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RADIONUCLIDE BASELINE IN SOIL NEAR PROJECT GNOME AND THE WASTE ISOLATION PILOT PLANT

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FOREWORD

The purpose of the New Mexico Environmental Evaluation Group (EEG) is to conduct an independent technical evaluation of the Waste Isolation Pilot Plant (WIPP) Project to ensure the protection of the public health and safety and the environment. The WIPP Project, located in southeastern New Mexico, is being constructed as a repository for the disposal of transuranic (TRU) radioactive wastes generated by the national defense programs. The EEG was established in 1978 with funds provided by the U. S. Department of Energy (DOE) to the State of New Mexico. Public Law 100-456, the National Defense Authorization Act, Fiscal Year 1989, Section 1433, assigned EEG to the New Mexico Institute of Mining and Technology and continued the original contract DE-AC04-79AL10752 through DOE contract DE-ACO4-89AL58309. The National Defense Authorization Act for Fiscal Year 1994, Public Law 103-160, continues the authorization.

EEG performs independent technical analyses of the suitability of the proposed site; the design of the repository, its planned operation, and its long-term integrity; suitability and safety of the transportation systems; suitability of the Waste Acceptance Criteria and the generator sites' compliance with them; and related subjects. These analyses include assessments of reports issued by the DOE and its contractors, other federal agencies and organizations, as they relate to the potential health, safety and environmental impacts from WIPP. Another important function of EEG is the independent environmental monitoring of background radioactivity in air, water, and soil, both on-site and off-site.

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ACRONYMS

AEC . . . . Atomic Energy Commission
CERCLA . Comprehensive Environmental Response, Compensation, and Liability Act
CTC . . . . Chemrad Tennessee Corporation
DAC . . . . Derived Air Concentration
DOE . . . . Department of Energy
EEG . . . . . Environmental Evaluation Group
EPA . . . . . Environmental Protection Agency
GM . . . . . Geiger-Müller
NaI(Tl) . . . Sodium Iodide Detector
NCRP . . . . National Council on Radiation Protection and Measurements
NIST . . . . National Institute of Standards and Technology
NTS . . . . Nevada Test Site
REEco . . . Reynolds Electrical & Engineering Co., Inc.
TLD . . . . Thermoluminescent Dosimeters
TRU . . . . Transuranic
USRADS . Ultrasonic Ranging and Data System
WID . . . . Waste Isolation Division
WIPP . . . Waste Isolation Pilot Plant

EXECUTIVE SUMMARY

The Gnome site is the location of a 1961 underground nuclear detonation in the Atomic Energy Commission (AEC) Plowshare program that vented radioactive contamination to the atmosphere. The resulting ground contamination was cleaned up in 1968-1969 and again in 1977 as weathering affected some shallow burial. Subsequent environmental surveys revealed slightly elevated ^{137}Cs levels, but no transuranic contamination.

The Waste Isolation Pilot Plant (WIPP) is approximately 8.8 km (5.5 mi) northeast of the Gnome site, and the Gnome site is within the preoperational radiological surveillance area for the WIPP. The Environmental Evaluation Group (EEG) conducts a WIPP preoperational radiological surveillance program, and the EEG initiated field surveys at Gnome in 1994.

The EEG used a combination of traditional and state-of-the-art radiological survey techniques. In addition, soil samples were collected for analysis in the newly established EEG radiochemistry laboratory, and the EEG results were compared to commercial laboratory analyses. New methods for contamination surveys, sample screening and telemetry were evaluated and found to be more sensitive and efficient than historical methods.

Localized surface contamination was identified, and soil samples were taken from selected areas and control locations outside the Gnome site. Radiochemical analyses by EEG and a commercial laboratory indicated elevated levels of ^{238}Pu, $^{239+240}Pu$, and ^{241}Am at Gnome. The radioactivity was heterogeneously distributed within the samples which is consistent with contamination from atmospheric nuclear weapons testing. Samples outside the Gnome area did not indicate transuranic contamination.

The EEG radiochemical analyses, limited to surface soil samples, show the presence of transuranic contamination at the Gnome site. Although there is measurable transuranic

contamination at Gnome, the levels do not appear to present any immediate health and safety concerns. Additional work is needed to determine if contamination is at greater soil depths, and if further remedial action is needed.

CONCLUSIONS

The Gnome site is a unique study area that can provide valuable information about the long term trend in radionuclide transport in the environment surrounding the WIPP. The current study shows that field surveys are useful in determining the areas of radionuclide accumulation. The USRADS technology provides the most detailed information and should be considered by organizations involved in preoperational and operational environmental monitoring. Additional γ survey information is needed in the vicinity of Gnome, the WIPP facility, surrounding communities and along WIPP transportation routes to complete the baseline. This information would provide data that would allow for an analysis of long and short term changes that may occur as a result of WIPP activities or changes in world-wide fallout. Field survey methodology would also be useful in post-accident evaluation and response.

Gamma spectroscopy can be used to identify the individual radionuclides responsible for elevated field γ measurements. Timely identification of individual radionuclides will be necessary in the event of a release of radioactivity related to WIPP activities. Preoperational knowledge of the distribution of various radionuclides at the WIPP and surrounding areas is required to evaluate the impact of WIPP on the environment.

Radiochemical analysis can be used to quantify radionuclide concentrations in soil with much lower detection limits. The EEG radiochemical laboratory located in Carlsbad, NM, is an integral part of the EEG environmental monitoring program which enables good control of quality assurance activities, rapid analysis and ongoing participation in the EPA Performance Evaluation Studies Program.

The following specific conclusions relate to the Gnome study:

1. The EEG measured heterogeneously distributed transuranic contamination (^{238}Pu, $^{239+240}Pu$, and ^{241}Am) on the surface of the Gnome site. This result was independently confirmed by commercial laboratory analyses. Although the contamination was measurable, the levels do not appear to present any immediate health and safety concerns.

2. Only limited surface measurements were made. Additional work is needed to determine if contamination exists at greater soil depths or outside the identified survey areas. The DOE is considering the need for additional Gnome site remedial action (USDOE 1995). It is also possible that Gnome may require action in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA).

3. Previous survey methods used at Gnome were not adequate nor appropriate for locating and quantifying low-level transuranic contamination. The following comments relate to EEG radiological methods:

    a. The traditional grid plat of potentially contaminated areas and subsequent γ survey is a minimum pre-requisite for identifying possible contamination and soil sampling locations.

    b. The Ultrasonic Ranging and Data System (USRADS), employed by CTC, was a significant advance in identifying surface γ and beta contamination. This method has the advantages of detecting contamination trends and hot spots that might otherwise be undetected. In addition, thousands of measurements are made and documented in a substantially reduced survey time.

    c. Gamma spectroscopic screening of potentially contaminated environmental samples is a necessary prerequisite to radiochemical analysis. It was found that heterogeneously distributed radioactivity in Gnome samples may cause high measurement variability.

d. The current EEG radiochemical methodology is appropriate for identification of ^{238}Pu, $^{239+240}Pu$, and ^{241}Am in environmental samples.

INTRODUCTION

The Environmental Evaluation Group (EEG) conducts an on-site and off-site radiological environmental monitoring program at the Waste Isolation Pilot Plant (WIPP) near Carlsbad, New Mexico (NM&USDOE 1984; NDAA 1993). Since WIPP is a planned repository for the permanent disposal of nuclear transuranic wastes from the nations defense programs it is important to quantify ^{238}Pu, $^{239+240}Pu$, ^{241}Am and other radionuclides that already exist in the WIPP environment. As part of this program, the EEG obtained and analyzed environmental samples from the Gnome site, a Plowshare test site located 8.8 km (5.5 mi) southwest of the WIPP facility boundary. This report contains the results of the EEG's Gnome survey.

The EEG began collecting environmental samples at the WIPP site and in surrounding communities in 1985, and since then has systematically improved both the field and laboratory measurement capabilities. In 1989, the EEG added radiological survey equipment capable of detecting ^{238}Pu, $^{239+240}Pu$ and ^{241}Am radionuclide contamination. In 1994, the EEG began developing radiochemical methods for measuring transuranic radionuclides in environmental samples.

This report includes Gnome historical information, a general description of EEG's radiological measurement methods, an evaluation of the Ultrasonic Ranging and Data System (USRADS) survey methods available from Chemrad Tennessee Corporation (CTC), and the overall results of the EEG's Gnome study.

In 1961, the surface area of the Gnome site was contaminated with fission radionuclides when an underground nuclear explosion vented to the surface (USDOC 1962). The site was decontaminated in 1968-1969 and again in 1978 (Berry 1981). The second 1978 cleanup used more conservative measurement criteria than the 1968-1969 cleanup. However the survey techniques were not designed to find ^{238}Pu, $^{239+240}Pu$ and ^{241}Am radionuclides. A follow-up decontamination and decommissioning project in 1979 indicated negligible plutonium contamination (Berry 1981).

BACKGROUND INFORMATION

The following sections briefly describe and provide references to the WIPP project, Project Gnome, and the WIPP project's preoperational environmental monitoring programs.

The WIPP Project

The WIPP is a Department of Energy (DOE) facility whose mission is to dispose of 176,000 m^3 (6,200,000 cubic feet) of transuranic (TRU) waste (WIPP 1992). The TRU wastes result from defense activities of the United States and primarily contain the radionuclides ^{241}Am, ^{137}Cs, ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{241}Pu, ^{90}Sr, and ^{90}Y (USDOE 1990b). After approval of the DOE certification application by the Environmental Protection Agency (EPA) that disposal meets the EPA standards (40 CFR 191) for safe disposal of TRU wastes (USEPA 1994a), wastes are to be disposed of in this deep geologic repository at a depth of 655 m (2,150 ft) below land surface in a bedded salt formation.

The WIPP is located approximately 42 km (26 mi) east-southeast of Carlsbad, New Mexico, in the Los Medanos area that consists of sand dunes covered with a variety of desert vegetation and wildlife.

The Gnome Site

The Gnome site is approximately 8.8 km (5.5 mi) southwest of the WIPP facility boundary (Figure 1), in the same Los Medanos tract as the WIPP. The region supports flora and fauna common to both the northern Chihuahuan desert and southern Great Plains. The characteristic vegetation and topography are evident in Figure 2. The site is unrestricted, with cattle grazing and hunting as typical land uses.

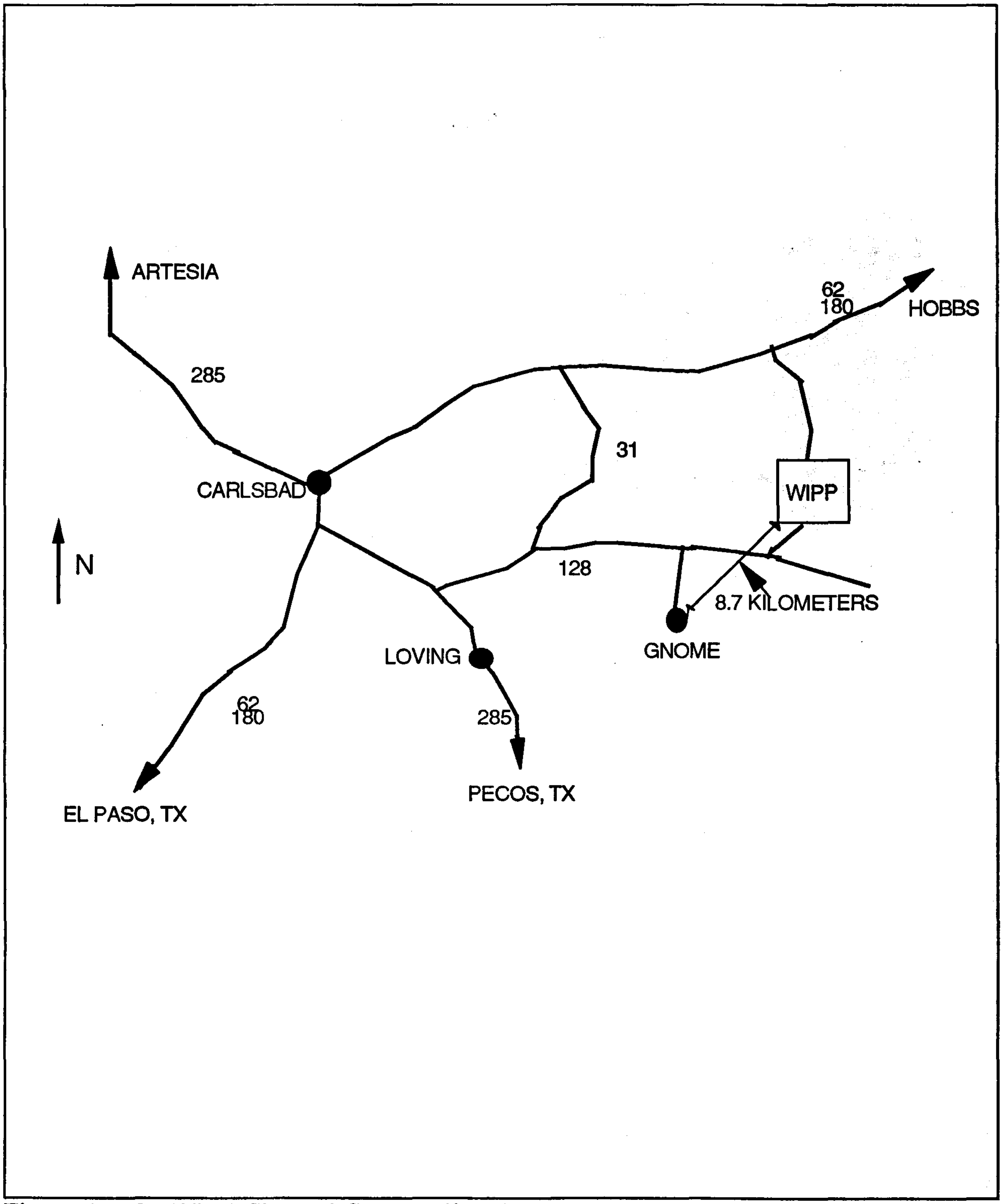

Figure 1. The WIPP Site and Surrounding Areas

Figure 2. Typical Gnome Vegetation

Project Gnome was part of the Atomic Energy Commission's (AEC) Plowshare program for the peaceful uses of nuclear explosives. The overall objectives were to use "nuclear explosives in civil engineering projects, development of natural resources, production of isotopes and power, and scientific studies" (USAEC 1961).

To accomplish the stated objectives the AEC detonated a 3-kiloton ^{239}Pu device 370 m (1,216 ft.) below the land surface in the Salado formation on December 10, 1961 (UNS 1988). Figures 3a and 3b represent the surface and subsurface configurations of the Gnome site. Plans were to contain all radioactivity underground; however, venting from the access shaft occurred for more than 24 hours following detonation (USDOC 1962). During the venting process fission products were released, contaminating the surrounding environment (Rawson et al. 1961).

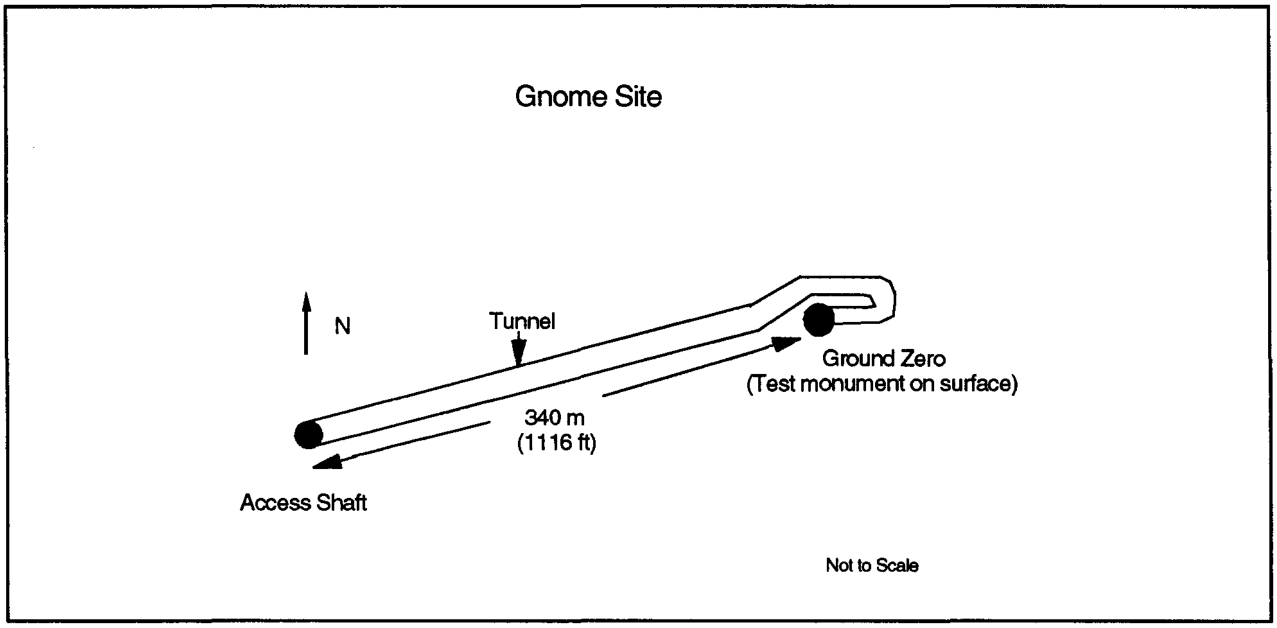

Figure 3a. Diagram of the Gnome Site Underground Configuration

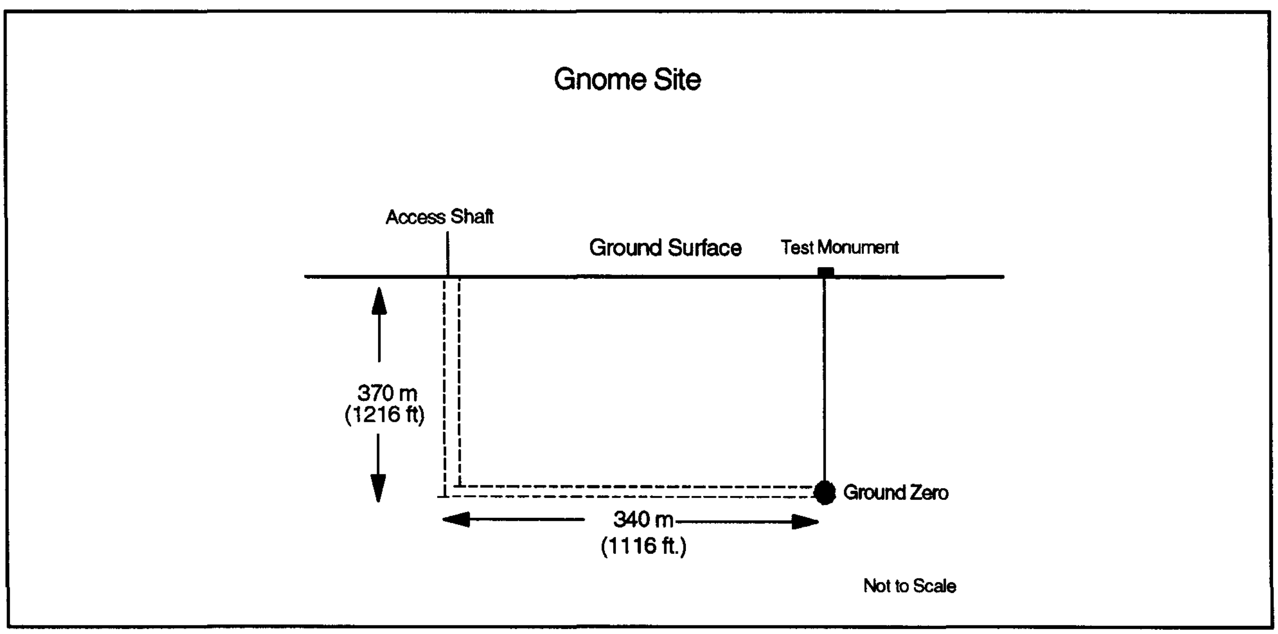

Figure 3b. Lateral Diagram of the Gnome Site Underground Configuration

In 1968 the AEC began the initial cleanup of the Gnome site. Dose-rate guidelines for cleanup of the site specified the removal of material above 0.1 mR/h (β plus γ)[1] as measured by Geiger-Müller (GM) portable survey instrument with a 30 mg/cm^2 window (Tappan and Lorenz 1969). All surface facilities were removed and all drill holes were plugged with the exception of wells LRL7 and DD1 (Figure 4) which were left for use as monitoring wells. Contaminated material was removed from the surface and placed into the Gnome cavity or transported to off-site disposal facilities (Berry 1981).

A 1972 inspection revealed that contaminated material buried northeast of the access shaft was becoming exposed to the environment (Berry 1981). From 1972 to 1977, the DOE continued to monitor the site, but remedial action was not taken. In 1977 the DOE contracted with Reynolds Electrical & Engineering Co., Inc. (REEco) and Fenix & Scisson, Inc. to decontaminate the site. After the 1968 cleanup, the guidelines for remediation changed. The new guidelines (Berry 1981) required soil decontamination to levels below 20 pCi/g (β plus γ)[1], averaged over 0.25 hectares, and 30,000 pCi/ml of tritium in soil moisture. Berry (1981) described the decontamination tasks as follows. The first task completed by REEco was an aerial gamma survey that identified ^{137}Cs as the primary gamma emitter in the vicinity of the Gnome site. All subsequent cleanup activities were based solely upon ^{137}Cs and ^{3}H contamination. As soil was removed, the newly exposed soil was surveyed with a Ludlum micro-R-meter (Model 19). Excavation stopped when the survey revealed exposure rates below 25 μR/hr, and random soil samples were collected and analyzed for comparison to the decontamination criteria. Contaminated crushed soil was mixed with water, and the resulting slurry was pumped into the Gnome cavity. Material not placed in the cavity was packaged and transported to the Nevada Test Site low-level waste facility for disposal.

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[1]The 1968 cleanup guidelines were based on dose rate measurements; the 1977 guidelines were based on soil concentration limits. These two measurements are not comparable.

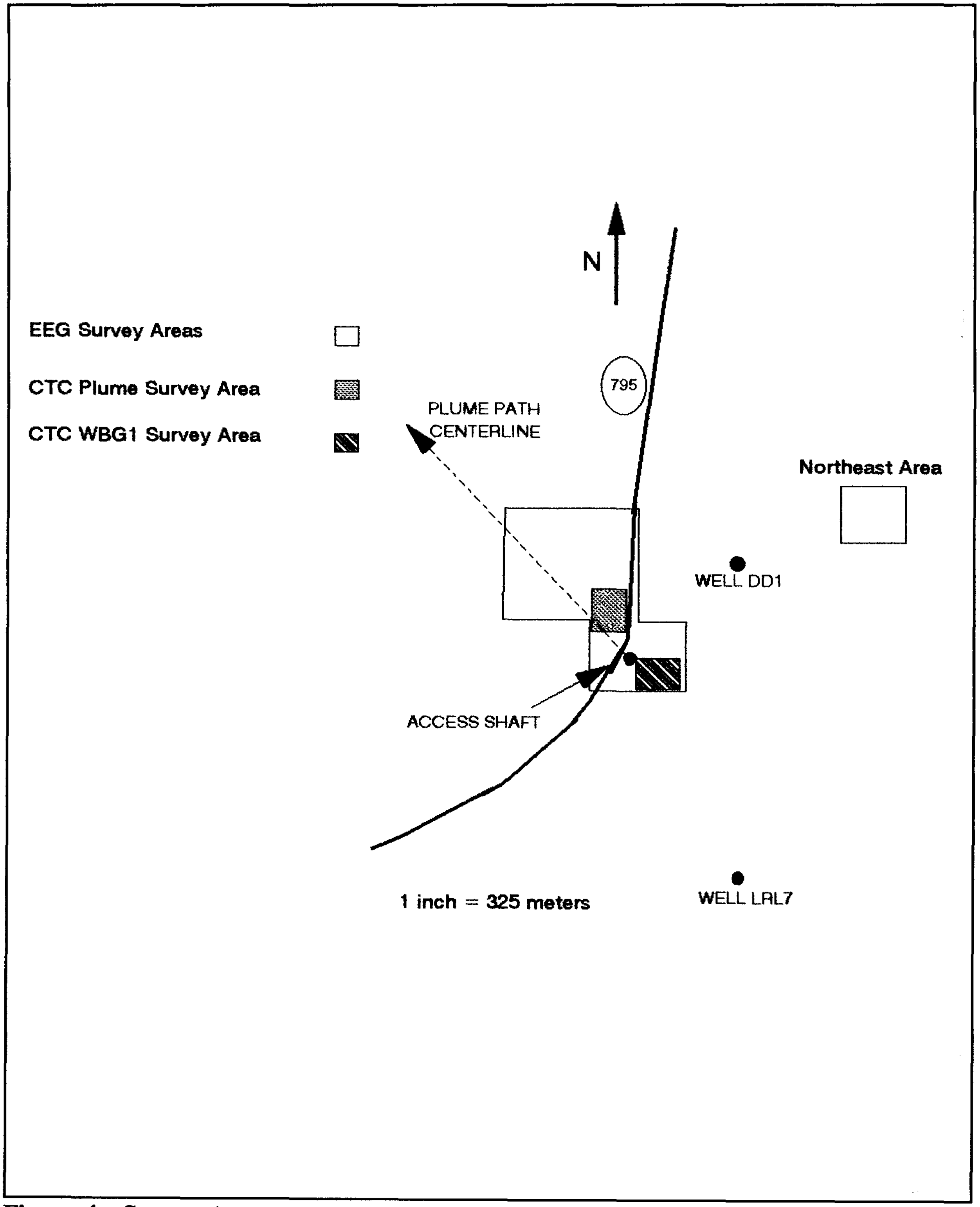

Figure 4. Survey Areas

WIPP Preoperational Monitoring Programs

The goal of the EEG's environmental monitoring program is to establish independent baseline measurements of radionuclide concentrations in the environment and communities surrounding the WIPP facility. In 1984 EEG developed an environmental surveillance network radionuclide measurements as described in Environmental measurements began in 1985 as described in EEG report #26, "Proposed Pre-operational Environmental Monitoring Program for the WIPP" (Spiegler 1984). The EEG has published five environmental data reports that contain pre-operational baseline concentrations of selected radionuclides (Kenney et al. 1990; Kenney and Ballard 1990; Kenney 1991; Kenney 1992; and Kenney 1994).

The EEG environmental monitoring program is similar to the program conducted by the Waste Isolation Division (WID) of Westinghouse Electric Corporation, the prime contractor for the WIPP. WID environmental monitoring data are documented in eight environmental reports (Reith et al. 1986; Banz et al. 1987; USDOE 1988; USDOE 1989; USDOE 1990a; USDOE 1991; USDOE 1992; and USDOE 1993). None of these EEG or WID environmental reports contain radionuclide data specific to Gnome area soil.

The DOE conducted a pre-operational aerial gamma survey of the WIPP area that included the Gnome site in 1988 (Berry 1989). The aerial survey distinguished between ^{137}Cs and naturally occurring ^{40}K. The survey identified man-made ^{137}Cs activity at the Gnome site and the presence of naturally occurring ^{40}K in other areas.

In 1991, the EPA conducted spot measurements of the Gnome site using a pressurized ionization chamber, and high-purity germanium detector (HpGe) for in-situ measurements at 22 locations (USEPA 1994b). Limited radiochemical analyses of soil samples were performed, but the results were reported only as ^{90}Sr to ^{137}Cs ratios. The EPA identified ^{137}Cs contamination as high as 11.49 kBq/m^2 (3.1 x 10^5 pCi/m^2) based upon gamma spectrometry.

MATERIALS AND METHODS

The EEG conducted field gamma surveys, collected soil samples, developed soil screening protocols and performed radiochemical analyses of selected soil samples. The literature indicates the relative locations of the predominate plume release pathway, burial sites for contaminated materials, and structures associated with the project (USDOC 1962; USAEC 1969; Berry 1989; US EPA 1994b). The EEG selected gamma survey locations according to information in these Gnome reports. Soil samples were collected from "hot spots" identified in the field gamma surveys, rainwater catchment basins and control points outside of the Gnome study area. The EEG also contracted with the Chemrad Tennessee Corporation (CTC) to performed detailed β, γ and dose rate surveys.

The EEG radiological surveys were conducted over a seven-month period between September 1994 and March 1995. The survey locations are identified in Figure 4. The EEG typically worked at the site for short periods of time (1-3 hours) on 22 separate days. On December 12 -13, 1994, the CTC conducted comprehensive surveys at predesignated locations within the EEG survey areas.

The access shaft was used as the survey reference point because it was the origin of the plume release and it was an easily identified landmark. Distance from the access shaft was determined with the rangefinder function of a DataScope™ (digital compass/rangefinder). The Gnome access shaft was designated as (0,0) on a Cartesian coordinate system with the X-axis representing the east/west distance and the Y-axis representing the north/south distance for all survey locations in this report. Magnetic north was determine with a DataScope™ , and each grid point was referenced in meters east/west and north/south of the access shaft (0,0).

EEG Field Survey Equipment

Initial γ surveys were performed with a 2.54 cm by 2.54 cm (1 in. by 1 in.) sodium iodide detector (NaI(Tl)) coupled to a Bicron (Analyst Model) portable ratemeter. Initial calibration and daily performance checks were made with a nominal activity 1 μCi ^{137}Cs button source (Eberline, Model CS-7B). The ^{137}Cs source produced 3,200 cpm/μCi in the reference position. The detector manufacturer suggests a low energy cut off point of approximately 60 keV. A nominal activity 3 μCi ^{241}Am (59 keV) source was placed at the reference position, with no measurable instrument response. Field measurements were made with the detector approximately 10 cm (4 in.) above the ground.

A standard Geiger-Müller pancake probe, Ludlum Model 44-9, with a thin detector window (1.7 mg/cm^2), was used for personnel and equipment contamination surveys. The GM probe has a nominal sensitivity to alpha, but typical background counts cause this instrument to be more appropriate for beta than for alpha contamination surveys. Swipe surveys of clothing and equipment were performed with filter papers which were subsequently counted on a Protean Instrument Corporation, Model MPC 9310, gas-flow proportional counter.

Elevation within a topographic depression was determined by using a surveyor's transit and steel tape. The NaI(Tl) detector was positioned 10 cm (4 in.) above the surface, as in other field measurements, and the measurement and elevation recorded.

Chemrad Tennessee Corporation

The EEG contracted with CTC to perform more detailed ground surveys in selected areas at Gnome. The CTC team used USRADS™ technology that combines radio-frequency communications, ultrasonics, and microcomputers. The surveyor carried a pack containing the radiation detection instrumentation, the electronic data gathering and positioning equipment while walking the survey area. The operator managed the microcomputer and the master receiver. As the surveyor walked, signals were sent at one second intervals to the master receiver that recorded β, γ, and dose rate measurements. The measurements were instantaneously correlated with the location of the surveyor. The location and corresponding data values were continuously plotted by the computer. The β, γ, and dose rate surveys were conducted simultaneously in a single walkover of each survey grid.

During the CTC survey the following Quality Control measures were taken to assure data quality objectives were met:

1. daily source checks of instrumentation using sources dimensionally traceable to the National Institute of Standards and Technology (NIST) to verify accuracy of radiological data;

2. continuous monitoring of the survey position and the individual data channels, by the computer operator, to quickly note any discrepancies in the data;

3. cross checks of stationary receiver locations to confirm accuracy of survey coordinates;

4. redundancy measurements on each grid surveyed to insure the ability to reproduce data;

5. review and analysis of the data by CTC's data processing staff; and

6. review and analysis of the final data by CTC management.

<u>Sample Collection Method</u>

Soil samples were collected as follows. A square aluminum form 20 cm (7.9 in) by 2.5 cm (1 in) deep was pressed into the sampling area and soil was removed from within the form.

Each soil sample was placed into a 1ℓ Marinelli beaker to achieve a counting geometry consistent with a multi-γ soil calibration source dimensionally traceable to the NIST.

Gamma Spectroscopic Analyses

Gamma spectroscopic analyses were conducted using a liquid-nitrogen-cooled Canberra high-purity germanium detector, Model GR-3021 is housed in a Nuclear Data shield, Model 1260-FO. A mixed-gamma soil standard, (Analytics Inc. Model 37654-249 in a Marinelli geometry) was used to calibrate the gamma spectroscopy system. Gnome soil samples were placed in the shield in the same geometry as the mixed-gamma soil standard and counted for 3600 seconds. Spectra were analyzed using Quantum Technology software GDR version 6.1.

Radiochemistry Methods

Radiochemical analyses were performed on four of the eight soil samples collected. Representative aliquots of the four samples were dissolved using acid leaching, addition of hydrofluoric acid, and carbonate fusion. Separation and purification of transuranics was achieved using extraction chromatography methodology (Horwitz et al. 1993). Preparation for alpha spectroscopy measurements included electrodeposition of the purified fraction based on published methods (Talvitie 1972; Mitchell 1960). A Tennelec 4-detector alpha-spectrometer was used in conjunction with DMR-II software for spectral analyses.

Radiological Protection

The primary health physics concerns at the Gnome site were the potential for personnel radiological contamination, internal uptake of radioactive material and exposure from γ emitting radionuclides. The health physics surveys and protective measures are described below. The health physics surveys also serve as indicators of the mobility of Gnome contamination.

To prevent possible personnel contamination, the staff routinely wore protective clothing and shoe covers while in suspect areas. Protective clothing was removed after exiting survey areas. In addition, α and β contamination surveys of personnel and equipment were performed in the field prior to entering the Carlsbad facility. The entrance to the radiochemistry laboratory is controlled and adhesive pads are used on floors at laboratory entrances to ensure radiation protection control. Contamination was not detected by the surveys or on the adhesive pads.

The preliminary EEG surveys indicated that γ exposure rates were extremely low. The EEG staff wore Eberline thermoluminescent dosimeters (TLDs) while in the Gnome area. As expected, the TLDs received no measurable doses although two staff members were in the area approximately 48 hours.

If residual Gnome soil contamination was resuspended in the air by wind or mechanical means, then personnel could potentially inhale the radioactive material. An air sampler was positioned at worst-case locations for particle resuspension and used to sample ambient air during some field operations. The air filters showed no measurable activity when analyzed using α and β pancake probe survey instruments and no detectable activity by laboratory γ spectroscopic analysis. The lower limit of detectable activity for ^{241}Am by γ spectroscopic analysis is 13 pCi. The total air volume sample collected was 110 m^3 resulting in a minimum detectable concentration of 10^{-13} μCi/ml. The radiation worker derived air concentration (DAC) for controlling radiation dose by inhalation of ^{241}Am is 2×10^{-12} μCi/ml (USEPA 1994a). The dose rate limit for radiation workers is 5000 mrem/yr, based on a 2040 hour work year. Considering the limited time spent at Gnome (48 hrs) and the minimum detectable concentration (1.13×10^{-13} μCi/ml) , the maximum potential dose to EEG workers from ^{241}Am inhalation is approximately 7 mrem which is well below the 5000 mrem limit.

The National Council on Radiation Protection and Measurements (NCRP) states that many parameters are involved with the resuspension of surface contamination, such as the age and physical activities (NCRPM 1985). The NCRP also suggests that the resuspension factor is the most appropriate method for characterizing air concentration at sites contaminated after nuclear bomb testing in the southwestern United States and is defined as follows:

$$K(t) = \frac{Xr(t)}{S}$$

where:

K(t) = Resuspension Factor (m^{-1})

Xr(t) = Air concentration of resuspended activity at time t after the deposition has been completed (pC/m^3), and

S = Surface deposition per unit area (pC/m^2).

For material deposited greater than 25 years, the suggested NCRP resuspension factor is K(t) = 10^{-9} (m^{-1}) and is consistent with historical values (Bennett 1974).

RESULTS

Both the EEG and CTC area surveys indicate elevated environmental γ measurements in the probable Gnome plume release pathway. In addition, EEG measurements in an area identified as a contaminated waste burial site (Berry 1981) also indicate elevated environmental γ measurements. Laboratory γ spectroscopic analysis of soil samples indicated that ^{137}Cs was the principle radionuclide associated with the Gnome site γ measurements. Radiochemical analysis of the same soil samples revealed elevated levels of $^{239+240}$Pu, ^{238}Pu, and ^{241}Am radionuclide contamination.

EEG Surveys

In Figure 4, EEG survey locations are shown relative to the road leading to Gnome, sampling wells and the access shaft. The EEG environmental γ measurements using the NaI(Tl) survey instrument are graphically displayed in Figure 5. All measurements are gross counts, that is, background is not subtracted. The yellow areas indicate γ count rates less than 1000 cpm, blue indicates count rates between 1000 and 3000 cpm, and red indicates count rates greater than 3000 cpm. The data are in Appendix A.

Elevated γ count rate measurements were found around the access shaft and leading to the northwest. The northwest trend appears to correspond with the predominate Gnome plume release pathway. The area southeast of the access shaft has isolated areas of elevated count rates including the two highest count rates found (see red marks on Figure 5). A γ count rate approximately 20 times the background count rate was measured at the southern most red mark in Figure 5 which corresponds to soil sample location 2 as shown in Figure 6.

Because of the high γ measurements, soil samples were collected for additional analyses from the two red locations, and these results are discussed in the section below on Radiochemical Analyses of Soil Samples.

The EEG surveyed an area northeast of the access shaft and again found a pattern of elevated γ measurements (Figure 5). This area corresponds to the contaminated waste burial area described by Berry (1981).

In an undisturbed area approximately 750 m north of the access shaft (sample location 6, Figure 6), γ measurements as high two times background were identified. It was suspected that these elevated measurements were related to the water catch basin topography. As described previously, the elevation within the water catch basin was recorded with each γ survey measurement. The results are shown in Figure 7, and there appears to be strong correlation (R-squared = 0.92) between γ count rate and elevation.

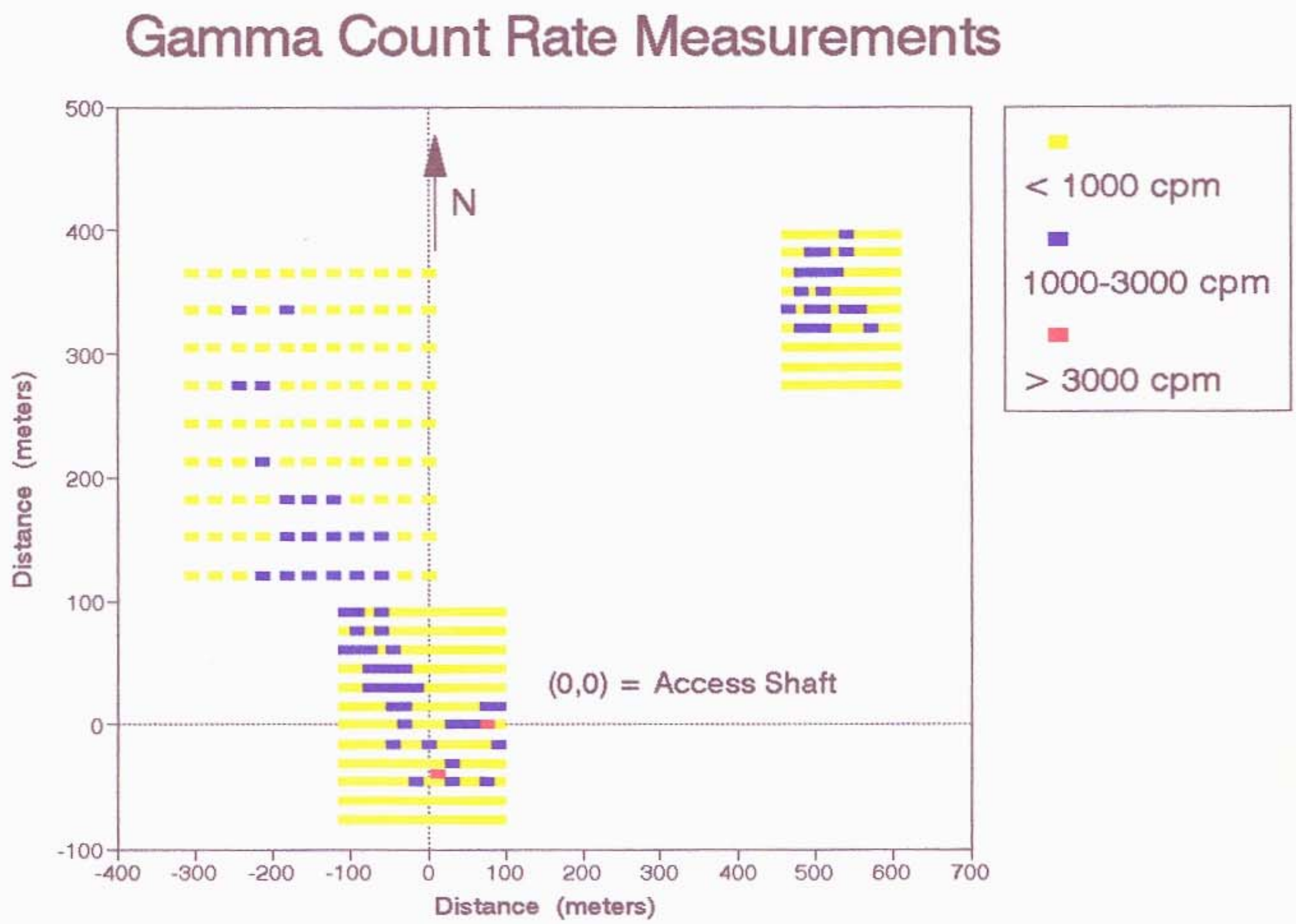

Figure 5. Gamma Count Rates at the Gnome Site

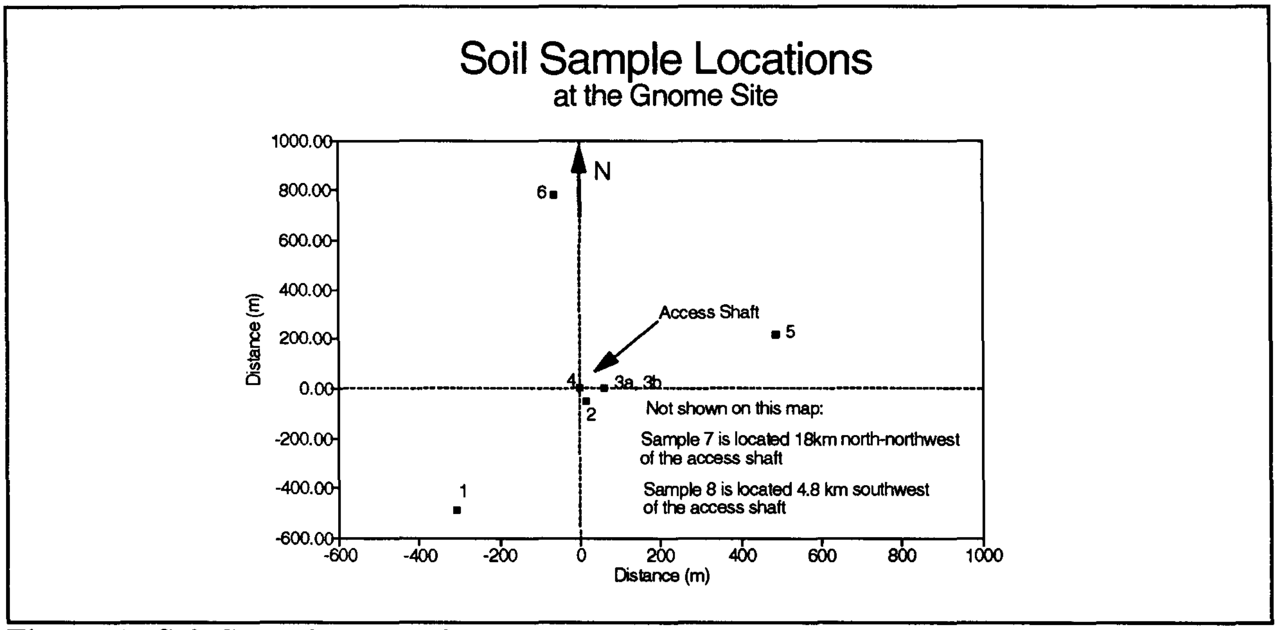

Figure 6. Soil Sampling Locations

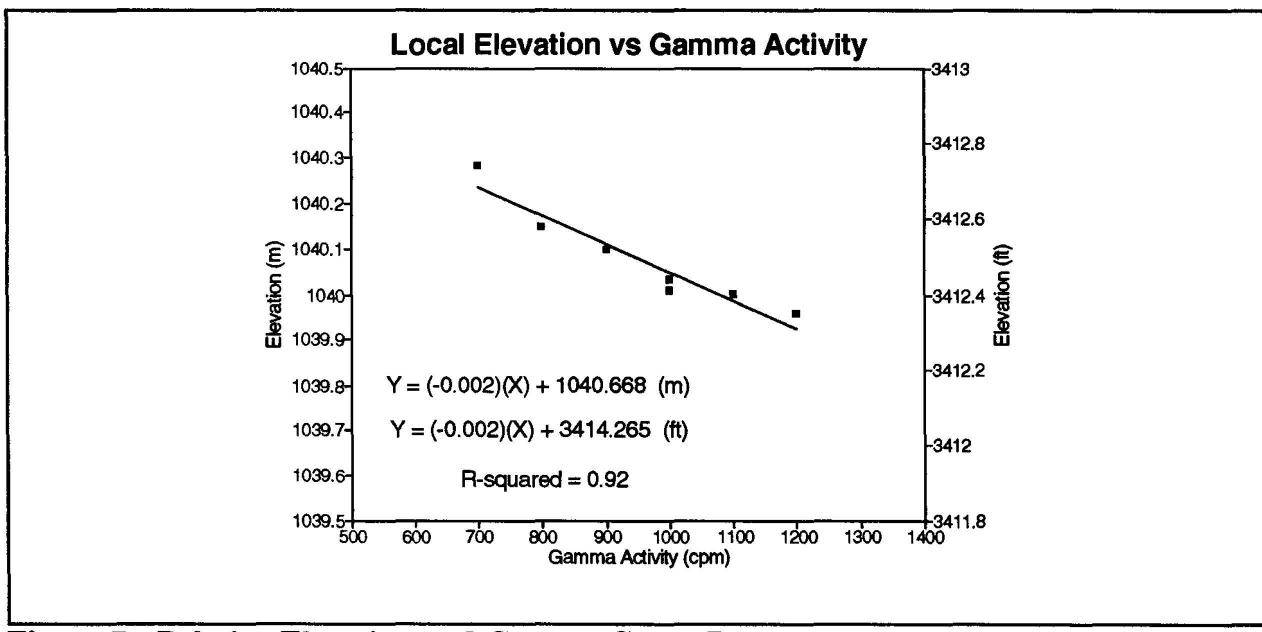

Figure 7. Relative Elevation and Gamma Count Rate

Chemrad Tennessee Corporation (CTC) Surveys

The CTC radiological surveys were performed on December 12 - 13, 1994, in the two locations shown in Figure 4 and identified as the CTC plume and CTC WBG1 surveys. The CTC plume survey data are in Appendix B, Figure B1 and identified as USRADS v1.10d Track Map, Plume C. The NaI(Tl) γ measurements in Figure B1 indicate a pattern of elevated count rate along a northwest path from the access shaft release point. This pattern appears to correspond to the main Gnome release pathway and to the apparent plume trend shown in the EEG survey (Figure 5). The elevated CTC measurements were generally three to four times the background count rate with one isolated measurement at about seven times background.

The CTC WBG1 survey data are in Appendix B, Figure B2 and identified as WBG1(A), Track Map. The CTC WBG1 data indicated several areas with count rates of two to three times background and two points as high as six to seven times background. The two highest count rates are shown in red in Figure 5 and are map coordinates x = 12.25 m, y = -43.13 m and x = 45.1 m, y = -41.3 m. At the first location, the EEG NaI(Tl) measurement was 11,000 cpm, and the CTC NaI(Tl) measurement was about 12,000 cpm. At the second location, EEG measured 3800 cpm and CTC 5660 cpm.

The CTC reported a mean of 5.47 +/- 1.83 μrem h^{-1} in the plume area and 3.95 +/- 3.42 μrem h^{-1} in the burial area. The measurements were made with a Bicron MicroRem Model Tissue Equivalent Survey Meter carried in the same geometry as the CTC NaI(Tl) survey meter.

Soil Sample Gamma Spectroscopic Screening

A total of nine soil samples were collected for γ spectroscopic analysis with relative locations shown in Figure 6. Samples 1 and 6 were outside the EEG survey area, but on the Gnome site. Samples 2 and 3 were at the red markers shown in Figure 5, and two samples were collected at location 3. Sample 4 was near the access shaft, and sample 5 was in the suspected burial area. Samples 7 and 8 were collected outside the Gnome area.

Table 1 contains the results of the γ spectroscopic analyses. The R-squared value for the correlation between γ count rate and ^{137}Cs is 0.95. The ^{40}K concentrations are relatively constant for all samples. The ratio of ^{40}K to ^{137}Cs is highly variable due to great variation in the ^{137}Cs concentrations.

Table 1. ^{40}K and ^{137}Cs Soil Concentrations

Location	K-40		Cs-137		Ratio	Gross γ
	(Bq/g)	(pCi/g)	(Bq/g)	(pCi/g)	^{137}Cs:^{40}K	CPM
1	**0.22**	(6.00)	**0.01**	(0.20)	0.03	800
2	**0.20**	(5.37)	**3.09**	(83.40)	15.53	11000
3A	**0.26**	(7.07)	**0.58**	(15.60)	2.21	3800
3B	**0.23**	(6.08)	**0.41**	(11.20)	1.84	3800
4	**0.17**	(4.48)	**0.07**	(1.89)	0.42	NA
5	**0.24**	(6.44)	**0.22**	(5.92)	0.92	1400
6	**0.24**	(6.58)	**0.10**	(2.63)	0.40	1200
7	**0.67**	(18.00)	**0.02**	(0.64)	0.03	2500
8	**0.23**	(6.13)	**0.003**	(0.07)	0.01	800

Radiochemical Analyses of Soil Samples

Table 2 shows the activity concentrations of transuranic radionuclides as determined by radiochemistry. Four aliquots from sample 3A were sent to a commercial laboratory for independent analyses. The commercial samples are samples 3A-4 through 3A-7. The highest concentration of transuranic contamination was found in the soil sample from location 3A, near some exposed metallic debris located approximately 76 m (250 ft) east-southeast of the access shaft (Figure 8).

Table 2. Radiochemical Data

	$^{239+240}Pu$		^{238}Pu		^{241}Am	
Location	**Bq/g**	(pCi/g)	**Bq/g**	(pCi/g)	**Bq/g**	(pCi/g)
2	**0.0044**	(0.12)	**0.00081**	(0.022)	**0.00059**	(0.16)
3A	**0.63**	(17)	**0.10**	(2.7)	**0.14**	(3.9)
3A-1	**0.48**	(13)	**0.067**	(1.8)	**0.085**	(2.3)
3A-2	**0.31**	(8.5)	**0.044**	(1.2)	**0.052**	(1.4)
3A-3	**48**	(1290)	**6.8**	(184)	**7.6**	(205)
3A-4**	**0.041**	(1.1)	**0.0067**	(0.18)	**0.0067**	(0.18)
3A-5**	**0.063**	(1.7)	**0.011**	(0.31)	**0.022**	(0.60)
3A-6**	**15**	(410)	**2.4**	(66)	**1.8**	(48)
3A-7**	**0.010**	(0.27)	**0.015**	(0.40)	**0.048**	(1.3)
3B	**0.059**	(1.6)	**0.0089**	(0.24)	**NA**	NA
7	**0.0008**	(0.022)	**0.0002**	(0.005)	**0.0004**	(0.011)

Note: ** identifies analyses by a Commercial Laboratory
NA sample lost in processing

Figure 8. Exposed Debris Southeast of the Access Shaft

DISCUSSION

The EEG study was more detailed than previous studies conducted near the Gnome site. The increased detail and use of new methodologies identified radionuclides not previously found at the Gnome site. Most likely this is because the EEG data were not averaged over large areas as in previous remedial surveys. The EEG study identified isolated areas of contamination and soil samples were then collected from these locations for radiochemical analysis. Therefore, the probability of the EEG finding transuranic contaminants was greatly increased. EEG radiochemistry methodology involved complete dissolution of the sample which enabled analyses of all radioactive constituents regardless of solubility.

Field Gamma Surveys

The field γ surveys performed by the EEG identified the probable plume path and located the contaminated waste burial areas. Field γ surveys proved to be useful in identifying local areas of elevated γ count rates. Ritchie and McHenry (1990) reported numerous findings of ^{137}Cs accumulation in water catchment basins which is consistent with the limited EEG data set. Table 1 shows positive correlation between γ count rate and ^{137}Cs concentrations (R-squared = 0.95) while Figure 7 shows a strong relationship between γ count rate and local elevation, (R-squared = 0.92). Another major γ contributor, ^{40}K, was found to be relatively constant in all soil samples. Future work should include additional measurements of γ count rates and radionuclide concentrations in water catchment basins and elevated locations near WIPP and along the waste transportation routes. Such information could be helpful in predicting where radionuclides will accumulate in the environment.

The CTC survey identified areas with elevated γ count rates that the EEG survey did not identify due to greater detail provided by the USRADS system used by CTC. Variations in the EEG and CTC measurements conducted at the same locations can be attributed to differences in calibration methods, and variations in field geometry (detector-to-ground distance). The CTC instrument response was approximately 50% greater than the EEG instrument response in the same geometry.

In addition to the γ count rate surveys, CTC also provided a detailed track map of dose rates which indicated no significantly elevated measurements. The average dose rates reported by CTC were 5.47 μR/h for the plume survey and 3.95 μR/h for the WBG1 survey. The detailed contour maps of dose rates are not included in this report.

The β measurements taken by CTC were near background and inconclusive, however, ^{90}Sr is expected to have dispersed with ^{137}Cs at the time of the Gnome detonation. The CTC β measurements are not included in this report. Gilbert (Gilbert et al 1988) reported that ^{90}Sr bioaccumulates in the roots of vegetation and is transferred to the leaves. The EEG is in the process of developing radiochemical methodology to measure β emitters such as ^{90}Sr. Additional γ, β, and dose surveys in the vicinity of Gnome and the WIPP site may be useful as WIPP preoperational and operational studies continue.

Gamma Spectroscopy

Field γ surveys were useful in identifying areas of elevated γ activity but did not distinguish individual radionuclides (natural and man-made) that contributed to the gross γ activity. Gamma spectroscopy was used to quantify ^{137}Cs and ^{40}K concentrations in soil samples using a Marinelli beaker configuration. Berry (1989) identified elevated levels of ^{40}K associated with potash tailing deposits. The influence of these large deposits of ^{40}K must be evaluated in various topographies near the WIPP site and along WIPP transportation routes as an additional part of the environmental baseline studies.

Gamma spectroscopy was also used to screen soil samples for ^{241}Am activity, however, the sensitivity can be reduced because of self-attenuation. High variability in measurements could be caused by non-uniform distribution of radioactive particles within a sample (Doctor et al. 1980).

Radiochemistry

Gamma spectroscopy was not capable of quantifying ^{238}Pu and $^{239+240}Pu$ at the concentrations present in Gnome site soil. Therefore, radiochemical analysis was used to determine concentrations of ^{238}Pu and $^{239+240}Pu$ in selected soil samples. The first radiochemical data from soil samples was collected in 1989 as a part of the EEG preoperational monitoring program for the WIPP. Previous soil radiochemical data obtain from a commercial laboratory is included in appendix C along with data obtained from the Gnome baseline study. The ^{228}Th, ^{230}Th, ^{232}Th, $^{233+234}U$, ^{235}U, and ^{238}U radionuclide concentrations found at the WIPP and the Gnome site are similar. As expected the concentrations of ^{238}Pu and $^{239+240}Pu$ are significantly greater in the Gnome samples.

Watters et al. (1980) found wind erosion to be the primary transport mechanism for deposited radioactive isotopes of plutonium in arid regions. Lee and Tamura (1981) determined that ^{241}Am is not uniformly distributed within the first 5 cm of soil depth. Radiochemical analysis of soil from the Gnome area will provide data that could be used to predict where these radionuclides accumulate. Previous WIPP baseline studies have not included this type of isotopic soil profile.

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APPENDIX A:

Gamma Count Rate Data

GAMMA COUNT RATE DATA

X (m)	Y (m)	Gross Gamma Counts	X (m)	Y (m)	Gross Gamma Counts
-304.8	121.92	700	-243.84	335.28	1100
-304.8	152.4	700	-243.84	365.76	900
-304.8	182.88	700	-213.36	121.92	1200
-304.8	213.36	900	-213.36	152.4	900
-304.8	243.84	700	-213.36	182.88	1000
-304.8	274.32	800	-213.36	213.36	1100
-304.8	304.8	900	-213.36	243.84	1000
-304.8	335.28	900	-213.36	274.32	1100
-304.8	365.76	900	-213.36	304.8	900
-304.8	365.76	900	-213.36	335.28	950
-277.3	304.8	900	-213.36	365.76	900
-274.3	121.92	1000	-182.88	121.92	1200
-274.3	152.4	900	-182.88	152.4	1100
-274.3	182.88	900	-182.88	182.88	1100
-274.3	213.36	800	-182.88	213.36	900
-274.3	243.84	800	-182.88	243.84	800
-274.3	274.32	1000	-182.88	274.32	900
-274.3	335.28	800	-182.88	304.8	900
-274.3	365.76	900	-182.88	335.28	1100
-243.8	121.92	900	-182.88	365.76	900
-243.8	152.4	1000	-152.4	121.92	1200
-243.8	182.88	1000	-152.4	152.4	1500
-243.8	213.36	900	-152.4	182.88	1250
-243.8	243.84	1000	-152.4	213.36	1000
-243.8	274.32	1100	-152.4	243.84	1000
-243.8	304.8	700	-152.4	274.32	900

GAMMA COUNT RATE DATA

X (m)	Y (m)	Gross Gamma Counts	X (m)	Y (m)	Gross Gamma Counts
-152.4	304.8	800	-91.44	-45.72	700
-152.4	335.28	1000	-91.44	-30.48	900
-152.4	365.76	900	-91.44	-15.24	600
-121.92	121.92	1600	-91.44	0	750
-121.92	152.4	1600	-91.44	15.24	850
-121.92	182.88	1100	-91.44	30.48	900
-121.92	213.36	950	-91.44	45.72	850
-121.92	243.84	1000	-91.44	60.96	1250
-121.92	274.32	900	-91.44	76.2	1100
-121.92	304.8	900	-91.44	91.44	1300
-121.92	335.28	1000	-91.44	121.92	1400
-121.92	365.76	900	-91.44	152.4	1300
-106.68	-76.2	700	-91.44	182.88	1000
-106.68	-60.96	750	-91.44	213.36	800
-106.68	-45.72	800	-91.44	243.84	850
-106.68	-30.48	900	-91.44	274.32	1000
-106.68	-15.24	900	-91.44	304.8	1000
-106.68	0	700	-91.44	335.28	900
-106.68	15.24	800	-91.44	365.76	900
-106.68	30.48	900	-76.2	-76.2	800
-106.68	45.72	700	-76.2	-60.96	400
-106.68	60.96	1200	-76.2	-45.72	1000
-106.68	76.2	1000	-76.2	-30.48	700
-106.68	91.44	1500	-76.2	-15.24	800
-91.44	-76.2	800	-76.2	0	700
-91.44	-60.96	800	-76.2	15.24	1000

GAMMA COUNT RATE DATA

X (m)	Y (m)	Gross Gamma Counts	X (m)	Y (m)	Gross Gamma Counts
-76.2	30.48	1150	-45.72	-76.2	400
-76.2	45.72	1400	-45.72	-60.96	600
-76.2	60.96	1400	-45.72	-45.72	500
-76.2	76.2	1000	-45.72	-30.48	500
-76.2	91.44	1000	-45.72	-15.24	1400
-60.96	-76.2	350	-45.72	0	900
-60.96	-60.96	500	-45.72	15.24	1100
-60.96	-45.72	500	-45.72	30.48	1100
-60.96	-30.48	500	-45.72	45.72	1400
-60.96	-15.24	650	-45.72	60.96	1050
-60.96	0	900	-45.72	76.2	850
-60.96	15.24	850	-45.72	91.44	950
-60.96	30.48	1050	-30.48	-76.2	400
-60.96	45.72	1100	-30.48	-60.96	450
-60.96	60.96	1000	-30.48	-45.72	500
-60.96	76.2	1350	-30.48	-30.48	900
-60.96	91.44	2000	-30.48	-15.24	800
-60.96	121.92	1400	-30.48	0	1300
-60.96	152.4	1800	-30.48	15.24	1100
-60.96	182.88	900	-30.48	30.48	1250
-60.96	213.36	900	-30.48	45.72	1200
-60.96	243.84	1000	-30.48	60.96	900
-60.96	274.32	800	-30.48	76.2	850
-60.96	304.8	1000	-30.48	91.44	750
-60.96	335.28	800	-30.48	121.92	1000
-60.96	365.76	700	-30.48	152.4	900

GAMMA COUNT RATE DATA

X (m)	Y (m)	Gross Gamma Counts	X (m)	Y (m)	Gross Gamma Counts
-30.48	182.88	900	0	30.48	900
-30.48	213.36	1000	0	45.72	600
-30.48	243.84	800	0	60.96	600
-30.48	274.32	900	0	76.2	600
-30.48	304.8	800	0	91.44	700
-30.48	335.28	1000	0	121.92	800
-30.48	365.76	700	0	152.4	750
-15.24	-76.2	300	0	182.88	900
-15.24	-60.96	400	0	213.36	1000
-15.24	-45.72	2900	0	243.84	900
-15.24	-30.48	900	0	274.32	700
-15.24	-15.24	850	0	304.8	700
-15.24	0	500	0	335.28	700
-15.24	15.24	1000	0	365.76	700
-15.24	30.48	1100	12.192	-39.624	11000
-15.24	45.72	1000	15.24	-76.2	250
-15.24	60.96	900	15.24	-60.96	300
-15.24	76.2	800	15.24	-45.72	1000
-15.24	91.44	800	15.24	-30.48	600
0	-76.2	300	15.24	-15.24	850
0	-60.96	400	15.24	0	800
0	-45.72	900	15.24	15.24	700
0	-30.48	800	15.24	30.48	850
0	-15.24	1500	15.24	45.72	1000
0	0	500	15.24	60.96	800
0	15.24	550	15.24	76.2	800

GAMMA COUNT RATE DATA

X (m)	Y (m)	Gross Gamma Counts	X (m)	Y (m)	Gross Gamma Counts
15.24	91.44	650	60.96	-60.96	300
30.48	-76.2	250	60.96	-45.72	850
30.48	-60.96	200	60.96	-30.48	1000
30.48	-45.72	1100	60.96	-15.24	600
30.48	-30.48	1200	60.96	0	2800
30.48	-15.24	700	60.96	15.24	900
30.48	0	1200	60.96	30.48	800
30.48	15.24	700	60.96	45.72	700
30.48	30.48	950	60.96	60.96	750
30.48	45.72	850	60.96	76.2	750
30.48	60.96	850	60.96	91.44	700
30.48	76.2	750	76.2	-76.2	200
30.48	91.44	700	76.2	-60.96	300
45.72	-76.2	350	76.2	-45.72	1100
45.72	-60.96	300	76.2	-30.48	800
45.72	-45.72	1000	76.2	-15.24	600
45.72	-30.48	900	76.2	0	2200
45.72	-15.24	600	76.2	0	3800
45.72	0	1500	76.2	15.24	1100
45.72	15.24	800	76.2	30.48	950
45.72	30.48	700	76.2	45.72	600
45.72	45.72	750	76.2	60.96	700
45.72	60.96	800	76.2	76.2	600
45.72	76.2	900	76.2	91.44	700
45.72	91.44	800	91.44	-76.2	750
60.96	-76.2	250	91.44	-60.96	800

GAMMA COUNT RATE DATA

X (m)	Y (m)	Gross Gamma Counts	X (m)	Y (m)	Gross Gamma Counts
91.44	-45.72	800	464.82	381	800
91.44	-30.48	750	464.82	396.24	700
91.44	-15.24	2200	480.06	274.32	900
91.44	0	1000	480.06	289.56	800
91.44	15.24	1200	480.06	304.8	1000
91.44	30.48	900	480.06	320.04	1500
91.44	45.72	800	480.06	335.28	900
91.44	60.96	750	480.06	350.52	1300
91.44	76.2	600	480.06	365.76	1100
91.44	91.44	600	480.06	381	800
464.82	274.32	700	480.06	396.24	800
464.82	289.56	700	495.3	274.32	900
464.82	304.8	700	495.3	289.56	950
464.82	320.04	1000	495.3	304.8	950
464.82	335.28	1500	495.3	320.04	1100
464.82	350.52	900	495.3	335.28	2000
464.82	365.76	1000	495.3	350.52	900
464.82	381	800	495.3	365.76	1500
464.82	396.24	700	495.3	381	1200
480.06	274.32	900	495.3	396.24	900
480.06	289.56	800	510.54	274.32	800
480.06	304.8	1000	510.54	289.56	900
480.06	320.04	1500	510.54	304.8	900
480.06	335.28	900	510.54	320.04	3000
480.06	350.52	1300	510.54	335.28	1400
480.06	365.76	1100	510.54	350.52	1400

GAMMA COUNT RATE DATA

X (m)	Y (m)	Gross Gamma Counts	X (m)	Y (m)	Gross Gamma Counts
525.78	365.76	1200	571.5	350.52	900
525.78	381	750	571.5	365.76	700
525.78	396.24	800	571.5	381	700
541.02	274.32	700	571.5	396.24	700
541.02	289.56	700	586.74	274.32	700
541.02	304.8	700	586.74	289.56	1000
541.02	320.04	800	586.74	304.8	900
541.02	335.28	1900	586.74	320.04	700
541.02	350.52	700	586.74	335.28	700
541.02	365.76	750	586.74	350.52	700
541.02	381	1100	586.74	365.76	700
541.02	396.24	1200	586.74	381	700
556.26	274.32	700	586.74	396.24	700
556.26	289.56	700	601.98	274.32	700
556.26	304.8	700	601.98	289.56	700
556.26	320.04	600	601.98	304.8	700
556.26	335.28	1200	601.98	320.04	700
556.26	350.52	900	601.98	335.28	700
556.26	365.76	800	601.98	350.52	700
556.26	381	700	601.98	365.76	700
556.26	396.24	700	601.98	381	700
571.5	274.32	700	601.98	396.24	700
571.5	289.56	700			
571.5	304.8	1000			
571.5	320.04	1200			
571.5	335.28	900			

APPENDIX B:

Chemrad Tennessee Corporation Report

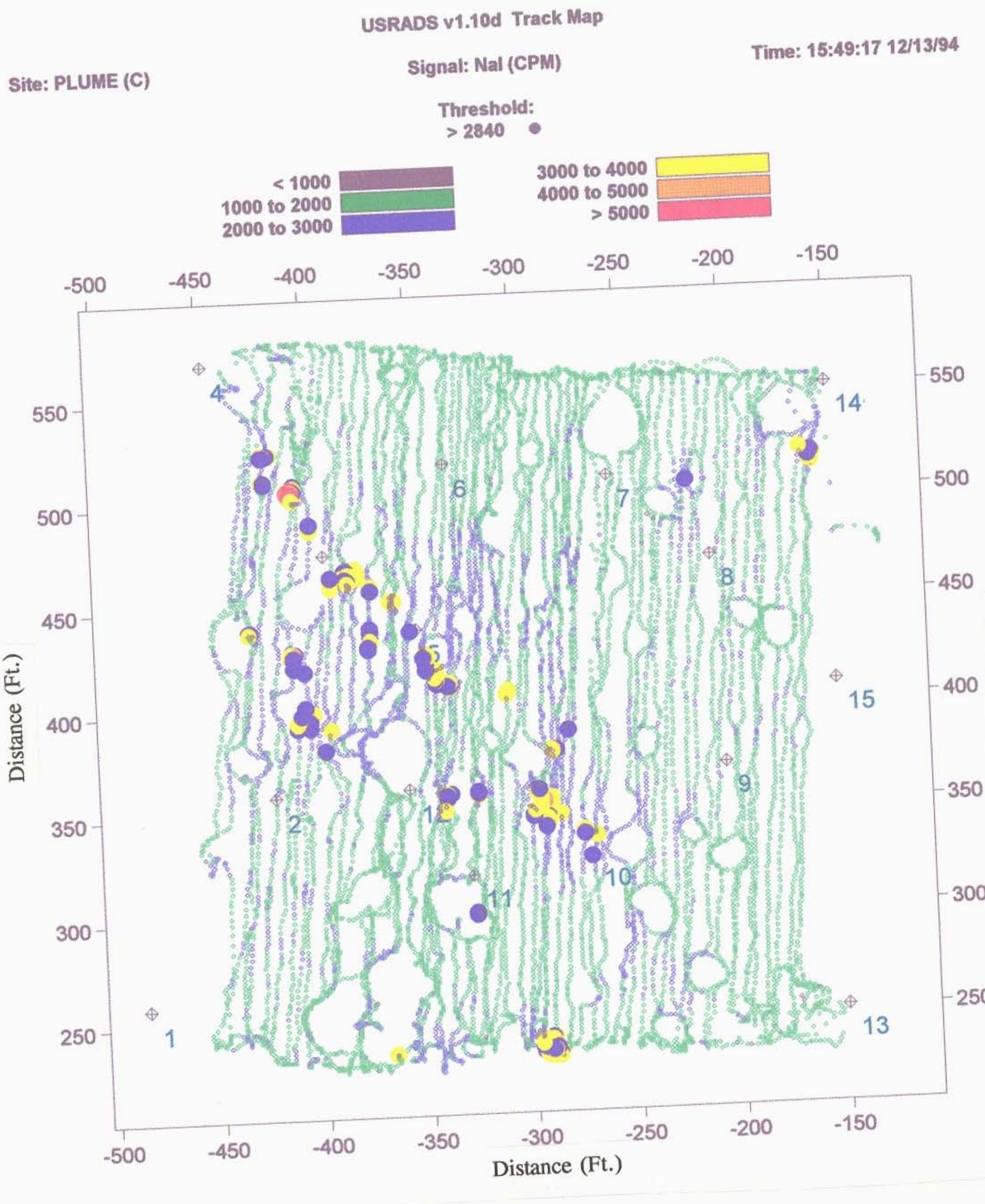

Figure B1. CTC Gamma Survey of the Plume

P.42 BLANK

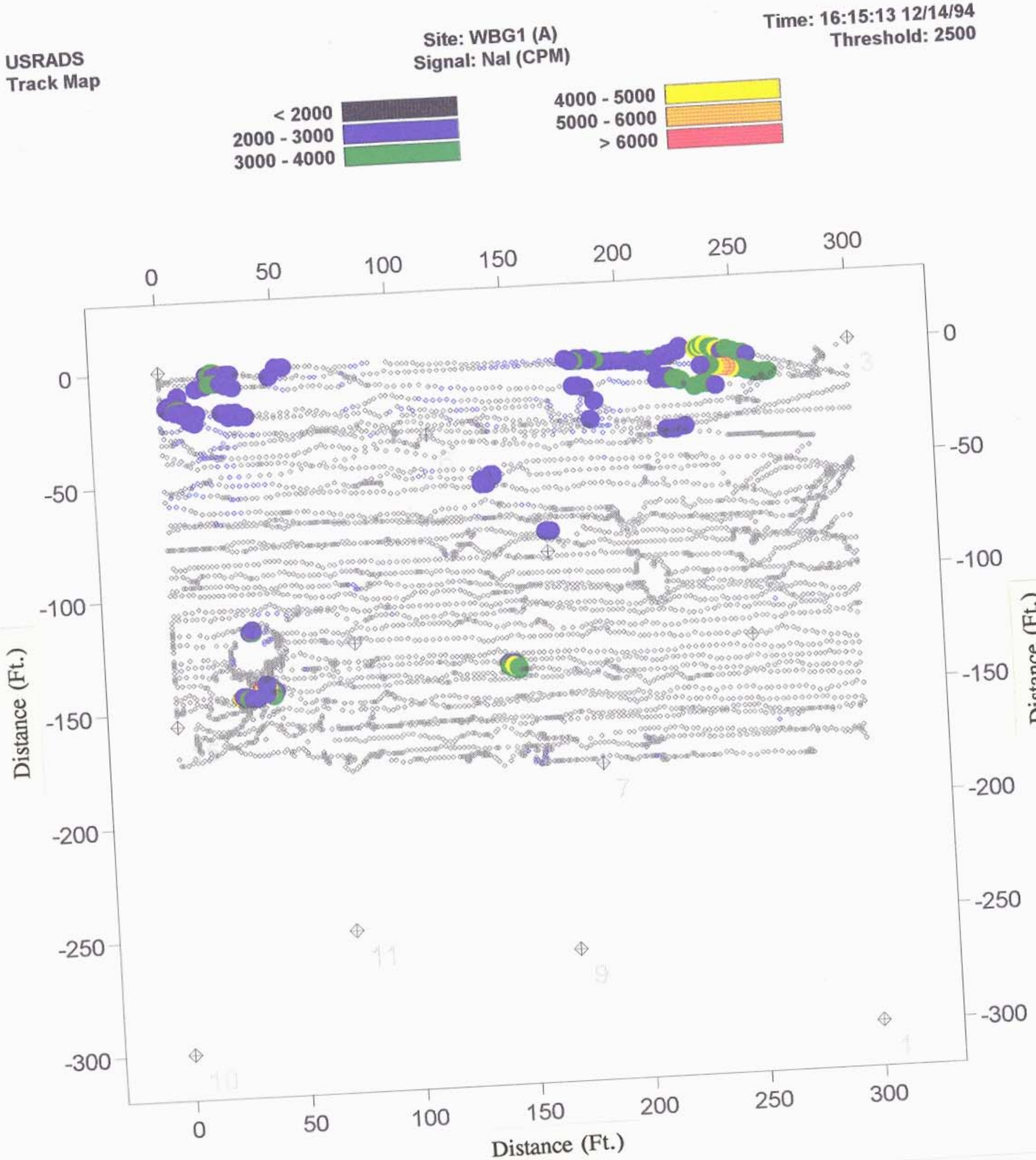

Figure B2. CTC Gamma Survey of WB61

APPENDIX C:

Radiochemical Soil Data

**** Indicates Commercial Laboratory Results**

WIPP SOIL SAMPLE RESULTS

1000 M NW WIPP EXHAUST **		
8/7/89		
NUCLIDE	**Bq/g**	(pCi/g)
PU238	**0.00037**	(0.01)
PU239+240	**0**	(0.00)
SR90	**0.015**	(0.41)
TH228	**N/A**	(N/A)
TH230	**N/A**	(N/A)
TH232	**N/A**	(N/A)
U233+234	**N/A**	(N/A)
U235	**N/A**	(N/A)
U238	**N/A**	(N/A)
CS137	**0.0074**	(0.20)

390 M EAST OF WIPP EXHAUST **		
08/01/90		
NUCLIDE	**Bq/g**	(pCi/g)
PU238	**-0.00037**	(-0.010)
PU239+240	**0.00037**	(0.010)
SR90	**-0.0074**	(-0.20)
TH228	**0.00**	(0.00)
TH230	**0.0074**	(0.20)
TH232	**0.0074**	(0.20)
U233+234	**0.0074**	(0.20)
U235	**0.00**	(0.00)
U238	**0.0074**	(0.20)
CS137	**0.0074**	(0.20)

575 M NORTH WIPP EXHAUST **		
08/01/90		
NUCLIDE	**Bq/g**	pCi/g
PU238	**-0.00037**	(-0.010)
PU239+240	**0**	(0.010)
SR90	**-0.011**	(-0.30)
TH228	**0**	(0.00)
TH230	**0.0074**	(0.20)
TH232	**0.0074**	(0.20)
U233+234	**0.0037**	(0.10)
U235	**0**	(0.00)
U238	**0.0037**	(0.10)
CS137	**0.0037**	(0.10)

530 M SOUTH WIPP EXHAUST **		
08/01/90		
NUCLIDE	**Bq/g**	(pCi/g)
PU238	**0.00**	(0.00)
PU239+240	**0.00074**	(0.20)
SR90	**0.0074**	(0.20)
TH228	**0.0074**	(0.20)
TH230	**0.0074**	(0.20)
TH232	**0.0074**	(0.20)
U233+234	**0.0074**	(0.20)
U235	**0.00**	(0.00)
U238	**0.0074**	(0.20)
CS137	**0.00**	(0.00)

WIPP SOIL SAMPLE RESULTS

775 M WEST OF WIPP EXHAUST **

08/01/90

NUCLIDE	Bq/g	(pCi/g)
PU238	**-0.00037**	(-0.01)
PU239+240	**0.00037**	(0.01)
SR90	**-0.0074**	(-0.20)
TH228	**0.011**	(0.30)
TH230	**0.0074**	(0.20)
TH232	**0.011**	(0.30)
U233+234	**0.0074**	(0.20)
U235	**0**	(0.00)
U238	**0.0074**	(0.20)
CS137	**0.0037**	(0.10)

100 M NW WIPP MET TOWER **

04/18/91

NULCIDE	Bq/g	(pCi/g)
PU238	**0.00**	(0.00)
PU239+240	**0.00**	(0.00)
SR90	**0.052**	(1.40)
TH228	**0.015**	(0.40)
TH230	**0.011**	(0.30)
TH232	**0.015**	(0.40)
U233+234	**0.0074**	(0.20)
U235	**0.00**	(0.00)
U238	**0.0074**	(0.20)
CS137	**0.00**	(0.00)

100 M NE OF WELL H2C **

4/18/91

NUCLIDE	Bq/g	(pCi/g)
PU238	**0.00**	(0.00)
PU239+240	**0.00**	(0.00)
SR90	**0.0074**	(0.20)
TH228	**0.015**	(0.40)
TH230	**0.022**	(0.60)
TH232	**0.015**	(0.40)
U233+234	**0.011**	(0.30)
U235	**0.00**	(0.00)
U238	**0.011**	(0.30)
CS137	**0.00**	(0.00)

390 M EAST OF WIPP EXHAUST **

12/01/92

NUCLIDE	Bq/g	(pCi/g)
PU238	**0.00**	(0.00)
PU239+240	**0.00**	(0.00)
SR90	**0.0037**	(0.10)
TH228	**0.0074**	(0.20)
TH230	**0.0074**	(0.20)
TH232	**0.011**	(0.30)
U233+234	**0.0074**	(0.20)
U235	**0.0000**	(0.00)
U238	**0.0074**	(0.20)
CS137	**0.0026**	(0.070)

WIPP SOIL SAMPLE RESULTS

512 M NE WIPP EXHAUST **

	12/1/92	
NUCLIDE	**Bq/g**	(pCi/g)
PU238	**0.00**	(0.00)
PU239+240	**0.00**	(0.00)
SR90	**-0.0074**	(-2.0)
TH228	**0.011**	(0.30)
TH230	**0.0037**	(0.10)
TH232	**0.0074**	(0.20)
U233+234	**0.0074**	(0.20)
U235	**0.00**	(0.00)
U238	**0.033**	(0.90)
CS137	**0.0052**	(0.14)

GNOME STUDY - SOIL SAMPLE RESULTS

SOIL SAMPLE 2

NUCLIDE	Bq/g	(pCi/g)
AM-241	**0.000407**	(0.110)
PU-238	**0.000787**	(0.0212)
PU-239	**0.00418**	(0.113)
TH-228	**0.0101**	(0.273)
TH-230	**0.0175**	(0.473)
TH-232	**0.00964**	(0.260)
U-234	**0.0174**	(0.470)
U-235	**0.000738**	(0.0199)
U-238	**0.0155**	(0.419)

SOIL SAMPLE 3A

NUCLIDE	Bq/g	(pCi/g)
AM-241	**0.133**	(3.59)
PU-238	**0.0978**	(2.64)
PU-239	**0.629**	(17.0)
TH-228	**0.0105**	(0.284)
TH-230	**0.0143**	(0.386)
TH-232	**0.00987**	(0.267)
U-234	**0.0149**	(0.402)
U-235	**0.000605**	(0.0163)
U-238	**0.0131**	(0.354)

SOIL SAMPLE 3B

NUCLIDE	Bq/g	(pCi/g)
AM-241	**0.00***	(0.00)*
PU-238	**0.00885**	(0.239)
PU-239	**0.0561**	(1.51)
TH-228	**0.0131**	(0.354)
TH-230	**0.0132**	(0.356)
TH-232	**0.00795**	(0.215)
U-234	**0.0112**	(0.302)
U-235	**0.000454**	(0.0123)
U-238	**0.0117**	(0.316)

SOIL SAMPLE 7

NUCLIDE	Bq/g	(pCi/g)
AM-241	**0.000202**	(0.00545)
PU-238	**0.000259**	(0.00699)
PU-239	**0.000621**	(0.0168)
TH-228	**0.0377**	(1.02)
TH-230	**0.0462**	(1.25)
TH-232	**0.0354**	(0.956)
U-234	**0.0257**	(0.694)
U-235	**0.00123**	(0.0332)
U-238	**0.0269**	(0.726)

APPENDIX D:

List of EEG Reports

LIST OF EEG REPORTS

EEG-1	Goad, Donna, A Compilation of Site Selection Criteria Considerations and Concerns Appearing in the Literature on the Deep Disposal of Radioactive Wastes, June 1979.
EEG-2	Review Comments on Geological Characterization Report, Waste Isolation Pilot Plant (WIPP) Site, Southeastern New Mexico SAND 78-1596, Volume I and II, December 1978.
EEG-3	Neill, Robert H., et al., (eds.) Radiological Health Review of the Draft Environmental Impact Statement (DOE/EIS-0026-D) Waste Isolation Pilot Plant, U.S. Department of Energy, August 1979.
EEG-4	Little, Marshall S., Review Comments on the Report of the Steering Committee on Waste Acceptance Criteria for the Waste Isolation Pilot Plant, February 1980.
EEG-5	Channell, James K., Calculated Radiation Doses From Deposition of Material Released in Hypothetical Transportation Accidents Involving WIPP-Related Radioactive Wastes, October 1980.
EEG-6	Geotechnical Considerations for Radiological Hazard Assessment of WIPP. A Report of a Meeting Held on January 17-18, 1980, April 1980.
EEG-7	Chaturvedi, Lokesh, WIPP Site and Vicinity Geological Field Trip. A Report of a Field Trip to the Proposed Waste Isolation Pilot Plant Project in Southeastern New Mexico, June 16 to 18, 1980, October 1980.
EEG-8	Wofsy, Carla, The Significance of Certain Rustler Aquifer Parameters for Predicting Long-Term Radiation Doses from WIPP, September 1980.
EEG-9	Spiegler, Peter, An Approach to Calculating Upper Bounds on Maximum Individual Doses From the Use of Contaminated Well Water Following a WIPP Repository Breach, September 1981.
EEG-10	Radiological Health Review of the Final Environmental Impact Statement (DOE/EIS-0026) Waste Isolation Pilot Plant, U. S. Department of Energy, January 1981.
EEG-11	Channell, James K., Calculated Radiation Doses From Radionuclides Brought to the Surface if Future Drilling Intercepts the WIPP Repository and Pressurized Brine, January 1982.

EEG-12 Little, Marshall S., Potential Release Scenario and Radiological Consequence Evaluation of Mineral Resources at WIPP, May 1982.

EEG-13 Spiegler, Peter, Analysis of the Potential Formation of a Breccia Chimney Beneath the WIPP Repository, May, 1982.

EEG-14 Not published.

EEG-15 Bard, Stephen T., Estimated Radiation Doses Resulting if an Exploratory Borehole Penetrates a Pressurized Brine Reservoir Assumed to Exist Below the WIPP Repository Horizon - A Single Hole Scenario, March 1982.

EEG-16 Radionuclide Release, Transport and Consequence Modeling for WIPP. A Report of a Workshop Held on September 16-17, 1981, February 1982.

EEG-17 Spiegler, Peter, Hydrologic Analyses of Two Brine Encounters in the Vicinity of the Waste Isolation Pilot Plant (WIPP) Site, December 1982.

EEG-18 Spiegler, Peter and Dave Updegraff, Origin of the Brines Near WIPP from the Drill Holes ERDA-6 and WIPP-12 Based on Stable Isotope Concentration of Hydrogen and Oxygen, March 1983.

EEG-19 Channell, James K., Review Comments on Environmental Analysis Cost Reduction Proposals (WIPP/DOE-136) July 1982, November 1982.

EEG-20 Baca, Thomas E., An Evaluation of the Non-Radiological Environmental Problems Relating to the WIPP, February 1983.

EEG-21 Faith, Stuart, et al., The Geochemistry of Two Pressurized Brines From the Castile Formation in the Vicinity of the Waste Isolation Pilot Plant (WIPP) Site, April 1983.

EEG-22 EEG Review Comments on the Geotechnical Reports Provided by DOE to EEG Under the Stipulated Agreement Through March 1, 1983, April 1983.

EEG-23 Neill, Robert H., et al., Evaluation of the Suitability of the WIPP Site, May 1983.

EEG-24 Neill, Robert H. and James K. Channell, Potential Problems From Shipment of High-Curie Content Contact-Handled Transuranic (CH-TRU) Waste to WIPP, August 1983.

LIST OF EEG REPORTS (CONTINUED)

EEG-25 Chaturvedi, Lokesh, Occurrence of Gases in the Salado Formation, March 1984.

EEG-26 Spiegler, Peter, Proposed Preoperational Environmental Monitoring Program for WIPP, November 1984.

EEG-27 Rehfeldt, Kenneth, Sensitivity Analysis of Solute Transport in Fractures and Determination of Anisotropy Within the Culebra Dolomite, September 1984.

EEG-28 Knowles, H. B., Radiation Shielding in the Hot Cell Facility at the Waste Isolation Pilot Plant: A Review, November 1984.

EEG-29 Little, Marshall S., Evaluation of the Safety Analysis Report for the Waste Isolation Pilot Plant Project, May 1985.

EEG-30 Dougherty, Frank, Tenera Corporation, Evaluation of the Waste Isolation Pilot Plant Classification of Systems, Structures and Components, July 1985.

EEG-31 Ramey, Dan, Chemistry of the Rustler Fluids, July 1985.

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EEG-34 Chaturvedi, Lokesh, (ed.), The Rustler Formation at the WIPP Site, February 1987.

EEG-35 Chapman, Jenny B., Stable Isotopes in Southeastern New Mexico Groundwater: Implications for Dating Recharge in the WIPP Area, October 1986.

EEG-36 Lowenstein, Tim K., Post Burial Alteration of the Permian Rustler Formation Evaporites, WIPP Site, New Mexico, April 1987.

EEG-37 Rodgers, John C., Exhaust Stack Monitoring Issues at the Waste Isolation Pilot Plant, November 1987.

EEG-38 Rodgers, John C. and Jim W. Kenney, A Critical Assessment of Continuous Air Monitoring Systems at the Waste Isolation Pilot Plant, March 1988.

EEG-39 Chapman, Jenny B., Chemical and Radiochemical Characteristics of Groundwater in the Culebra Dolomite, Southeastern New Mexico, March 1988.

EEG-40 Review of the Final Safety Analyses Report (Draft), DOE Waste Isolation Pilot Plant, December 1988, May 1989.

EEG-41 Review of the Draft Supplement Environmental Impact Statement, DOE Waste Isolation Pilot Plant, July 1989.

EEG-42 Chaturvedi, Lokesh, Evaluation of the DOE Plans for Radioactive Experiments and Operational Demonstration at WIPP, September 1989.

EEG-43 Kenney, Jim W., et al., Preoperational Radiation Surveillance of the WIPP Project by EEG 1985-1988, January 1990.

EEG-44 Greenfield, Moses A., Probabilities of a Catastrophic Waste Hoist Accident at the Waste Isolation Pilot Plant, January 1990.

EEG-45 Silva, Matthew K., Preliminary Investigation into the Explosion Potential of Volatile Organic Compounds in WIPP CH-TRU Waste, June 1990.

EEG-46 Gallegos, Anthony F. and James K. Channell, Risk Analysis of the Transport of Contact Handled Transuranic (CH-TRU) Wastes to WIPP Along Selected Highway Routes in New Mexico Using RADTRAN IV, August 1990.

EEG-47 Kenney, Jim W. and Sally C. Ballard, Preoperational Radiation Surveillance of the WIPP Project by EEG During 1989, December 1990.

EEG-48 Silva, Matthew, An Assessment of the Flammability and Explosion Potential of Transuranic Waste, June 1991.

EEG-49 Kenney, Jim, Preoperational Radiation Surveillance of the WIPP Project by EEG During 1990, November 1991.

EEG-50 Silva, Matthew K. and James K. Channell, Implications of Oil and Gas Leases at the WIPP on Compliance with EPA TRU Waste Disposal Standards, June 1992.

EEG-51 Kenney, Jim W., Preoperational Radiation Surveillance of the WIPP Project by EEG During 1991, October 1992.

EEG-52 Bartlett, William T., An Evaluation of Air Effluent and Workplace Radioactivity Monitoring at the Waste Isolation Pilot Plant, February 1993.

EEG-53 Greenfield, Moses A. and Thomas J. Sargent, A Probabilistic Analysis of a Catastrophic Transuranic Waste Hoist Accident at the WIPP, June 1993.

EEG-54 Kenney, Jim W., Preoperational Radiation Surveillance of the WIPP Project by EEG During 1992, February 1994.

EEG-55 Silva, Matthew K., Implications of the Presence of Petroleum Resources on the Integrity of the WIPP, June 1994.

EEG-56 Silva, Matthew K. and Robert H. Neill, Unresolved Issues for the Disposal of Remote-Handled Transuranic Waste in the Waste isolation Pilot Plant, September 1994.

EEG-57 Lee, William W.-L, Lokesh Chaturvedi, Matthew K. Silva, Ruth Weiner, and Robert H. Neill, An Appraisal of the 1992 Preliminary Performance Assessment for the Waste Isolation Pilot Plant, September 1994.

EEG-58 Kenney, Jim W., Paula S. Downes, Donald H. Gray, Sally C. Ballard, Radionuclide Baseline in Soil Near Project Gnome and the Waste Isolation Pilot Plant, June 1995.