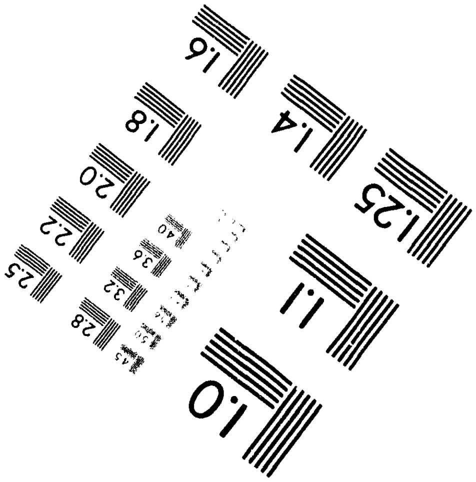

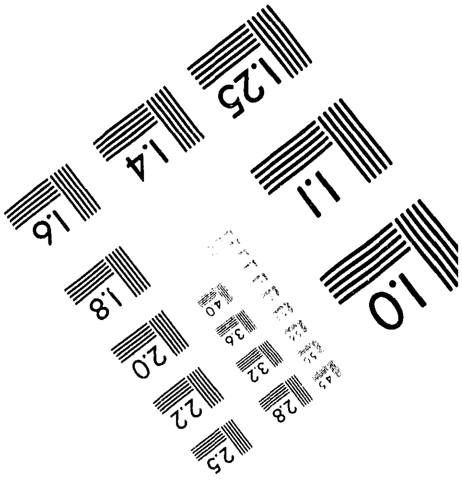

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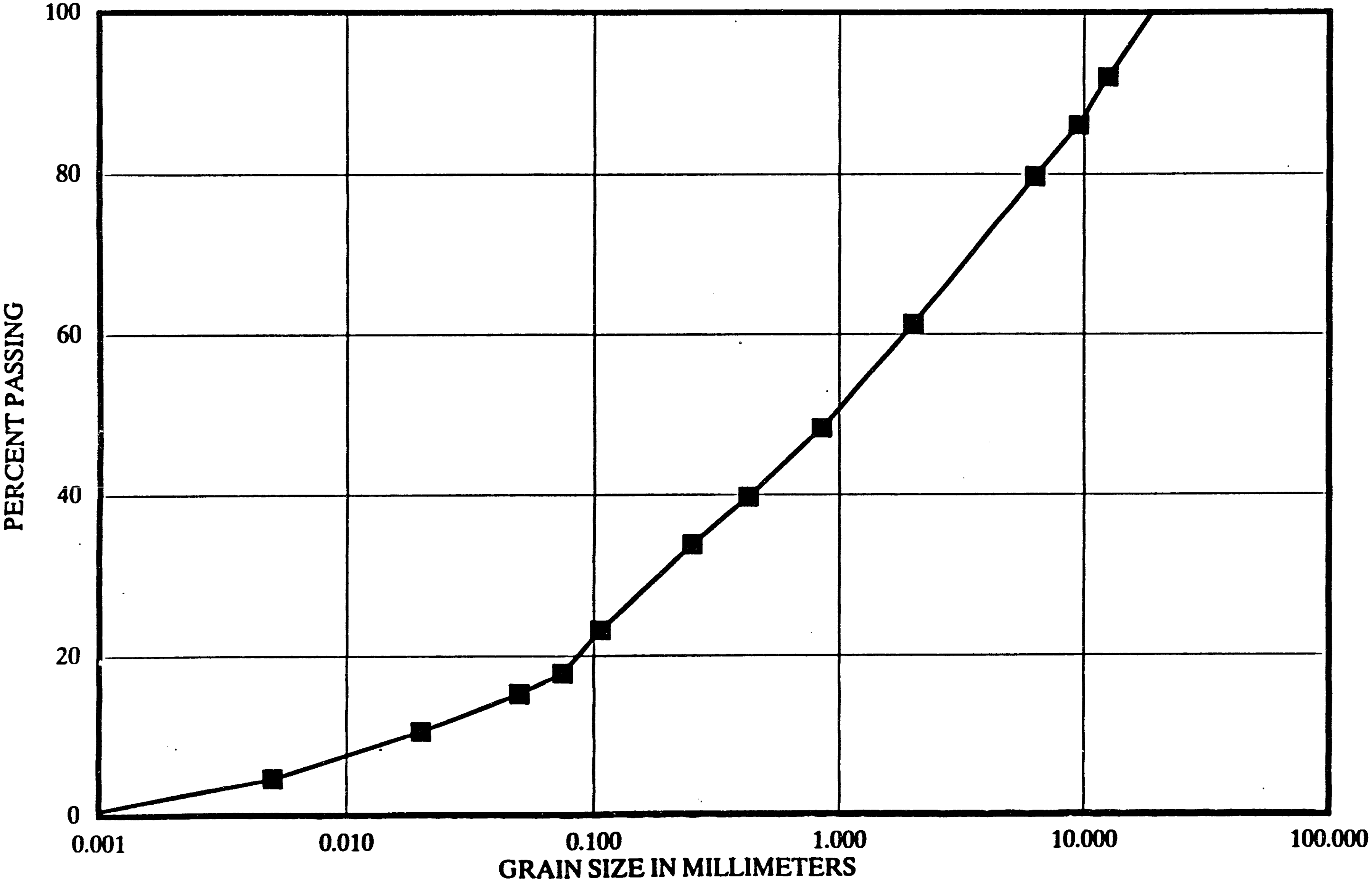
3 of 3

GRAIN SIZE ACCUMULATION CURVE

YPG FIRING RANGE RESTORATION PROJECT



YPG–110492–NP–01–PP
92–4575

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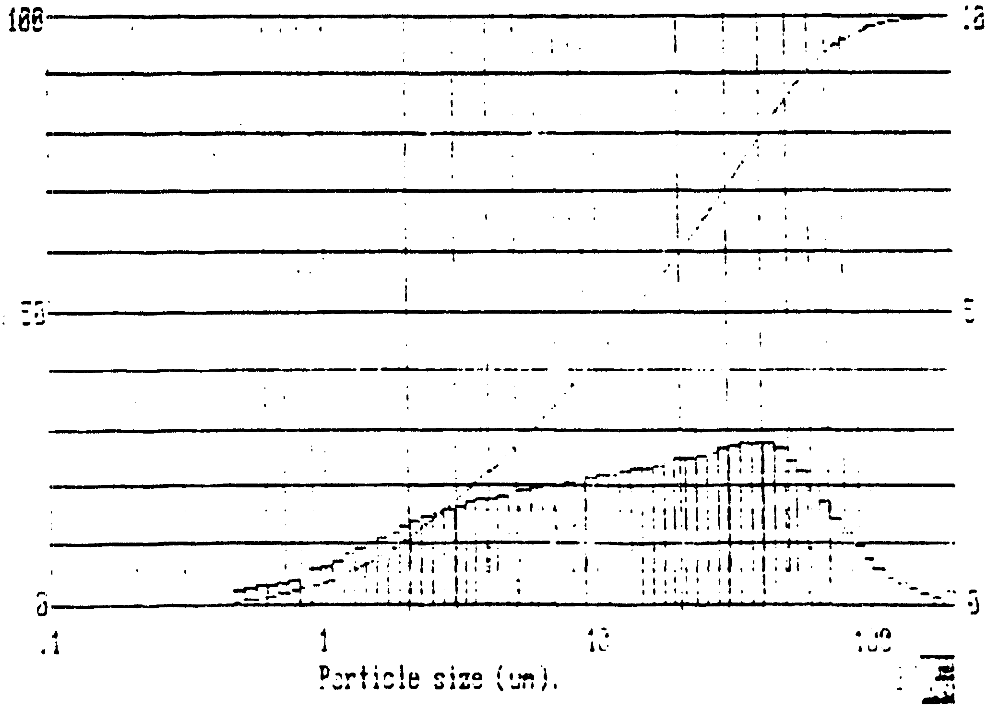

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                          ALL WEIGHTS ARE IN GRAMS
SAMPLE PREP ASTM D421
                          TARE WT. FULL WT.  NET WT.  % TOTAL % PASSING
     STARTING SOIL WEIGHT   1199.1   1847.1    648.0 RETAINED
         #10 SIEVE WEIGHT    592.1    832.2    240.1
COURSE TOTAL SOIL WEIGHT                       229.0     35.5
         PAN SIEVE WEIGHT    368.4    757.0    388.6
       WASH WATER SOIL WT    413.3    429.2     15.9
  FINES TOTAL SOIL WEIGHT                      415.6     64.5
SUM COURSE & FINE WEIGHTS                      644.6    100.0
                     LOSS                        3.4
         PERCENT RECOVERY                       99.5

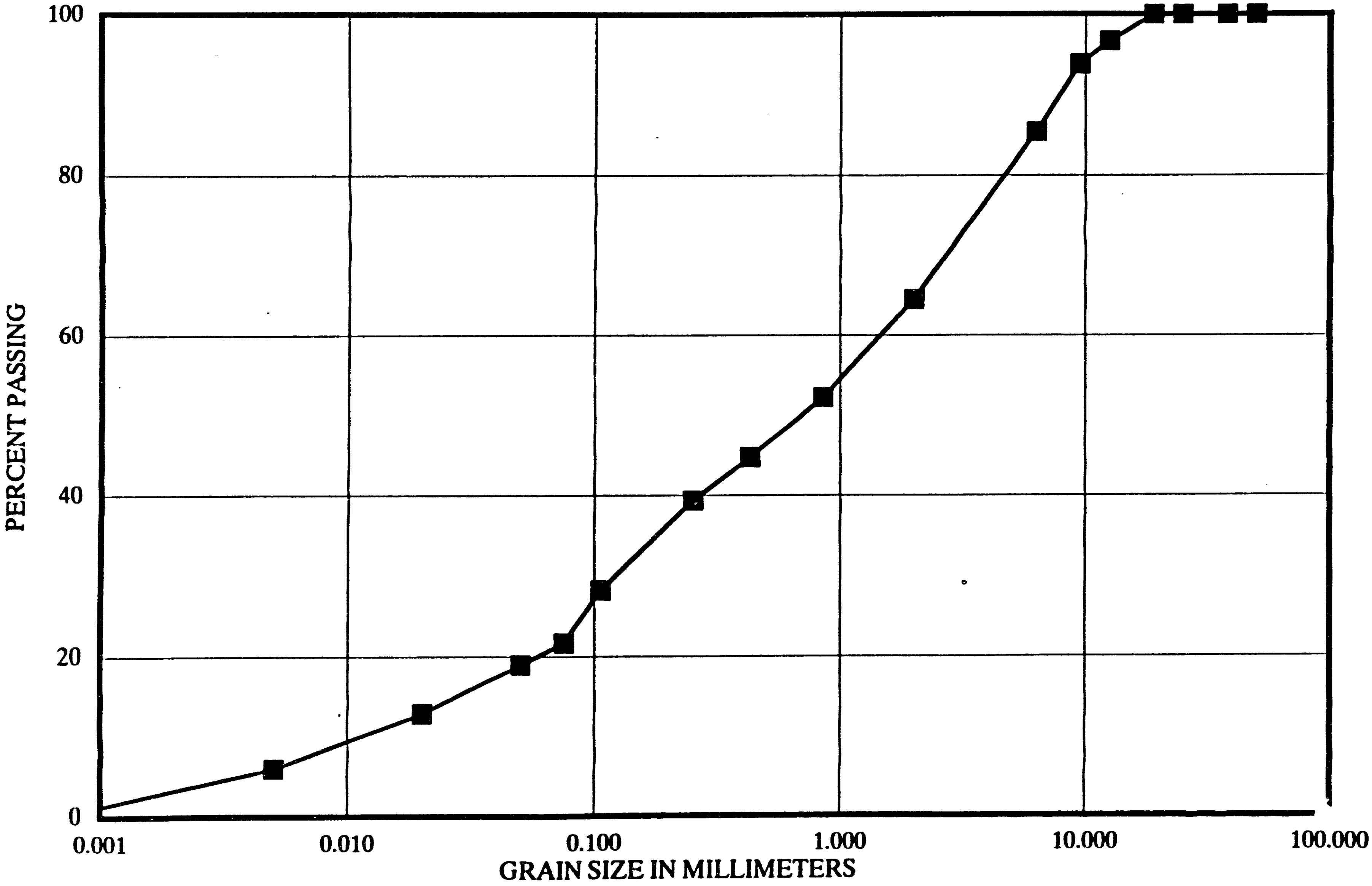
COURSE SIEVE ASTM D422
        SIEVE SIZE        TARE WT. FULL WT.  NET WT.
     50.0 MM   2.000 INCH    778.1    778.1      0.0      0.0    100.0
     38.1 MM   1.500 INCH    793.4    793.4      0.0      0.0    100.0
     25.0 MM   1.000 INCH    844.8    844.8      0.0      0.0    100.0
     19.0 MM   0.750 INCH    773.8    773.8      0.0      0.0    100.0
     12.5 MM   0.500 INCH    793.2    815.0     21.8      3.4     96.6
      9.5 MM   0.375 INCH    840.6    859.1     18.5      2.9     93.7
      6.3 MM   0.250 INCH    808.2    862.4     54.2      8.4     85.3
     2.00 MM          #10    457.7    592.2    134.5     20.9     64.5
                      PAN    372.3    383.4     11.1      1.7
                    TOTAL                      240.1
                     LOSS                        0.0
         PERCENT RECOVERY                      100.0
ADJUSTED TOTAL REMOVE PAN WEIGHT <#10 SIEVE    229.0     35.5

FINES SIEVE ASTM D422
                          TARE WT. FULL WT.  NET WT.
        FINES SOIL WEIGHT    144.1    246.5    102.4     64.5
   PERCENT OF TOTAL FINES                       24.6
        SIEVE SIZE
           0.850 MM   #20    416.2    435.1     18.9     12.3     52.2
           0.425 MM   #40    378.2    389.7     11.5      7.5     44.7
           0.250 MM   #60    358.9    367.1      8.2      5.3     39.3
           0.106 MM  #140    353.1    370.2     17.1     11.1     28.2
           0.075 MM  #200    351.7    361.8     10.1      6.6     21.6
                      PAN    789.9    823.1     33.2     21.6
                SUB TOTAL                       99.0     64.5
                     LOSS                        3.4
         PERCENT RECOVERY                       96.7

LASER PARTICLE SIZING         %         %    % PASSING
     MICROM BRACKET RANGE     53.4     48.7
                 0.050 MM     89.4     86.9     87.6      2.7     18.9
     MICRON BRACKET RANGE     21.0     19.1
                 0.020 MM     61.1     58.5     59.7      6.0     12.9
     MICRON BRACKET RANGE      5.2      4.7
                 0.005 MM     28.7     27.0     28.1      6.8      6.1
     MICRON BRACKET RANGE      1.1      1.0
                 0.001 MM      6.2      5.4      5.7      4.8      1.2
       LESS THAN 0.001 MM                                 1.2
                SUB TOTAL                                21.6
```

GRAIN SIZE ACCUMULATION CURVE

YPG FIRING RANGE RESTORATION PROJECT



YPG–110492–NP–02–PP
92–4578

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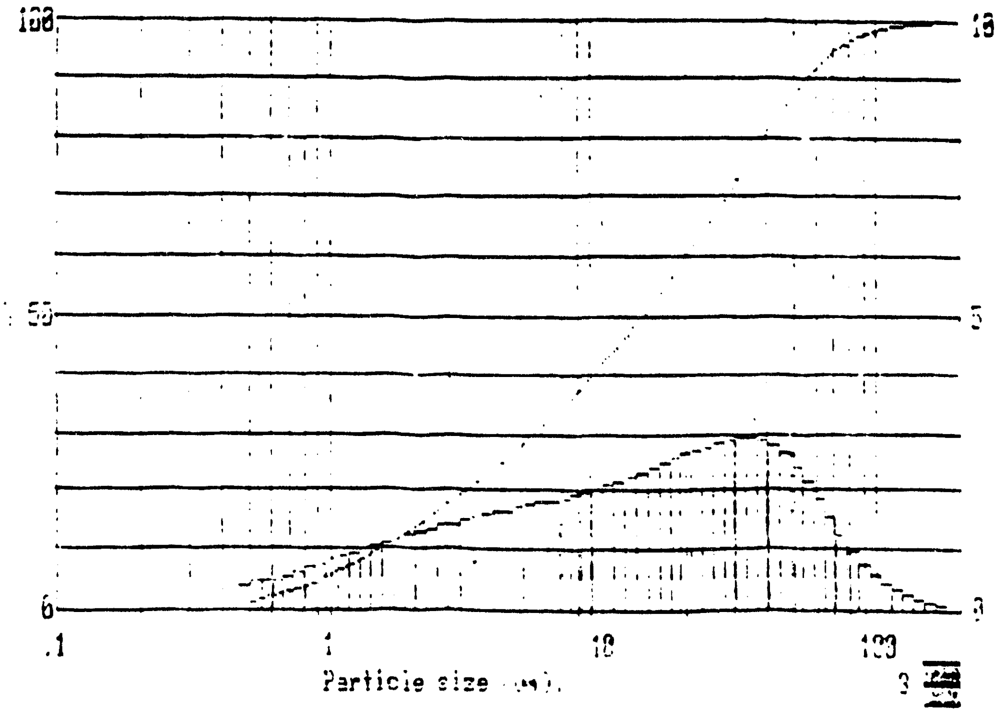


YUMA PROVING GROUND B-35

```
      SAMPLE NUMBER  =   YPG-110492-NP-03-PP (92-4581)
                         ALL WEIGHTS ARE IN GRAMS
SAMPLE PREP ASTM D421
                         TARE WT. FULL WT.  NET WT.  % TOTAL % PASSING
     STARTING SOIL WEIGHT  1109.2   1829.4    720.2 RETAINED
         #10 SIEVE WEIGHT   502.2    788.9    286.7
COURSE TOTAL SOIL WEIGHT                      275.0     38.3
         PAN SIEVE WEIGHT   368.5    789.1    420.6
       WASH WATER SOIL WT   408.3    419.1     10.8
   FINES TOTAL SOIL WEIGHT                    443.1     61.7
SUM COURSE & FINE WEIGHTS                     718.1    100.0
                     LOSS                       2.1
         PERCENT RECOVERY                      99.7

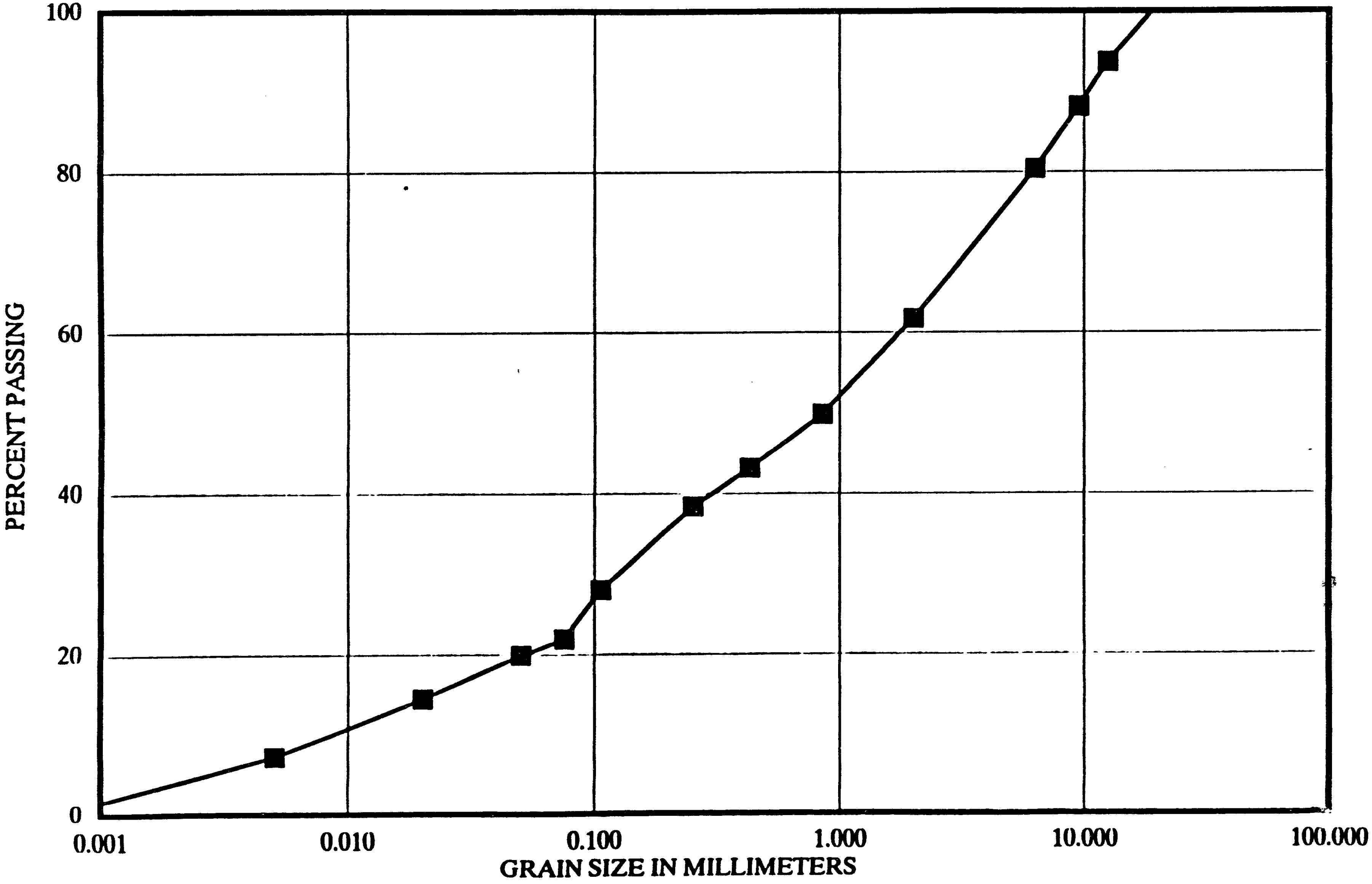
COURSE SIEVE ASTM D422
        SIEVE SIZE       TARE WT. FULL WT.  NET WT.
     50.0 MM   2.000 INCH   778.1    778.1      0.0      0.0     100.0
     38.1 MM   1.500 INCH   793.4    793.4      0.0      0.0     100.0
     25.0 MM   1.000 INCH   844.8    844.8      0.0      0.0     100.0
     19.0 MM   0.750 INCH   773.8    773.8      0.0      0.0     100.0
     12.5 MM   0.500 INCH   793.2    838.7     45.5      6.3      93.7
      9.5 MM   0.375 INCH   840.5    880.5     40.0      5.6      88.1
      6.3 MM   0.250 INCH   808.2    863.8     55.6      7.7      80.4
     2.00 MM          #10   457.4    591.6    134.2     18.7      61.7
                      PAN   372.4    384.1     11.7      1.6
                    TOTAL                     287.0
                     LOSS                      -0.3
         PERCENT RECOVERY                     100.1
ADJUSTED TOTAL REMOVE PAN WEIGHT <#10 SIEVE   275.3     38.3

FINES SIEVE ASTM D422
                         TARE WT. FULL WT.  NET WT.
        FINES SOIL WEIGHT   144.1    245.3    101.2     61.7
    PERCENT OF TOTAL FINES                     22.8
        SIEVE SIZE
           0.850 MM   #20   416.3    435.4     19.1     12.0      49.7
           0.425 MM   #40   378.3    389.0     10.7      6.7      43.0
           0.250 MM   #60   358.8    366.3      7.5      4.7      38.3
           0.106 MM  #140   353.2    369.8     16.6     10.4      27.9
           0.075 MM  #200   351.7    361.4      9.7      6.1      21.9
                      PAN   795.0    829.9     34.9     21.9
                SUB TOTAL                      98.5     61.7
                     LOSS                       2.7
         PERCENT RECOVERY                      97.3

LASER PARTICLE SIZING          %        %    % PASSING
     MICROM BRACKET RANGE    53.4     48.7
                 0.050 MM    92.2     90.3     90.8      2.0      19.9
     MICRON BRACKET RANGE    21.0     19.1
                 0.020 MM    67.6     65.0     66.2      5.4      14.5
     MICRON BRACKET RANGE     5.2      4.7
                 0.005 MM    34.1     32.2     33.4      7.2       7.3
     MICRON BRACKET RANGE     1.1      1.0
                 0.001 MM     8.1      7.1      7.5      5.7       1.6
       LESS THAN 0.001 MM                               1.6
                SUB TOTAL                              21.9
```

GRAIN SIZE ACCUMULATION CURVE

YPG FIRING RANGE RESTORATION PROJECT



YPG−110492−NP−03−PP
92−4581

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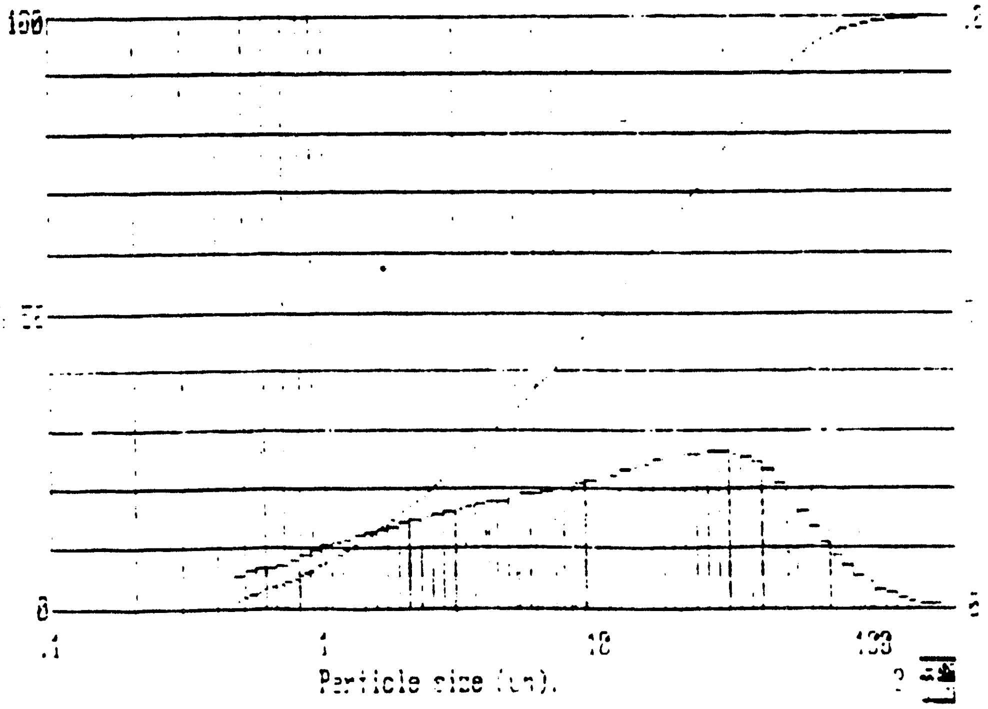

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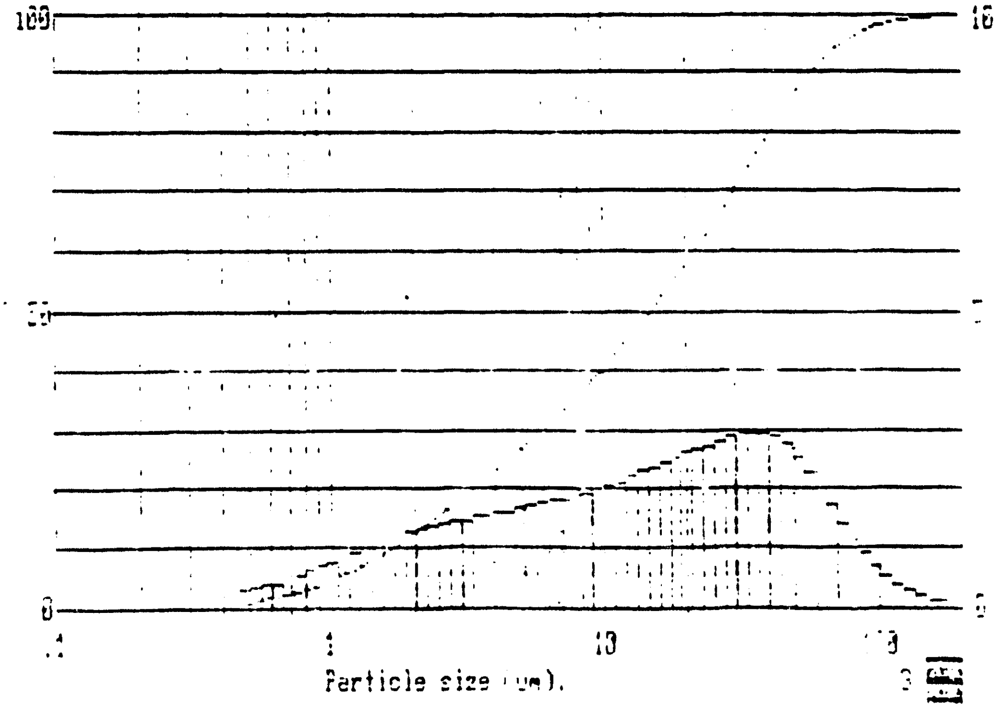


YUMA PROVING GROUND B-39

```
       SAMPLE NUMBER  =    YPG-110492-NP-04-PP (92-4584)
                           ALL WEIGHTS ARE IN GRAMS
SAMPLE PREP ASTM D421
                           TARE WT.  FULL WT.   NET WT.   % TOTAL % PASSING
     STARTING SOIL WEIGHT   1198.6    1826.0     627.4 RETAINED
        #10 SIEVE WEIGHT     591.9     763.1     171.2
COURSE TOTAL SOIL WEIGHT                         162.0      26.0
        PAN SIEVE WEIGHT     368.2     806.1     437.9
      WASH WATER SOIL WT     380.5     395.3      14.8
   FINES TOTAL SOIL WEIGHT                       461.9      74.0
SUM COURSE & FINE WEIGHTS                        623.9     100.0
                     LOSS                          3.5
        PERCENT RECOVERY                          99.4

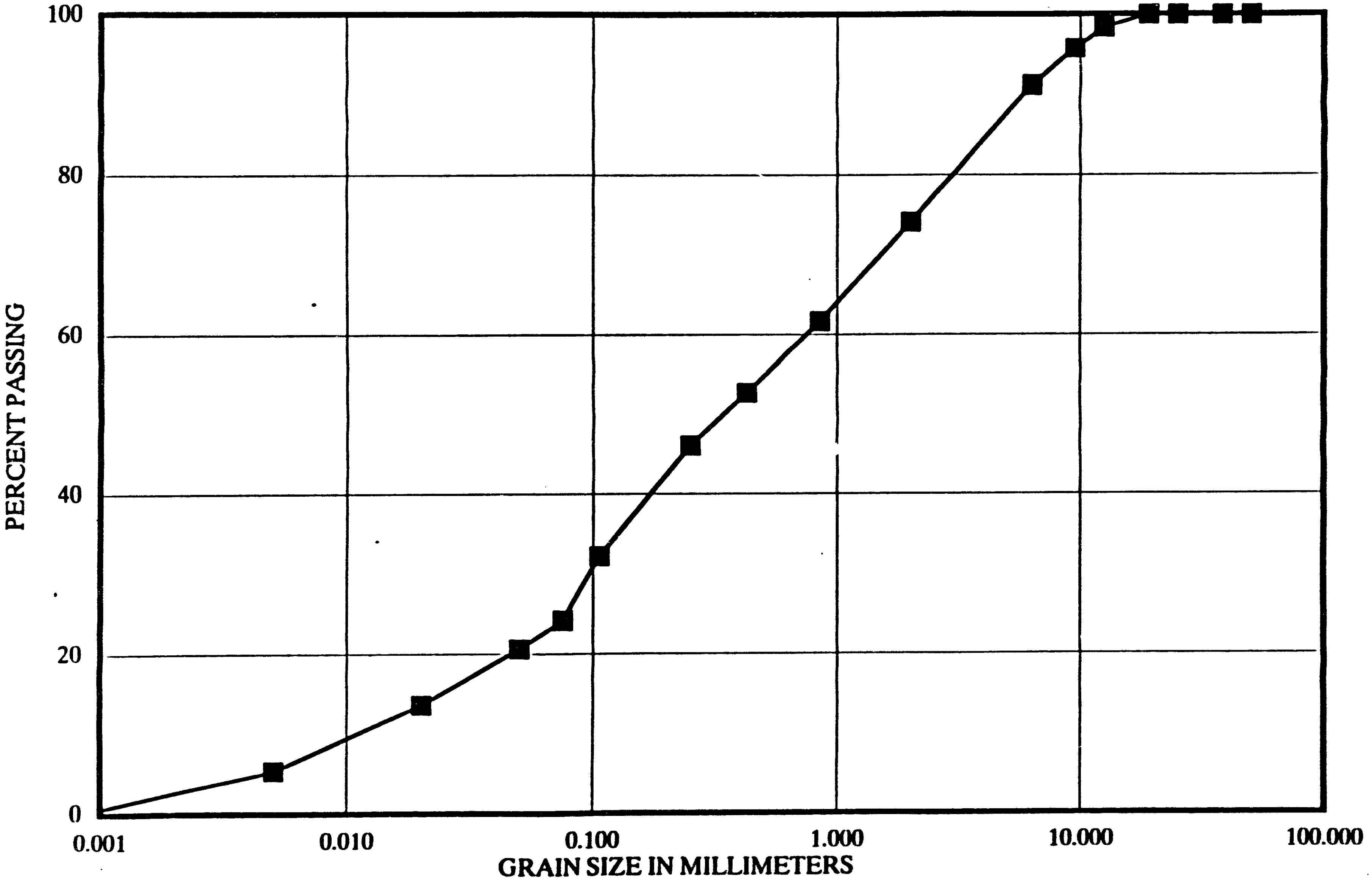
COURSE SIEVE ASTM D422
        SIEVE SIZE         TARE WT.  FULL WT.   NET WT.
     50.0 MM    2.000 INCH   778.1     778.1       0.0       0.0      99.9
     38.1 MM    1.500 INCH   793.4     793.4       0.0       0.0      99.9
     25.0 MM    1.000 INCH   844.8     844.8       0.0       0.0      99.9
     19.0 MM    0.750 INCH   773.8     773.8       0.0       0.0      99.9
     12.5 MM    0.500 INCH   793.1     802.9       9.8       1.6      98.3
      9.5 MM    0.375 INCH   840.8     857.5      16.7       2.7      95.7
      6.3 MM    0.250 INCH   808.2     836.4      28.2       4.5      91.2
     2.00 MM           #10   457.4     564.2     106.8      17.1      74.0
                       PAN   372.4     381.6       9.2       1.5
                     TOTAL                       170.7
                      LOSS                         0.5
        PERCENT RECOVERY                          99.7
ADJUSTED TOTAL REMOVE PAN WEIGHT <#10 SIEVE      161.5      25.9

FINES SIEVE ASTM D422
                           TARE WT.  FULL WT.   NET WT.
        FINES SOIL WEIGHT    144.1     246.3     102.2      74.0
   PERCENT OF TOTAL FINES                         22.1
        SIEVE SIZE
            0.850 MM   #20   416.0     432.4      16.4      12.4      61.6
            0.425 MM   #40   378.3     390.2      11.9       9.0      52.6
            0.250 MM   #60   358.9     367.6       8.7       6.6      46.0
            0.106 MM  #140   353.1     371.4      18.3      13.9      32.2
            0.075 MM  #200   351.8     362.4      10.6       8.0      24.1
                       PAN   543.2     575.1      31.9      24.1
                 SUB TOTAL                        97.8      74.0
                      LOSS                         4.4
        PERCENT RECOVERY                          95.7

LASER PARTICLE SIZING         %         %     % PASSING
     MICROM BRACKET RANGE    53.4      48.7
                 0.050 MM    87.2      84.5      85.2       3.6      20.6
     MICRON BRACKET RANGE    21.0      19.1
                 0.020 MM    57.9      55.1      56.4       7.0      13.6
     MICRON BRACKET RANGE     5.2       4.7
                 0.005 MM    23.4      21.7      22.8       8.1       5.5
     MICRON BRACKET RANGE     1.1       1.0
                 0.001 MM     3.1       2.6       2.8       4.8       0.7
       LESS THAN 0.001 MM                                  0.7
                SUB TOTAL                                 24.1
```

GRAIN SIZE ACCUMULATION CURVE

YPG FIRING RANGE RESTORATION PROJECT



YPG–110492–NP–04–PP
92–4584

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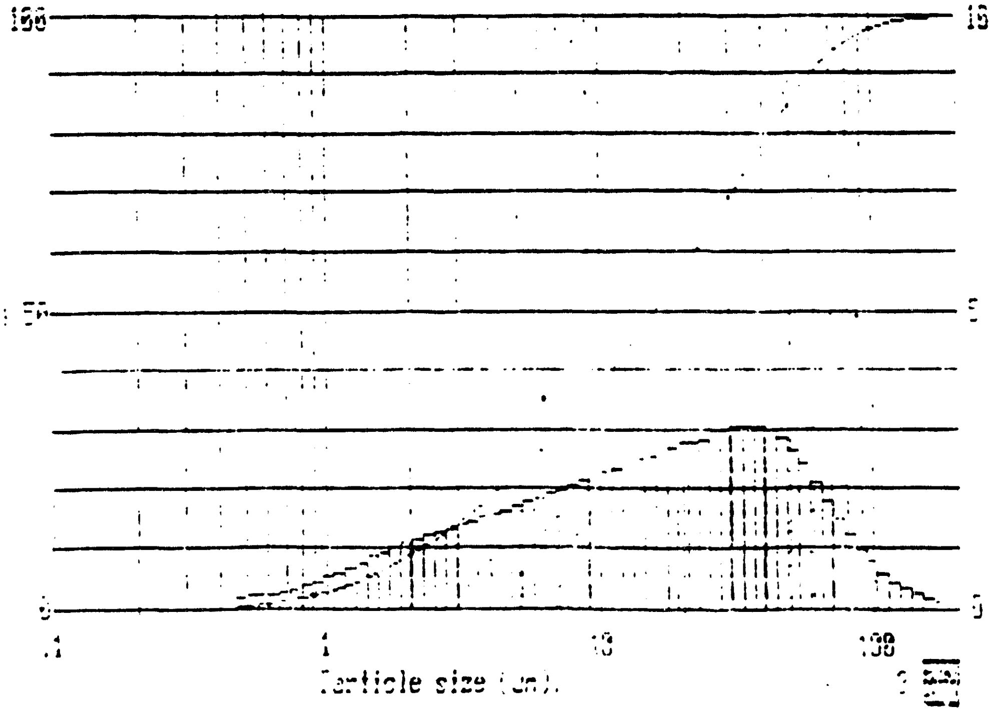

Particle size (um).

YUMA PROVING GROUND B-42

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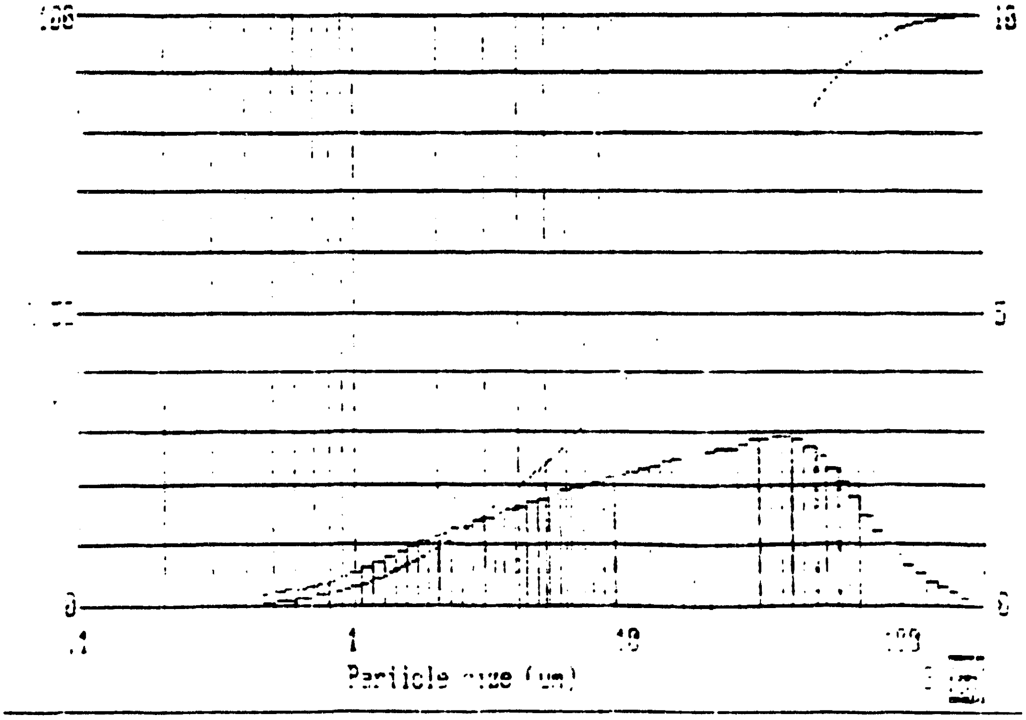
Volume distribution



YUMA PROVING GROUND

```
       SAMPLE NUMBER  =   YPG-110592-WP-01-PP (92-4659)
                          ALL WEIGHTS ARE IN GRAMS
SAMPLE PREP ASTM D421
                          TARE WT. FULL WT.  NET WT.  % TOTAL % PASSING
     STARTING SOIL WEIGHT   1108.8   1761.9    653.1 RETAINED
         #10 SIEVE WEIGHT    502.2    666.9    164.7
COURSE TOTAL SOIL WEIGHT                       153.8     23.7
         PAN SIEVE WEIGHT    368.1    819.6    451.5
       WASH WATER SOIL WT    376.6    410.6     34.0
  FINES TOTAL SOIL WEIGHT                      496.4     76.3
SUM COURSE & FINE WEIGHTS                      650.2    100.0
                     LOSS                        2.9
         PERCENT RECOVERY                       99.6

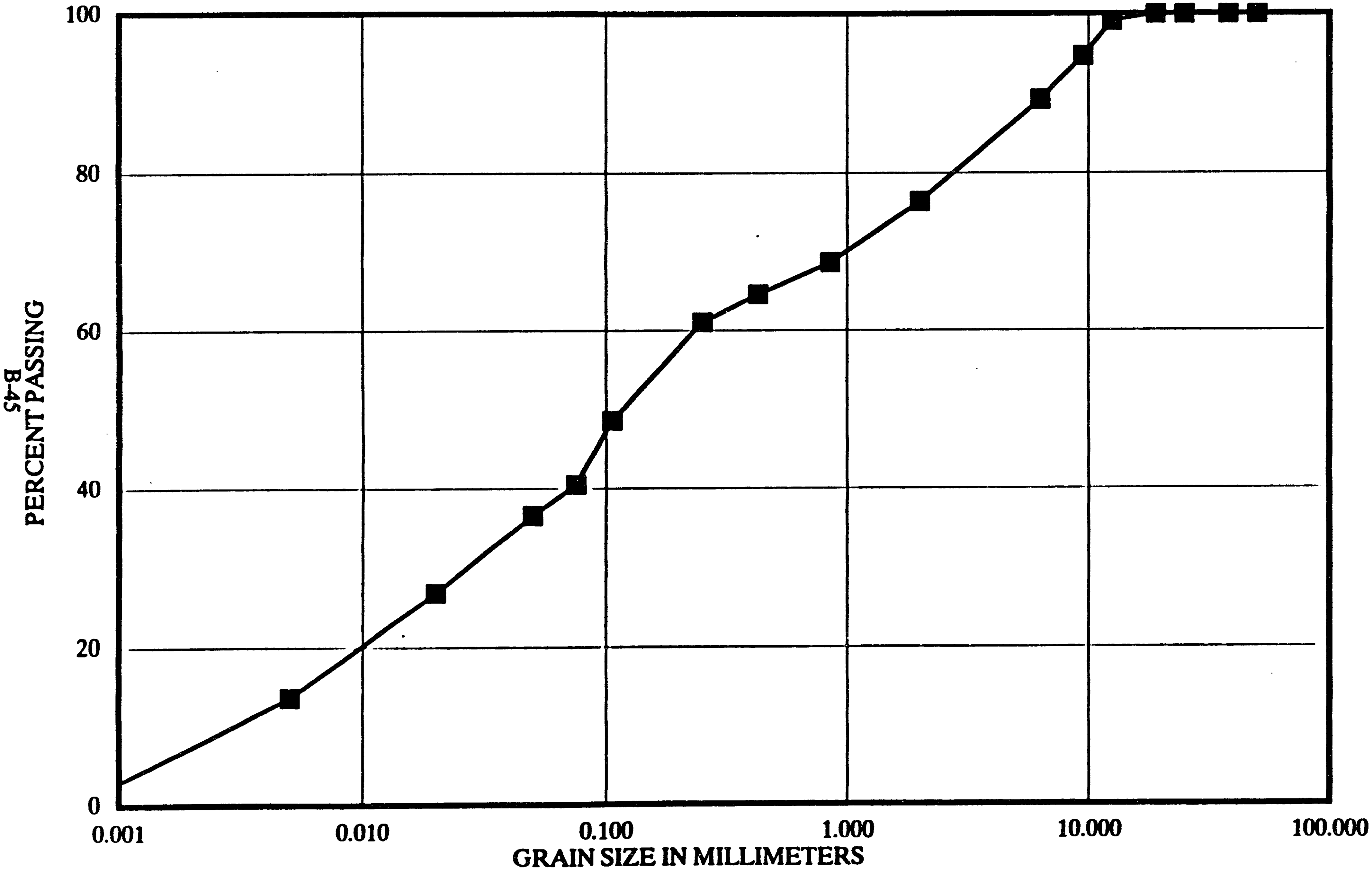
COURSE SIEVE ASTM D422
        SIEVE SIZE        TARE WT. FULL WT.  NET WT.
     50.0 MM   2.000 INCH    778.1    778.1      0.0      0.0     99.9
     38.1 MM   1.500 INCH    793.4    793.4      0.0      0.0     99.9
     25.0 MM   1.000 INCH    844.8    844.8      0.0      0.0     99.9
     19.0 MM   0.750 INCH    773.8    773.8      0.0      0.0     99.9
     12.5 MM   0.500 INCH    793.2    798.5      5.3      0.8     99.1
      9.5 MM   0.375 INCH    840.5    869.0     28.5      4.4     94.7
      6.3 MM   0.250 INCH    808.3    844.1     35.8      5.5     89.2
     2.00 MM          #10    457.4    541.1     83.7     12.9     76.3
                      PAN    372.4    383.3     10.9      1.7
                    TOTAL                      164.2
                     LOSS                        0.5
         PERCENT RECOVERY                       99.7
ADJUSTED TOTAL REMOVE PAN WEIGHT <#10 SIEVE    153.3     23.6

FINES SIEVE ASTM D422
                          TARE WT. FULL WT.  NET WT.
        FINES SOIL WEIGHT    144.1    245.0    100.9     76.3
   PERCENT OF TOTAL FINES                       20.3
        SIEVE SIZE
           0.850 MM   #20    416.2    425.9      9.7      7.7     68.6
           0.425 MM   #40    378.3    383.4      5.1      4.1     64.6
           0.250 MM   #60    358.8    363.3      4.5      3.6     61.0
           0.106 MM  #140    353.1    368.8     15.7     12.5     48.5
           0.075 MM  #200    351.8    362.0     10.2      8.1     40.4
                      PAN    789.9    840.8     50.9     40.4
                SUB TOTAL                       96.1     76.3
                     LOSS                        4.8
         PERCENT RECOVERY                       95.2

LASER PARTICLE SIZING         %        %    % PASSING
     MICROM BRACKET RANGE     53.4     48.7
                 0.050 MM     91.8     89.9     90.4      3.9     36.6
     MICRON BRACKET RANGE     21.0     19.1
                 0.020 MM     67.7     65.1     66.3      9.7     26.8
     MICRON BRACKET RANGE      5.2      4.7
                 0.005 MM     34.4     32.6     33.7     13.2     13.6
     MICRON BRACKET RANGE      1.1      1.0
                 0.001 MM      8.1      7.0      7.4     10.6      3.0
       LESS THAN 0.001 MM                                 3.0
                SUB TOTAL                                40.4
```

GRAIN SIZE ACCUMULATION CURVE

YPG FIRING RANGE RESTORATION PROJECT



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92–4659

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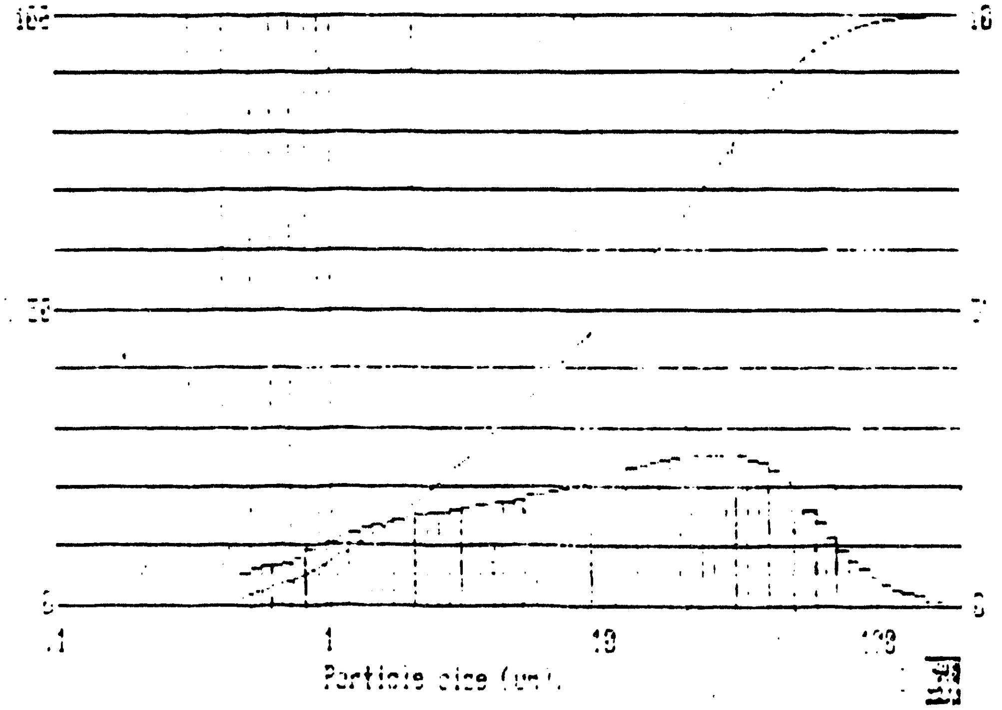


YUMA PROVING GROUND

SAMPLE NUMBER = YPG-110592-WP-02-PP (92-4662)
ALL WEIGHTS ARE IN GRAMS

SAMPLE PREP ASTM D421

	TARE WT.	FULL WT.	NET WT.	% TOTAL RETAINED	% PASSING
STARTING SOIL WEIGHT	1198.5	1848.4	649.9		
#10 SIEVE WEIGHT	592.0	782.6	190.6		
COURSE TOTAL SOIL WEIGHT			182.0	28.2	
PAN SIEVE WEIGHT	368.3	798.9	430.6		
WASH WATER SOIL WT	543.1	568.3	25.2		
FINES TOTAL SOIL WEIGHT			464.4	71.8	
SUM COURSE & FINE WEIGHTS			646.4	100.0	
LOSS			3.5		
PERCENT RECOVERY			99.5		

COURSE SIEVE ASTM D422

SIEVE SIZE	TARE WT.	FULL WT.	NET WT.		
50.0 MM 2.000 INCH	778.1	778.1	0.0	0.0	100.0
38.1 MM 1.500 INCH	793.4	793.4	0.0	0.0	100.0
25.0 MM 1.000 INCH	844.8	844.8	0.0	0.0	100.0
19.0 MM 0.750 INCH	773.8	773.8	0.0	0.0	100.0
12.5 MM 0.500 INCH	793.1	801.3	8.2	1.3	98.7
9.5 MM 0.375 INCH	840.5	865.1	24.6	3.8	94.9
6.3 MM 0.250 INCH	808.3	852.7	44.4	6.9	88.0
2.00 MM #10	457.6	562.3	104.7	16.2	71.8
PAN	372.4	381.0	8.6	1.3	
TOTAL			190.5		
LOSS			0.1		
PERCENT RECOVERY			99.9		
ADJUSTED TOTAL REMOVE PAN WEIGHT <#10 SIEVE			181.9	28.1	

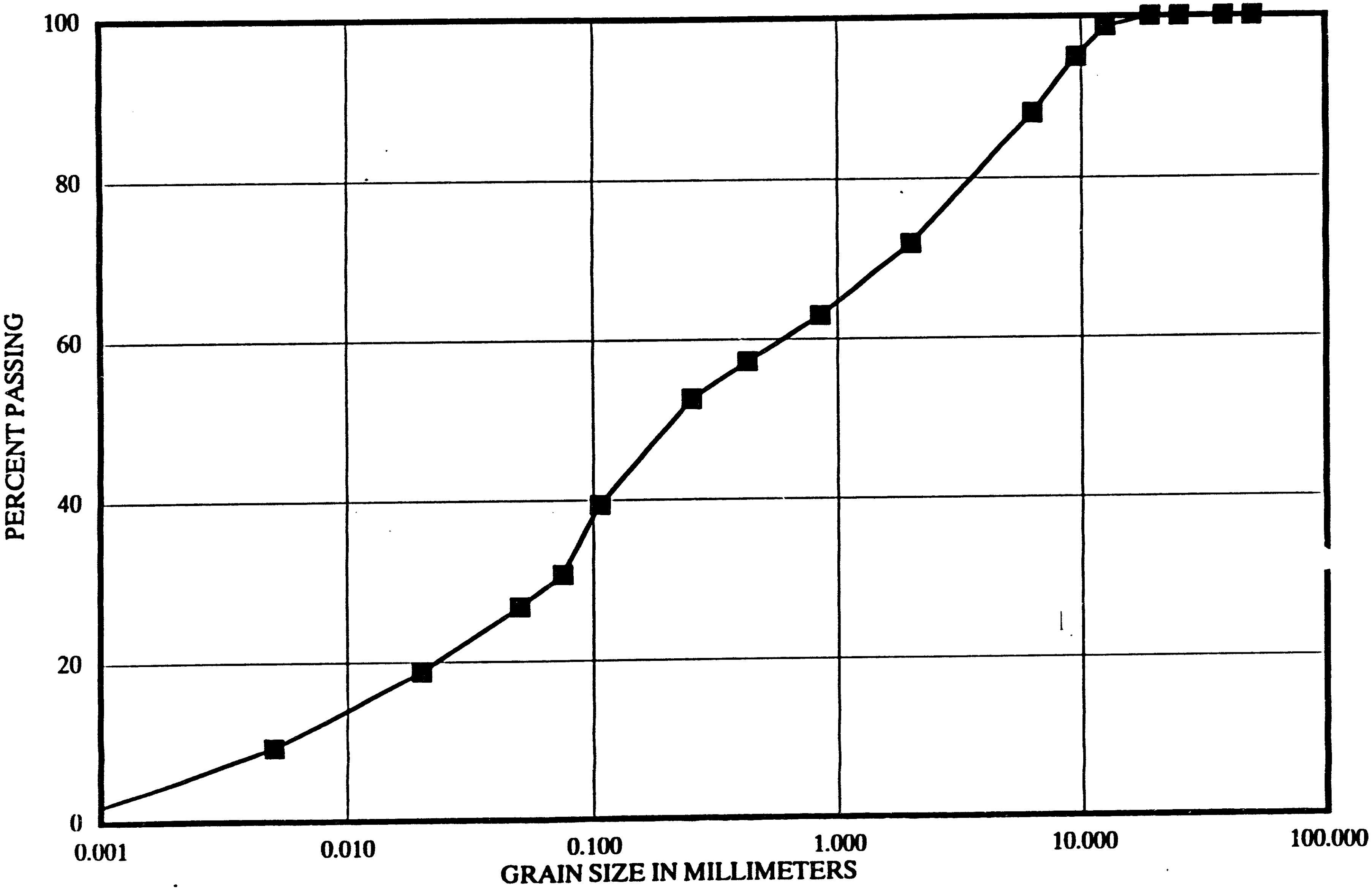
FINES SIEVE ASTM D422

	TARE WT.	FULL WT.	NET WT.		
FINES SOIL WEIGHT	144.1	244.3	100.2	71.8	
PERCENT OF TOTAL FINES			21.6		
SIEVE SIZE					
0.850 MM #20	416.2	428.1	11.9	9.0	62.9
0.425 MM #40	378.2	385.7	7.5	5.7	57.2
0.250 MM #60	358.8	365.0	6.2	4.7	52.5
0.106 MM #140	353.2	370.7	17.5	13.2	39.4
0.075 MM #200	351.7	363.1	11.4	8.6	30.8
PAN	543.2	584.0	40.8	30.8	
SUB TOTAL			95.3	71.8	
LOSS			4.9		
PERCENT RECOVERY			95.1		

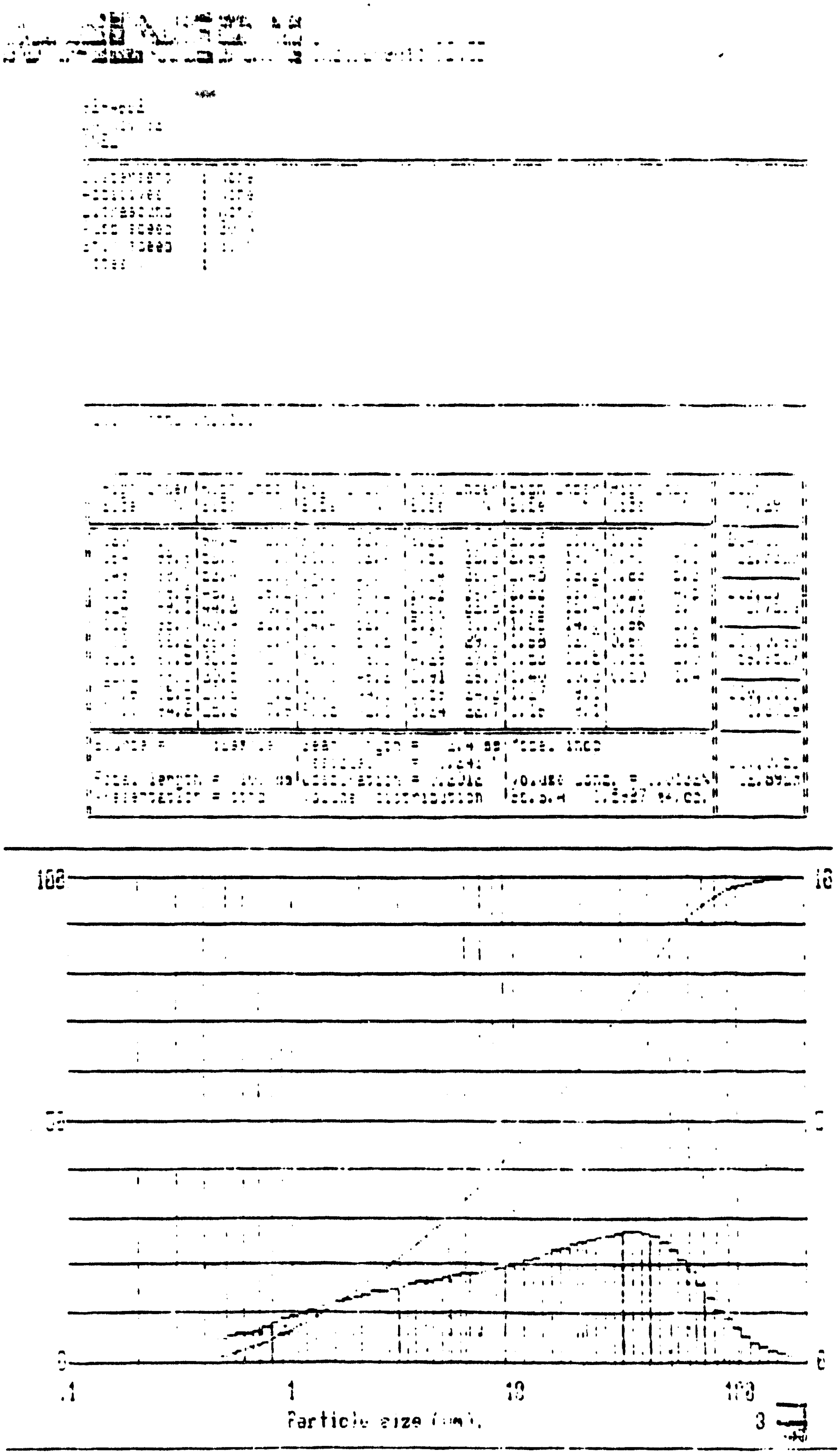
LASER PARTICLE SIZING	%	%	% PASSING		
MICROM BRACKET RANGE	53.4	48.7			
0.050 MM	88.6	86.3	86.9	4.0	26.7
MICRON BRACKET RANGE	21.0	19.1			
0.020 MM	62.4	59.9	61.1	8.0	18.8
MICRON BRACKET RANGE	5.2	4.7			
0.005 MM	31.0	29.3	30.4	9.4	9.3
MICRON BRACKET RANGE	1.1	1.0			
0.001 MM	7.1	6.1	6.5	7.3	2.0
LESS THAN 0.001 MM				2.0	
SUB TOTAL				30.8	

GRAIN SIZE ACCUMULATION CURVE

YPG FIRING RANGE RESTORATION PROJECT



YPG–110592–WP–02–PP
92–4662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                          ALL WEIGHTS ARE IN GRAMS
SAMPLE PREP ASTM D421
                          TARE WT. FULL WT.  NET WT.  % TOTAL % PASSING
     STARTING SOIL WEIGHT   1108.7   1765.5    656.8 RETAINED
         #10 SIEVE WEIGHT    502.4    722.1    219.7
COURSE TOTAL SOIL WEIGHT                       205.6     31.3
         PAN SIEVE WEIGHT    368.4    778.9    410.5
       WASH WATER SOIL WT    567.1    593.5     26.4
   FINES TOTAL SOIL WEIGHT                     451.0     68.7
SUM COURSE & FINE WEIGHTS                      656.6    100.0
                     LOSS                        0.2
         PERCENT RECOVERY                      100.0

COURSE SIEVE ASTM D422
        SIEVE SIZE        TARE WT. FULL WT.  NET WT.
     50.0 MM   2.000 INCH    778.1    778.1      0.0      0.0    100.0
     38.1 MM   1.500 INCH    793.4    793.4      0.0      0.0    100.0
     25.0 MM   1.000 INCH    844.8    844.8      0.0      0.0    100.0
     19.0 MM   0.750 INCH    773.8    773.8      0.0      0.0    100.0
     12.5 MM   0.500 INCH    793.2    820.0     26.8      4.1     95.9
      9.5 MM   0.375 INCH    840.5    867.0     26.5      4.0     91.9
      6.3 MM   0.250 INCH    808.2    852.8     44.6      6.8     85.1
     2.00 MM          #10    457.7    565.3    107.6     16.4     68.7
                      PAN    372.7    386.8     14.1      2.1
                    TOTAL                      219.6
                     LOSS                        0.1
         PERCENT RECOVERY                      100.0
ADJUSTED TOTAL REMOVE PAN WEIGHT <#10 SIEVE    205.5     31.3

FINES SIEVE ASTM D422
                          TARE WT. FULL WT.  NET WT.
        FINES SOIL WEIGHT    144.1    245.0    100.9     68.7
   PERCENT OF TOTAL FINES                       22.4
        SIEVE SIZE
           0.850 MM   #20    416.2    430.3     14.1     10.0     58.7
           0.425 MM   #40    378.2    385.6      7.4      5.2     53.5
           0.250 MM   #60    358.8    365.0      6.2      4.4     49.1
           0.106 MM  #140    353.2    371.1     17.9     12.7     36.4
           0.075 MM  #200    351.8    363.7     11.9      8.4     28.0
                      PAN   1177.9   1217.4     39.5     28.0
                SUB TOTAL                       97.0     68.7
                     LOSS                        3.9
         PERCENT RECOVERY                       96.1

LASER PARTICLE SIZING          %        %   % PASSING
     MICROM BRACKET RANGE     53.4     48.7
                 0.050 MM     86.9     84.2     84.9      4.2     23.8
     MICRON BRACKET RANGE     21.0     19.1
                 0.020 MM     58.8     56.3     57.5      7.7     16.1
     MICRON BRACKET RANGE      5.2      4.7
                 0.005 MM     29.0     27.4     28.4      8.1      7.9
     MICRON BRACKET RANGE      1.1      1.0
                 0.001 MM      6.7      5.8      6.2      6.2      1.7
       LESS THAN 0.001 MM                                 1.7
                SUB TOTAL                                28.0
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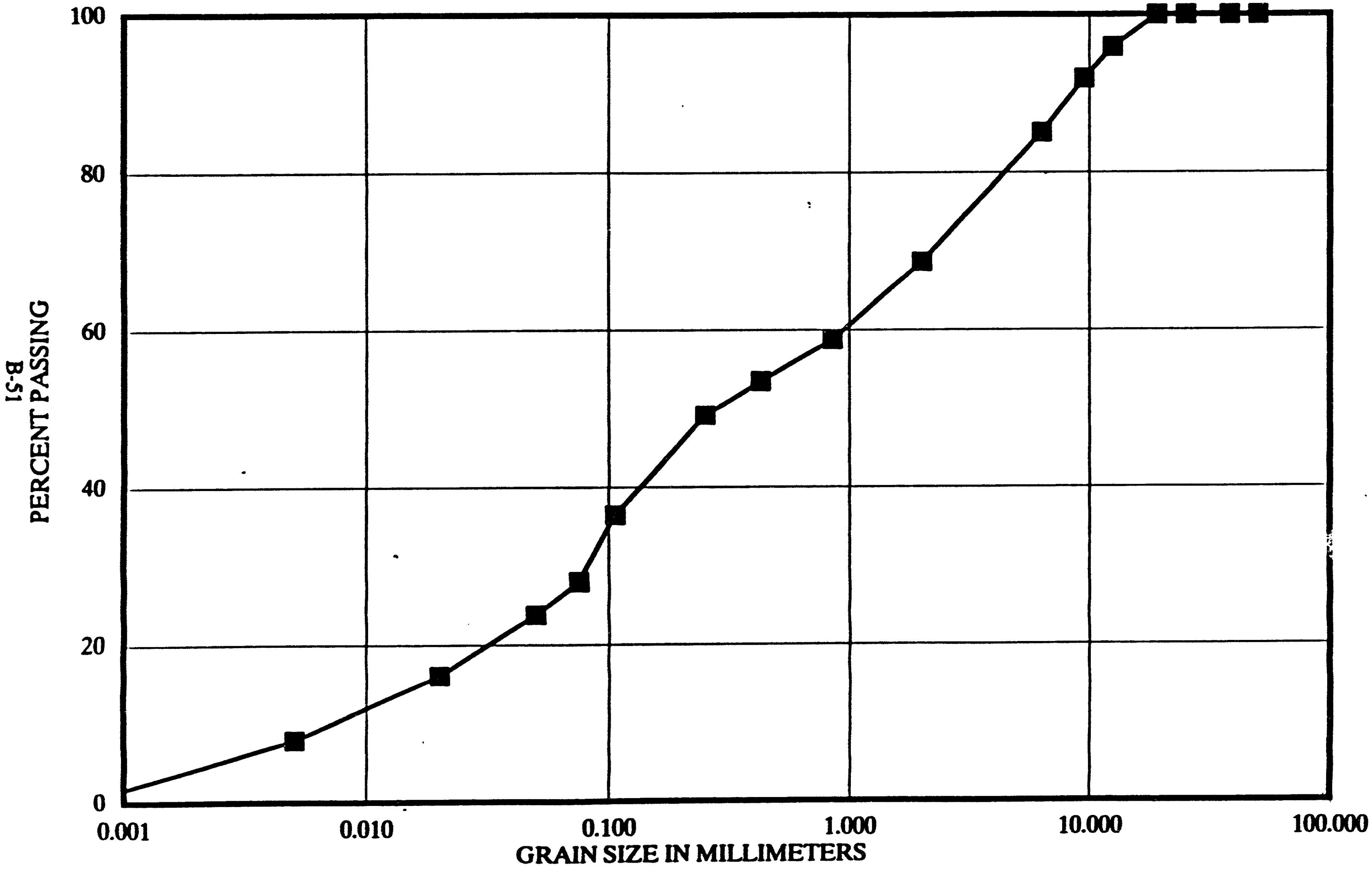
GRAIN SIZE ACCUMULATION CURVE

YPG FIRING RANGE RESTORATION PROJECT



YPG–110592–WP–02–PP(b)
92–4665

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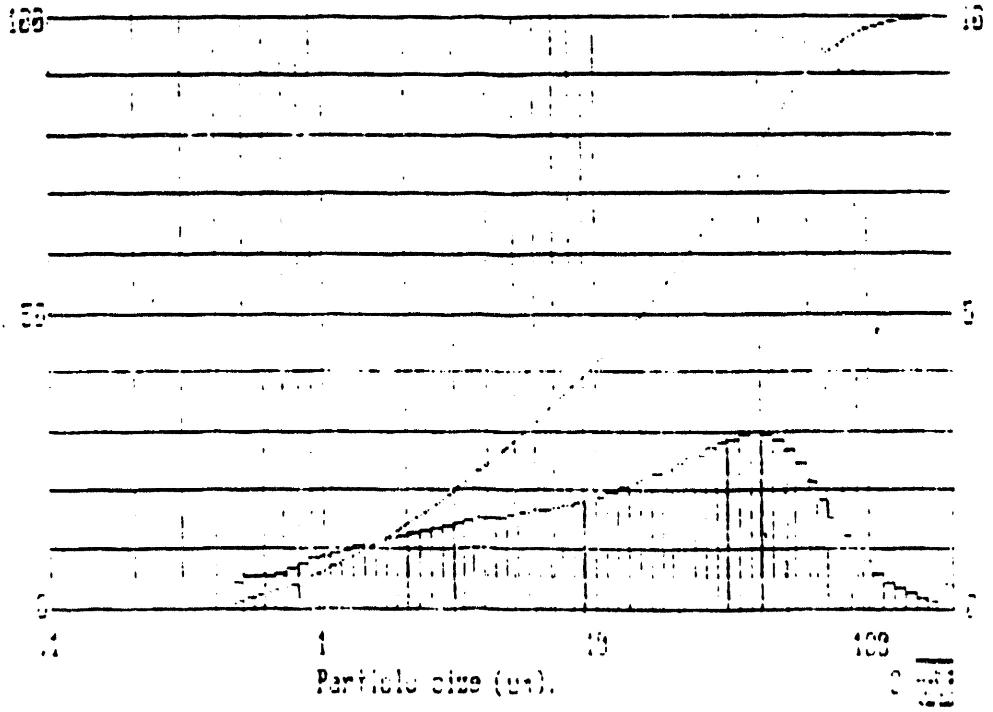

YUMA PROVING GROUND B-52

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      SAMPLE NUMBER  =   YPG-110592-WP-03-PP (92-4668)
                         ALL WEIGHTS ARE IN GRAMS
SAMPLE PREP ASTM D421
                         TARE WT. FULL WT.  NET WT.  % TOTAL % PASSING
    STARTING SOIL WEIGHT  1198.5   1860.3    661.8 RETAINED
        #10 SIEVE WEIGHT   592.5    762.1    169.6
COURSE TOTAL SOIL WEIGHT                     161.4     24.5
        PAN SIEVE WEIGHT   368.3    815.6    447.3
      WASH WATER SOIL WT   567.9    609.7     41.8
  FINES TOTAL SOIL WEIGHT                    497.3     75.5
SUM COURSE & FINE WEIGHTS                    658.7    100.0
                     LOSS                      3.1
         PERCENT RECOVERY                     99.5

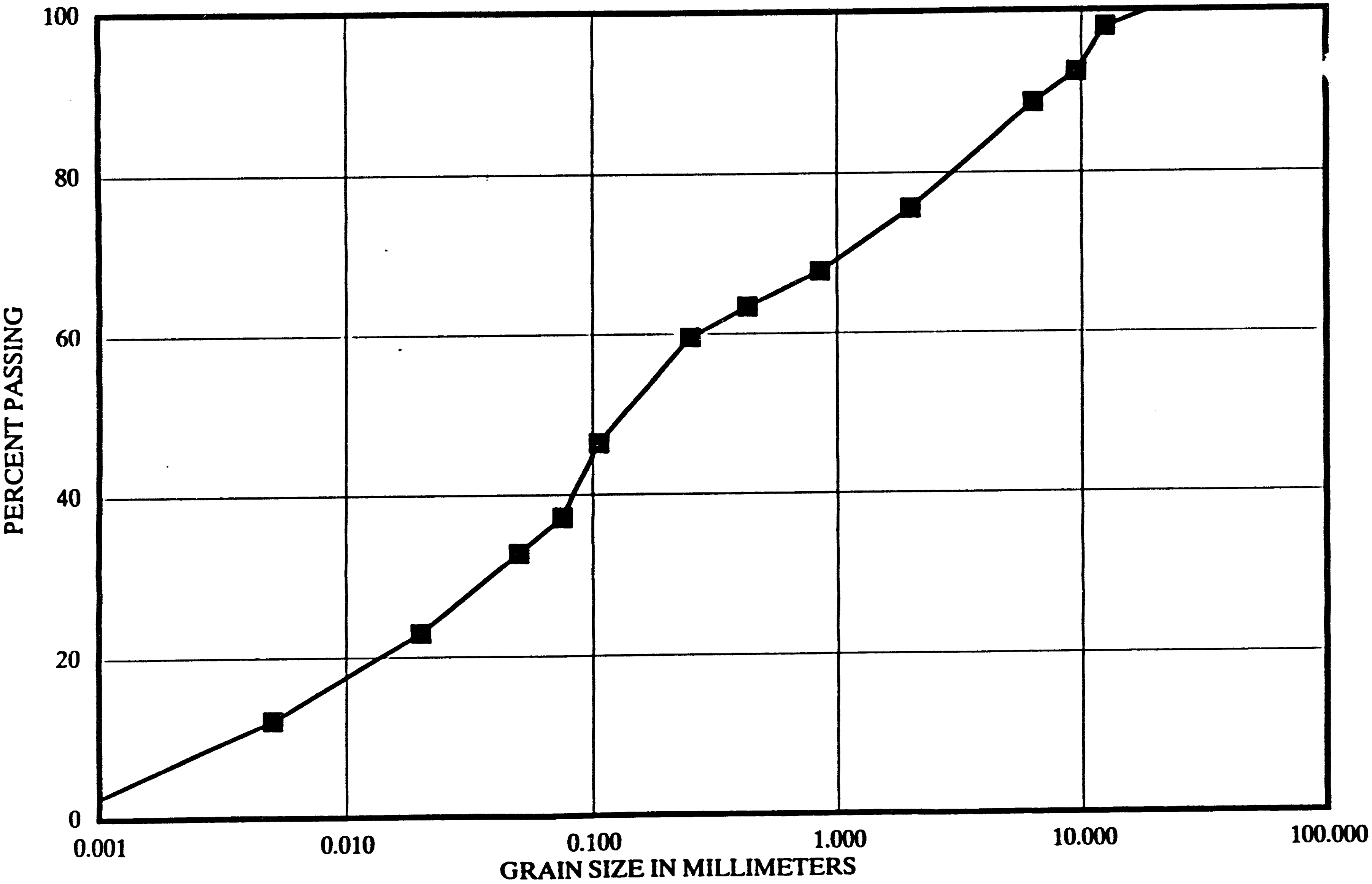
COURSE SIEVE ASTM D422
       SIEVE SIZE        TARE WT. FULL WT.  NET WT.
    50.0 MM   2.000 INCH   778.1    778.1      0.0      0.0     100.0
    38.1 MM   1.500 INCH   793.4    793.4      0.0      0.0     100.0
    25.0 MM   1.000 INCH   844.8    844.8      0.0      0.0     100.0
    19.0 MM   0.750 INCH   773.8    773.8      0.0      0.0     100.0
    12.5 MM   0.500 INCH   793.5    806.8     13.3      2.0      98.0
     9.5 MM   0.375 INCH   840.5    877.1     36.6      5.6      92.5
     6.3 MM   0.250 INCH   808.2    833.6     25.4      3.9      88.6
    2.00 MM          #10   457.6    543.9     86.3     13.1      75.5
                     PAN   372.4    380.6      8.2      1.2
                   TOTAL                     169.8
                    LOSS                      -0.2
         PERCENT RECOVERY                    100.1
ADJUSTED TOTAL REMOVE PAN WEIGHT <#10 SIEVE  161.6     24.5

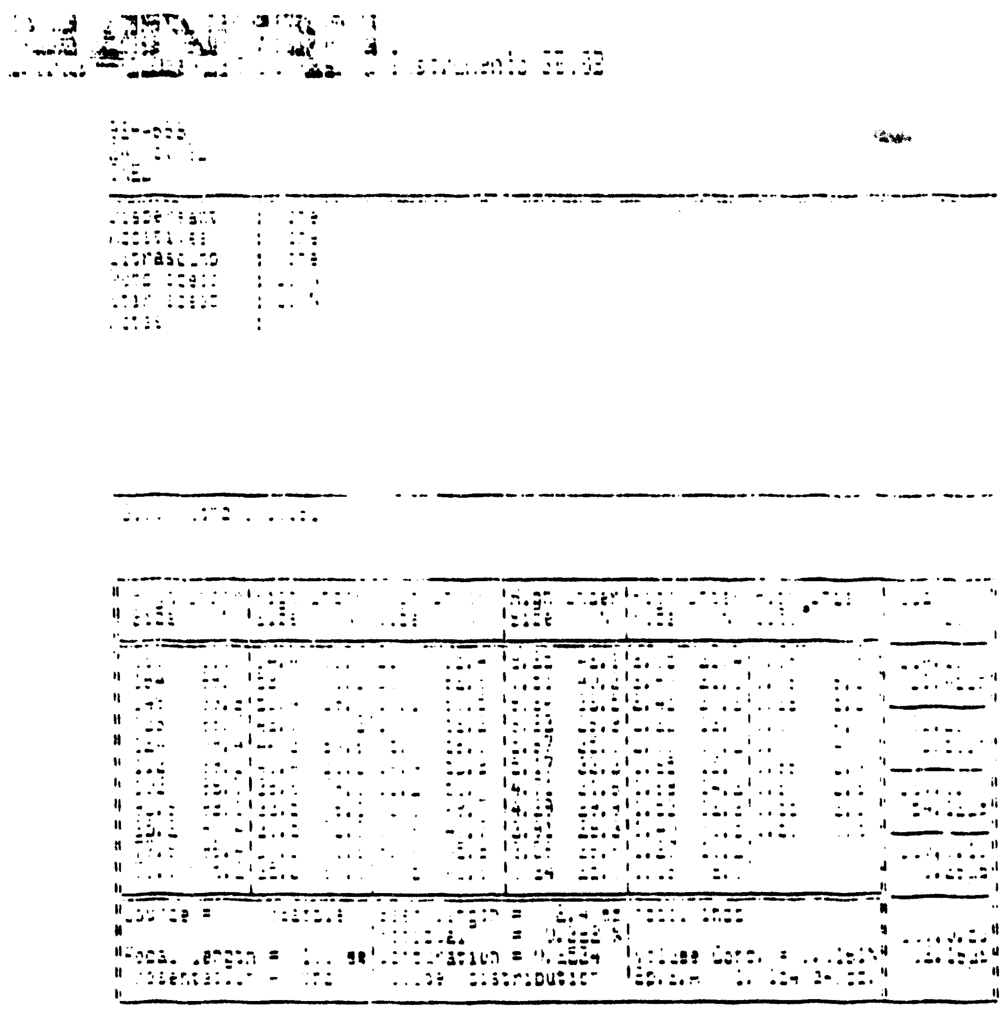
FINES SIEVE ASTM D422
                         TARE WT. FULL WT.  NET WT.
       FINES SOIL WEIGHT   144.1    245.7    101.6     75.5
   PERCENT OF TOTAL FINES                     20.4
       SIEVE SIZE
          0.850 MM   #20   416.2    426.5     10.3      7.8      67.7
          0.425 MM   #40   378.3    384.1      5.8      4.4      63.4
          0.250 MM   #60   358.8    363.9      5.1      3.8      59.5
          0.106 MM  #140   353.2    370.6     17.4     13.1      46.4
          0.075 MM  #200   351.8    364.1     12.3      9.3      37.2
                     PAN   567.9    617.3     49.4     37.2
               SUB TOTAL                     100.3     75.5
                    LOSS                       1.3
         PERCENT RECOVERY                     98.7

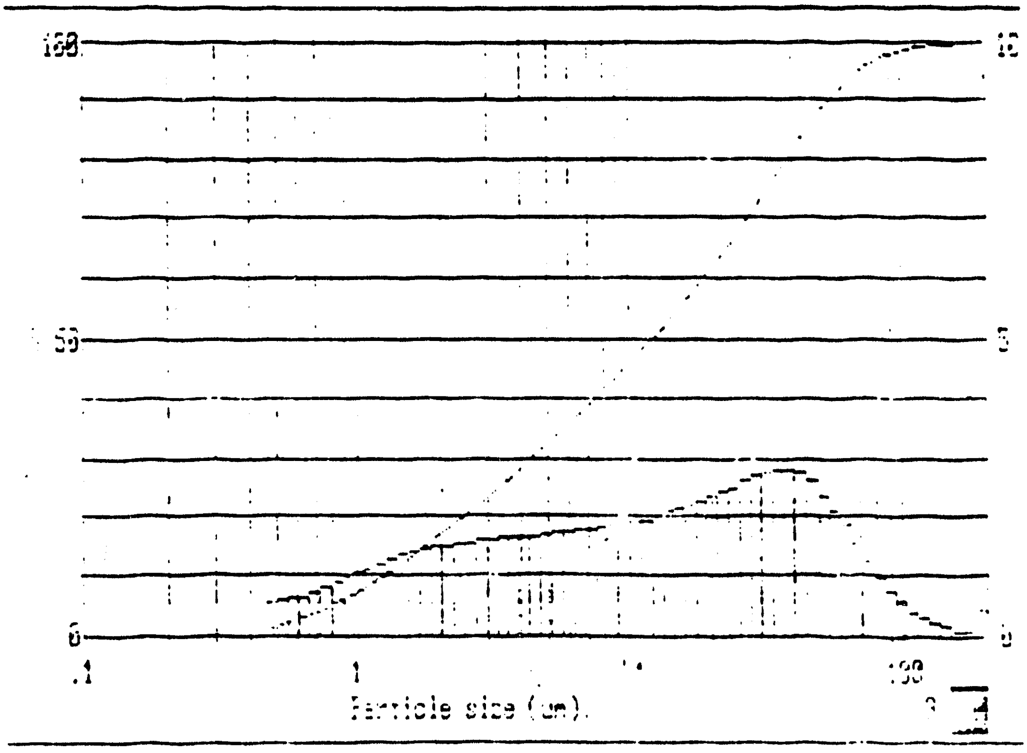
LASER PARTICLE SIZING        %        %    % PASSING
    MICROM BRACKET RANGE    53.4     48.7
                0.050 MM    89.7     87.3     88.0      4.5      32.7
    MICRON BRACKET RANGE    21.0     19.1
                0.020 MM    62.9     60.5     61.6      9.8      22.9
    MICRON BRACKET RANGE     5.2      4.7
                0.005 MM    33.3     31.6     32.7     10.8      12.1
    MICRON BRACKET RANGE     1.1      1.0
                0.001 MM     7.8      6.8      7.2      9.5       2.7
      LESS THAN 0.001 MM                               2.7
               SUB TOTAL                              37.2
```

GRAIN SIZE ACCUMULATION CURVE

YPG FIRING RANGE RESTORATION PROJECT







YUMA PROVING GROUND B-55

```
      SAMPLE NUMBER  =   YPG-110592-BK-01-PP (92-4674)
                         ALL WEIGHTS ARE IN GRAMS
SAMPLE PREP ASTM D421
                         TARE WT. FULL WT.  NET WT.  % TOTAL % PASSING
    STARTING SOIL WEIGHT  1108.8   1811.0    702.2 RETAINED
        #10 SIEVE WEIGHT   502.3    812.4    310.1
COURSE TOTAL SOIL WEIGHT                     296.5     42.4
        PAN SIEVE WEIGHT   368.3    749.4    381.1
      WASH WATER SOIL WT   541.0    549.4      8.4
  FINES TOTAL SOIL WEIGHT                    403.1     57.6
SUM COURSE & FINE WEIGHTS                    699.6    100.0
                     LOSS                      2.6
        PERCENT RECOVERY                      99.6

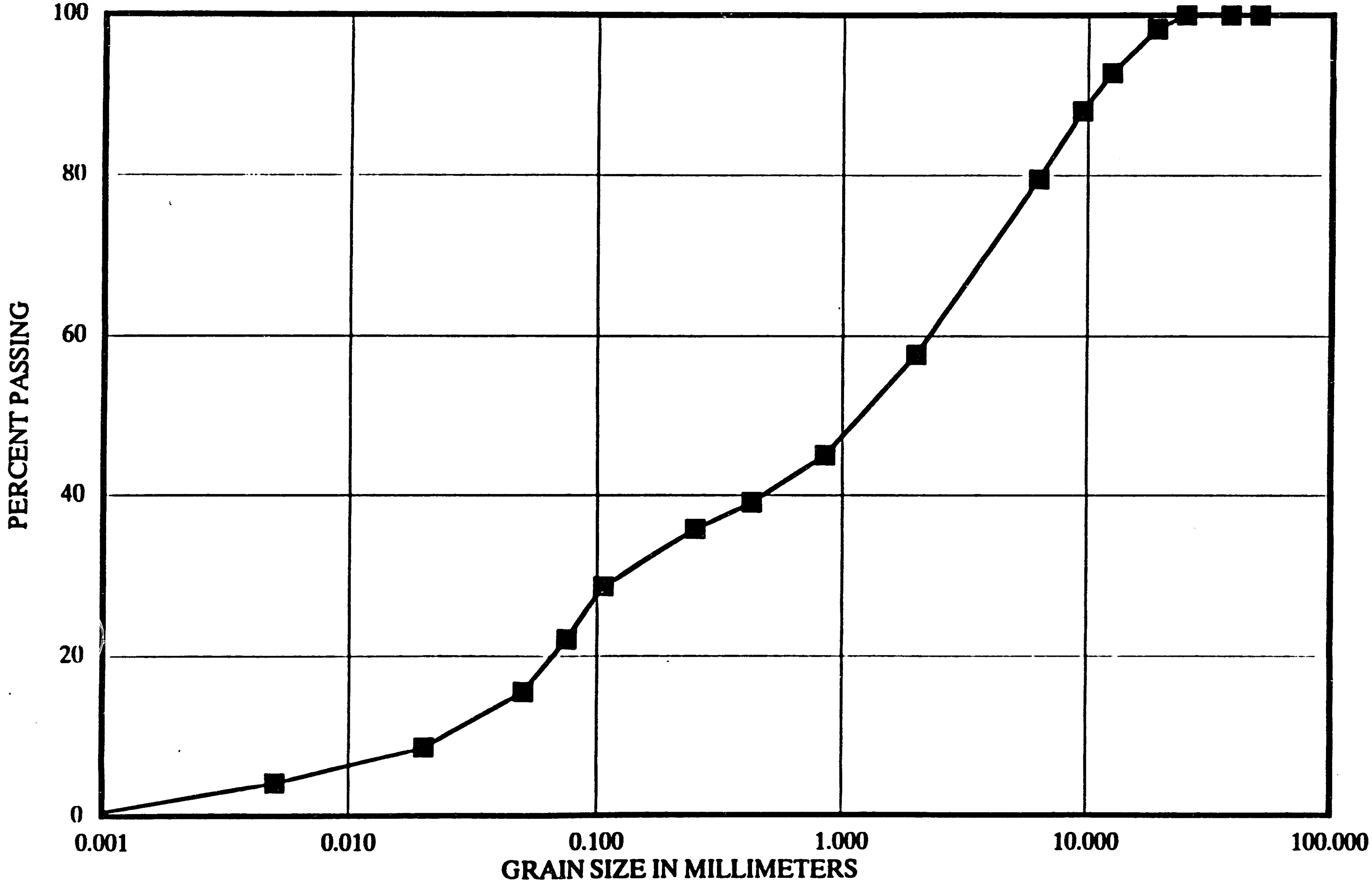
COURSE SIEVE ASTM D422
       SIEVE SIZE        TARE WT. FULL WT.  NET WT.
    50.0 MM   2.000 INCH   778.1    778.1      0.0      0.0     100.0
    38.1 MM   1.500 INCH   793.4    793.4      0.0      0.0     100.0
    25.0 MM   1.000 INCH   844.8    844.8      0.0      0.0     100.0
    19.0 MM   0.750 INCH   773.8    785.9     12.1      1.7      98.3
    12.5 MM   0.500 INCH   793.2    831.1     37.9      5.4      92.9
     9.5 MM   0.375 INCH   840.6    874.1     33.5      4.8      88.1
     6.3 MM   0.250 INCH   808.2    867.7     59.5      8.5      79.6
    2.00 MM          #10   457.6    611.1    153.5     21.9      57.6
                     PAN   372.4    386.0     13.6      1.9
                   TOTAL                     310.1
                    LOSS                       0.0
        PERCENT RECOVERY                     100.0
ADJUSTED TOTAL REMOVE PAN WEIGHT <#10 SIEVE  296.5     42.4

FINES SIEVE ASTM D422
                         TARE WT. FULL WT.  NET WT.
       FINES SOIL WEIGHT   144.1    248.7    104.6     57.6
   PERCENT OF TOTAL FINES                     25.9
       SIEVE SIZE
          0.850 MM   #20   416.3    438.9     22.6     12.7      44.9
          0.425 MM   #40   378.3    388.7     10.4      5.8      39.1
          0.250 MM   #60   358.8    364.7      5.9      3.3      35.8
          0.106 MM  #140   353.3    365.9     12.6      7.1      28.7
          0.075 MM  #200   351.8    363.6     11.8      6.6      22.0
                     PAN   541.0    580.2     39.2     22.0
               SUB TOTAL                     102.5     57.6
                    LOSS                       2.1
        PERCENT RECOVERY                      98.0

LASER PARTICLE SIZING       %        %     % PASSING
     MICROM BRACKET RANGE  53.4     48.7
                0.050 MM   73.6     68.7      70.1      6.6      15.4
     MICRON BRACKET RANGE  21.0     19.1
                0.020 MM   39.4     37.5      38.4      7.0       8.5
     MICRON BRACKET RANGE   5.2      4.7
                0.005 MM   18.9     17.8      18.5      4.4       4.1
     MICRON BRACKET RANGE   1.1      1.0
                0.001 MM    2.8      2.3       2.5      3.5       0.6
       LESS THAN 0.001 MM                               0.6
               SUB TOTAL                               22.0
```

GRAIN SIZE ACCUMULATION CURVE

YPG FIRING RANGE RESTORATION PROJECT



YPG–110592–BK–01–PP
92–4674

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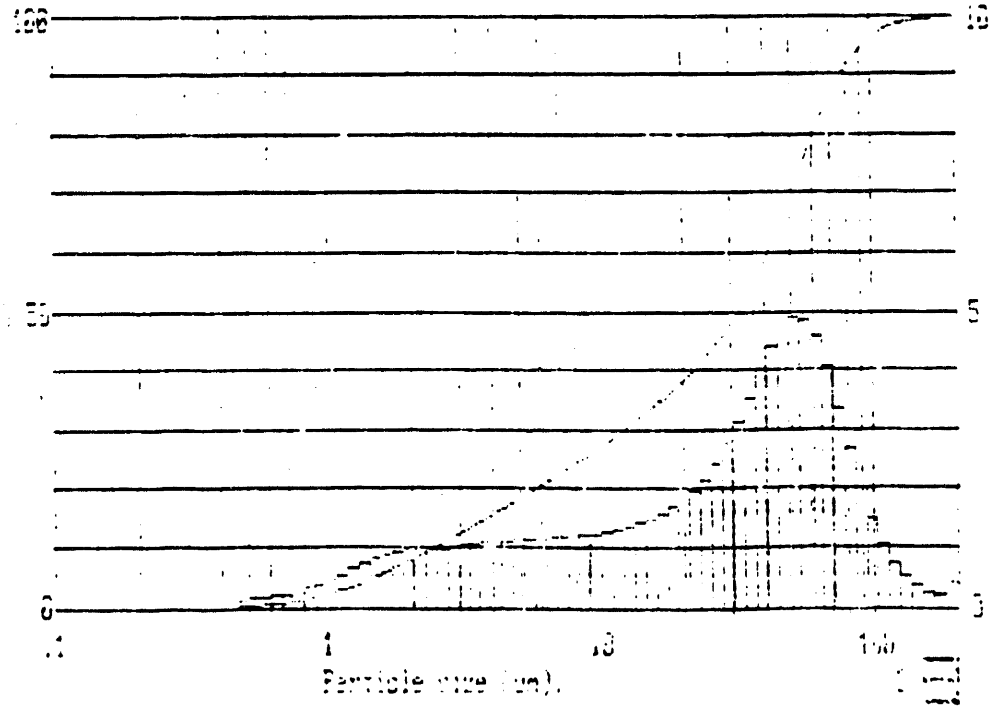


YUMA PROVING GROUND

SAMPLE NUMBER = YPG-110592-WP-04-PP (92-4675)
ALL WEIGHTS ARE IN GRAMS

SAMPLE PREP ASTM D421

	TARE WT.	FULL WT.	NET WT.	% TOTAL RETAINED	% PASSING
STARTING SOIL WEIGHT	1198.9	1909.5	710.6		
#10 SIEVE WEIGHT	592.0	850.0	258.0		
COURSE TOTAL SOIL WEIGHT			249.8	35.3	
PAN SIEVE WEIGHT	368.6	799.3	430.7		
WASH WATER SOIL WT	386.7	405.7	19.0		
FINES TOTAL SOIL WEIGHT			457.9	64.7	
SUM COURSE & FINE WEIGHTS			707.7	100.0	
LOSS			2.9		
PERCENT RECOVERY			99.6		

COURSE SIEVE ASTM D422

SIEVE SIZE		TARE WT.	FULL WT.	NET WT.		
50.0 MM	2.000 INCH	778.1	778.1	0.0	0.0	100.0
38.1 MM	1.500 INCH	793.4	793.4	0.0	0.0	100.0
25.0 MM	1.000 INCH	844.8	844.8	0.0	0.0	100.0
19.0 MM	0.750 INCH	773.8	781.0	7.2	1.0	99.0
12.5 MM	0.500 INCH	793.1	834.5	41.4	5.8	93.1
9.5 MM	0.375 INCH	840.7	865.7	25.0	3.5	89.6
6.3 MM	0.250 INCH	808.3	851.5	43.2	6.1	83.5
2.00 MM	#10	457.5	590.4	132.9	18.8	64.7
	PAN	372.4	380.6	8.2	1.2	
	TOTAL			257.9		
	LOSS			0.1		
	PERCENT RECOVERY			100.0		
ADJUSTED TOTAL REMOVE PAN WEIGHT <#10 SIEVE				249.7	35.3	

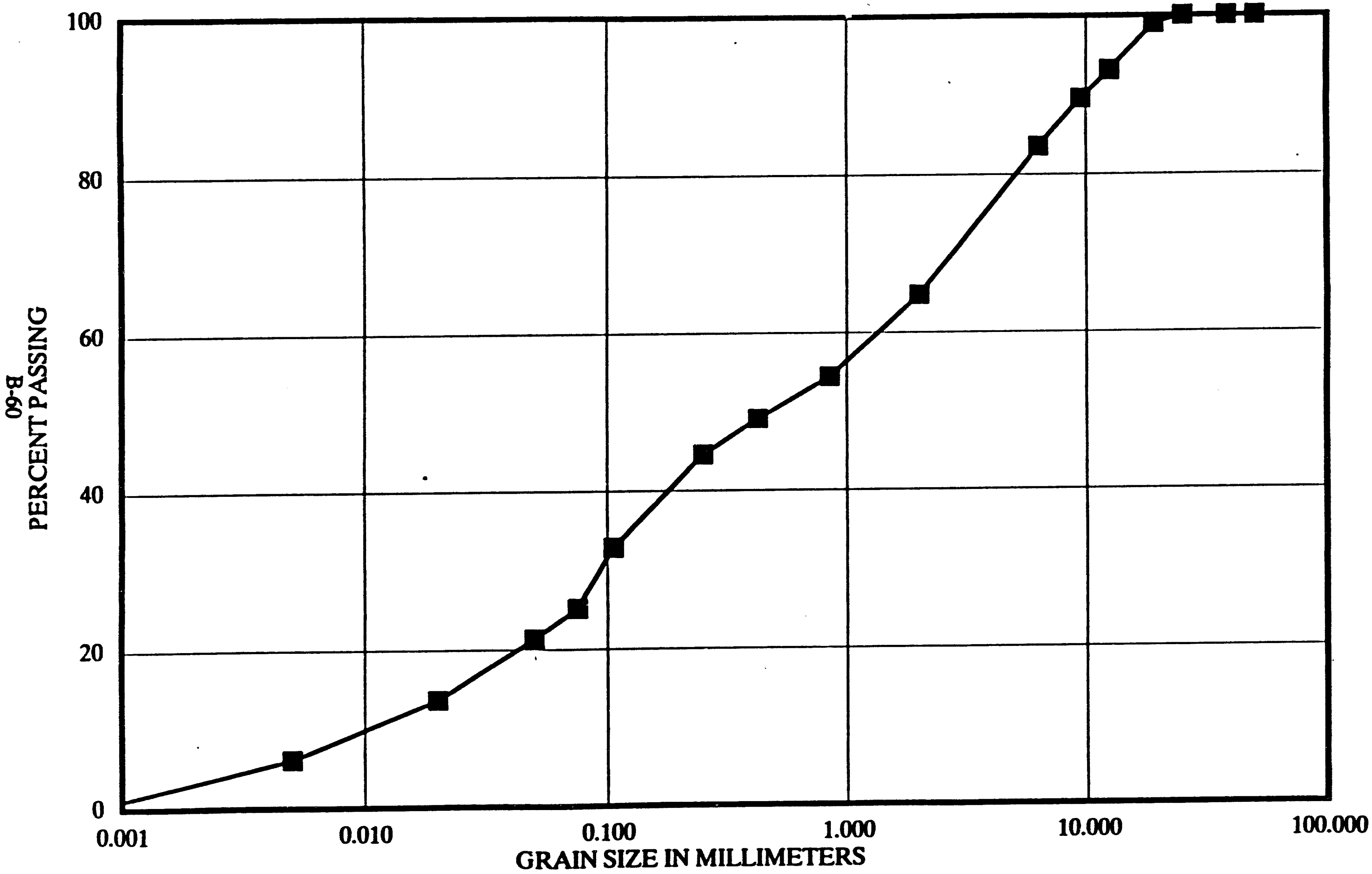
FINES SIEVE ASTM D422

		TARE WT.	FULL WT.	NET WT.		
FINES SOIL WEIGHT		144.1	244.1	100.0	64.7	
PERCENT OF TOTAL FINES				21.8		
SIEVE SIZE						
0.850 MM	#20	416.2	431.5	15.3	10.3	54.4
0.425 MM	#40	378.3	386.2	7.9	5.3	49.0
0.250 MM	#60	358.8	365.5	6.7	4.5	44.5
0.106 MM	#140	353.3	370.7	17.4	11.7	32.8
0.075 MM	#200	351.8	363.2	11.4	7.7	25.1
	PAN	793.3	830.5	37.2	25.1	
	SUB TOTAL			95.9	64.7	
	LOSS			4.1		
	PERCENT RECOVERY			95.9		

LASER PARTICLE SIZING	%	%	% PASSING		
MICROM BRACKET RANGE	53.4	48.7			
0.050 MM	86.9	84.0	84.8	3.8	21.3
MICRON BRACKET RANGE	21.0	19.1			
0.020 MM	55.7	53.0	54.3	7.7	13.6
MICRON BRACKET RANGE	5.2	4.7			
0.005 MM	25.2	23.7	24.6	7.4	6.2
MICRON BRACKET RANGE	1.1	1.0			
0.001 MM	4.7	4.0	4.3	5.1	1.1
LESS THAN 0.001 MM				1.1	
SUB TOTAL				25.1	

GRAIN SIZE ACCUMULATION CURVE

YPG FIRING RANGE RESTORATION PROJECT



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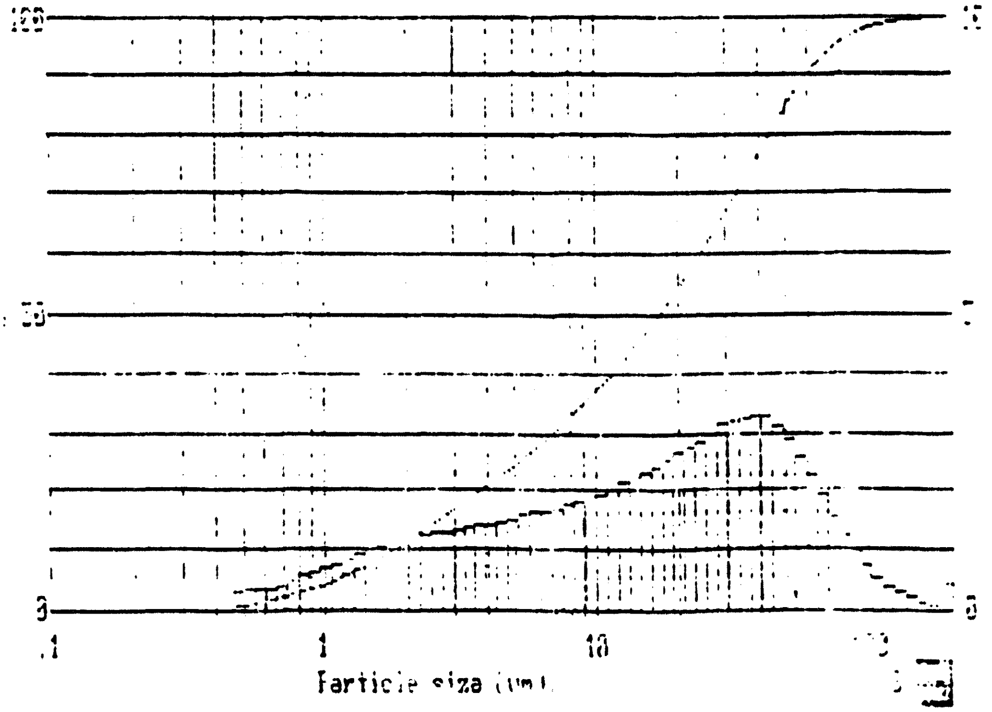

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