CONFIRMATORY SURVEY OF PORTIONS OF THE HERITAGE MINERALS INCORPORATED FACILITY LAKEHURST, NEW JERSEY

J.R. Morton and W.C. Adams

Prepared for the
U.S. Nuclear Regulatory Commission
Region I Office

ORISE
OAK RIDGE INSTITUTE FOR SCIENCE AND EDUCATION
Environmental Survey and Site Assessment Program

The Oak Ridge Institute for Science and Education (ORISE) is a U.S. Department of Energy facility focusing on scientific initiatives to research health risks from occupational hazards, assess environmental cleanup, respond to radiation medical emergencies, support national security and emergency preparedness, and educate the next generation of scientists. ORISE is managed by Oak Ridge Associated Universities. Established in 1946, ORAU is a consortium of 86 colleges and universities.

NOTICES

CONFIRMATORY SURVEY OF PORTIONS OF THE HERITAGE MINERALS INCORPORATED FACILITY LAKEHURST, NEW JERSEY (DOCKET NO. 040-08980; RFTA NO. 01-012)

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FINAL REPORT

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ABBREVIATIONS AND ACRONYMS

ϵ_i	instrument efficiency
ϵ_s	surface efficiency
µrem/h	microrem per hour
µR/h	microroentgens per hour
b_i	background counts in observation interval
BKG	background
cm	centimeter
cm^2	square centimeter
cpm	counts per minute
dpm	disintegrations per minute
dpm/100 cm^2	disintegrations per minute per one hundred square centimeters
EML	Environmental Measurements Laboratory
EPA	Environmental Protection Agency
ESSAP	Environmental Survey and Site Assessment Program
FSS	final status survey
GM	Geiger-Mueller
ha	hectares
HMI	Heritage Minerals, Inc.
ITP	Intercomparison Testing Program
kg	kilogram
km	kilometer
m	meter
mm	millimeter
m^2	square meter
MAPEP	Mixed Analyte Performance Evaluation Program
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
MDC	minimum detectable concentration
MDCR	minimum detectable count rate
MeV	mega electron volts
MRI	Mineral Recovery, Inc.
NaI	sodium iodide
NIST	National Institute of Science and Technology
NRC	Nuclear Regulatory Commission
NRIP	NIST Radiochemistry Intercomparison Program
ORISE	Oak Ridge Institute for Science and Education
pCi/g	picocuries per gram
RSI	Radiation Science, Inc.
SU	survey unit
ZnS	zinc sulfide

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INTRODUCTION AND SITE HISTORY

From 1973 to 1982, the Heritage Minerals, Inc. site was operated by ASARCO, Incorporated. ASARCO's operations consisted of the hydraulic mining (dredging) of sand deposits and the processing of these sands to extract the titanium mineral, ilmenite. The deposits contained approximately 95% silica (common sand) and 5% heavy minerals. There are many mineral constituents in the deposits that are heavier than silica; ilmenite is the predominant heavy mineral, followed by zircon, kyanite, sillimanite, rutile, staurolite, tourmaline and monazite. The monazite contains thorium and uranium causing the deposits to be radioactive.

ASARCO's process involved creating a pond for the dredge. The raw material was then brought in and placed in the dredge pond where the dredge sand was pumped to a screening barge where large roots, clay balls, and gravel were removed from the sand. The screened sand was pumped in slurry form to a land based processing plant where the heavy metals were concentrated using spiral separators in a Wet Mill. The Wet Mill tailings, consisting of silica sand and water, were pumped back to the dredge pond as backfill. The heavy metals followed a different path and were dewatered and stockpiled outside the Wet Mill. ASARCO then used water to wash away the fine clay which coated the mineral particles. Excess wash water and suspended clay were decanted off using large holding tanks before pumping out the sand. Clay-laden water was pumped to a series of large-area settling ponds on the north side of the Wet Mill. It should be noted that the monazite concentration was increased by the ratio of 24:1 as a result of going through the Wet Mill and concentrating the heavy minerals down from 1,200 tons to 50 tons.

The heavy mineral concentrate was then allowed to drain before it was transferred to a storage silo. The material was then fed onto a conveyor belt and dumped into an oil-fired rotary dryer where the sands were heated to 300 °F and completely dried. The heated sand was then conveyed to the Dry Mill which contains high-tension electrostatic separators and high-intensity magnetic separators.

The high tension separators removed the ilmenite which is electrically conductive while the other heavy minerals remaining in the concentrate are non-conductors. The ilmenite was then placed in storage bins for shipping to customers while the non-conductor minerals, referred to as the Dry Mill tailings, contained virtually all of the monazite material at a ratio of 2.5:1. These tailings were then mixed with water and pumped to a storage area east of the mill. ASARCO had planned to process the Dry Mill tailings at a later date for the extraction and sale of the zircon and monazite; however, deteriorating market conditions caused ASARCO to discontinue all operations at the site in 1982 and the property was sold to Heritage Minerals, Inc. (HMI) in 1986 (RSI 1997).

After the property was purchased by HMI, the plant facilities were leased to Mineral Recovery, Inc. (MRI). MRI performed laboratory tests for the recovery of zircon and additional titanium minerals left behind by ASARCO; the monazite was to remain as part of the Dry Mill tailings. MRI began plant operations in October 1986 and continued until August 1987 when their lease expired. HMI then took over operation of the mill until August 1990, when all production was stopped (RSI 1997).

It was during the period when HMI began operations that the Dry Mill tailings, containing the monazite, were reprocessed through the mills. The Dry Mill tailings, now referred to as the New Feed for the zircon plant, were mixed with water and pumped to the Wet Mill. The slurry was then processed through Humphreys spirals to remove any remaining silica sand and some of the aluminum minerals. Practically all of the monazite makes it through this process. The tailings were then collected in a holding tank (sump) and pumped to the area north of the Wet Mill where it was dewatered and dried in the rotary dryer. The product was then fed to the Dry Mill where titanium minerals were separated using the high tension machines. The remaining material, containing the zircon and monazite, was reslurried with water and pumped back to the Wet Mill where the material was fed into a hydraulic classifier and then into shaking tables to remove remaining aluminum minerals. The table concentrate was then dewatered on a vacuum filter and dried and heated in a second oil-fired rotary dryer. The material was then conveyed over to the Dry Mill and processed through the zircon circuit to remove the zircon (and monazite). Another process produced market-grade zircon with some monazite impurities. The remaining product, containing the majority of the monazite was then processed through the wet mill where it was combined with the spiral tailings and table tailings to make up the plant tailings which were then pumped to a storage area (RSI 1997).

In March, 1990, HMI decided that sufficient zircon and titanium products remained in the plant tailings to warrant a second round of processing known as Phase II of the operation. HMI incorporated some minor variations to the above mentioned process during Phase II operations. One of these changes, which was dictated by the U.S. Nuclear Regulatory Commission (NRC) during the licensing process, involved isolating the monazite-rich tailings. The new procedure had the mill tailings being stored in an area southeast of the Dry Mill known as the Monazite Pile. In August 1990, after about 200,000 tons of tailings were processed through the plant, HMI decided to terminate all operations due to the economic turndown which resulted in a reduced demand for plant products (RSI 1997).

The reprocessing of the 200,000 tons of plant tailings resulted in the production of about 150,000 tons of tailings that were relatively monazite free. These tailings were stored separately from the Monazite Pile. As a result, approximately 1,400 tons of monazite-rich product were generated and were stored in the Monazite Pile. The Monazite Pile and the plant buildings are under control of the NRC according to terms of License No. SMB-1541 because of the thorium and uranium concentrations.

After the plant shutdown in August 1990, both mills were subjected to a thorough cleaning and decommissioning. All the equipment in the Wet Mill which was used in the project was washed down with high-pressure water hoses and nozzles until no sand was visible on or around the equipment. The sand and water collected in the sumps and pumps were drained on the concrete floor and the sand was collected and transported to the Monazite Pile using shovels and wheelbarrows. Because of the electrical equipment present in the Dry Mill, water was not used to clean the equipment. Instead, high pressure air hoses were used to blow down the sand and dust from the equipment, structural steel, walls, and other surfaces (RSI 1997).

After the plant cleanup, a gamma survey was performed within the plant building and on selected pieces of equipment which were known to have been in contact with the monazite-containing product. Direct measurements were also performed on selected pieces of equipment (wet tables, dryer, and dry magnets). These survey activities were performed in January 1991 (RSI 1997).

Radiation Science, Inc. (RSI), the health physics contractor to HMI, performed a survey of the natural background levels of uranium and thorium within the soils and background exposure rates in 1996 (RSI 1996). This information was used to correct final survey soil sample and exposure rate data.

Currently, the site has been decommissioned with some support buildings still being used for equipment storage and repair. The Wet and Dry Mill equipment is non-operational but both buildings contain millions of dollars worth of heavy equipment including tanks, elevators, high tension separators, piping, and hundreds of tons of heavy equipment and structural supports.

RSI used two classifications to distinguish survey units for final surveys—these included Affected and Unaffected areas. NUREG/CR-5849 was used by RSI as the governing document for releasing the Wet and Dry Mills (NRC 1992a). The major radiological contaminants of concern for the Wet and Dry Mills are thorium and uranium (and associated decay products).

The NRC Division of Waste Management requested that the Environmental Survey and Site Assessment Program (ESSAP) of the Oak Ridge Institute for Science and Education (ORISE) perform radiological confirmatory survey activities on various portions of the HMI facility in Lakehurst, New Jersey.

SITE DESCRIPTION

HMI is located in Lakehurst, New Jersey and is approximately 50 kilometers [km (30 miles)] southeast of downtown Trenton, New Jersey (Figure 1). The HMI facility consists of two large milling buildings known as the Wet and Dry Mills and other support (warehouse and office areas) and laboratory buildings occupying approximately 2,800 hectares [ha (7,000 acres)]. The site is bounded on the north and west by Route 70, the east by Route 37 and to the south by two residential areas and Pinewald Keswick Road (Figure 2).

The portion of the facility where the NRC licensed work (monazite milling) was performed was within the two milling buildings and the area known as the Monazite Pile (Figure 3). The mill

buildings consist of metal frames and roofs and the siding is corrugated steel. The floor construction varies from area to area and is a combination of poured concrete, brick and bare earth. There are few windows, several garage-type doors, several standard entrances, and several roof ventilator fans. The stairs and upper floor areas are of steel/aluminum deck grating, typical of milling/manufacturing buildings.

The Wet Mill contains the process equipment that was used to extract the product material from the raw materials. The Dry Mill contains the process equipment used to extract the product materials from the Wet Mill process feed. A ten meter square grid system was established by RSI around the Monazite Pile and extended out to ten meters beyond the fenced borders of the pile. The pile has since been removed exposing natural soils below and the grid system is no longer in place.

There are also five other buildings on the site—these are the Laboratory, Maintenance, Warehouse, Main Office, and Change House buildings where monazite-rich products may have been handled. Monazite was also sampled or analyzed in the laboratory, so the Laboratory Building was considered in the survey. However, affected process equipment was repaired in the mill buildings rather than being repaired in the Maintenance Building therefore, this building was not included in the survey activities (RSI 1997).

OBJECTIVES

The objectives of the radiological confirmatory survey were to provide independent contractor field data reviews and radiological data for use by the NRC in evaluating the adequacy and accuracy of the licensee's procedures and final status survey results, relative to established guidelines. Information was gathered to evaluate the facility's current radiological status as reported by the licensee.

DOCUMENT REVIEW

ESSAP reviewed some of the site documentation and the final status survey plan prior to visiting the site and reviewed the final status survey report while on site (RSI 1997 and 2001).

RADIOLOGICAL SURVEY PROCEDURES

ESSAP personnel visited and performed a confirmatory survey of the HMI facility during the period of December 10 through 13, 2001. Survey activities were conducted in accordance with a site-specific survey plan, submitted to and approved by the NRC (ORISE 2001a), and the ORISE/ESSAP Survey Procedures and Quality Assurance Manuals (ORISE 2000 and 2001b). Survey activities included gamma, alpha plus beta, and beta surface scans, direct measurements, soil sampling, miscellaneous sampling, and exposure rate measurements. This report summarizes the procedures and results of the survey.

ESSAP used the following radiological survey procedures to conduct confirmatory survey activities on building, equipment, and soil surfaces that are to be released for unrestricted use. Specific survey units (SU) were surveyed based on RSI's two classifications (Affected and Unaffected)—these classifications were based on the potential for radiological contamination; on historical process knowledge; and, on RSI's characterization survey findings. ESSAP performed confirmatory surveys in 17 of the SUs in the Dry and Wet Mills for which RSI has provided data—these SUs were selected based on RSI's final status data.

INTERIOR

ESSAP used the following procedures for the interior surfaces of the Laboratory and Mill Buildings.

Reference System

The complexity of the interior of both buildings posed a challenge to the application of a two-dimensional grid systems as described in Draft NUREG/CR-5849 (NRC 1992a). Therefore, ESSAP used digital pictures created by both ESSAP and RSI to document surface activity measurement locations on equipment surfaces. The floor plan figures provided by RSI were used to document surface activity measurements on floor surfaces.

Surface Scans

Based on the classification of the interior SUs by the licensee, surface scans for alpha plus beta, beta, and gamma radiation were performed at up to 20% of the structural surfaces in affected survey units and at judgmental locations within the structural surfaces in unaffected survey units. Surface scans for alpha plus beta and gamma radiation were performed on up to 100% of the ground floor surfaces of the Dry Mill and the eastern half of the Wet Mill. Particular attention was given to cracks and joints in the structural surfaces where material may have accumulated. Interior scans were performed using gas proportional, ZnS, GM, and NaI scintillation detectors coupled to ratemeters or ratemeter-scalers with audible indicators. Locations of elevated direct radiation detected by surface scans were marked for further investigation.

Surface Activity Measurements

Initially, construction material-specific backgrounds were determined in areas of similar construction, but without a history of radioactive material use. Additionally, ambient backgrounds were determined in areas where direct surface activity measurements were performed. These background measurements were used to correct gross surface activity measurements.

Direct measurements of surface activity were performed at a total of 129 locations on equipment and building surfaces (Figures 4 through 21). The majority of the direct measurements were performed using gas proportional detectors—GM and ZnS scintillation detectors were used in areas that were inaccessible to the gas proportional detectors. All detectors were coupled to ratemeter-scalers. Smear samples, for the determination of removable gross alpha and gross beta activity levels, were collected from each accessible direct measurement location.

Exposure Rate Measurements

Interior background exposure rate measurements were performed within the Main Office Building which has similar construction, but no history of radioactive material use. Exposure rates were performed at a total of ten locations within both the Wet Mill and Dry Mill buildings (Figures 21 and

22) and three locations within the Laboratory Building (no figure). Exposure rates were performed at one meter from the surface using a microrem meter.

Residue Sampling

Residue samples were collected from two locations in the Dry Mill and one location in the Wet Mill (Figures 7, 18, and 20).

EXTERIOR

ESSAP used the following procedures for the Monazite Pile and the adjacent areas surrounding the Monazite Pile and the Dry Mill Building.

Reference System

Since the reference system utilized by RSI was no longer in place, ESSAP established a 10 m × 10 m reference grid system for the former Monazite Pile area. An aerial photo and landmarks were used for referencing other exterior locations that were not within the Monazite Pile area.

Surface Scans

Gamma scans were conducted over 100 percent of accessible soil surfaces within and in the immediate vicinity (5 meters) of the Monazite Pile area. Cursory gamma scans were performed at other suspect locations, i.e., near the Dry Mill and in areas between the Dry Mill, Monazite Pile and the pond. Gamma scans were performed using NaI scintillation detectors coupled to ratemeters with audible indicators. Locations of elevated radiation were marked for further investigation.

Exposure Rates

Exterior background exposure rate measurements were performed at six locations within a 0.5 to 10 km radius of the site (Figure 23). Site exposure rates were measured at 23 surface soil sample locations (Figures 24 and 25). Exposure rate measurements were performed at one meter above the surface using a microrem meter.

Soil Sampling

Background soil samples were collected from each external background exposure rate measurement location (Figure 23). Surface (0 to 15 cm) soil samples were collected from 17 locations in three grid blocks within the former Monazite Pile (Figure 24). Four soil samples were collected from each of the selected grid blocks at the points midway between the center and grid block corners of the selected grid blocks. Several soil samples were also collected within these three grid blocks at locations of elevated direct radiation identified by surface scans. Additional soil samples were collected at locations outside the former Monazite Pile at locations of elevated direct radiation identified by surface scans (Figure 25). Subsurface soil samples were collected from ten locations where elevated radiation was suspected to be present below the initial 15 cm of exposed soils (Figures 24 and 25). Samples collected by RSI were also requested for confirmatory analysis.

SAMPLE ANALYSIS AND DATA INTERPRETATION

Samples and data were returned to ORISE's ESSAP laboratory in Oak Ridge, Tennessee for analysis and interpretation. Sample analyses were performed in accordance with the ORISE/ESSAP Laboratory Procedures Manual (ORISE 2001c). Soil and residue samples were analyzed by gamma spectroscopy and results reported in picocuries per gram (pCi/g). The radionuclides of interest are uranium and thorium; however, spectra were reviewed for other identifiable photopeaks. Smears were analyzed for gross alpha and gross beta activity using a low-background gas proportional counter. Direct measurement data and smear data were converted to units of disintegrations per minute per one hundred square centimeters (dpm/100 cm^2). Exposure rates were reported in microroentgens per hour (μR/h). Additional information concerning major instrumentation, sampling equipment, and analytical procedures is provided in Appendices A and B.

FINDINGS AND RESULTS

Although the final status survey (FSS) report was not available until ESSAP was on-site, electronic versions of figures and data for surface activity measurements were provided prior to the survey site visit. NRC inspection of licensee documentation for surface scans and samples taken after the pile removal showed soil concentrations to be within unrestricted release guideline values. The confirmatory survey was performed based upon the licensee's indication that remediation activities were completed. The FSS report containing the remaining text and the soil sample data were provided at the time of the survey.

DOCUMENT REVIEW

Review of the FSS report indicated that:

- documentation was described for alpha surface activity measurements only. Prescribed ESSAP survey procedures have been developed based on previous experience which shows that surface activity measurements for thorium and/or uranium should also include consideration for beta activity measurements, due to attenuation problems associated with measuring alpha contamination on rough, porous, or dirty surfaces;
- interpretation of averaging guidelines for soils within the Monazite Pile did not follow NUREG/CR-5849 guidance. Soil samples were collected at a rate of one per 100 square meter grid and averaged over the entire Monazite Pile area (approximately fifteen 10 m × 10 m grid blocks);
- soil backgrounds were typically elevated in the Monazite Pile area and around the Mill buildings. This did not agree with RSI's Report of Site Backgrounds, performed in July 1996, which indicated that the average U-238 and Th-232 background concentrations were 0.31 and 0.25 pCi/g, respectively. The average background level was 3 μrem/h (RSI 1996); and,
- the Monazite Pile was scanned over 100% of the surface area with a NaI probe suspended approximately 2 feet above the surface of the soil. The scanning methodology was not

consistent with NUREG/CR-5849 guidelines which specifies measurements to be taken in closer proximity to the soil surface.

INTERIOR

The results for the Wet and Dry Mills and the Laboratory Building are discussed below.

Surface Scans

Several areas of elevated alpha plus beta and beta activity were detected on the floors and equipment within the Mill Buildings. Most of the activity appeared to be in locations where sand, dust, or debris had gathered. Surface scans also detected alpha plus beta activity within the Laboratory Building.

Surface Activity Measurements

Results of total alpha and alpha plus beta surface activity levels for the interior areas are summarized in Table 1. Total activity levels in the Laboratory Building ranged from 9 to 720 dpm/100 cm^2 for alpha and -240 to 3,500 dpm/100 cm^2 for alpha plus beta. Total activity levels in the Wet Mill ranged from 140 to 2,300 dpm/100 cm^2 for alpha and 810 to 35,000 dpm/100 cm^2 for alpha plus beta. Total activity levels in the Dry Mill ranged from 200 to 2,600 dpm/100 cm^2 for alpha and 73 to 89,000 dpm/100 cm^2 for alpha plus beta. Removable activities for all areas ranged from 0 to 150 dpm/100 cm^2 for alpha and -5 to 730 dpm/100 cm^2 for beta.

Exposure Rate Measurements

The exposure rates for the Laboratory and the Wet and Dry Mills are summarized in Table 2 and ranged from 7 to 17 μR/h. Background exposure rates in the main equipment building ranged from 4 to 8 μR/h and averaged 6 μR/h.

Residue Sampling

Concentrations of radionuclides in site residue samples are summarized in Table 3. The radionuclide concentrations for the three samples were: 120, 870, and 1,400 pCi/g for total uranium and 640, 1,300 and 3,100 pCi/g for total thorium.

EXTERIOR

The results for the Monazite Pile and exterior areas adjacent to the Pile and Mill Buildings are discussed below.

Surface Scans

Gamma scans conducted over the former Monazite Pile and the surrounding areas of the Pile and the Mill Buildings identified multiple locations of elevated direct gamma radiation.

Exposure Rates

Site and background exposure rates are summarized in Table 4. Site exposure rates ranged from 15 to 30 μR/h. Background exposure rates ranged from 3 to 7 μR/h and averaged 4 μR/h.

Soil Sampling

Radionuclide concentrations in site soil samples are summarized in Table 4. The radionuclide concentration for the individual samples ranged as follows: 2.3 to 120 pCi/g for total uranium and 5.6 to 1540 pCi/g for total thorium. The grid block average concentrations for surface samples collected within the three 100 m^2 grid blocks of the former Monazite Pile were 6.9, 29 and 31 pCi/g for total uranium and 15, 75 and 150 pCi/g for total thorium.

Concentrations of radionuclides in background samples are summarized in Table 4 and ranged as follows: 0.5 to 1.0 pCi/g for total uranium and 0.3 to 0.6 pCi/g for total thorium.

Confirmatory Sample Analyses

Three samples that RSI had analyzed at a contracted, off-site laboratory were also analyzed by ESSAP. The analytical results for the comparative evaluation of the RSI archived samples are provided in Table 5 and indicated that the RSI contractor laboratory data were consistent and in agreement with ESSAP's analytical results.

COMPARISON OF RESULTS WITH GUIDELINES

The primary contaminants at this site are thorium and uranium. The applicable NRC guidelines for natural thorium and natural uranium surface activity levels are (NRC 1987):

Natural Uranium

5,000 α dpm/100 cm^2, averaged over a 1 m^2 area

15,000 α dpm/100 cm^2, total, maximum in a 100 cm^2 area

1,000 α dpm/100 cm^2, removable

Natural Thorium

1,000 dpm/100 cm^2, averaged over a 1 m^2 area

3,000 dpm/100 cm^2, total, maximum in a 100 cm^2 area

200 dpm/100 cm^2, removable

Because RSI has elected to use the more restrictive guidelines for thorium contamination, ESSAP used RSI's approach for confirmatory measurements and data comparison. Natural thorium emits both alpha and beta radiations, therefore, either alpha or beta activity may be measured for determining the residual activity of the thorium contaminant. As interpreted by the NRC, the average 1,000 dpm/100 cm^2 and maximum 3,000 dpm/100 cm^2 should apply independently to both alpha and beta measurements for surface contamination involving natural thorium (NRC 1992b). ESSAP's experience has shown that beta measurements typically provide a more accurate evaluation of thorium contamination on structural surfaces due to problems inherent in measuring alpha

contamination on rough, porous, and/or dirty surfaces. For the thorium series in secular equilibrium, the activity level providing 1,000 alpha dpm/100 cm^2 would result in about 670 beta dpm/100 cm^2. Therefore, a beta activity measurement that is greater than 670 dpm/100 cm^2 was considered to have exceeded the alpha activity guideline for thorium. However, based on the standard thorium guideline, of the 129 direct measurements that were performed for alpha plus beta activity, 20 exceeded the average guideline and 75 exceeded the maximum. Even with the attenuation of alpha particles due to the heavy dust levels, seven of the 26 alpha direct measurements still exceeded the average guideline—none exceeded the maximum guideline. One smear sample collected from SU42 in the Dry Mill exceeded the removable guideline.

The NRC guideline for exposure rates at one meter above building surfaces is 5 μR/h above background (NRC 1991). Of the 18 exposure rates that were performed in the Laboratory and Mill Buildings, three measurements in the Dry Mill and two in the Wet Mill exceeded this guideline.

The NRC guideline for exposure rates at one meter above the surface for exterior areas is 10 μR/h above background (NRC 1981). All on-site exposure rate measurements exceeded this guideline value with the average background exposure rate of 4 μR/h.

The soil guidelines are as follows (NRC 1981 and 1983):

Radionuclide	Soil Concentration Above Background (pCi/g)
Total uranium	10
Total thorium	10

Of the 34 surface and subsurface soil samples that were collected from the HMI site, 27 exceeded the guideline for total uranium and 32 exceeded the guideline for total thorium. Only two of the samples that were collected did not exceed either guideline.

SUMMARY

The Environmental Survey and Site Assessment Program of the Oak Ridge Institute for Science and Education performed confirmatory survey activities of the Wet and Dry Mill Buildings, the Laboratory, the former Monazite Pile, and soil areas adjacent to these areas at the Heritage Minerals Site during the period of December 10 through 13, 2001. Survey activities included a review of the final status survey report and performance of independent gamma and alpha plus beta scans, direct surface activity measurements, exposure rate measurements, and miscellaneous and soil sampling.

The results of the verification activities indicated that surface activity levels and radionuclide concentrations in soil exceeded guideline levels. The majority of surface activity measurements and soil samples collected by ESSAP exceeded the appropriate guidelines. Furthermore, each of the three residue samples collected from the Mill Buildings had total uranium and total thorium levels in excess of 120 and 640 pCi/g, respectively. While elevated radionuclide concentrations were present in surface soil samples, it was apparent that elevated concentrations were also present at various subsurface depths. Scoping surveys of unaffected mill and other exterior areas also showed indication of residual radionuclide contamination.

FIGURES

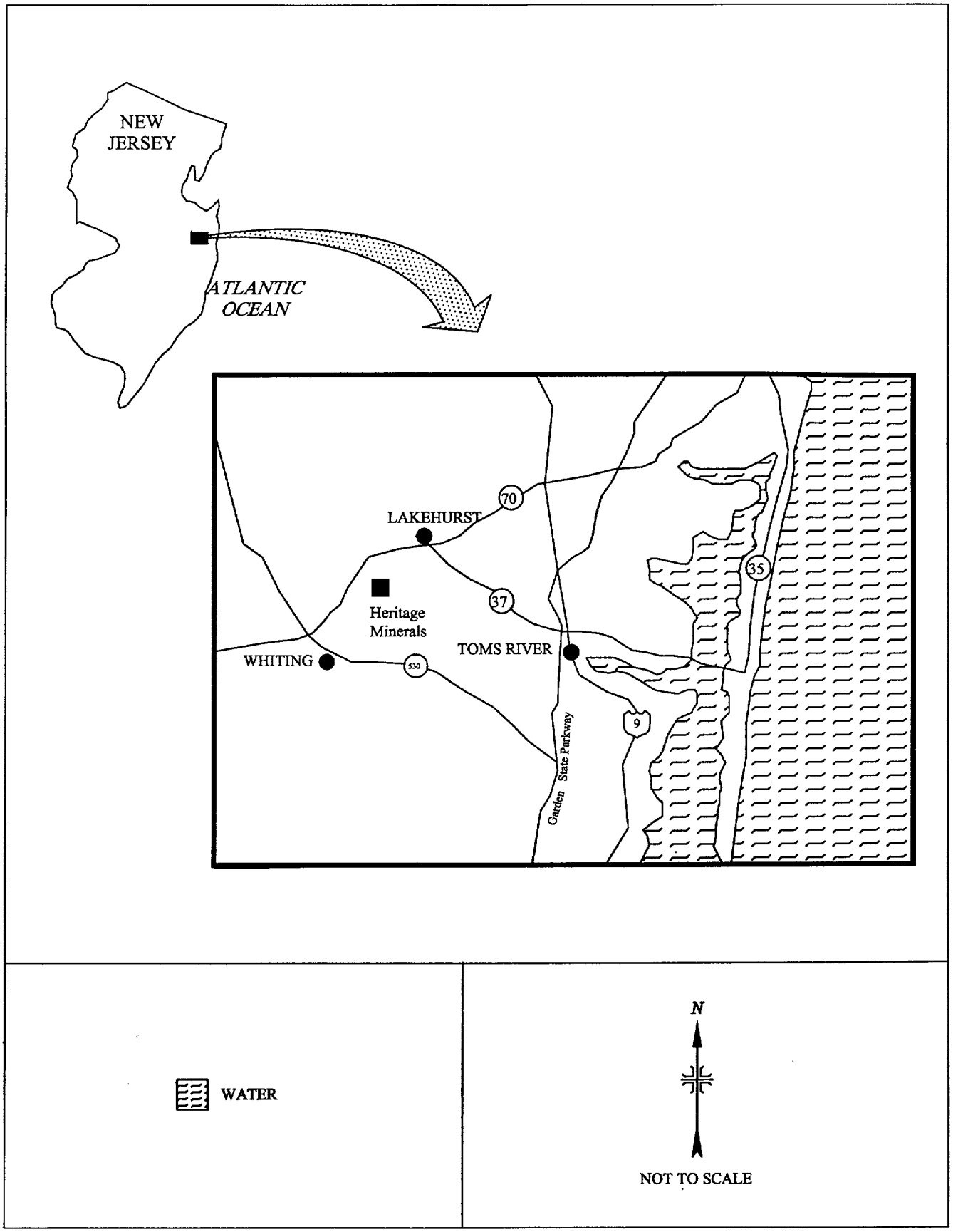


FIGURE 1: Location of the Heritage Minerals Site - Lakehurst, New Jersey

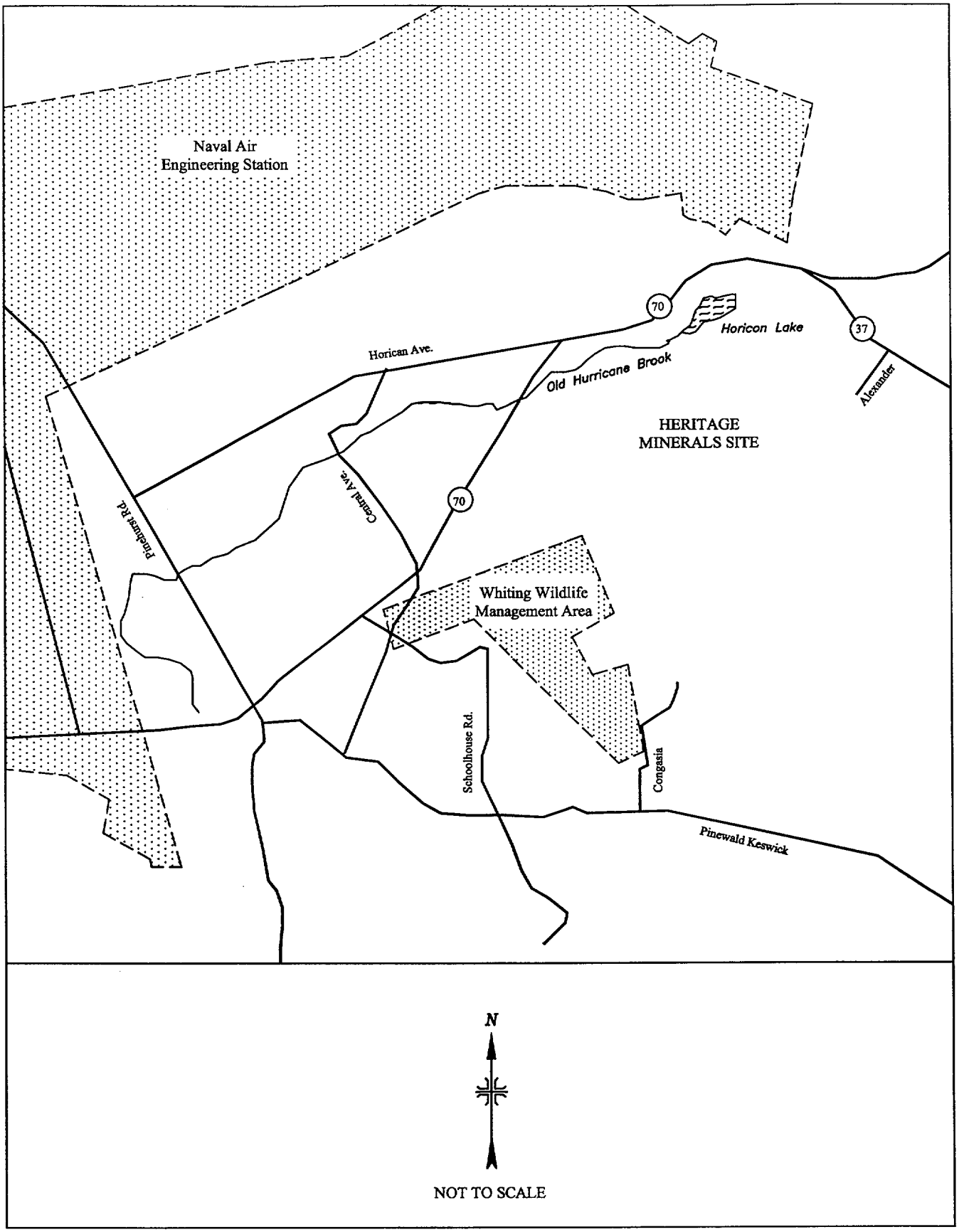


FIGURE 2: Heritage Minerals Site - Lakehurst, New Jersey

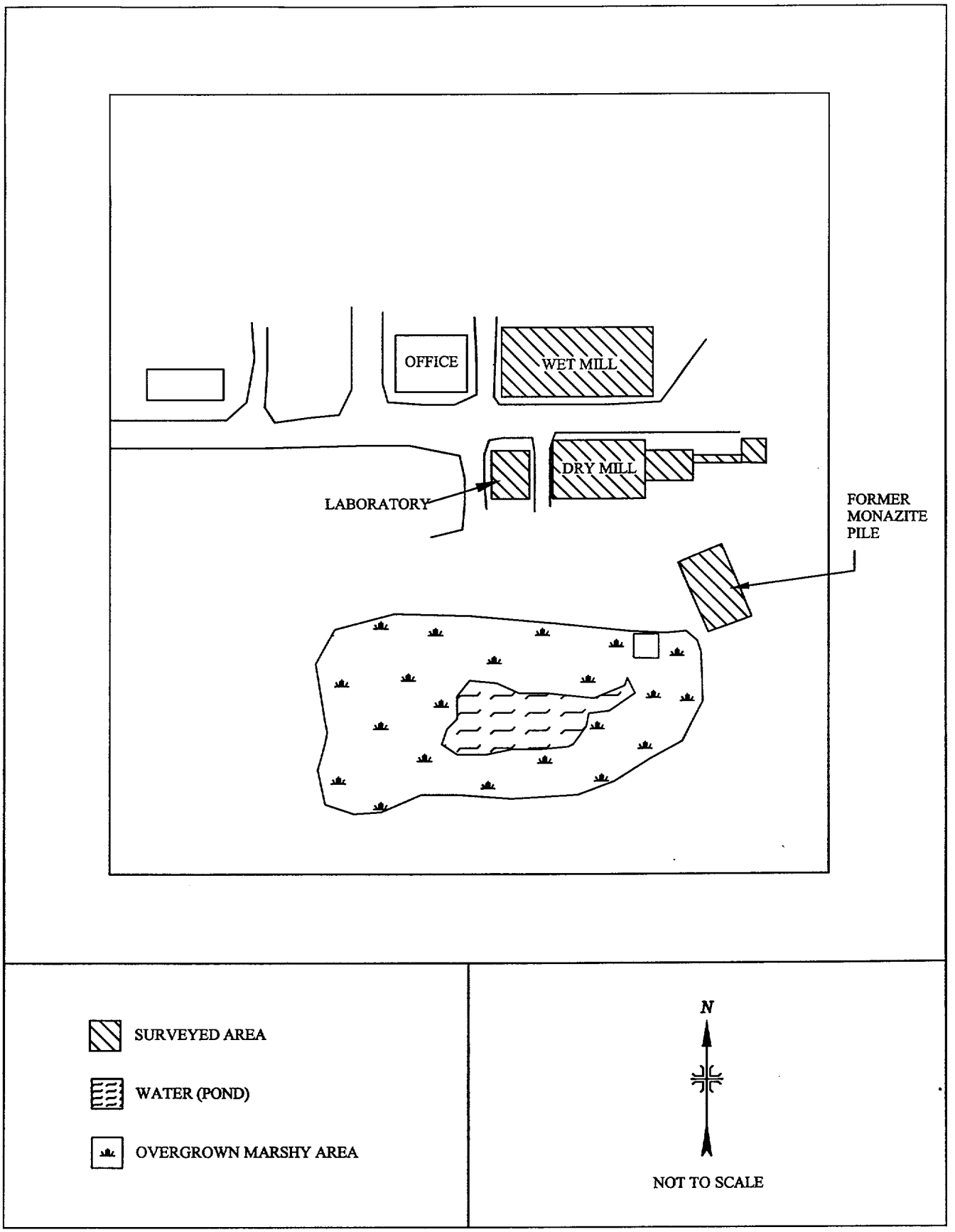
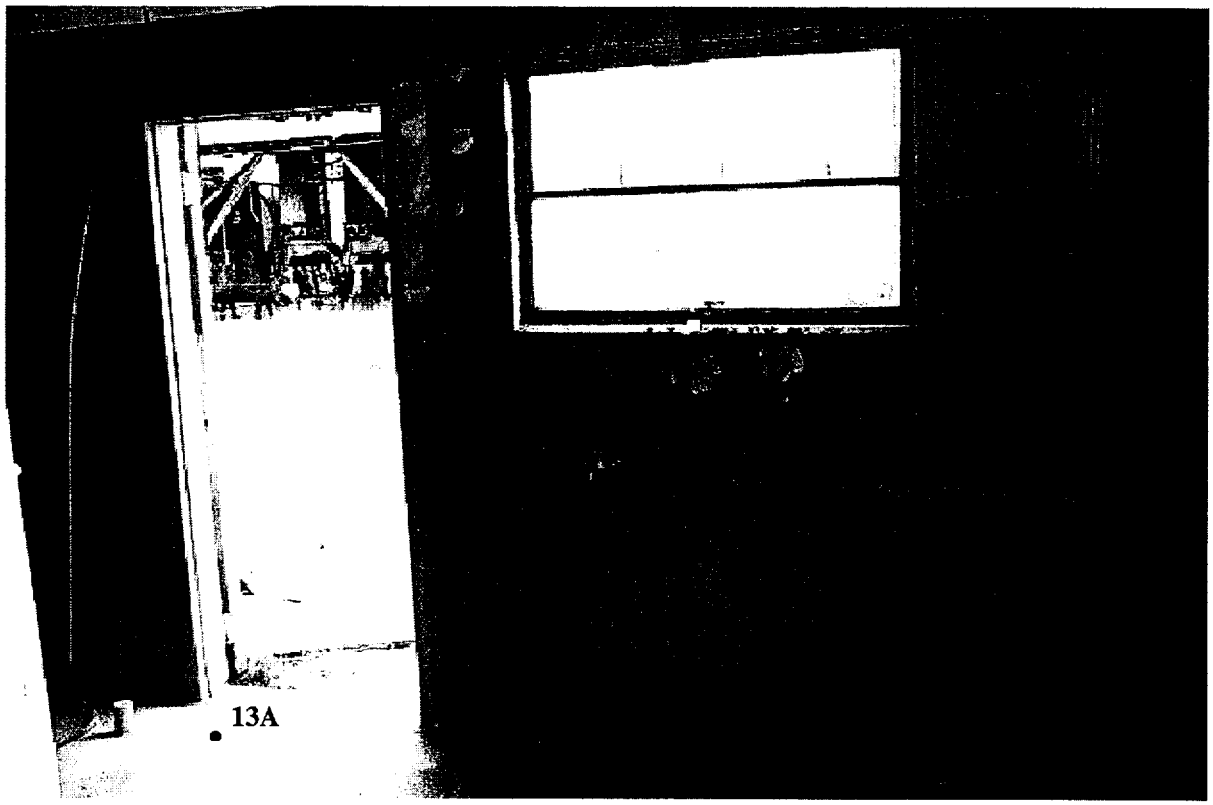
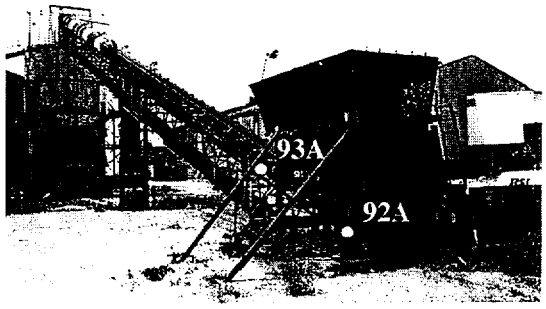


FIGURE 3: Heritage Minerals Site - Location of Surveyed Areas



MEASUREMENT/SAMPLING LOCATIONS	NOT TO SCALE
• # SINGLE POINT	

FIGURE 4: Laboratory — Location of Measurement 13A

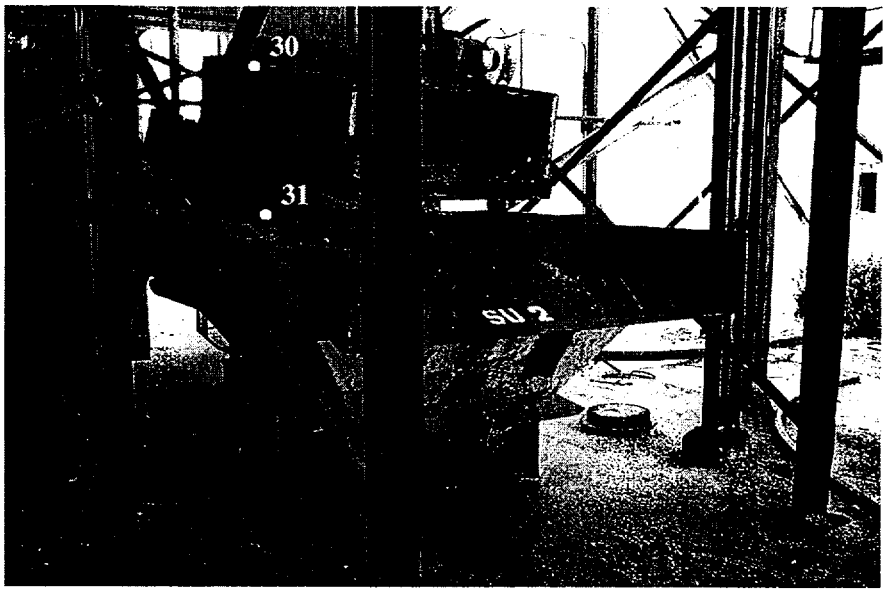


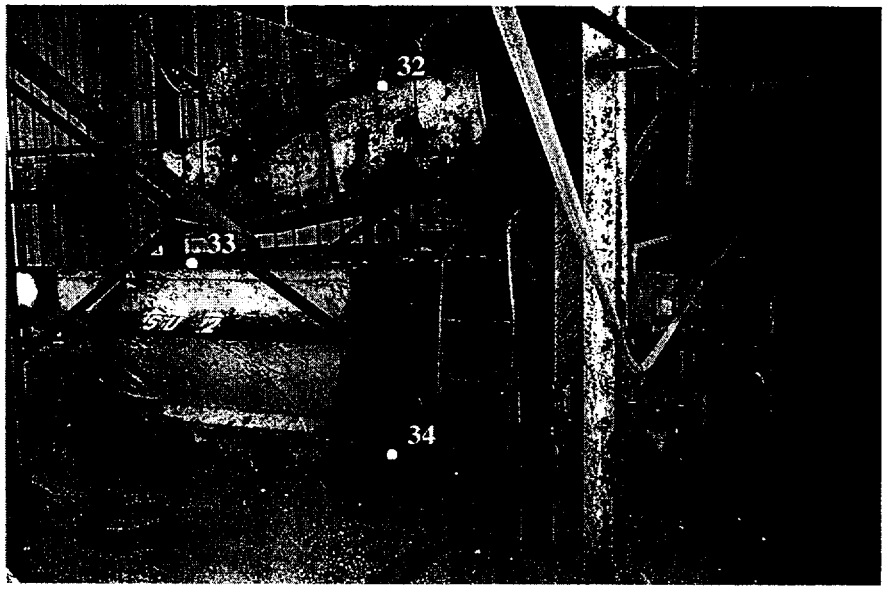
MEASUREMENT/SAMPLING LOCATIONS

• # SINGLE POINT

NOT TO SCALE

FIGURE 5: Survey Unit 1 — Direct Measurement and Sampling Locations



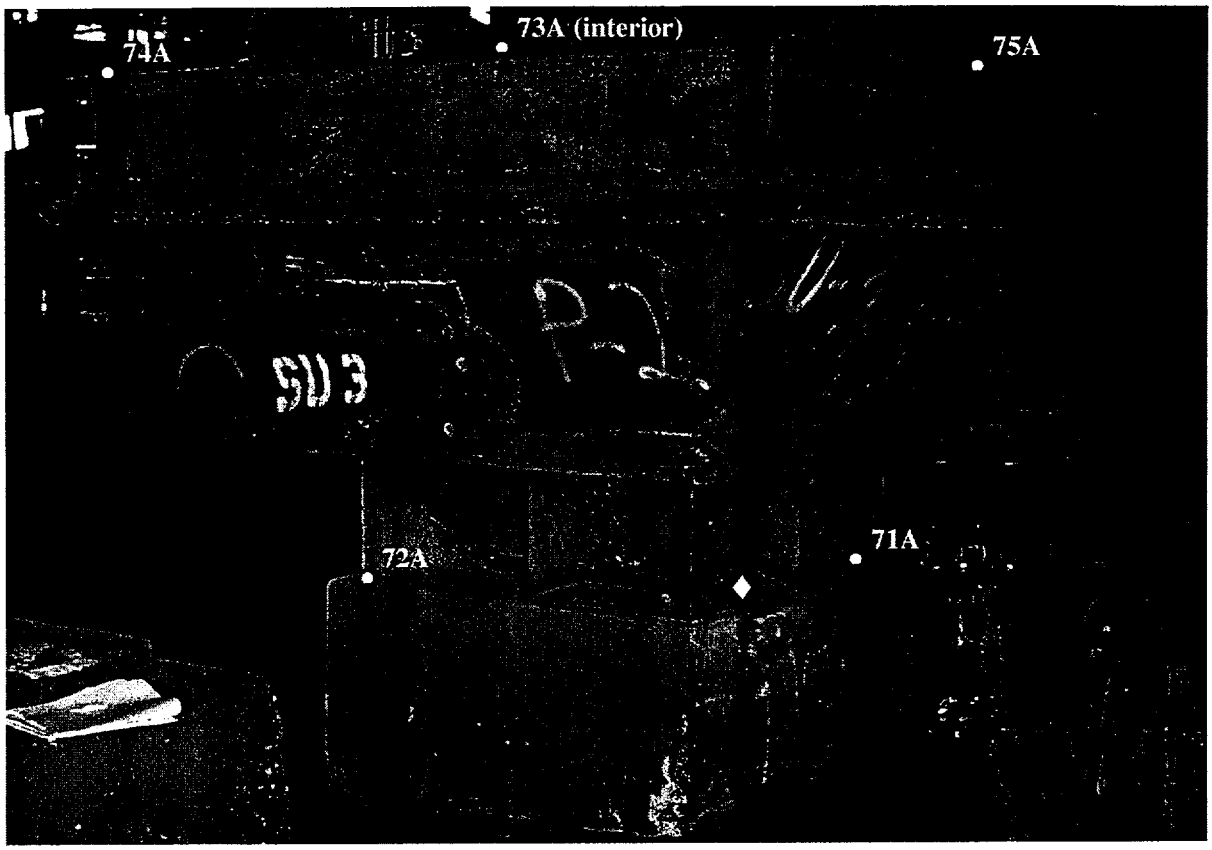


MEASUREMENT/SAMPLING LOCATIONS

• # SINGLE POINT

NOT TO SCALE

FIGURE 6: Wet Mill, Survey Unit 2— Direct Measurement and Sampling Locations

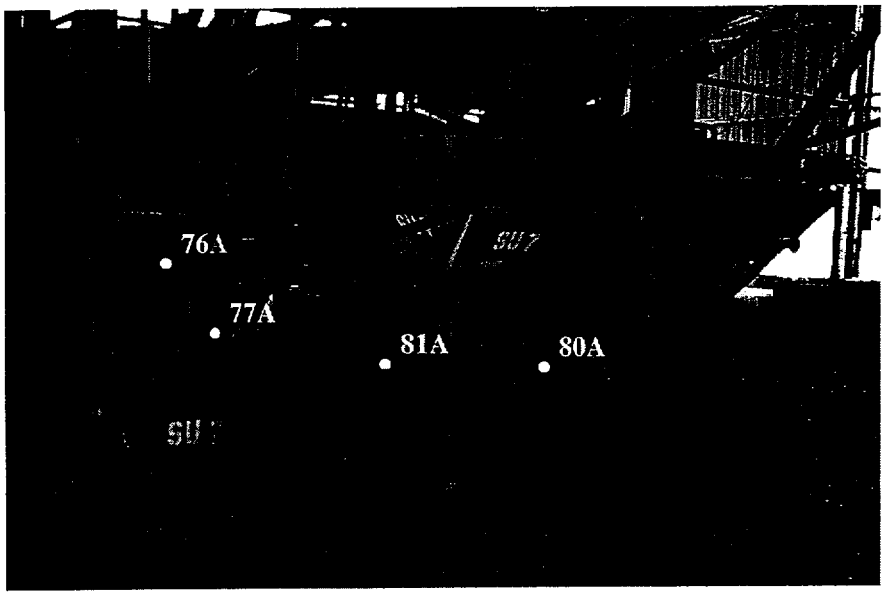


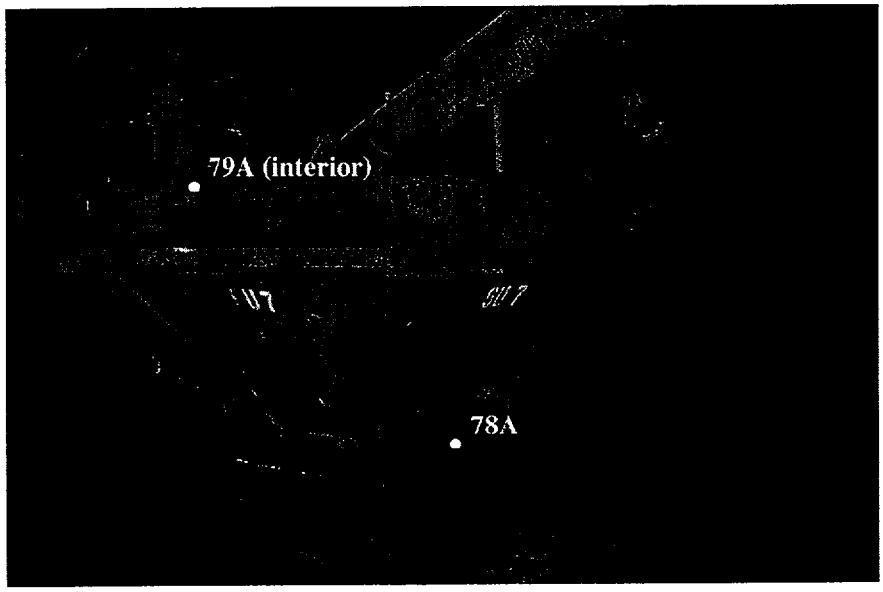
MEASUREMENT/SAMPLING LOCATIONS

- # SINGLE POINT
- ♦ RESIDUE SAMPLE

NOT TO SCALE

FIGURE 7: Wet Mill, Survey Unit 3 — Direct Measurement and Sampling Locations



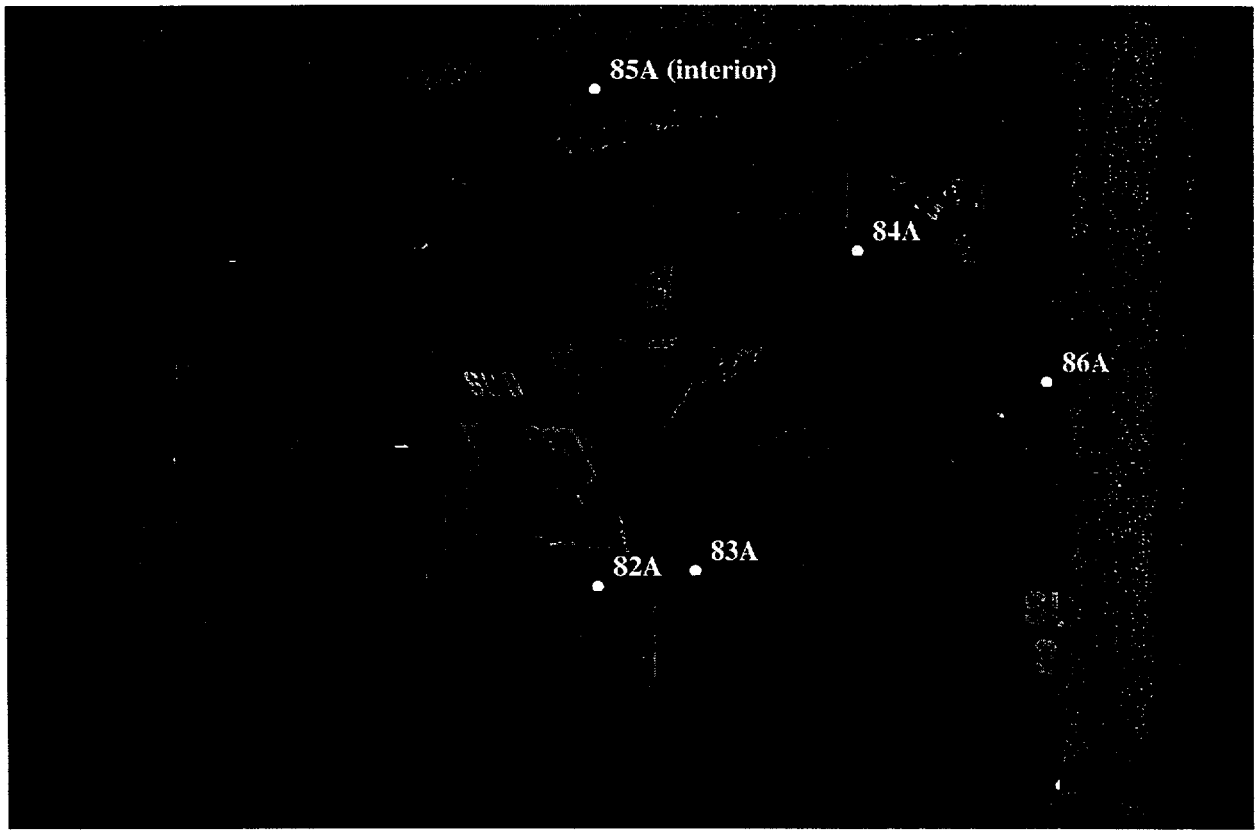


MEASUREMENT/SAMPLING LOCATIONS

• # SINGLE POINT

NOT TO SCALE

FIGURE 8: Wet Mill, Survey Unit 7 — Direct Measurement and Sampling Locations

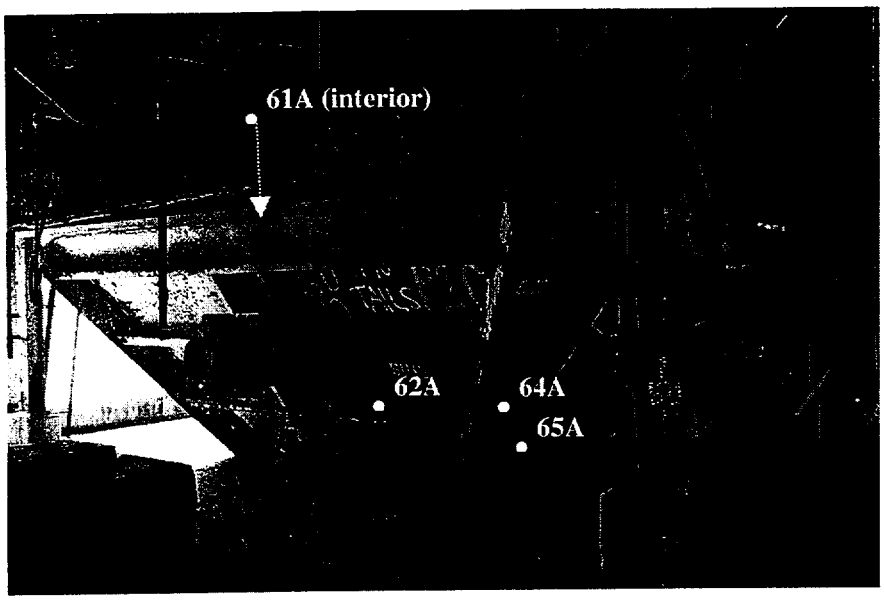


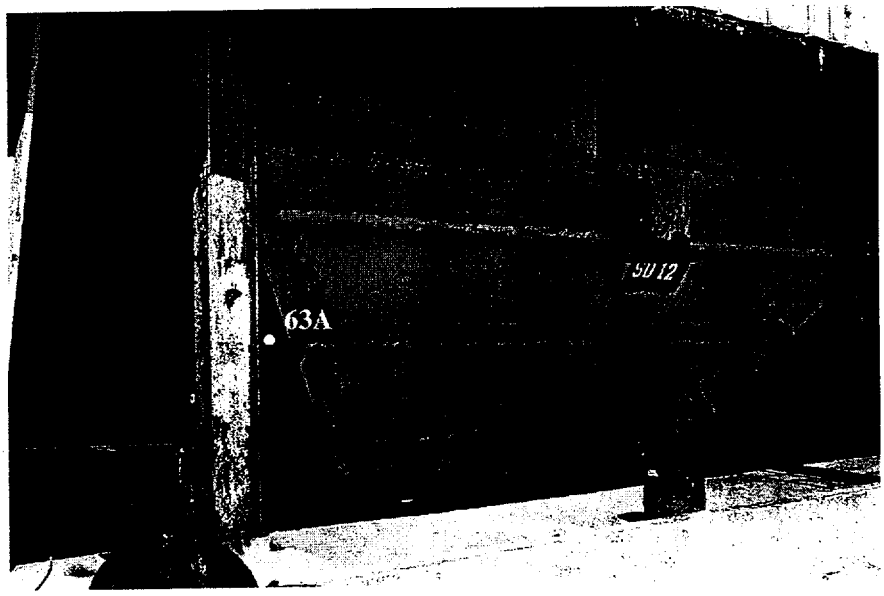
MEASUREMENT/SAMPLING LOCATIONS

• # SINGLE POINT

NOT TO SCALE

FIGURE 9: Wet Mill, Survey Unit 9 — Direct Measurement and Sampling Locations



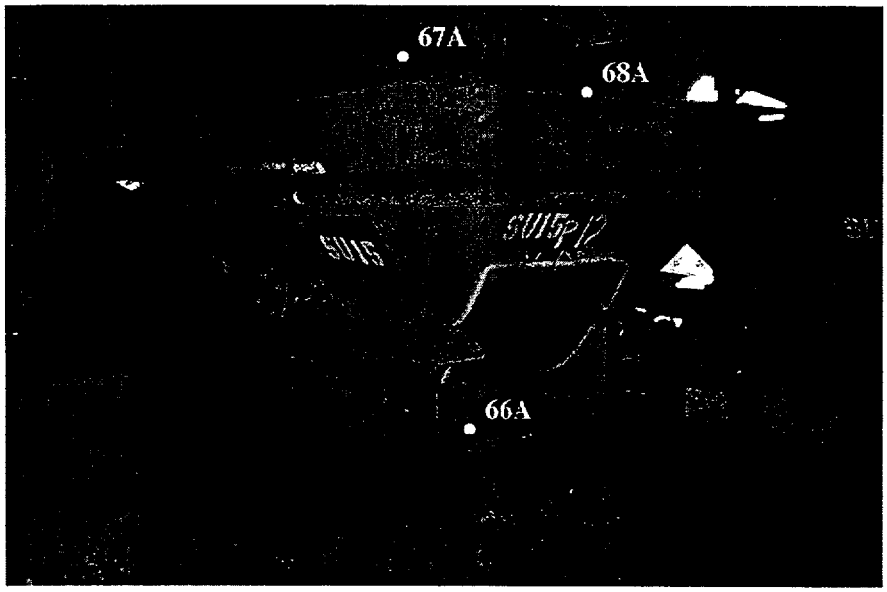


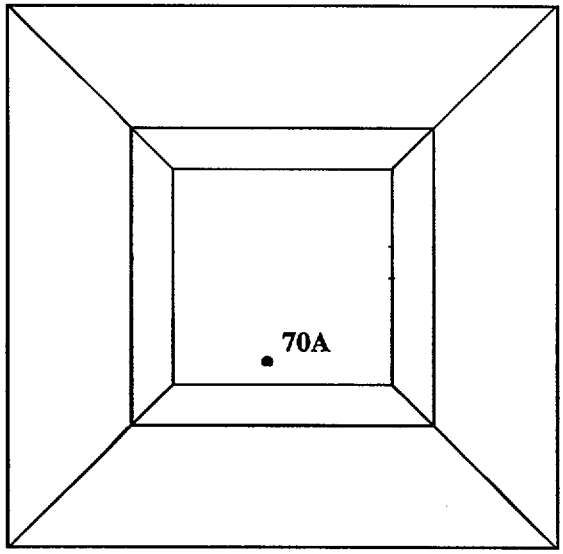
MEASUREMENT/SAMPLING LOCATIONS

• # SINGLE POINT

NOT TO SCALE

FIGURE 10: Wet Mill, Survey Unit 12 — Direct Measurement and Sampling Locations





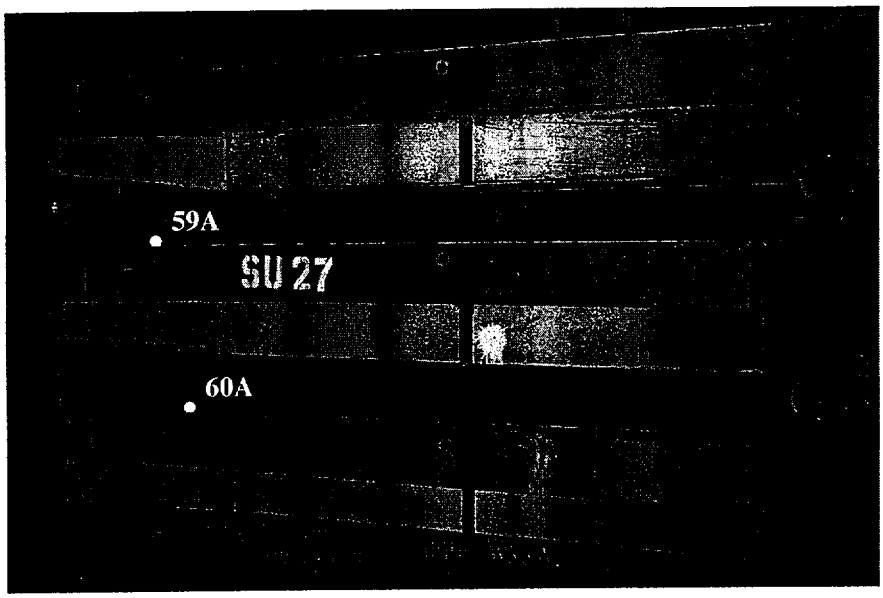
INTERIOR

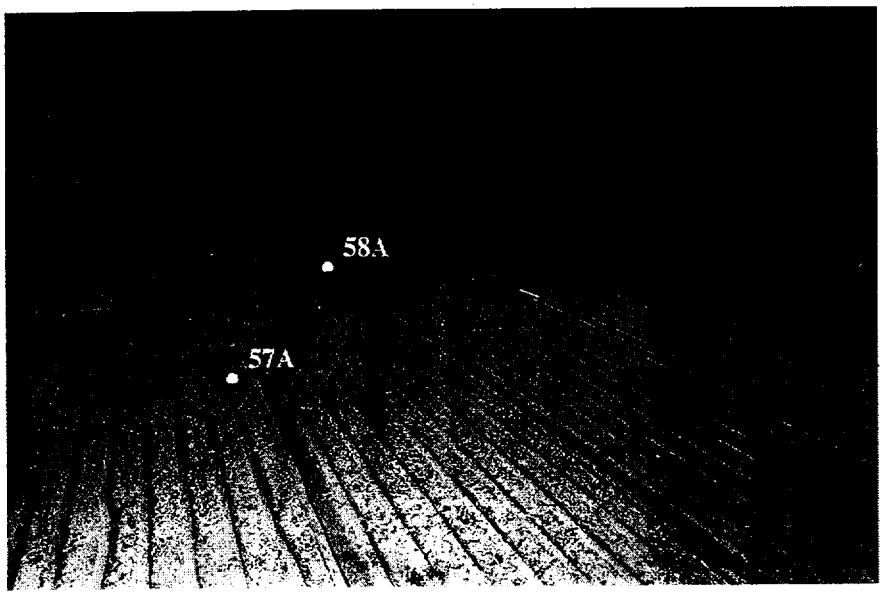
MEASUREMENT/SAMPLING LOCATIONS

• # SINGLE POINT

NOT TO SCALE

FIGURE 11: Wet Mill, Survey Unit 15 — Direct Measurement and Sampling Locations



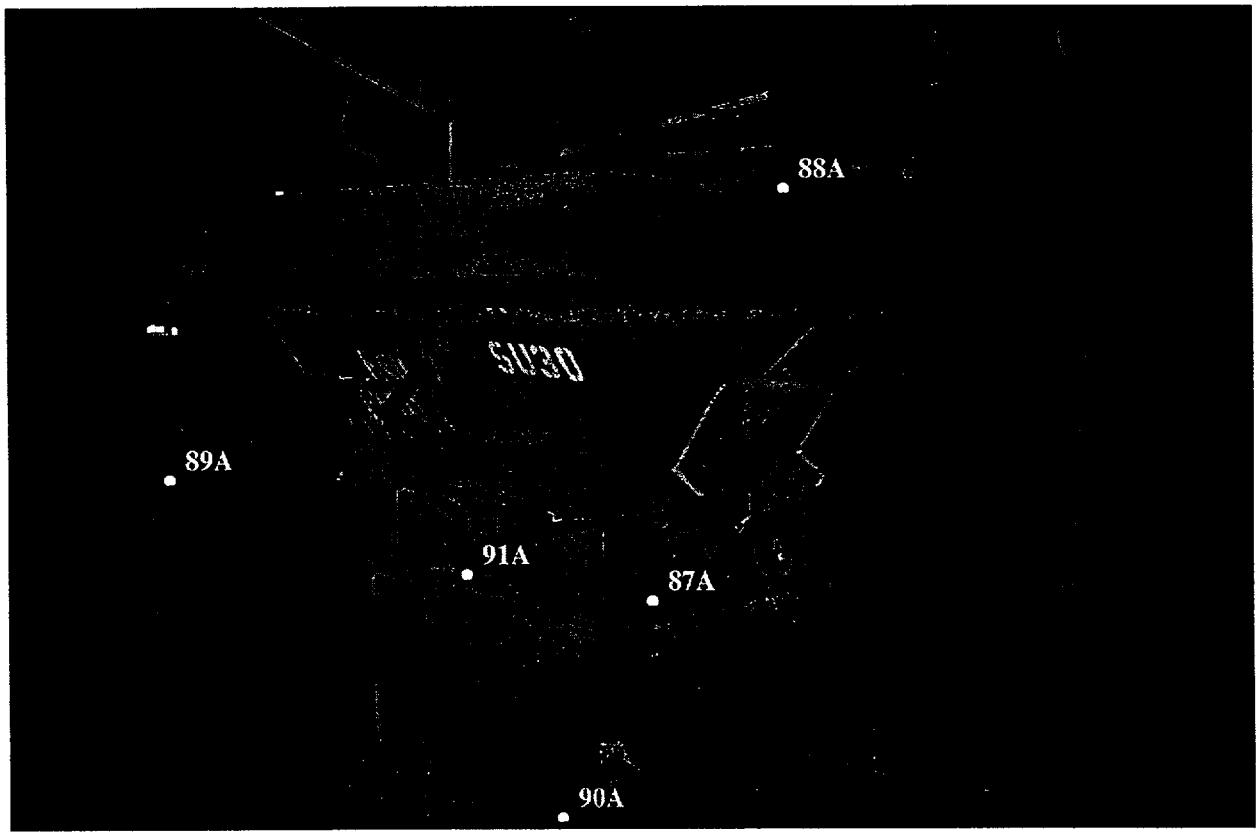


MEASUREMENT/SAMPLING LOCATIONS

• # SINGLE POINT

NOT TO SCALE

FIGURE 12: Wet Mill, Survey Unit 27 — Direct Measurement and Sampling Locations

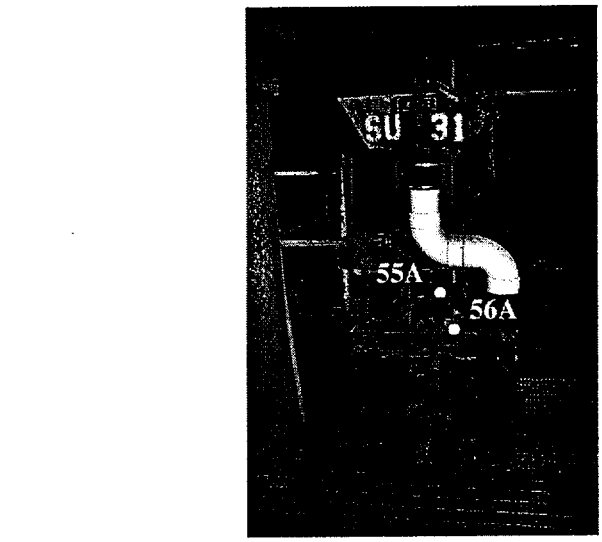


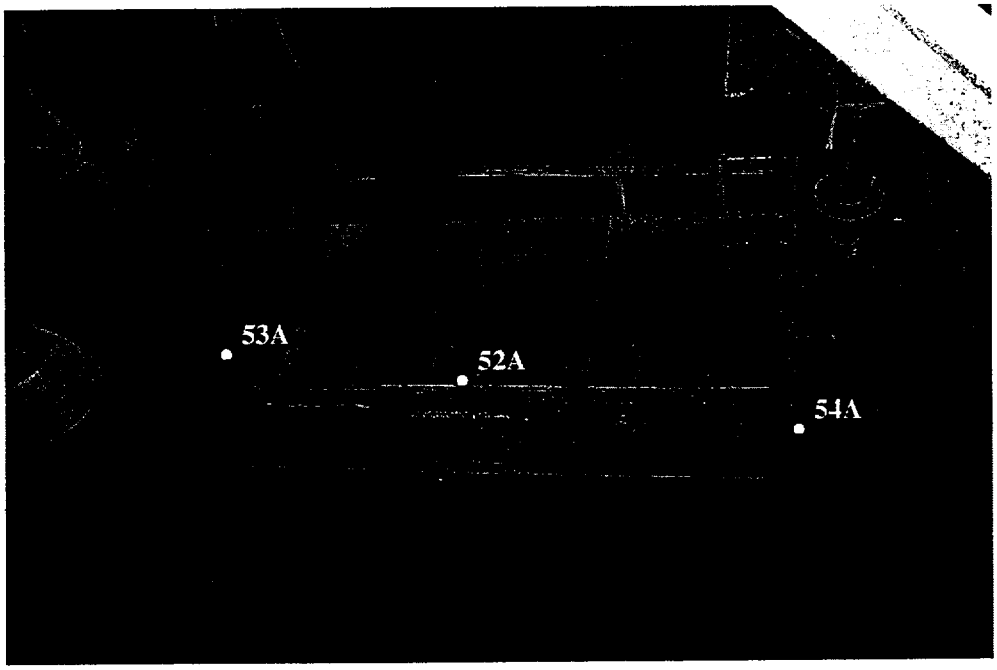
MEASUREMENT/SAMPLING LOCATIONS

• # SINGLE POINT

NOT TO SCALE

FIGURE 13: Wet Mill, Survey Unit 30 — Direct Measurement and Sampling Locations



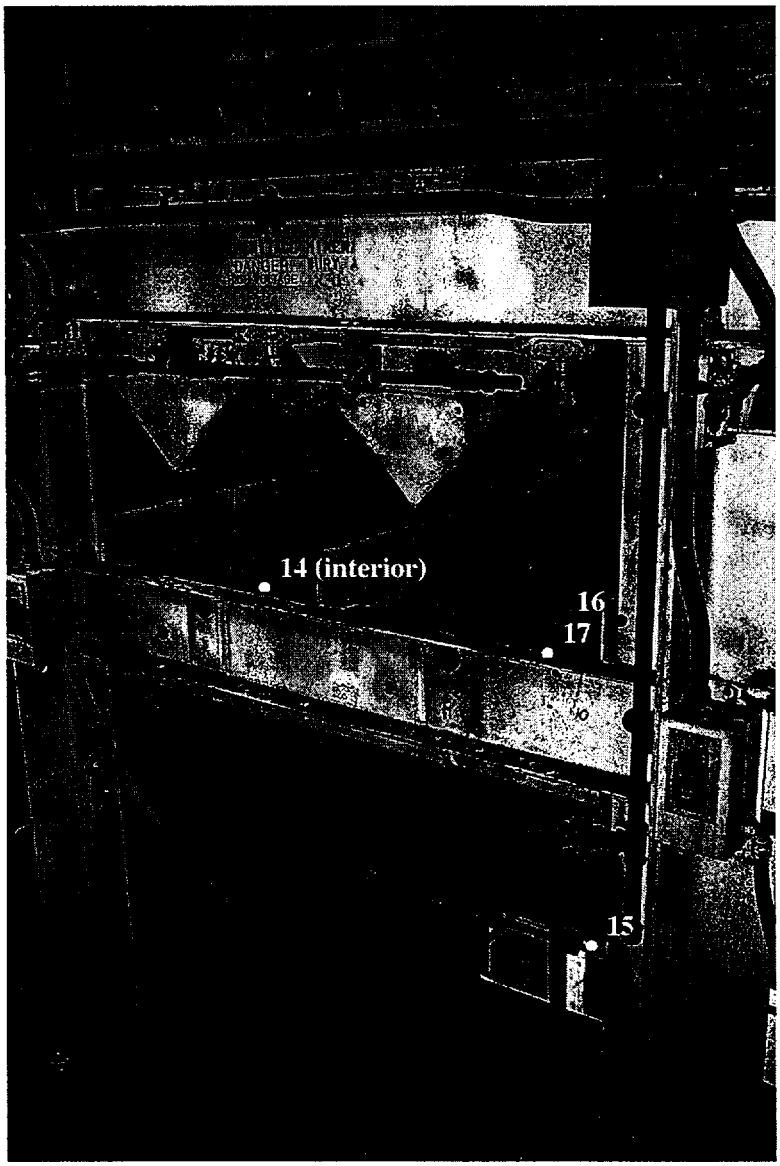


MEASUREMENT/SAMPLING LOCATIONS

• # SINGLE POINT

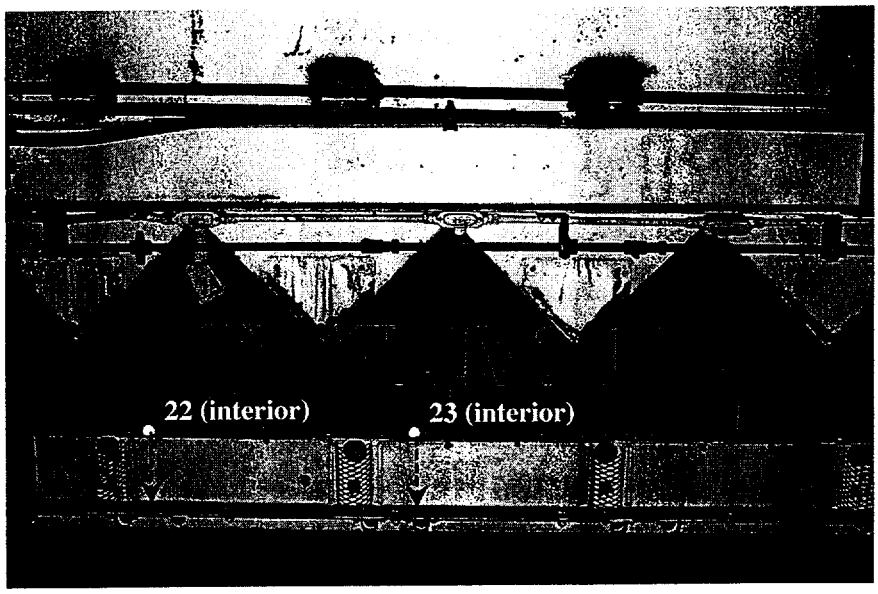
NOT TO SCALE

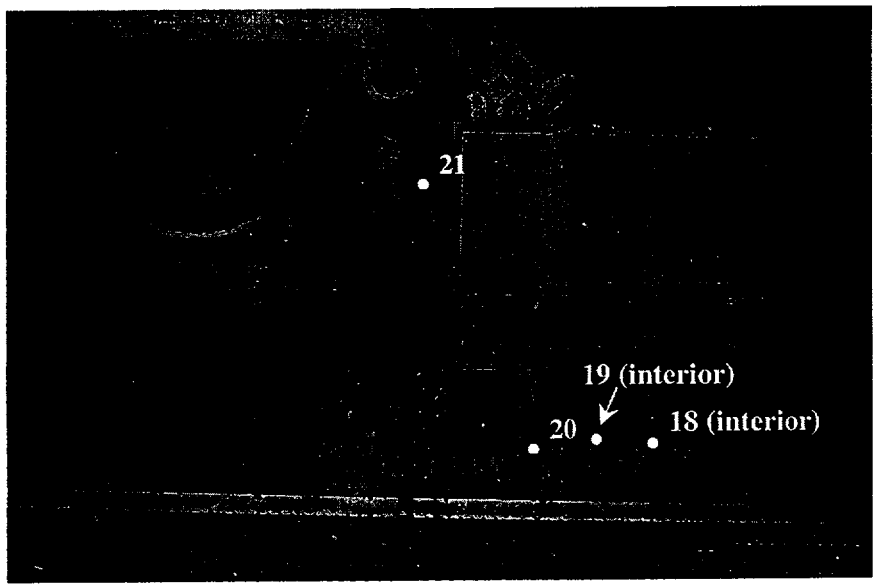
FIGURE 14: Wet Mill, Survey Unit 31 — Direct Measurement and Sampling Locations



MEASUREMENT/SAMPLING LOCATIONS	NOT TO SCALE
• # SINGLE POINT	

FIGURE 15: Dry Mill, Survey Unit 35 — Direct Measurement and Sampling Locations



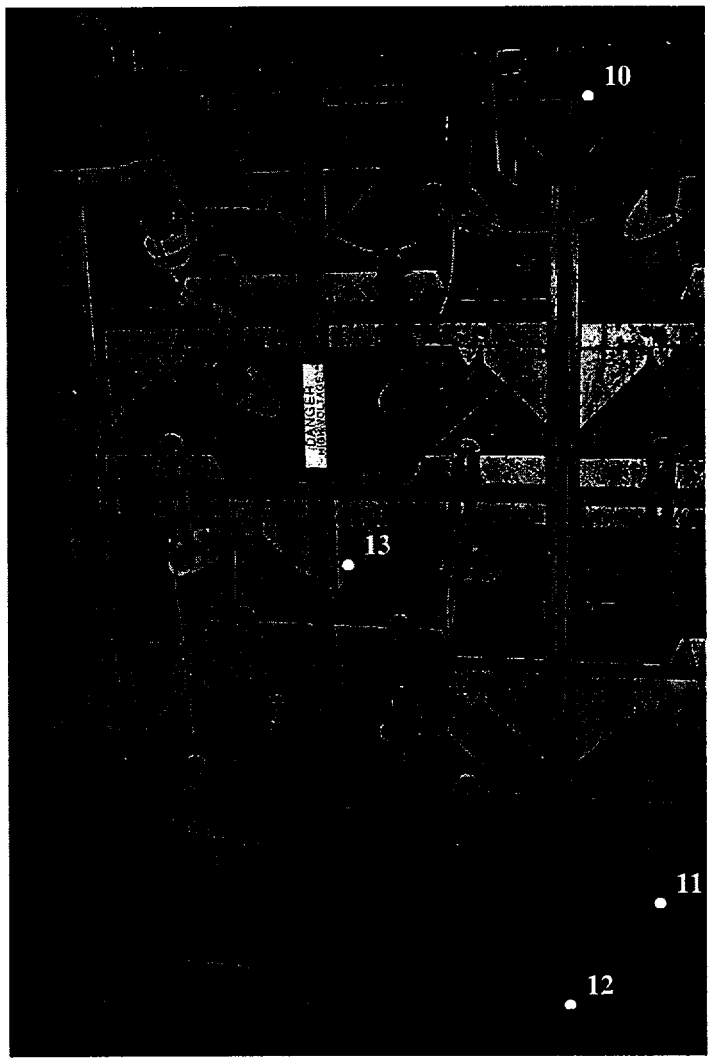


MEASUREMENT/SAMPLING LOCATIONS

• # SINGLE POINT

NOT TO SCALE

FIGURE 16: Dry Mill, Survey Unit 37 — Direct Measurement and Sampling Locations

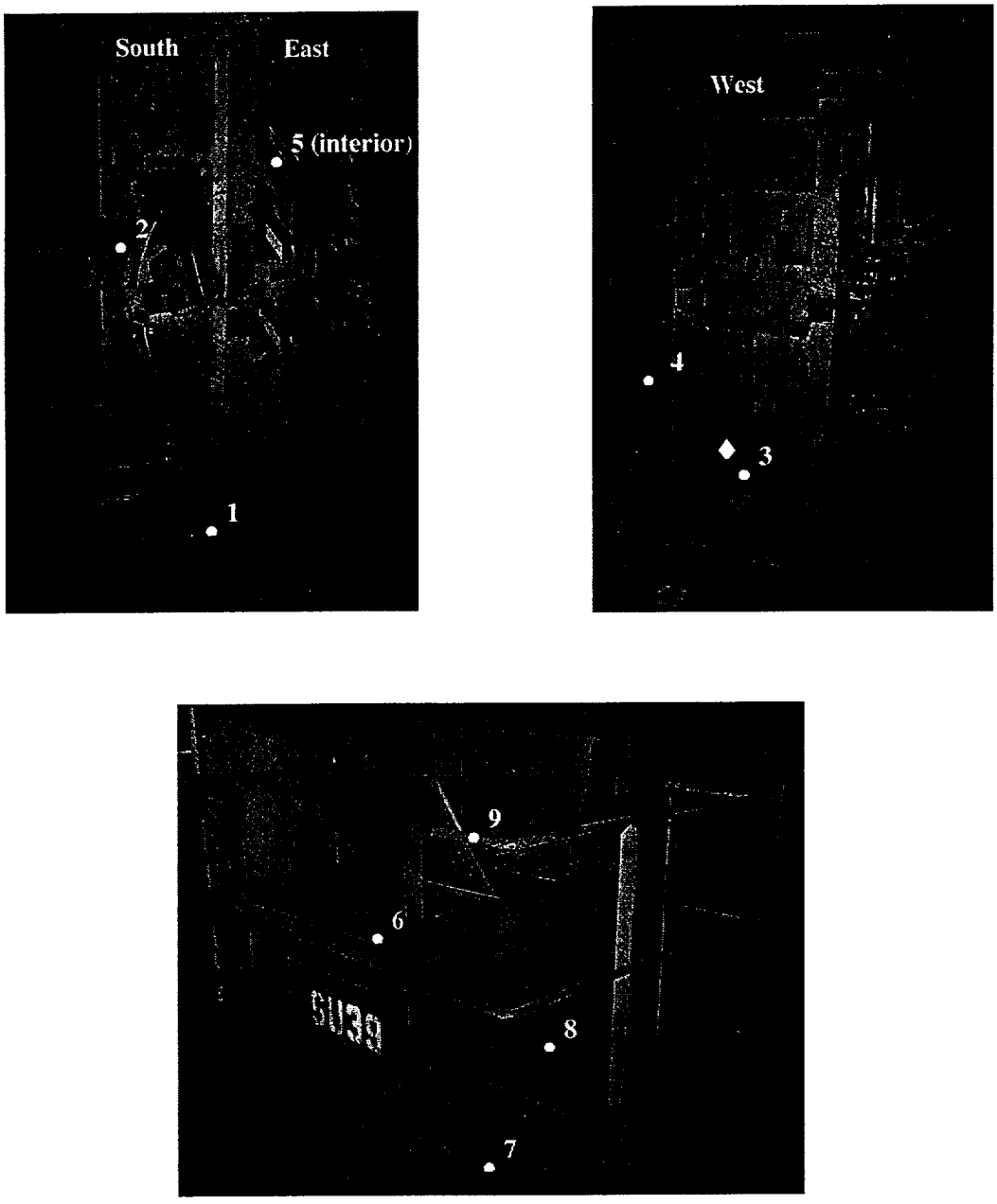


MEASUREMENT/SAMPLING LOCATIONS

• # SINGLE POINT

NOT TO SCALE

FIGURE 17: Dry Mill, Survey Unit 38 — Direct Measurement and Sampling Locations

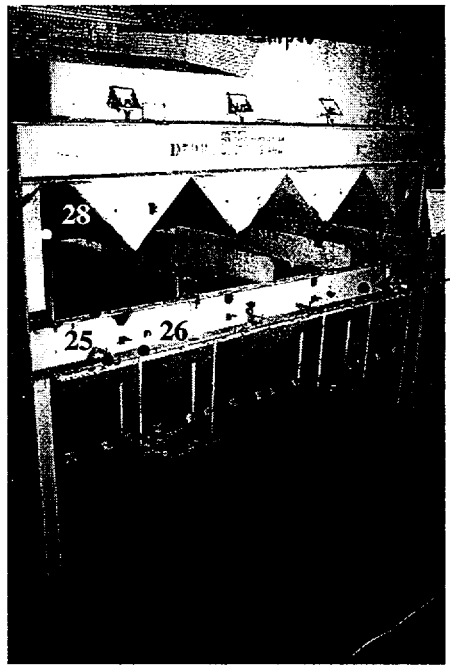


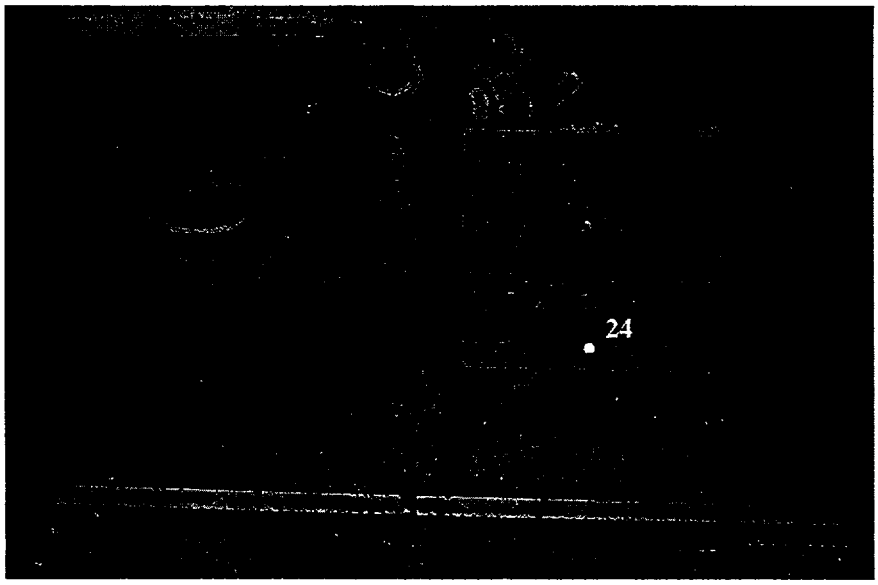
MEASUREMENT/SAMPLING LOCATIONS

- • # SINGLE POINT
- ♦ RESIDUE SAMPLE

NOT TO SCALE

FIGURE 18: Dry Mill, Survey Unit 39 — Direct Measurement and Sampling Locations



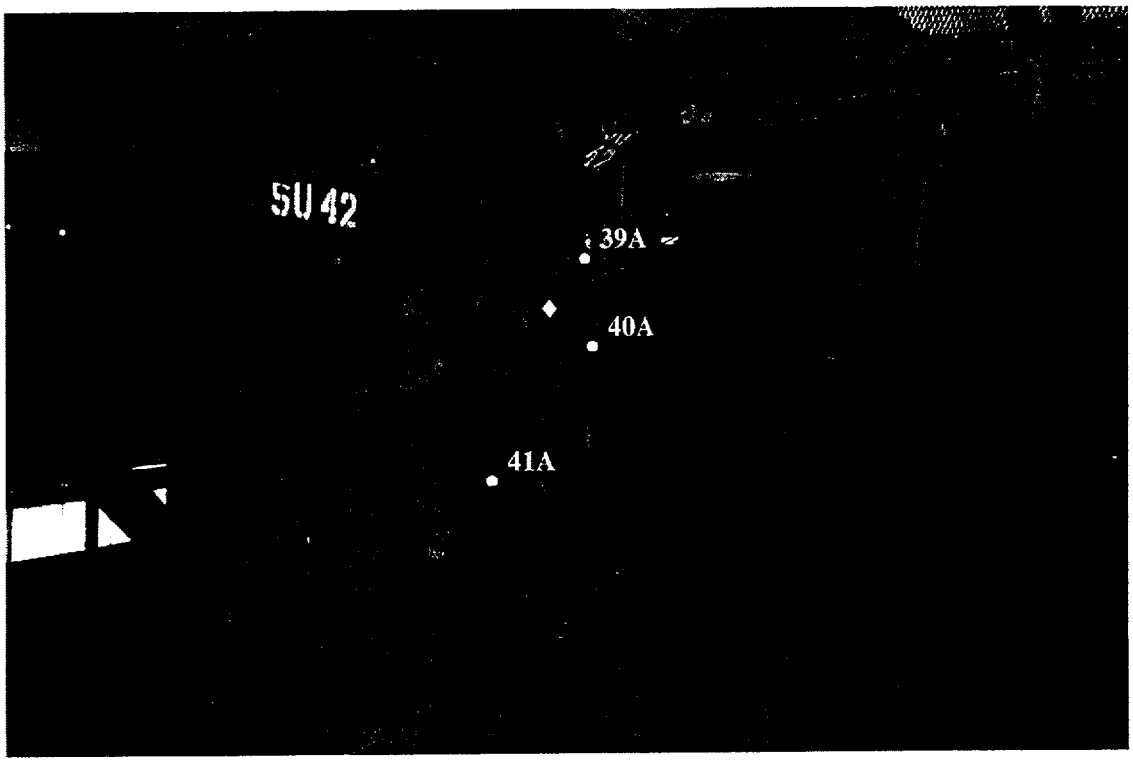


MEASUREMENT/SAMPLING LOCATIONS

• # SINGLE POINT

NOT TO SCALE

FIGURE 19: Dry Mill, Survey Unit 40 — Direct Measurement and Sampling Locations



MEASUREMENT/SAMPLING LOCATIONS

- ● # SINGLE POINT
- ♦ RESIDUE SAMPLE

NOT TO SCALE

FIGURE 20: Dry Mill, Survey Unit 42 — Direct Measurement and Sampling Locations

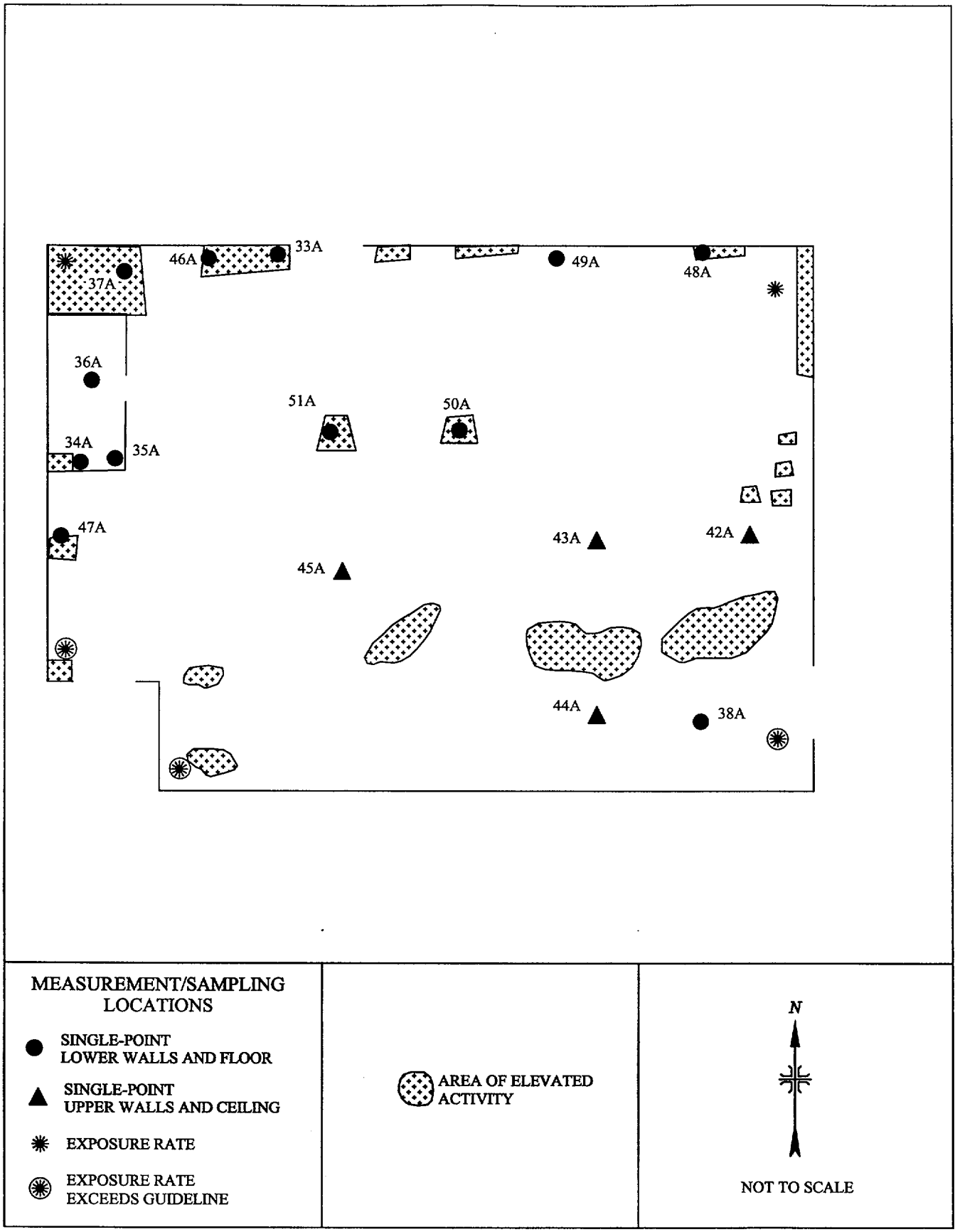


FIGURE 21: Dry Mill, Ground Floor - Measurement and Sampling Locations

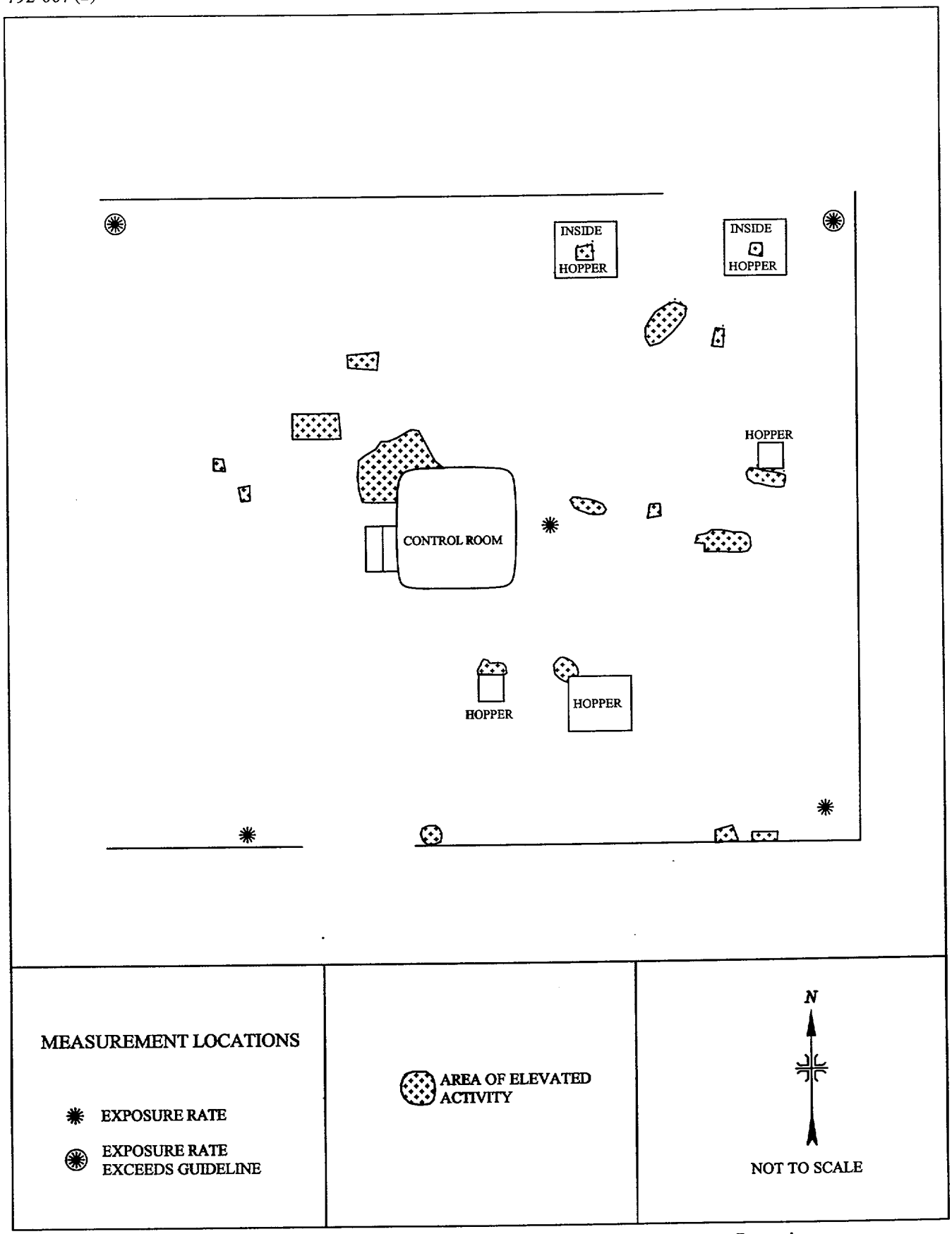


FIGURE 22: Wet Mill East End, Ground Floor - Measurements Locations

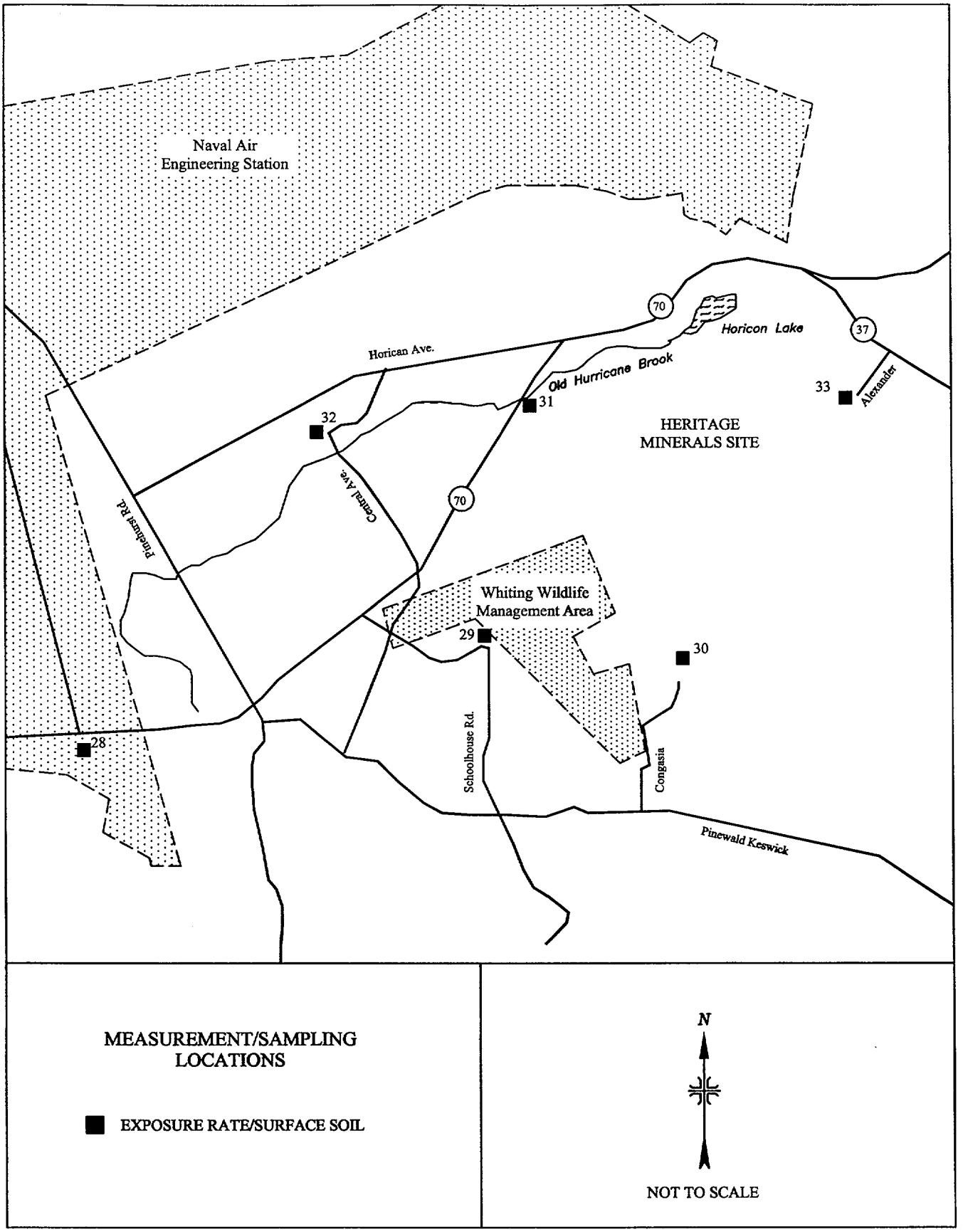


FIGURE 23: Heritage Minerals - Background Measurement and Sampling Locations

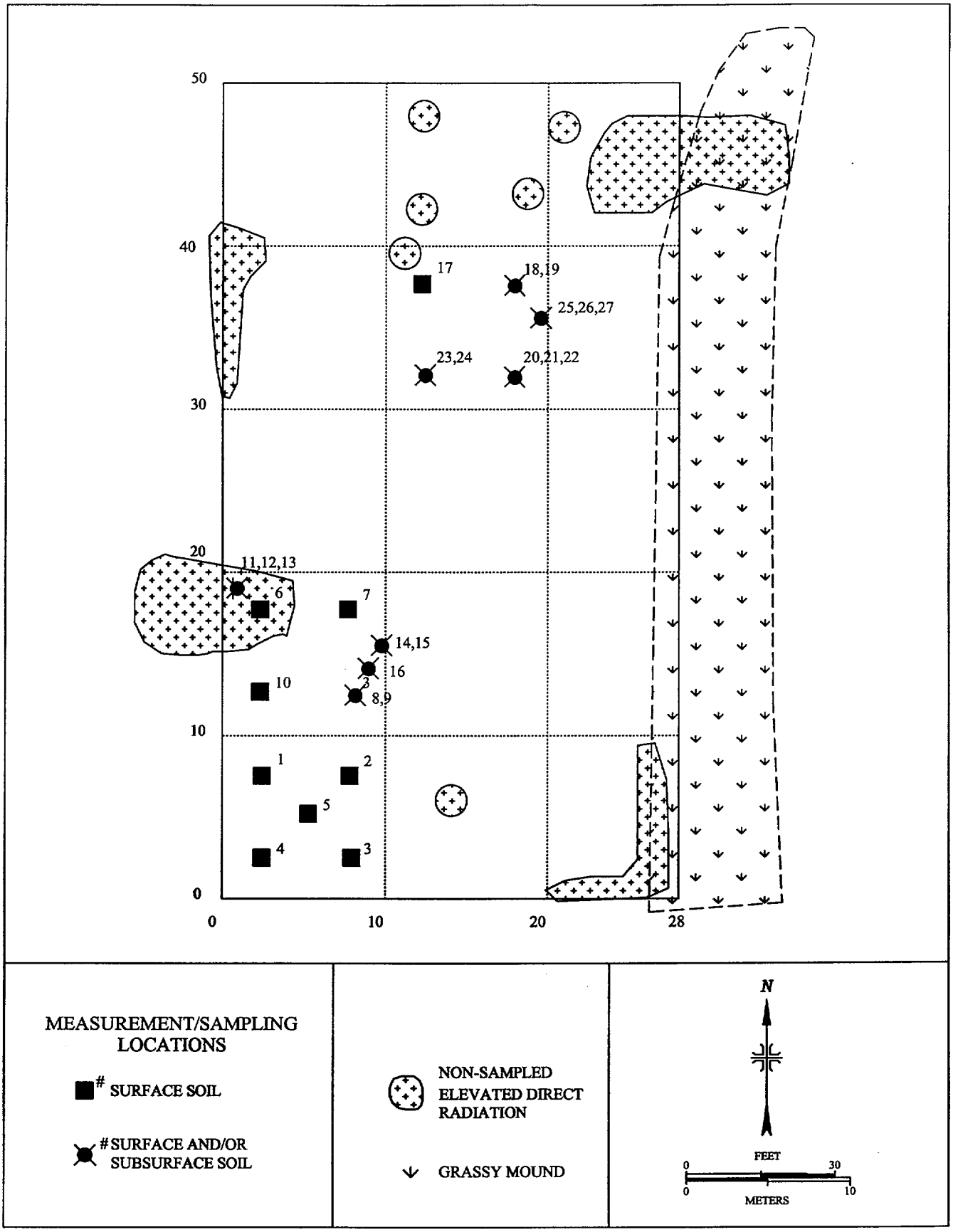


FIGURE 24: Former Monazite Pile - Measurement and Sampling Locations

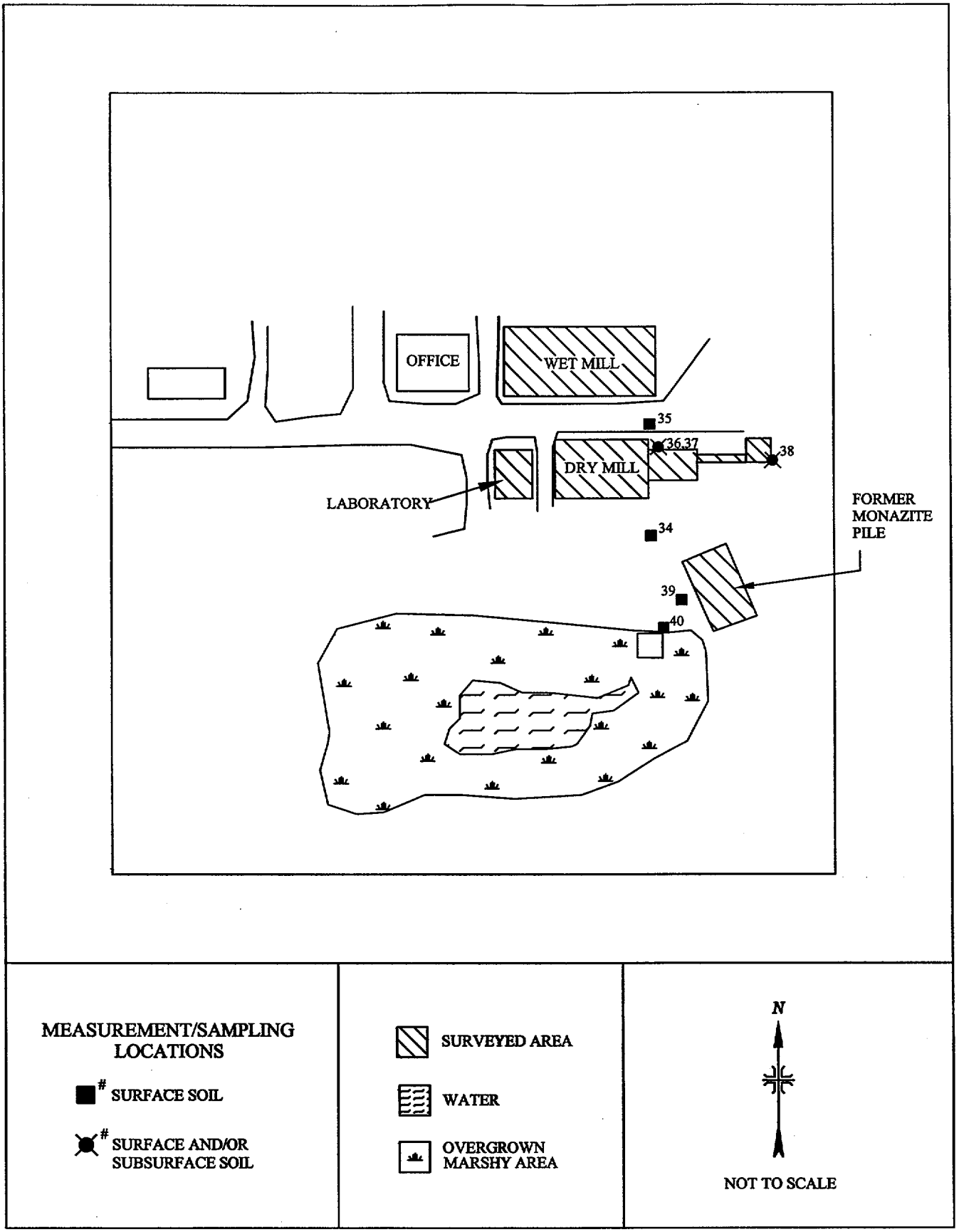


FIGURE 25: Heritage Minerals Site - Exterior Measurement and Sampling Locations

TABLES

TABLE 1

SUMMARY OF SURFACE ACTIVITY LEVELS
HERITAGE MINERALS INCORPORATED FACILITY
LAKEHURST, NEW JERSEY

Location[a]	Total Activity (dpm/100 cm^2)		Removable Activity (dpm/100 cm^2)	
	Alpha	Alpha plus Beta[b]	Alpha	Beta
Laboratory Building				
Room 1, Wall	9	-51	1	-3
Room 1, Table	NA	-44	0	-1
Room 1, Floor	NA	-200	0	1
Room 1, Door	NA	-73	3	3
Room 1, Wall	NA	-80	0	-4
Room 2, Cabinet	NA	130	0	2
Room 2, Sink	NA	100	3	-2
Room 2, Floor	NA	-170	0	3
Room 2, Wall	NA	-160	0	-2
Room 2, Sink	NA	25	0	-1
Room 2, Bench	120	270	1	-3
Room 2, Floor	NA	-200	1	1
Room 3, Floor-13A	720	3,500	1	-4
Room 3, Sill	NA	740	1	-1
Room 3, Floor	NA	210	5	6
Room 3, Floor	NA	1,100	5	16
Room 4, Floor	NA	-170	3	1
Room 4, Sill	160	1,100	1	-2
Room 4, Floor	NA	-110	3	1
Room 4, Door	NA	-170	1	-3

TABLE 1 (continued)

SUMMARY OF SURFACE ACTIVITY LEVELS
HERITAGE MINERALS INCORPORATED FACILITY
LAKEHURST, NEW JERSEY

Location[a]	Total Activity (dpm/100 cm^2)		Removable Activity (dpm/100 cm^2)	
	Alpha	Alpha plus Beta[b]	Alpha	Beta
Laboratory Building (continued)				
Room 5, Floor	NA	460	1	2
Room 5, Sill	120	300	5	-2
Room 5, Floor	NA	-130	0	-3
Room 5, Sill	NA	-100	3	2
Room 6, Wall	NA	-110	1	-2
Room 6, Floor	NA	-110	0	-3
Room 6, Floor	NA	-240	0	-2
Room 7, Floor	120	150	0	3
Room 7, Wall	310	1,100	1	1
Room 7, Floor	NA	-83	1	-3
Room 9, Sink	NA	200	1	-2
Room 9, Floor	NA	130	0	-1
Wet Mill				
SU1-92A	NA	4,400	0	-5
SU1-93A	NA	810	0	1
SU1-94A	NA	3,300	1	-2
SU1-95A	NA	5,400	1	-1
SU1-29	NA	2,100	0	-3
SU2-30	NA	1,900	1	-1
SU2-31	NA	1,600	5	-4

TABLE 1 (continued)

SUMMARY OF SURFACE ACTIVITY LEVELS
HERITAGE MINERALS INCORPORATED FACILITY
LAKEHURST, NEW JERSEY

Location[a]	Total Activity (dpm/100 cm^2)		Removable Activity (dpm/100 cm^2)	
	Alpha	Alpha plus Beta[b]	Alpha	Beta
Wet Mill (continued)				
SU2-32	NA	1,200	3	-1
SU2-33	NA	1,000	1	2
SU2-34	230	3,100	0	-3
SU3-71A	NA	6,300	1	-1
SU3-72A	NA	3,700	0	3
SU3-73A	NA	2,300	3	3
SU3-74A	NA	5,100	0	-2
SU3-75A	NA	2,900	0	-2
SU7-76A	NA	3,800	0	5
SU7-77A	NA	5,800	3	2
SU7-78A	NA	3,600	0	-3
SU7-79A	320	6,100	0	20
SU7-80A	NA	2,900	1	-3
SU7-81A	NA	5,400	0	9
SU9-82A	NA	5,000	3	2
SU9-83A	1,200	7,200	0	1
SU9-84A	NA	8,600	5	-2
SU9-85A	NA	5,500	9	14
SU9-86A	NA	5,200	0	-1
SU12-61A	NA	17,000	0	5

TABLE 1 (continued)

SUMMARY OF SURFACE ACTIVITY LEVELS
HERITAGE MINERALS INCORPORATED FACILITY
LAKEHURST, NEW JERSEY

Location[a]	Total Activity (dpm/100 cm^2)		Removable Activity (dpm/100 cm^2)	
	Alpha	Alpha plus Beta[b]	Alpha	Beta
Wet Mill (continued)				
SU12-62A	1,500	27,000	1	-1
SU12-63A	NA	8,900	3	5
SU12-64A	NA	5,600	1	4
SU12-65A	NA	4,000	3	-3
SU15-66A	NA	5,900	3	2
SU15-67A	700	9,500	0	1
SU15-68A	NA	7,600	0	-4
SU15-70A	NA	3,900	0	-1
SU27-57A	NA	19,000	1	10
SU27-58A	NA	11,000	0	-2
SU27-59A	240	19,000	0	-3
SU27-60A	NA	20,000	0	5
SU30-87A	NA	12,000	0	-2
SU30-88A	NA	3,300	0	-2
SU30-89A	NA	3,400	0	2
SU30-90A	NA	4,300	0	-3
SU30-91A	NA	2,200	3	5
SU31-52A	2,300	35,000	7	10
SU31-53A	NA	32,000	7	5

TABLE 1 (continued)

SUMMARY OF SURFACE ACTIVITY LEVELS
HERITAGE MINERALS INCORPORATED FACILITY
LAKEHURST, NEW JERSEY

Location[a]	Total Activity (dpm/100 cm^2)		Removable Activity (dpm/100 cm^2)	
	Alpha	Alpha plus Beta[b]	Alpha	Beta
Wet Mill (continued)				
SU31-54A	NA	8,800	3	4
SU31-55A	NA	8,900	1	-3
SU31-56A	390	11,000	0	-2
Dry Mill				
SU35-14	NA	7,200	NA	NA
SU35-15	NA	3,500	0	3
SU35-16	NA	3,300	9	1
SU35-17	2,400	14,000	0	-1
SU37-18	NA	8,600	3	-1
SU37-19	NA	17,000	16	4
SU37-20	NA	8,100	13	-1
SU37-21	NA	3,500	11	11
SU37-22	NA	2,500	9	2
SU37-23	660	6,500	3	-1
SU38-10	NA	1,100	1	2
SU38-11	NA	250	3	12
SU38-12	NA	4,000	1	5
SU38-13	NA	1,800	0	6
SU39-1	NA	28,000	3	-2
SU39-2	200	28,000	9	2

TABLE 1 (continued)

SUMMARY OF SURFACE ACTIVITY LEVELS
HERITAGE MINERALS INCORPORATED FACILITY
LAKEHURST, NEW JERSEY

Location[a]	Total Activity (dpm/100 cm^2)		Removable Activity (dpm/100 cm^2)	
	Alpha	Alpha plus Beta[b]	Alpha	Beta
Dry Mill (continued)				
SU39-3	2,600	89,000	5	21
SU39-4	NA	9,000	0	4
SU39-5	NA	9,500	NA	NA
SU39-6	NA	3,000	0	1
SU39-7	NA	8,300	33	25
SU39-8	NA	250	0	-2
SU39-9	NA	580	0	-2
SU40-24	1,100	2,700	5	4
SU40-25	NA	21,000	0	3
SU40-26	1,100	23,000	1	4
SU40-27	NA	2,100	1	-3
SU40-28	NA	12,000	0	-2
SU42-39A	960	15,000	160	730
SU42-40A	NA	5,700	0	1
SU42-41A	NA	4,500	5	8
Floor - 33A	NA	1,600	0	-3
Floor - 34A	1,000	4,800	5	4
Desk - 35A	NA	3,400	0	-2
Floor - 36A	NA	73	1	-2

TABLE 1 (continued)

SUMMARY OF SURFACE ACTIVITY LEVELS
HERITAGE MINERALS INCORPORATED FACILITY
LAKEHURST, NEW JERSEY

Location[a]	Total Activity (dpm/100 cm^2)		Removable Activity (dpm/100 cm^2)	
	Alpha	Alpha plus Beta[b]	Alpha	Beta
Dry Mill (continued)				
Floor - 37A	NA	6,200	1	-3
Column - 38A	370	6,600	13	20
I-Beam - 42A	2,400	16,000	3	-1
I-Beam - 43A	670	12,000	3	5
I-Beam - 44A	NA	5,800	5	6
I-Beam - 45A	NA	4,600	5	36
Wall - 46A	NA	4,500	0	-3
Wall - 47A	560	6,100	0	2
Wall - 48A	NA	4,800	1	2
Floor - 49A	NA	6,100	1	5
Floor - 50A	NA	2,300	1	4
Floor - 51A	NA	2,100	0	4

[a]Refer to Figures 4 through 21.
[b]ESSAP's data indicate that the alpha contribution to the alpha plus beta surface activity measurement count rate was consistently less than ten percent.

TABLE 2

INTERIOR EXPOSURE RATES
HERITAGE MINERALS INCORPORATED FACILITY
LAKEHURST, NEW JERSEY

Location[a]	Exposure Rate Range @ 1m (μR/h)
Laboratory	7 to 10
Wet Mill	8 to 17
Dry Mill	11 to 14
Background: Office Building	4 to 8

[a]Refer to Figures 21 through 22 for Wet and Dry Mill exposure rate locations. Exposure rate locations within the Laboratory and Main Office Building are not provided. Laboratory exposure rate measurements were performed at the center of each room.

TABLE 3

RADIONUCLIDE CONCENTRATIONS IN RESIDUE SAMPLES HERITAGE MINERALS INCORPORATED FACILITY LAKEHURST, NEW JERSEY

Location[a]	Radionuclide Concentration (pCi/g)					
	U-238	U-235	Total Uranium[b]	Th-228	Th-232	Total Thorium[c]
Dry Mill, SU39	59 ± 11[d]	5.0 ± 2.4	120	310 ± 17	325 ± 26	640
Dry Mill, SU42	670 ± 140	31 ± 37	1400	1520 ± 130	1580 ± 150	3100
Wet Mill, SU3	410 ± 370	49 ± 130	870	690 ± 100	610 ± 260	1300

[a]Refer to Figures 7, 18, and 20.
[b]Total uranium concentrations are calculated by multiplying the U-238 result by two and adding the U-235 concentrations.
[c]Total thorium was calculated by adding the Th-228 and Th-232 concentrations.
[d] Uncertainties represent the 95% confidence levels based on total propagated uncertainties.

TABLE 4

RADIONUCLIDE CONCENTRATIONS IN SOIL
FORMER MONZITE PILE AND ADJACENT AREAS
HERITAGE MINERALS INCORPORATED FACILITY
LAKEHURST, NEW JERSEY

Sample Number[a]	Depth (cm)	Exposure Rate @ 1m (µR/h)	Radionuclide Concentration (pCi/g)					
			U-238	U-235	Total Uranium[b]	Th-228	Th-232	Total Thorium[c]
Monazite Pile								
1	0-15	17	4.0 ± 1.0[d]	0.1 ± 0.2	8.1	9.4 ± 0.5	9.1 ± 0.8	19
2	0-15	20	2.4 ± 1.0	0.1 ± 0.2	4.9	5.9 ± 0.3	5.8 ± 0.5	12
3	0-15	17	3.6 ± 1.0	0.1 ± 0.2	7.3	9.3 ± 0.5	9.1 ± 0.8	18
4	0-15	20	4.0 ± 1.1	0.1 ± 0.1	8.1	6.6 ± 0.4	6.4 ± 0.6	13
5	0-15	22	2.9 ± 0.9	-0.1 ± 0.1	5.7	6.0 ± 0.3	5.8 ± 0.5	12
Grid Block, 0N, 0E Surface (0-15 cm) Average					*6.8*			*15*
6	0-15	30	10.6 ± 3.5	0.1 ± 0.4	21	21.0 ± 1.2	20.2 ± 1.8	41
7	0-15	15	1.1 ± 0.8	0.1 ± 0.1	2.3	2.8 ± 0.2	2.8 ± 0.3	5.6
8	0-15	25	12.2 ± 3.6	0.7 ± 0.7	25	40.0 ± 2.2	38.7 ± 3.3	79
9	15-30	NA	36.7 ± 5.6	1.1 ± 1.3	75	205 ± 11	211 ± 17	420
10	0-15	20	2.1 ± 0.8	0.1 ± 0.1	4.3	3.9 ± 0.2	3.8 ± 0.4	7.7
11	0-15	NA	50 ± 11	2.0 ± 2.5	100	330 ± 18	330 ± 27	660
12	15-30	NA	45 ± 30	7.9 ± 7.7	97	720 ± 39	820 ± 67	1540
13	30-45	NA	61 ± 23	1.5 ± 4.1	120	430 ± 23	460 ± 37	890

TABLE 4 (continued)

RADIONUCLIDE CONCENTRATIONS IN SOIL
FORMER MONZITE PILE AND ADJACENT AREAS
HERITAGE MINERALS INCORPORATED FACILITY
LAKEHURST, NEW JERSEY

Sample Number[a]	Depth (cm)	Exposure Rate @ 1m (μR/h)	Radionuclide Concentration (pCi/g)					
			U-238	U-235	Total Uranium[b]	Th-228	Th-232	Total Thorium[c]
14	0-15	20	17.0 ± 4.6	0.0 ± 0.7[e]	34	64.0 ± 3.5	61.4 ± 5.0	130
15	15-30	NA	8.2 ± 3.2	-0.1 ± 0.5	16	23.9 ± 1.3	23.3 ± 2.0	47
16	15-30	30	51 ± 20	1.7 ± 4.7	100	380 ± 20	400 ± 33	770
Grid Block 10N, 0E Surface (0-15 cm) Average					*31*			*150*
17	0-15	15	7.5 ± 1.5	0.4 ± 0.3	15	13.6 ± 0.8	13.0 ± 1.1	27
18	0-15	18	19.0 ± 3.8	1.7 ± 1.1	40	29.9 ± 1.7	32.0 ± 2.9	62
19	15-30	NA	19.9 ± 4.7	2.2 ± 1.2	42	32.9 ± 1.9	35.3 ± 3.3	68
20	0-15	30	11.1 ± 3.2	0.6 ± 0.6	23	32.9 ± 1.8	32.7 ± 2.8	66
21	15-30	NA	15.3 ± 3.7	1.3 ± 0.7	32	46.9 ± 2.5	48.5 ± 4.0	95
22	30-45	NA	17.9 ± 4.4	1.2 ± 0.9	37	60.2 ± 3.2	61.1 ± 5.1	120
23	0-15	15	9.1 ± 1.8	0.4 ± 0.3	19	22.3 ± 1.2	21.8 ± 1.8	44
24	15-30	NA	7.4 ± 1.5	0.5 ± 0.2	15	16.3 ± 0.9	16.5 ± 1.4	33
25	0-15	20	22.8 ± 4.6	1.7 ± 1.5	47	89.1 ± 4.8	89.7 ± 7.4	180
26	15-30	NA	23.6 ± 5.1	1.7 ± 1.2	49	93.7 ± 5.1	94.8 ± 7.8	190
27	30-45	NA	8.1 ± 1.8	0.4 ± 0.3	17	15.2 ± 0.8	14.8 ± 1.3	30
Grid Block 30N, 10E Surface (0-15 cm) Average					*29*			*75*

TABLE 4 (continued)

RADIONUCLIDE CONCENTRATIONS IN SOIL
FORMER MONZITE PILE AND ADJACENT AREAS
HERITAGE MINERALS INCORPORATED FACILITY
LAKEHURST, NEW JERSEY

Sample Number[a]	Depth (cm)	Exposure Rate @ 1m (µR/h)	Radionuclide Concentration (pCi/g)					
			U-238	U-235	Total Uranium[b]	Th-228	Th-232	Total Thorium[c]
Areas Outside the Monazite Pile Area								
34	0-15	NA	23.4 ± 5.5	2.0 ± 1.3	49	30.6 ± 1.8	30.3 ± 3.0	61
35	0-15	NA	19.4 ± 5.4	0.7 ± 0.9	40	44.9 ± 2.5	46.2 ± 4.0	91
36	0-15	NA	9.5 ± 1.7	0.6 ± 0.3	20	15.6 ± 0.9	15.9 ± 1.3	32
37	15-30	NA	9.3 ± 1.9	0.8 ± 0.4	19	18.4 ± 1.0	18.1 ± 1.6	37
38	15-30	NA	6.8 ± 1.1	0.4 ± 0.2	14	10.7 ± 0.6	10.6 ± 0.9	21
39	0-15	NA	24.2 ± 6.2	0.9 ± 1.3	49	95.3 ± 5.2	97.1 ± 8.0	190
40	0-15	24	22.3 ± 5.3	2.4 ± 1.5	47	64.1 ± 3.6	70.2 ± 6.0	130
Backgrounds								
28	0-15	3	0.2 ± 0.2	0.1 ± 0.0	0.5	0.3 ± 0.0	0.3 ± 0.1	0.6
29	0-15	3	0.3 ± 0.2	0.0 ± 0.0	0.6	0.1 ± 0.0	0.2 ± 0.1	0.3
30	0-15	5	0.5 ± 0.3	0.0 ± 0.0	1.0	0.3 ± 0.0	0.3 ± 0.1	0.6
31	0-15	4	0.3 ± 0.4	0.0 ± 0.1	0.6	0.3 ± 0.0	0.3 ± 0.1	0.6
32	0-15	7	0.4 ± 0.4	0.0 ± 0.1	0.8	0.3 ± 0.0	0.3 ± 0.1	0.6
33	0-15	4	1.1 ± 0.4	0.1 ± 0.1	2.3	0.5 ± 0.0	0.5 ± 0.1	1.0

[a]Refer to Figures 23 through 25.
[b]Total uranium concentrations are calculated by multiplying the U-238 result by two and adding the U-235 concentrations.
[c]Total thorium was calculated by adding the Th-228 and Th-232 concentrations.
[d]Uncertainties represent the 95% confidence levels based on total propogated uncertainties.
[e] Zero values are due to rounding.

TABLE 5

ANALYTICAL COMPARISON OF RSI SAMPLES
HERITAGE MINERALS INCORPORATED FACILITY
LAKEHURST, NEW JERSEY

Sample Number	Radionuclide Concentration (pCi/g)			
	RSI		ESSAP	
	Total Uranium[a]	Total Thorium[b]	Total Uranium[a]	Total Thorium[b]
50722068	15.1 ± 3.2	18.6 ± 1.8	17.5 ± 2.4	21.0 ± 1.1
50722002	39.3 ± 11.7	103.3 ± 9.8	45.2 ± 5.4	104.8 ± 5.2
50722052	18.0 ± 6.7	31.8 ± 3.0	20.0 ± 2.5	31.2 ± 1.6

[a]Total uranium calculated by doubling the Th-234 (63 keV) concentration and adding the U-235 (143 keV) concentration.
[b]Total thorium calulated by adding the Ac-228 (911 keV) concentration to the Pb-212 (239 keV) concentration.

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APPENDIX A
MAJOR INSTRUMENTATION

APPENDIX A
MAJOR INSTRUMENTATION

The display of a specific product is not to be construed as an endorsement of the product or its manufacturer by the authors or their employers.

SCANNING INSTRUMENT/DETECTOR COMBINATIONS

Alpha

Ludlum Ratemeter-Scaler Model 2221
coupled to
Ludlum Gas Proportional Detector Model 43-68, Physical Area: 126 cm^2
(Ludlum Measurements, Inc., Sweetwater, TX)

Ludlum Ratemeter-Scaler Model 2221
(Ludlum Measurements, Inc., Sweetwater, TX)
coupled to
Eberline ZnS Scintillation Detector Model AC-3-7, Physical Area: 74 cm^2
(Eberline, Santa Fe, NM)

Alpha Plus Beta

Ludlum Floor Monitor Model 239-1
combined with
Ludlum Ratemeter-Scaler Model 2221
coupled to
Ludlum Gas Proportional Detector Model 43-37, Physical Area: 550 cm^2
(Ludlum Measurements, Inc., Sweetwater, TX)

Ludlum Ratemeter-Scaler Model 2221
coupled to
Ludlum Gas Proportional Detector Model 43-68, Physical Area: 126 cm^2
(Ludlum Measurements, Inc., Sweetwater, TX)

Beta

Ludlum Ratemeter-Scaler Model 2221
(Ludlum Measurements, Inc., Sweetwater, TX)
coupled to
Eberline GM Detector Model HP-260, Physical Area: 20 cm^2
(Eberline, Santa Fe, NM)

Gamma

Eberline Pulse Ratemeter Model PRM-6
(Eberline, Santa Fe, NM)
coupled to
Victoreen NaI Scintillation Detector Model 489-55, Crystal: 3.2 cm x 3.8 cm
(Victoreen, Cleveland, OH)

DIRECT MEASUREMENT INSTRUMENT/DETECTOR COMBINATIONS

Alpha

Ludlum Ratemeter-Scaler Model 2221
coupled to
Ludlum Gas Proportional Detector Model 43-68, Physical Area: 126 cm^2
(Ludlum Measurements, Inc., Sweetwater, TX)

Ludlum Ratemeter-Scaler Model 2221
(Ludlum Measurements, Inc., Sweetwater, TX)
coupled to
Eberline ZnS Scintillation Detector Model AC-3-7, Physical Area: 74 cm^2
(Eberline, Santa Fe, NM)

Alpha plus Beta

Ludlum Ratemeter-Scaler Model 2221
coupled to
Ludlum Gas Proportional Detector Model 43-68, Physical Area: 126 cm^2
(Ludlum Measurements, Inc., Sweetwater, TX)

Beta

Ludlum Ratemeter-Scaler Model 2221
(Ludlum Measurements, Inc., Sweetwater, TX)
coupled to
Eberline GM Detector Model HP-260, Physical Area: 20 cm^2
(Eberline, Santa Fe, NM)

Gamma (Exposure Rate)

Bicron Micro-Rem Meter
(Bicron Corporation, Newburg, OH)

LABORATORY ANALYTICAL INSTRUMENTATION

High Purity Extended Range Intrinsic Detector
Canberra/Tennelec Model No: ERVDS30-25195
(Canberra, Meriden, CT)
Used in conjunction with:
Lead Shield Model G-11
(Nuclear Lead, Oak Ridge, TN) and
Multichannel Analyzer
DEC ALPHA Workstation
(Canberra, Meriden, CT)

High-Purity Extended Range Intrinsic Detector
Model No. GMX-45200-5
(EG&G ORTEC, Oak Ridge, TN)
used in conjunction with:
Lead Shield Model SPG-16-K8
(Nuclear Data) and
Multichannel Analyzer
3100 Vax Workstation
(Canberra, Meriden, CT)

Low Background Gas Proportional Counter
Model LB-5100-W
(Tennelec/Canberra, Meriden, CT)

APPENDIX B
SURVEY AND ANALYTICAL PROCEDURES

APPENDIX B
SURVEY AND ANALYTICAL PROCEDURES

PROJECT HEALTH AND SAFETY

All survey and laboratory activities were conducted in accordance with ORISE health and safety and radiation protection procedures.

CALIBRATION AND QUALITY ASSURANCE

Calibration of all field and laboratory instrumentation was based on standards/sources, traceable to NIST, when such standards/sources were available. In cases where they were not available, standards of an industry-recognized organization were used.

Detectors used for assessing surface activity were calibrated in accordance with ISO-7503[1] recommendations. The total efficiency (ϵ_{total}) was determined for each instrument/detector combination and consisted of the product of the 2π instrument efficiency (ϵ_i) and surface efficiency (ϵ_s):

$$\epsilon_{total} = \epsilon_i \times \epsilon_s$$

The alpha calibration ϵ_i ranged from 0.38 - 0.41 for the gas proportional detectors and from 0.31 - 0.34 for the ZnS scintillation detectors calibrated to Th-230; the beta calibration ϵ_i ranged from 0.50 - 0.52 for the gas proportional detectors and 0.36 - 0.37 for the GM detectors calibrated to Tl-204. The beta calibration source was selected based on the beta energy distribution of the radionuclide. ISO-7503 recommends an ϵ_s of 0.25 when measuring alpha emitters and beta emitters with a maximum energy of less than 0.4 MeV and an ϵ_s of 0.5 for maximum beta energies greater than

[1]International Standard. ISO 7503-1, Evaluation of Surface Contamination - Part 1: Beta-emitters (maximum beta energy greater than 0.15 MeV) and alpha-emitters. August 1, 1988.

0.4 MeV. The total alpha efficiency factors ranged from 0.09 to 0.10 for the gas proportional detectors and 0.08 to 0.09 for the ZnS detectors. The total beta efficiency factors ranged from 0.25 to 0.26 for the gas proportional detectors and were 0.18 for the GM detectors.

Analytical and field survey activities were conducted in accordance with procedures from the following documents of the Environmental Survey and Site Assessment Program:

- Survey Procedures Manual, (September 2000)
- Laboratory Procedures Manual, (May 2001)
- Quality Assurance Manual, (June 2001)

The procedures contained in these manuals were developed to meet the requirements of DOE Order 414.1A and the U.S. Nuclear Regulatory Commission Quality Assurance Manual for the Office of Nuclear Material Safety and Safeguards and contain measures to assess processes during their performance.

Quality control procedures include:

- Daily instrument background and check-source measurements to confirm that equipment operation is within acceptable statistical fluctuations.
- Participation in MAPEP, NRIP, ITP and EML Laboratory Quality Assurance Programs.
- Training and certification of all individuals performing procedures.
- Periodic internal and external audits.

SURVEY PROCEDURES

Surface Scans

Surface scans were performed by passing the detectors slowly over the surface; the distance between the detector and the surface was maintained at a minimum—nominally about 1 cm. A large surface area, gas proportional floor monitor was used to scan the floors of the surveyed areas. Other surfaces

were scanned using small area (20 cm^2, 74 cm^2, or 126 cm^2) hand-held detectors. Identification of elevated levels was based on increases in the audible signal from the recording and/or indicating instrument.

Scan minimum detectable concentrations (MDCs) were estimated using the calculational approach described in NUREG-1507.[2] The scan MDC is a function of many variables, including the background level. Typical beta background levels range from 800 to 1400 counts per minute (cpm) for the floor monitor, range from 250 to 450 cpm for the hand-held gas proportional detector, and range from 35 to 60 cpm for the GM detectors. Additional parameters selected for the calculation of scan MDCs include a three-second observation interval, a specified level of performance at the first scanning stage of 95% true positive rate and 25% false positive rate, which yields a d' value of 2.32 (NUREG-1507, Table 6.1), and a surveyor efficiency of 0.5. The approximate instrument scanning efficiencies for the floor monitor/hand-held gas proportional/GM detector calibrated to Tl-204 were 0.39, 0.46, and 0.08, respectively. To illustrate an example for the hand-held gas proportional, the minimum detectable count rate (MDCR) and scan MDC can be calculated as follows:

b_i = (250 cpm)(3 second obs. interval based on scan speed} s)(1 min/60 s) = 12.5 counts,

MDCR = (2.32)(12.5 counts)^{½} [(60 s/min)/(3 s)] = 164 cpm,

$MDCR_{surveyor}$ = 164/(0.5)^{½} = 231cpm

The scan MDC is calculated assuming a surface efficiency of 0.5 (for Tl-204):

$$Scan\ MDC = \frac{MDCR_{surveyor}}{(\epsilon_s)\ (\epsilon_i)} = xxx\ dpm/100\ cm^2$$

[2]NUREG-1507. Minimum Detectable Concentrations With Typical Radiation Survey Instruments for Various Contaminants and Field Conditions. US Nuclear Regulatory Commission. Washington, DC; June 1998.

For the given background range, the estimated scan MDC range for the floor monitor is 2,100 to 2,800 dpm/100 cm^2; 1,000 to 1,350 dpm/100 cm^2 for the hand-held gas proportional detector and 2,200 to 2,850 dpm/100 cm^2 for the GM detector.

The scan MDC for the NaI scintillation detector for uranium and thorium were obtained directly from NUREG-1507. The scan MDCs were 115 and 28.3 pCi/g, respectively, for total uranium and total thorium (includes sum of all radionuclides in the uranium and thorium decay series).

Surface Activity Measurements

Measurements of total surface activity levels were performed using gas proportional, GM, and ZnS detectors with portable ratemeter-scalers.

Count rates (cpm), which were integrated over one minute with the detector held in a static position, were converted to activity levels (dpm/100 cm^2) by dividing the net rate by the total efficiency ($\epsilon_i \times \epsilon_s$) and correcting for the physical probe area of the detector.

Because different building materials (poured concrete, brick, wood, steel, etc.) may have different background levels, average background count rates were determined for each material encountered in the surveyed area at a location of similar construction and having no known radiological history. The alpha activity background count rates for the ZnS and gas proportional detectors averaged 1 cpm. The beta activity background count rates for the gas proportional detectors averaged 263 cpm for concrete block, 226 cpm for painted metal, 303 cpm for poured concrete, and 236 cpm for wood. The beta activity background count rate averaged 45 cpm for the GM detectors. The alpha MDCs were 67 dpm/100 cm^2 for the gas proportional detectors and 115 dpm/100 cm^2 for the ZnS, calibrated to Th-230 while the beta activity MDCs ranged from 231 to 297 dpm/100 cm^2 for the gas proportional detectors and averaged 950 dpm/100 cm^2 for the GM, calibrated to Tl-204. The physical probe area of the gas proportional, ZnS scintillation, and GM detectors were 126 cm^2, 74 cm^2, and 20 cm^2, respectively.

Removable Activity Measurements

Removable gross alpha and gross beta activity levels were determined using numbered filter paper disks, 47 mm in diameter. Moderate pressure was applied to the smear and approximately 100 cm^2 of the surface was wiped. Smears were placed in labeled envelopes with the location and other pertinent information recorded.

Exposure Rate Measurements

Measurements of dose equivalent rates (μrem/h) were performed at 1 m above the surface using a Bicron microrem meter. Although the instrument displays data in μrem/h, the μrem/h to μR/h conversion is essentially unity.

Soil Sampling

Approximately 1 kg of soil was collected at each sample location. Collected samples were placed in a plastic bag, sealed, and labeled in accordance with ESSAP survey procedures.

Residue Sampling

In order to determine if any removable activity was present in the dust/dirt layers on surfaces, residue samples were collected by scrapping the residue into a labeled plastic container with the location and other pertinent information recorded.

Analytical Procedures

Gross Alpha/Beta

Smears were counted for two minutes on a low background gas proportional system for gross alpha and gross beta activity. The MDCs of the procedure were 9 dpm/100 cm^2 for gross alpha and 15 dpm/100 cm^2 for gross beta.

Gamma Spectroscopy

Samples of soil and residues were dried, mixed, crushed, and/or homogenized as necessary, and a portion sealed in a 0.5-liter Marinelli beaker or other appropriate container. The quantity placed in the beaker was chosen to reproduce the calibrated counting geometry. Net material weights were determined and the samples counted using intrinsic germanium detectors coupled to a pulse height analyzer system. Background and Compton stripping, peak search, peak identification, and concentration calculations were performed using the computer capabilities inherent in the analyzer system. All photopeaks associated with the radionuclides of concern were reviewed for consistency of activity. Photopeaks used for determining the activities of radionuclides of concern and the typical associated MDCs for a one-hour count time were:

Radionuclide	Photopeak	MDC soil (pCi/g)
Th-228	0.583 MeV from Tl-208*	0.05
	(or 0.239 MeV from Pb-212*)	0.02
Th-232	0.911 MeV from Ac-228*	0.05
U-235	0.143 MeV (or 0.186 MeV)	0.06
U-238	0.063 MeV from Th-234*	0.21
	(or 1.001 MeV from Pa-234 m)*	1.74

*Secular equilibrium assumed.

Spectra were also reviewed for other identifiable photopeaks.

UNCERTAINTIES AND DETECTION LIMITS

The uncertainties associated with the analytical data presented in the tables of this report represent the total propagated uncertainties for that data. These uncertainties were calculated based on both the gross sample count levels and the associated background count levels.

Detection limits, referred to as minimum detectable concentration (MDC), were based on 3 plus 4.65 times the standard deviation of the background count [$3 + (4.65\sqrt{BKG})$]. Because of variations in background levels, measurement efficiencies, and contributions from other radionuclides in samples, the detection limits differ from sample to sample and instrument to instrument.

APPENDIX C
GUIDELINES FOR DECONTAMINATION OF FACILITIES AND EQUIPMENT PRIOR TO RELEASE FOR UNRESTRICTED USE OR TERMINATION OF LICENSES FOR BYPRODUCT, SOURCE OR SPECIAL NUCLEAR MATERIAL

and

GUIDELINES FOR RESIDUAL CONCENTRATIONS OF THORIUM AND URANIUM WASTES IN SOIL

GUIDELINES FOR DECONTAMINATION OF FACILITIES AND EQUIPMENT PRIOR TO RELEASE FOR UNRESTRICTED USE OR TERMINATION OF LICENSES FOR BYPRODUCT, SOURCE OR SPECIAL NUCLEAR MATERIAL

The instructions in this guide, in conjunction with Table 1, specify the radionuclides and radiation exposure rate limits which should be used in decontamination and survey of surfaces or premises and equipment prior to abandonment or release for unrestricted use. The limits in Table 1 do not apply to premises, equipment, or scrap containing induced radioactivity for which the radiological considerations pertinent to their use may be different. The release of such facilities or items from regulatory control is considered on a case-by-case basis.

1. The licensee shall make a reasonable effort to eliminate residual contamination.

2. Radioactivity on equipment or surfaces shall not be covered by paint, plating, or other covering material unless contamination levels, as determined by a survey and documented, are below the limits specified in Table 1 prior to the application of the covering. A reasonable effort must be made to minimize the contamination prior to use of any covering.

3. The radioactivity on the interior surfaces of pipes, drain lines, or ductwork shall be determined by making measurements at all traps, and other appropriate access points, provided that contamination at these locations is likely to be representative of contamination on the interior of the pipes, drain lines, or ductwork. Surfaces or premises, equipment, or scrap which are likely to be contaminated, but are of such size, construction, or location as to make the surface inaccessible for purposes of measurement, shall be presumed to be contaminated in excess of the limits.

4. Upon request, the Commission may authorize a licensee to relinquish possession or control of premises, equipment, or scrap having surfaces contaminated with materials in excess of the limits specified. This may include, but would not be limited to special circumstances such as razing of buildings, transfer from premises to another organization continuing work with radioactive materials, or conversion of facilities to a long-term storage or standby status. Such requests must:

    a. Provide detailed, specific information describing the premises, equipment or scrap, radioactive contaminants, and the nature, extent, and degree of residual surface contamination.

    b. Provide a detailed health and safety analysis which reflects that the residual amounts of materials on surface areas, together with other considerations such as prospective use of the premises, equipment, or scrap, are unlikely to result in an unreasonable risk to the health and safety of the public.

5. Prior to release of premises for unrestricted use, the licensee shall make a comprehensive radiation survey which establishes that contamination is within the limits specified in Table 1. A copy of the survey report shall be filed with the Division of Fuel Cycle, Medical, Academic, and Commercial Use Safety, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555,

and also the Administrator of the NRC Regional Office having jurisdiction. The report should be filed at least 30 days prior to the planned date of abandonment. The survey report shall:

a. Identify the premises.

b. Show that reasonable effort has been made to eliminate residual contamination.

c. Describe the scope of the survey and general procedures followed.

d. State the findings of the survey in units specified in the instruction.

Following review of the report, the NRC will consider visiting the facilities to confirm the survey.

TABLE 1
ACCEPTABLE SURFACE CONTAMINATION LEVELS

Nuclides[a]	Average[b,c,f]	Maximum[b,d,f]	Removable[b,e,f]
U-nat, U-235, U-238, and associated decay products	5,000 dpm α/100 cm^2	15,000 dpm α/100 cm^2	1,000 dpm α/100 cm^2
Transuranics, Ra-226, Ra-228, Th-230, Th-228, Pa-231, Ac-227, I-125, I-129	100 dpm/100 cm^2	300 dpm/100 cm^2	20 dpm/100 cm^2
Th-nat, Th-232, Sr-90, Ra-223, Ra-224, U-232, I-126, I-131, I-133	1,000 dpm/100 cm^2	3,000 dpm/100 cm^2	200 dpm/100 cm^2
Beta-gamma emitters (nuclides with decay modes other than alpha emission or spontaneous fission) except Sr-90 and others noted above. cm^2	5,000 dpm $\beta\gamma$/100 cm^2	15,000 dpm $\beta\gamma$/100 cm^2	1,000 dpm $\beta\gamma$/100

[a]Where surface contamination by both alpha- and beta-gamma-emitting nuclides exists, the limits established for alpha- and beta-gamma- emitting nuclides should apply independently.

[b]As used in this table, dpm (disintegrations per minute) means the rate of emission by radioactive material as determined by correcting the counts per minute observed by an appropriate detector for background, efficiency, and geometric factors associated with the instrumentation.

[c]Measurements of average contaminant should not be averaged over more than 1 square meter. For objects of less surface area, the average should be derived for each such object.

[d]The maximum contamination level applies to an area of not more than 100 cm^2.

[e]The amount of removable radioactive material per 100 cm^2 of surface area should be determined by wiping that area with dry filter or soft absorbent paper, applying moderate pressure, and assessing the amount of radioactive material on the wipe with an appropriate instrument of known efficiency. When removable contamination on objects of less surface area is determined, the pertinent levels should be reduced proportionally and the entire surface should be wiped.

[f]The average and maximum radiation levels associated with surface contamination resulting from beta-gamma emitters should not exceed 0.2 mrad/h at 1 cm and 1.0 mrad/h at 1 cm, respectively, measured through not more than 7 milligrams per square centimeter of total absorber.

GUIDELINES FOR RESIDUAL CONCENTRATIONS OF THORIUM AND URANIUM WASTES IN SOIL

On October 23, 1981, the Nuclear Regulatory Commission published in the Federal Register a notice of Branch Technical Position on "Disposal or Onsite Storage of Thorium and Uranium Wastes from Past Operations." This document establishes guidelines for concentrations of uranium and thorium in soil, that will limit maximum radiation received by the public under various conditions of future land usage. These concentrations are as follows:

Material	Maximum Concentrations (pCi/g) above background for various options			
	1[a]	2[b]	3[c]	4[d]
Natural Thorium (Th-232 + Th-228) with daughters present and in equilibrium	10	50	---	500
Natural Uranium (U-238 + U-234) with daughters present and in equilibrium	10	--	40	200
Depleted Uranium:				
Soluble	35	100	---	1,000
Insoluble	35	300	---	3,000
Enriched Uranium:				
Soluble	30	100	---	1,000
Insoluble	30	250	---	2,500

[a]Based on EPA cleanup standards which limit radiation to 1 mrad/yr to lung and 3 mrad/yr to bone from ingestion and inhalation and 10 μR/h above background from direct external exposure.
[b]Based on limiting individual dose to 170 mrem/yr.
[c]Based on limiting equivalent exposure to 0.02 working level or less.
[d]Based on limiting individual dose to 500 mrem/yr and in case of natural uranium, limiting exposure to 0.02 working level or less.