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TITLE: "Radiological Survey of Buildings T019 and T013; An Area Northwest of T059, T019, T013 and T012; And A Storage Yard West of Buildings T626 and T038"

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ABSTRACT

A radiological survey was performed in four SSFL locations which were used in the 1960s to support the Systems for Nuclear Auxiliary Power (SNAP) program. These areas are located in the government-optioned portion of Area IV and include two facilities and two surrounding areas: 1) Building T019; 2) Building T013; 3) an outdoor area northwest of and adjacent to the SNAP complex (Buildings T059, T019, T013 and T012); and 4) a storage area west of Buildings T626 and T038. Building T019 was used for SNAP critical tests. Building T013 was used for SNAP assembly. Both buildings were cleared of SNAP components at the completion of the program. A radiological survey cleared these facilities for non-nuclear use. The outside areas are partially paved with asphalt concrete and are used for equipment storage and staging. The unpaved area is rugged terrain at the northern boundary of the SSFL property-line. No known contamination incidents occurred at any of these facilities to such a magnitude that would result in contaminating these inspected areas. Ground water into the T059 vacuum duct room has not released radioactivity to these inspected areas. Residual radioactivity is not suspect. This radiological survey was performed to determine if any radioactive material has been accidentally left behind to such an extent that further surveying or decontamination is warranted.

Ambient gamma exposure rate measurements were performed on a 6-m square plot plan inside the buildings and in the outside areas. This plan resulted in 502 measurements. Throughout the course of this survey, further inspection and investigation was necessary to evaluate a few outliers from expected distributions; and to assess "ambient background" as a function of topography, local materials near a measurement location, and measurement location relative to the RMDF, a facility which stores radioactive materials. Those factors affecting "ambient background" were assessed and estimated accordingly.

Results of this survey, analysis, reinspection, and interpretation show that all four locations are not contaminated with residual radioactivity. Gamma exposure rate measurements plotted against cumulative probability show Gaussian distributions with greater variability than expected. This greater variability is attributed to variations in "ambient background." All sample lots, when corrected independently for "ambient background," (this includes background variations due to natural phenomena, instrument noise, geometry changes, topography changes, and direct radiation and skyshine from RMDF) pass acceptance criteria for unrestricted use. No further investigation is necessary in these locations.

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1.0 INTRODUCTION

Four areas located in Area IV of Rockwell International's Santa Susana Field Laboratories (SSFL) were inspected and analyzed for residual radioactive material. Two of these areas were inside facilities; the other two were outside storage yards and natural terrain areas. The two facilities supported Atomics International's Systems for Nuclear Auxiliary Power (SNAP) program in the 1960s. The two outside areas surround these facilities and have been used for various functions: storing excess salvageable materials and scrap components; holding equipment; parking; and as access to other SNAP facilities. These facilities and areas supported AEC, ERDA, and DOE nuclear-related programs and include:

1. Building T019 (formerly SNAP System Nuclear Qualification Test Facility);
2. Building T013 (formerly SNAP Component Assembly and Performance Testing Facility);
3. An area northwest of T019, T013, T012, and T059; and
4. A storage yard west of Buildings T626 and T038.

Each location was inspected for radioactivity to determine whether any radioactive material has been accidentally left behind and if further investigation is necessary or remedial action is required. This radiological survey was conducted as prescribed in the "Radiological Survey Plan for SSFL," (Reference 4, Sections 5.4.16, and 5.4.18).

Located in Ventura County, California, Area IV of Rockwell International's SSFL has been used to develop and test nuclear powered reactors; fabricate nuclear reactor fuels; and disassemble irradiated nuclear fuel elements. A cluster of buildings located on what is now the northern boundary of the Energy Technology Engineering Center (ETEC) area was used in the 1960s for developing, assembling, and testing SNAP reactors for the AEC. These buildings and surrounding areas are the subject of this radiological survey. The SNAP program has ended, and the facilities that supported this program have been reassigned and modified for other non-nuclear DOE programs.

Residual radioactive material existing in these survey locations is not likely. No significant radioactivity releases from these facilities is known to have occurred. Furthermore, when these facilities were reassigned for non-nuclear use, radiological surveys were performed to ensure that the areas were clean.

Building T019 was used for testing SNAP reactors at zero power. Totally encapsulated highly enriched uranium was handled here. No releases or significant neutron activation occurred. Building T013 was a SNAP assembly facility. No nuclear or radioactive materials are known to have been handled here. A paved area northwest of these facilities was used for equipment staging. Further northwest, to the SSFL property-line is a significant drop in elevation by about 40 ft. This northwestern area borders many of the SNAP facilities. Similarly, the T626 Storage Area borders this SNAP complex and has been used for storing equipment and salvageable components. In 1978 this area was used for storing barrels of contaminated sand from the Building T059 vacuum duct room. Sand removal and packaging was a controlled project with no radioactive material incidents. No known incidents occurred in these facilities or equipment yards which would have spread contamination to surrounding areas. Although some minor radiological contamination incidents might have occurred, it was common practice to decontaminate and return an affected location to its natural condition. No residual contamination is suspect. The purpose of this survey was to detect any radioactive material accidentally left behind from these operations.

As part of the DOE SSFL Site Survey (Reference 4, sections 5.4.16 and 5.4.18), a radiation survey was performed in these areas to determine if any residual contamination exists. Ambient gamma exposure rates were measured on a 6-m by 6-m grid. These radiation measurements are sensitive to radiations emitted from the radioactive materials handled or produced at the SNAP facilities: enriched uranium, mixed fission products, and activation products. If radioactive contamination was indicated during performance of the gamma measurements, samples were to be collected and analyzed for radioactivity, and beta surface activity measurements were to be performed. Sample collection was not required for this particular survey. However, beta surface activity measurements were made in a couple of locations "for indication."

All ambient gamma exposure rate data were input into a Personal Computer (PC) graphics program which plots the radiation measurement value against its cumulative probability. The software also calculates a test statistic using inspection by variables techniques. This test statistic is that value greater than the mean value of the distribution, which corresponds to a consumer's risk of acceptance of 10% probability with a Lot Tolerance Percent Defective (LTPD) of 0.10. This method assumes the data follow a Gaussian probability density function. Inspection by variables techniques allows a thorough, understandable, and conclusive study for assessing the contamination level in an area.

Radiation measurements are compared against DOE residual radioactivity limits specified in "Guidelines for Residual Radioactivity at FUSRAP and Remote SFMP Sites," (Reference 1). This guide generally agrees with previously published guides and standards, including ANSI Standard N13.12 (Reference 7), Regulatory Guide 1.86, and USNRC License SNM-21 (Reference 2). Limits for acceptable ambient gamma exposure rates differ between the DOE and NRC. DOE specifies 20 μR/h above background while NRC specifies 5 μR/h above background as acceptable gamma exposure rate limits. "Natural background" at SSFL is very difficult to determine because of a large observed variability in the measurements. Because of this large variation, total-gross gamma measurements made in a survey area are plotted and compared against three independent "natural" background distributions. Then the average "background" exposure rate of the three "natural background" distributions is subtracted from each data set to compare the results against the 5 μR/h above background criteria. Finally, because the ambient exposure rate in some of these inspected areas is influenced by radioactive material stored at the nearby RMDF, an estimate of that contribution is necessary and was performed.

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2.0 IDENTIFICATION OF FACILITY PREMISES

2.1 Location

The areas covered in this report are identified in the "Radiological Survey Plan for SSFL," (Reference 4) as follows:

1) Building T019, (Section 5.4.16);
2) Building T013 (Section 5.4.16);
3) Area Northwest of T059, T019, T013, and T012, (Section 5.4.16); and
4) Storage Area West of Buildings T626 and T038, (Section 5.4.18).

Throughout this report the area northwest of T059, T019, T013, and T012 is referred to as the NW Area; the storage area west of Buildings T626 and T038 is referred to as the T626 Storage Area.

These buildings and areas are adjacent to each other, and are located within Rockwell International's Santa Susana Field Laboratory (SSFL) in the Simi Hills of southeastern Ventura County, California. The site is adjacent to the Los Angeles County line, and is approximately 29 miles northwest of downtown Los Angeles. The SSFL location relative to the Los Angeles area and surrounding vicinity is shown in Figure 2.1. Figure 2.2 is an enlarged map of neighboring SSFL communities.

The two buildings and adjacent areas covered in this report are located in the western portion of SSFL, which is referred to as Area IV. Figure 2.3 is a plot plan of Area IV showing the subject area locations. The buildings are government owned, and the grounds are located within the 90.26-acre Government-Optioned Area. Facilities in this area are known as the Energy Technology Engineering Center (ETEC), which is government-owned, and operated by Rocketdyne.

Figure 2.1 Map of Los Angeles Area

Figure 2.2 Map of Neighboring SSFL Communities

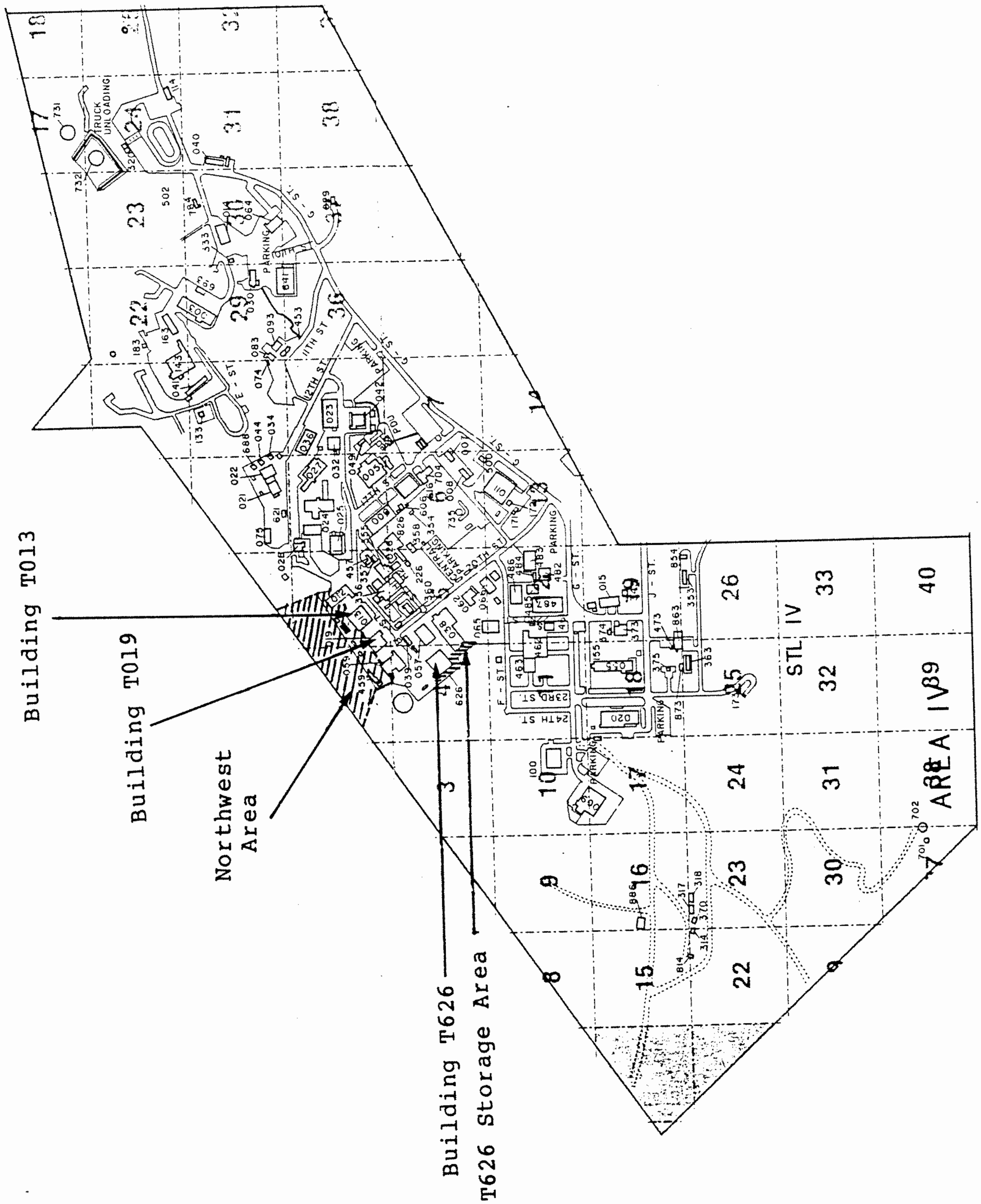


Figure 2.3 SSFL Layout, Showing Locations of Buildings T019 and T013, an Area to the Northwest d the T626 Storage Area

2.2 Facility Characteristics and Area Topography

These sites are situated near the northwest property-line of ETEC. The minimum distance from Buildings T059, T019, T013, and T012 to the property-line is about 250 ft. The property-line is situated significantly downgrade from these buildings. The storage area and facilities are surrounded by asphalt concrete pavement. Each facility is built on a concrete slab. Behind (north of) T059, T019, T013 and T012 is asphalt concrete for about 90 ft. This paved area is used for equipment staging and gas tanks. North of this paved area to the property-line is very rugged terrain; 50 ft from the paved fence-line of these buildings, the elevation drops 40 ft with large boulders and sandstone outcroppings. This area is covered with fairly dense brush and natural vegetation. This NW Area was the most rugged terrain surveyed throughout the entire site survey.

The general slope of Area IV, including these facilities and paved areas, is in a southerly direction. Water runoff is directed to the retention reservoirs which are part of the SSFL industrial effluent control system. Liquid effluent discharge from the final retention pond into the Bell Canyon drainage occurs only after controlled effluent hold-up and sampling. The NW Area, however, drains northerly to Simi Valley. Figure 2.4 is a topography map of these areas.

Building T019 was built in 1962 for flight systems nuclear qualification testing. The building was constructed of steel framing, with steel siding and a built-up roof. The building has a high bay, 32-ft high with a 10-ton bridge crane, and a low-bay office-control center, 10-ft high. A vault with cinder block walls is located in the southeast corner. This vault was originally built for nuclear fuel element storage. The high bay contains a below-grade test cell with hydraulic lift and an 8-ft vacuum test chamber. The total area of the building is 6,402 ft^2. Figure 2.5 shows a layout plan of Building T019 as it was used during SNAP.

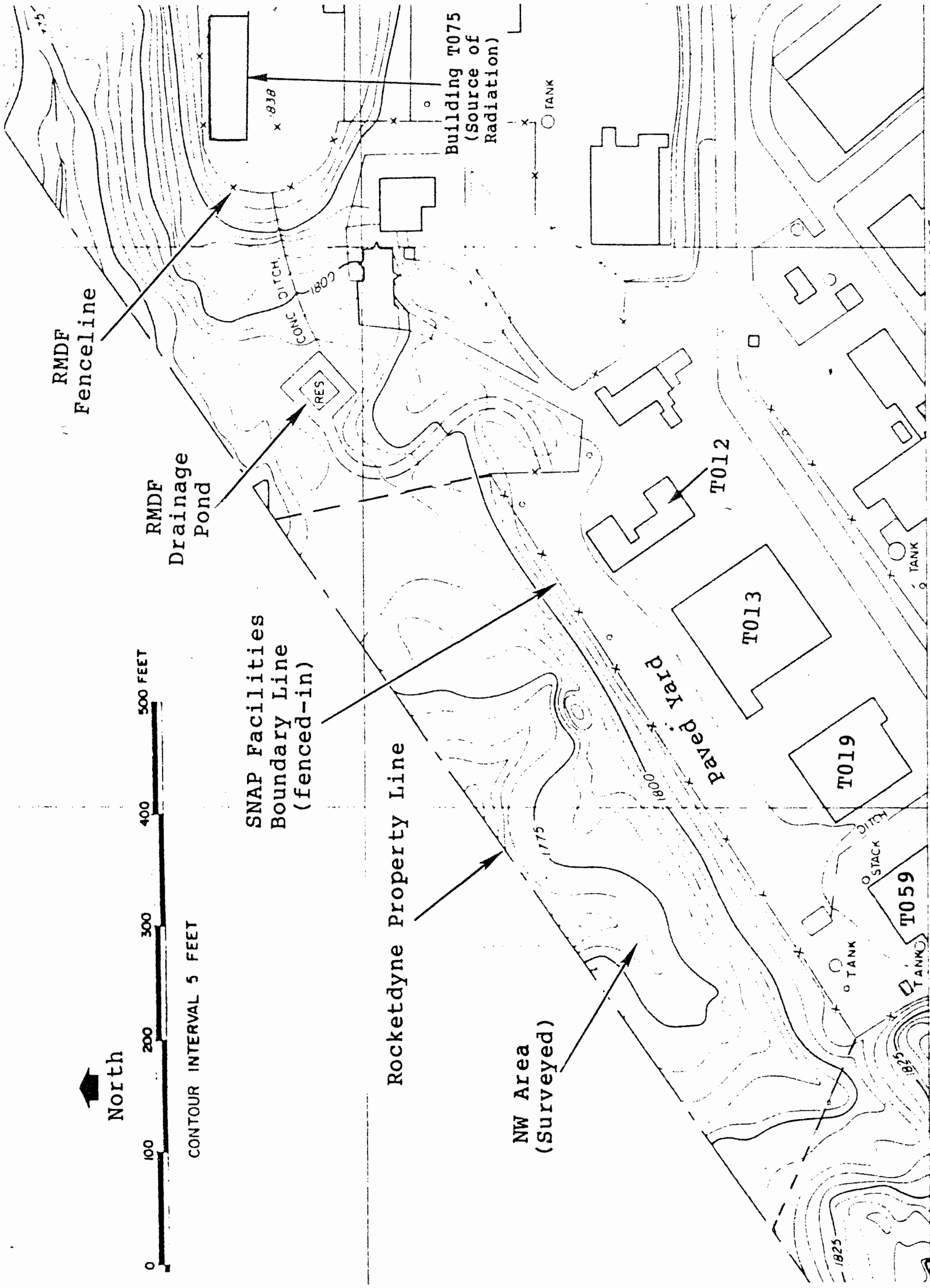
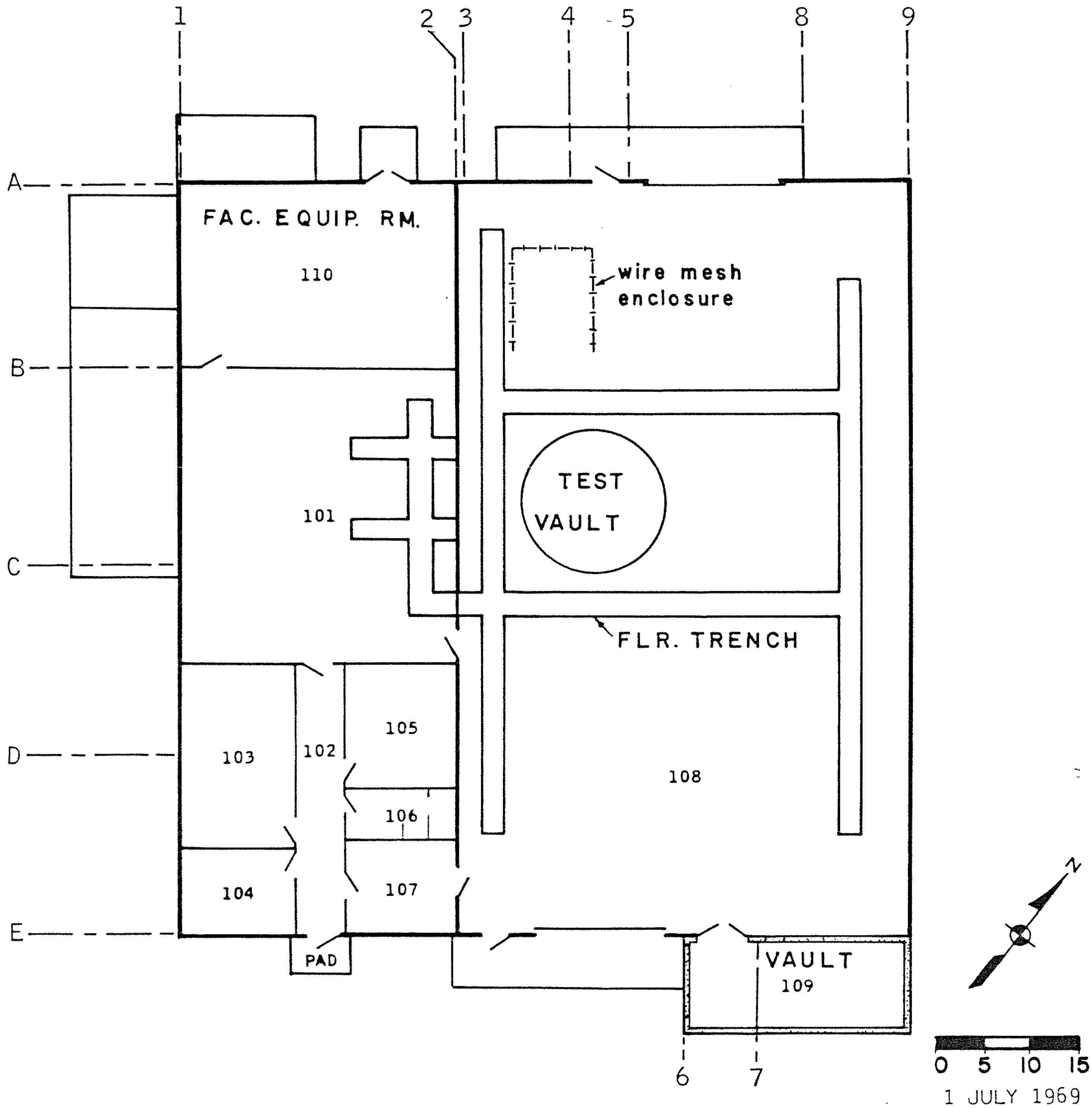


Figure 2.4 Topography Map of Surveyed Areas

Figure 2.5 SNAP System Nuclear Qualification Test Facility, Building T019



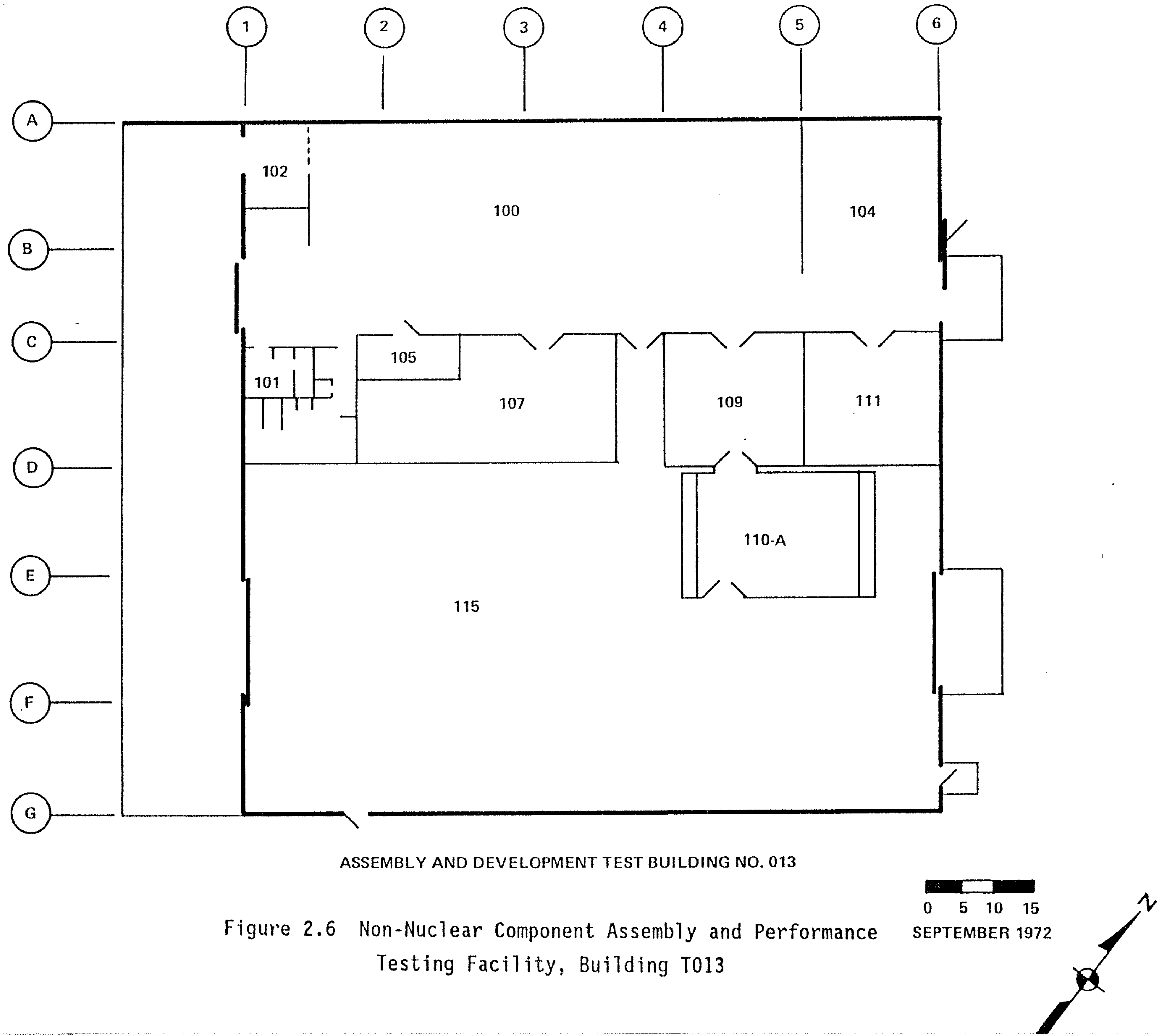
Building T013 was constructed in 1962 as a non-nuclear component assembly and performance test building. The building was made with a steel frame, steel siding and a built-up roof. There is a high bay 33-ft high with a 5-ton bridge crane, and a low bay 15-ft high. The building has a total area of 8,370 ft^2. A layout of the facility is shown in Figure 2.6.

Building T626 was constructed in 1963 as a warehouse and storage area. This building is made with a steel frame and has steel siding and a steel roof. The high bay area of the building is 25-ft high with a 2-ton bridge crane, and the low bay area is 15-ft high. A layout of the building is shown in Figure 2.7. Only the outside storage area is considered for this survey. The entire area is paved with asphalt concrete.

2.3 Facility Utilization and Present Radiological Condition

Buildings T059, T019, T013, T012, and T626 were built to support Atomic International's Systems for Nuclear Auxiliary Power (SNAP) program. The SNAP program began in about 1955 and facilities were constructed shortly thereafter. Several designs of SNAP were developed and tested in this location of SSFL, Area IV. SNAP-2 was a reactor-heated electrical power plant to produce 3 kW. SNAP-10A was a convection cooled SNAP-2 reactor, with a thermoelectric generator to produce 500 watts. Fuel for these reactors was highly enriched uranium as a zirconium hydride alloy, clad in Hastelloy.

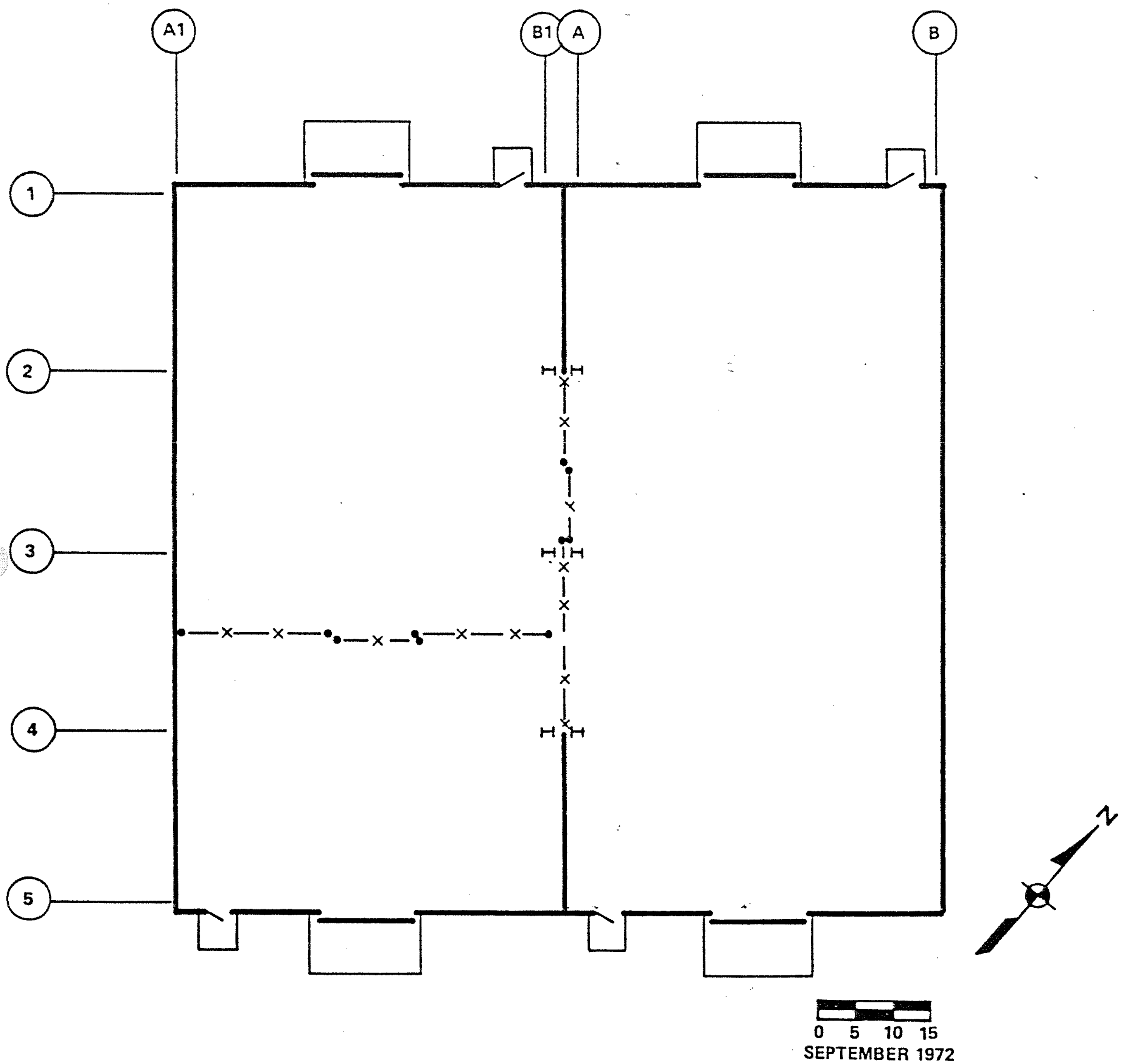
These facilities were designated either nuclear-related or non-nuclear-related based on whether radioactive or nuclear materials were handled there or not. Buildings T059, T019, and T012 were nuclear-related. Buildings T013 and T626 were non-nuclear-related. This radiological survey only covered Buildings T019 and T013. Outside areas surveyed in the vicinity of these facilities were considered non-nuclear-related. Figure 2.8 is a mid-1960s photograph showing the SNAP Building Complex. The facilities that supported SNAP have been reassigned and modified for other non-nuclear DOE programs.



ASSEMBLY AND DEVELOPMENT TEST BUILDING NO. 013

Figure 2.6 Non-Nuclear Component Assembly and Performance Testing Facility, Building T013

Figure 2.7 Warehouse and Staging, Building T626



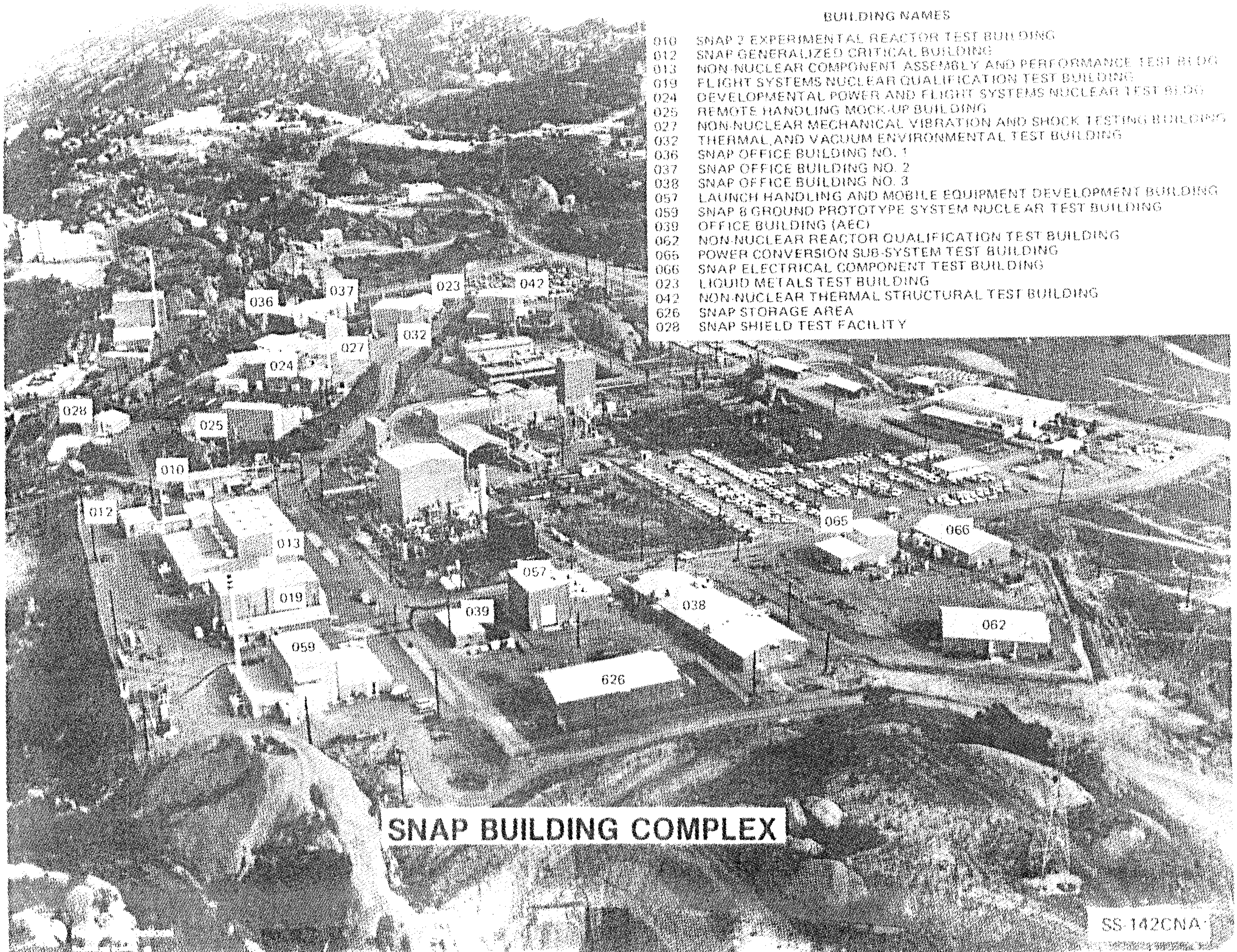


Figure 2.8 Photograph of SNAP Building Complex

2.3.1 Building T019

Building T019 was designated the SNAP System Nuclear Qualification Test Facility. Flight system tests FS-1, FS-4, and FS-5 were cold and hot critical tested at zero power in this facility. Highly enriched uranium was used for the tests. All nuclear or radioactive material handled here was fully encapsulated. No major contamination incidents are known to have occurred. No fission product releases occurred. Facility activation by neutrons was negligible. Upon termination of the SNAP program in 1970, SNAP components were removed and dispositioned. A radiation survey was then performed to ensure that no residual radioactivity existed. T019 was redesignated ETEC Construction Staging and Computer Facility and has been used for this purpose ever since. Computer digital data acquisition systems for ETEC test facilities are currently operated in the low-bay area. Residual radioactivity is not suspect in this facility.

2.3.2 Building T013

Building T013 was designated the Non-Nuclear Component Assembly and Performance Testing Facility in 1961. Assembly and checkout of the following SNAP units was accomplished in the 1960s; PSM-1, PSM-3, PSM-1A, FSEM-2, PSM-1B, FSM-1, FSEM-2A, FS-3, FSM-4, FS-4, and FS-5. No radioactive or nuclear material is known to have been handled here. In 1970, T013 was redesignated as the ETEC Thermal Transient Facility. Half the high bay has been used for thermal testing since that time; the other half is used for seismic test equipment. Residual radioactivity is not suspect in this facility.

2.3.3 NW Area

The northwest area between the SNAP facilities boundary-line (fenced-in) and the SSFL property-line (see Figure 2.4) is too rugged for any function. This area is northwest of buildings T059, T019, T013, and T012. T059 and T012 have known contamination. The radiological impact of these SNAP operations on the surrounding area is thought to be negligible. All fuel elements were totally clad with Hastelloy; no problems occurred. The possibility of a radioactive material spill occurring in the northern yards and then running down the northern hill is very unlikely. All analyses of ground water surrounding the T059 vacuum duct room has shown no unnatural radioactivity. Cleanup of this room is in process. Residual radioactivity is not suspect in this northwest area.

2.3.4 T626 Storage Area

Building T626 was originally used as a warehousing and staging area for SNAP components, subsystems, and systems. No nuclear fuel or radioactive material was ever stored inside. Following completion of the SNAP program in 1970, the building has been used for warehousing of the Materials Inventory used in support of ETEC test facility operations. A fenced-in yard west of T626 and T038 (see Figure 2.3) has been used for storing various equipment and salvageable items. Palletized barrels of Building T059 activated sand from the vacuum duct room were stored there in 1978. These barrels contained activation products of europium and the isotope Co-60. This storage was a controlled process; surveys were performed and the barrels were shipped off-site without incident. Residual radioactivity is not suspect in this area.

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3.0 SURVEY SCOPE

The following areas were radiologically inspected by measuring ambient gamma exposure rates 1 meter above the floor/ground in locations specified by the "Radiological Survey Plan for SSFL," (Reference 4):

1. Building T019 (Reference 4, Section 5.4.16)

   * Walk-through survey for gamma exposure rate (surface beta activity upon indication).

2. Building T013 (Reference 4, Section 5.4.16)

   * Walk-through survey for gamma exposure rate (surface beta activity upon indication).

3. Area Northwest of Buildings T059, T019, T013, and T012 to SSFL Property-Line (Reference 4, Section 5.4.16)

   * Survey gamma exposure rate.

4. T626 Storage Area (Reference 4, Section 5.4.18)

   * Survey gamma exposure rate.

These areas are shown in Figures 2.4., 2.5, and 2.8.

Gamma exposure rate measurements were made in 502 locations; 67 (Building T019); 75 (Building T013); 247 (NW Area); and 113 (T626 Storage Area). Soil samples were not collected and analyzed because no indication of contamination occurred. Beta surface activity measurements were performed in one location of Building T019 where a greater than expected exposure rate measurement was acquired. Beta activity measurements are reported as No Detectable Activity (NDA), or less than 50 counts per minute (cpm), 60 cpm, ...etc. Ambient gamma exposure rates are reported in microroentgens per hour (μR/h).

3.1 Unrestricted-use Acceptable Contamination Limits

A sampling inspection plan using variables, discussed in Section 4.2, was used to compare radiological contamination quantities against unrestricted-use acceptable contamination limits prescribed in DOE guidelines (Reference 1), Regulatory Guide 1.86, NRC license SNM-21, and other references. The limits shown in Table 3.1 below have been adopted by Rocketdyne and are based on enriched uranium used for SNAP. Measurements of average surface alpha/beta contamination are averaged over an area of no more than 1 m^2. The maximum allowable alpha/beta contamination level applies for a single area of not more than 100 cm^2 in that 1 m^2. Allowable removable alpha/beta contamination is based on a surface wipe with area equal to 100 cm^2.

Table 3.1 Maximum Acceptable Contamination Limits

Criteria	Alpha (dpm/100 cm^2)	Beta (dpm/100 cm^2)
Total Surface, averaged over 1 m^2	5000	5000
Maximum Surface, in 1 m^2	15000	15000
Removable Surface, over 100 cm^2	1000	1000
Ambient Gamma Exposure Rate*	5 μR/h above background	
Soil Activity Concentration**	46 pCi/g	100 pCi/g
Water Activity Concentration***	1×10^{-4} μCi/ml	1×10^{-5} μCi/ml

* Although DOE Guide (Reference 1) recommends a value of 20 μR/h above background for ambient gamma exposure rate, NRC has required

5 μR/h. For conservatism, we use 5 μR/h above background to compare survey results.

** Alpha activity concentration limit for enriched uranium is 30 pCi/g (Reference 24) plus that contribution from naturally occurring radioactivity, (about 16 pCi/g from Reference 17, p. 93). The total beta activity concentration limit is 100 pCi/g, including background which is about 24 pCi/g.

*** The most restrictive alpha/beta water radioactivity concentrations for a restricted area taken from DOE Order 5480.1 Chapter XI, Table 1, Column 2. Alpha corresponds to Pu-239, beta to Sr-90.

Three specific action levels were established for the survey. These are proactive action levels initiated when the surveyor detects radiation according to the following criteria:

1. Characterization Level - that level of radioactivity which is below 50% of the maximum acceptable limit. This level is typical of natural background levels, or slightly above, and requires no further action.

2. Reinspection Level - that level of radioactivity which is above 50% of the maximum acceptable limit. A general resurvey of the area and a few additional samples are required in this case.

3. Investigation Level - that level of radioactivity which exceeds 90% of the maximum acceptable limit. Specific investigation of the occurrence is required in this case.

3.2 Sample Lots

For purposes of this radiological survey, each of the four test-areas was initially treated as a single sample lot for characterization and interpretation. It was determined later by statistical analysis that the NW Area should be divided into two sample lots because of significant changes in topography: paved asphalt concrete and rugged terrain. Appendix D shows the sampling plan used by the surveyor for each test-area. The T019 vault (25 ft x 15 ft) was treated as a separate sample lot because of increased exposure rates from the cinder block walls. The T626 Storage Area was divided into three zones for convenience.

6-m square grids were superimposed over the terrain and within each subject facility. One ambient gamma exposure rate measurement was made in each 36-m^2 cell. Location (1,1) was the northwestern-most grid in each area. Each measurement location was marked on a map with its corresponding two figure Cartesian coordinate indicating the location from a local benchmark. The sampling inspection plan used was based upon a uniform 6-meter square grid superimposed on a uniform inspection area. We will see later in the results section that in severe rugged terrain, the inspection area is not uniform. Radiological conditions and physical surroundings fell into three categories: 1) Inside buildings (T019 and T013); 2) Paved asphalt concrete (Part of NW Area and T626 Storage Area); or 3) Rugged natural terrain (remaining NW Area).

3.3 Ambient Gamma Exposure Rate Measurements

In each 36-m^2 cell, a gamma exposure rate measurement was made 1 m from the surface. The particular location in each cell was chosen randomly, and identified on a map. A tripod was used to support a 1 in. x 1 in. NaI crystal coupled to a photomultiplier tube and fed to a Ludlum 2220-ESG scaler, at 1 m from the ground. In each cell, a 1-min. count was collected and converted to $\mu R/h$. The measurement location and exposure rate were recorded in tabular form. 502 1-min. measurements were acquired over the total area.

3.4 Surface Soil Samples and Surface Beta Radioactivity Measurements

Soil sampling and measurements of beta surface activity were required by the Site Survey Plan (Reference 4) for better characterization of radiological condition only if gamma exposure rate measurements indicated possible radioactivity. Soil samples were not collected and analyzed. Beta surface activity was measured in one location using a Ludlum 44-9 pancake Geiger-Mueller probe (active area = 20 cm^2) coupled to a Ludlum model 12 count rate meter. This detector was calibrated using a Tc-99 source.

3.5 Goals and Limitations of Survey Scope

The scope and detail of this radiological survey is based on the likelihood for residual radioactivity occurring in these areas from the nuclear operations which were performed. Buildings T019 and T013 are not suspect of containing residual radioactivity for several reasons:

1. Nuclear materials handled at T019 were fully encapsulated in Hastelloy. No releases ever occurred;

2. Activation of building materials at T019 was negligible; the test reactors were operated for short periods and low power;

3. When T019 was reassigned, a thorough radiation survey was performed to ensure no residual radioactivity remained undetected; and

4. T013 was never known to handle nuclear or radioactive material.

No known spills or releases occurred in the northern equipment yards which would have contaminated the NW Area hillside. No problems occurred at the T626 Storage Area; drums of activated sand from T059 never leaked. The scope of this survey was established in Reference 4 based on an unlikely occurrence of residual radioactivity being accidentally left behind from previous operations. The goal of this survey is to determine if contamination exists to such an extent that further surveying or remedial action is warranted.

Ambient gamma exposure rate measurements are sensitive enough to detect contaminants left behind. Most probable contaminants are mixed-fission products and activation products. The probability of existing residual enriched uranium is highly unlikely. Furthermore, no uranium powders or grinding fines were handled here. It is highly unlikely that any subsurface debris is currently in natural terrain areas; they were never used as dumping grounds or landfills. Subsurface transport of contaminants is also considered negligible. If any contaminants do exist on-site, they are most likely still on the surface.

Because of the large area surveyed, exposure rates were measured every 36 m^2. This sampling plan is sufficient for two reasons:

1) gamma measurements made on a 6-m square would detect Cs-137 at 100 pCi/g (the beta activity limit) if the surface layer was thicker than 1 cm. A 1 mCi Cs-137 source would be detectable at the greatest separation distance of 6 meters. These sensitivities meet the requirements of this survey; and

2) By applying Lot Tolerance Percent Defective techniques, we can determine with a statistical confidence of 0.90, that there is a probability of 90% that radioactive contamination does not exceed some predetermined acceptance limit. This determination varies inversely to the number of samples taken. This technique, along with the graphical representations of

cumulative distribution functions will identify trends, anomalies, outliers, and perturbations in the radiation levels.

We are able to conclude whether:

1. Any surface deposition, migration, or dispersion of radioactive materials has occurred; and

2. Any relatively intense gamma-emitting debris is buried (see Section 5.4.4).

We cannot conclude whether:

1. Any slight subsurface migration has occurred; or if

2. Any buried debris with low intensity radiation is present.

The likelihood for occurrence of the above two conditions is small. First, migration periods of contaminants below the surface are typically very long. It is much easier for surface water flowing downslope to carry with it any contaminants. The settling out of these contaminants into the subsurface also takes a long time. Second, no known burial or dumping activities took place in any of these areas.

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4.0 STATISTICS

4.1 Counting Statistics

The emission of atomic and nuclear radiation obeys the rules of quantum theory. As a result of this, only the probability that an emission will occur is determined. The absolute number of particles emitted by a radioactive source in a unit of time, is not constant in time; it has a statistical variability because of the probabilistic nature of the phenomenon under study. The number of particles emitted per unit time is different for successive units of time. Therefore, only the average number of particles emitted per unit time and per unit area or mass can be determined. The number of particles, x, emitted by a radiation source in time, T, obeys the Poisson distribution:

$$P_X = \frac{m^x e^{-m}}{x!} \qquad \text{(Eq. 4-1)}$$

where m is the average number of emissions in that time. x is what we measure each time an area or sample is surveyed. The standard deviation is the square root of the average squared deviation of x from its mean, m. For the Poisson distribution, the standard deviation is given by:

$$s = \sqrt{x}\ , \qquad \text{(Eq. 4-2)}$$

the square root of the counts observed, $(x \doteq \bar{x} = m)$. Since background radiation is always inherent in a given sample measurement, propagation of errors tells us that the total standard deviation is:

$$s = \frac{\sqrt{C + B}}{T} \qquad \text{(Eq. 4-3)}$$

where C = the number of counts recorded in time, T, of the sample

B = the number of counts recorded in time, T, of the background radiation environment

Equal values of the time, T, must be used for the sample and background counts for equation 4-3 to apply. This Poisson distribution and standard deviation applies for single radiation measurements, of the discrete random variable, x, and is applicable only when the observation times are short compared with the half-life. This is the case for the site survey.

Because of the probabilistic nature of particles emitted by radioactive elements, repeated measurements of the average number of emissions per unit time shows a distribution approximated by the Gaussian (or normal) probability density function (pdf); this is known as the central limit theorem. This theorem holds for any random sample with finite standard deviation. If measurements are made at many similar locations, these measurements will show a greater variability, but the distribution will remain adequately represented by a Gaussian function. This Gaussian approximation is good when the number of samples collected is at least 30. Thus the number of occurrences of particular mean radiological contamination values, g(x), shows a Gaussian pdf relative to the contamination value, and the data can be plotted accordingly. Subsequently, based on the results of the data analysis, a conclusion can be made regarding the amount of radioactive material in an area, and any anomalous values can be identified.

The Gaussian probability density function, g(x), is given by:

$$g(x)dx = \frac{1}{(\sqrt{2\pi})\sigma} \exp\left(\frac{-(x-m)^2}{2\ \sigma^2}\right) dx \qquad \text{(Eq. 4-4)}$$

where g(x)dx = probability that the value of x, lies between x and x+dx

m = average, or mean of the population distribution

σ = standard deviation of the population distribution.

A graph of x vs. g(x) gives the following bell-shaped curve:

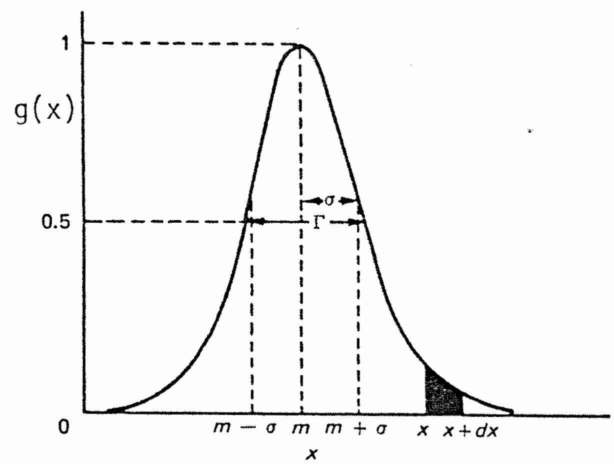

Figure 4.1 The Gaussian Probability Density Function

The cumulative distribution function (cdf), G(x), is equal to the integral of the pdf, for a continuous random variable, hence:

$$G(x) = \int_{\infty}^{X} g(x)dx \qquad \text{(Eq. 4-5)}$$

$$= P(x < X)$$

This function is commonly referred to as the error function, (erf). The graph of the Gaussian cdf is:

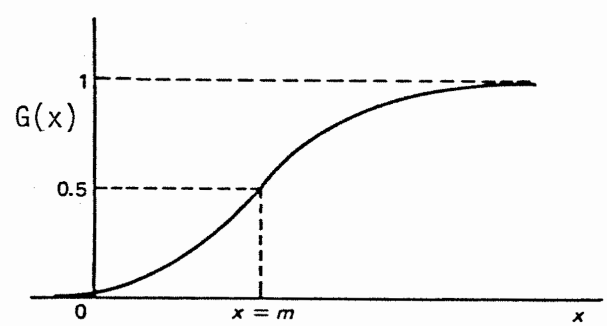

Figure 4.2 The Gaussian Cumulative Distribution Function

By plotting multiple measurements we make in the field; i.e. the average contamination values approximated by the Poisson distribution, as a cdf of the Gaussian distribution, we can identify whether the entire area is unacceptably contaminated, part of the area is contaminated more than the rest, or further radiological measurements are necessary. Furthermore, by making use of the Gaussian approximation, we can easily calculate the mean contamination value with its associated standard deviation, and apply inspection by variables techniques to either accept the area as clean or reject the area as contaminated.

This statistical summary presents fundamental principles used to reduce and analyze radiological measurement data from the site survey.

4.2 Sampling Inspection

4.2.1 By Variables

Acceptance inspection by variables is a method of judging whether a lot of items is of acceptable quality by examining a sample from the lot, or population. In the case of determining the extent of contamination in an area, it would be unacceptably time consuming and not cost effective to measure 100% of the population. However, by applying sampling inspection by variables methods, the accuracy of the conclusion made about the level of contamination is not sacrificed because of a decrease in number of sampling locations. We estimate the level of contamination in an area by making at least 30 measurements. This allows us to approximate a Gaussian distribution through the Central Limit Theorem. The entire area must have similar radiological characteristics and physical attributes. In acceptance inspection by variables, the result is recorded numerically and is not treated as a Boolean statistic, so fewer areas need to be inspected for a given degree of accuracy in judging a lot's acceptability.

4.2.2 By Attributes

By contrast, in acceptance inspection by attributes, the radiation measurement in a given area is recorded and classified as either being defective or nondefective, according to the acceptance criteria. A defect means an instance of a failure to meet a requirement imposed on a unit with respect to a single quality characteristic. Second, a decision is made from the number of defective areas in the sample whether the percentage of defective areas in the lot is small enough for the lot to be considered acceptable. More areas need to be inspected to obtain the same level of accuracy using this method. Consequently, we use inspection by variables.

4.3 Sampling Inspection by Variables

4.3.1 Calculated Statistics of the Gaussian Distribution

The test statistic for each sample area, $\bar{x} + ks$, is compared to the acceptance limit U, where:

$\bar{x}$ = average (arithmetic mean of measured values) of sample
s = observed sample distribution standard deviation
k = tolerance factor calculated from the number of samples to achieve the desired sensitivity for the test
U = acceptance limit.

The sample mean is given by:

$$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n} \qquad \text{(Eq. 4-6)}$$

where: x_i = individual measurement values
n = number of measurement values

The standard deviation, s is given by:

$$s = \sqrt{\frac{\sum_{i=1}^{n} (x_i - \bar{x})^2}{n-1}} \qquad \text{(Eq. 4-7)}$$

The sample mean, standard deviation, and acceptance limit are easily calculable quantities; the value of k, the tolerance factor, bears further discussion. Of the various criteria for selecting plans for acceptance sampling by variables, the most appropriate is the method of Lot Tolerance Percent Defective (LTPD), also referred to as the Rejectable Quality Level (RQL). The LTPD is some chosen limiting value of percent defective in a lot. Associated with the LTPD is a parameter referred to as consumer's risk (β), the risk or probability of accepting a lot with a percentage of defective items equal to the LTPD. It has been standard practice to assign a value of 0.10 for consumer's risk (β). Conventionally, the value assigned to the LTPD has been 10%. These a priori determinations are consistent with the literature and regulatory position, and are the same values used by the State of California (Reference 2). Thus, based on sampling inspection, we are willing to accept the hypothesis that the probability of accepting a lot as not being contaminated which is in fact 10 percent defective (i.e. above the test limit, U) is 0.10. The value of k, which is a function of the a priori determinations made for β and LTPD is given by equation 4-8.

Figure 4.3 demonstrates this principle. The operating characteristics curve of a Gaussian sample distribution shows the principles of consumer's and producer's risk, LTPD (or RQL), and acceptable quality level, (AQL). The criteria for acceptance of a lot are presented in section 4.3.3.

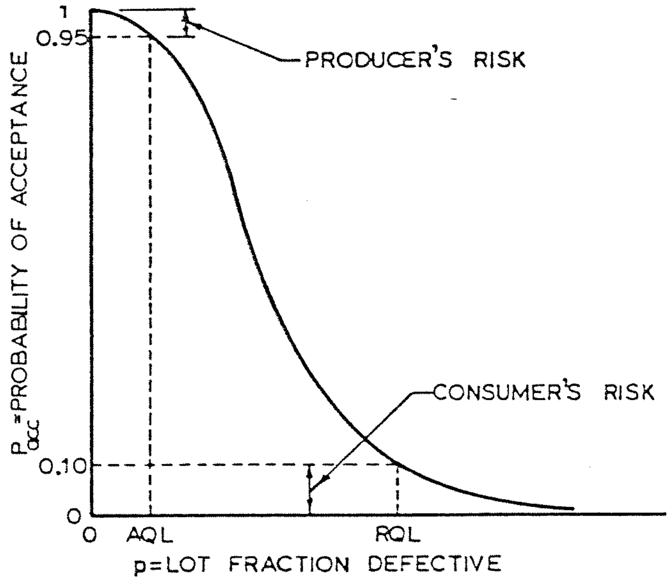

Figure 4.3 Operating Characteristics Curve

The value of k, and thus the value of $\overline{x}$ + ks, on which ultimately a decision is made whether the area is acceptably clean, is based on the conditions chosen for the test. k is calculated in accordance with the following equations, (Reference 8):

$$k = \frac{K_2 + \sqrt{K_2^2 - ab}}{a} \; ; \; a = 1 - \frac{K_\beta^2}{2(n-1)} \; ; \; b = K_2^2 - \frac{K_\beta^2}{n} \qquad \text{(Eq. 4-8)}$$

where:

k = tolerance factor

K_2 = the normal deviate exceeded with probability of β, 0.10 (from tables, K_2 = 1.282)

K_β = The normal deviate exceeded with probability equal to the LTPD. 0.10 (from tables, K_β = 1.282)

n = number of samples

As mentioned previously, the State of California has stated that the consumer's risk of acceptance (β) at 10% defective (LTPD) must be 0.1. For these choices of β and LTPD, $K_\beta = K_2 = 1.282$.

The coefficients $K\beta$ and K_2 are equal because of the choice for the values of both β and LTPD as 0.10. Refer to statistics handbooks listed in the reference section for additional description of this sampling principle. The values chosen for the sampling coefficients are consistent with industrial sampling practice and regulatory guidance.

4.3.2 Graphical Display of Gaussian Distribution

When the cdf G(x), the integral of the Gaussian pdf, (Eq. 4-4), is plotted against x, the measurement value, a graph of the error function is generated (Fig. 5.2) on a linear-grade scale. For convenience of this survey and for readability, G(x) is plotted as the abscissa (x-axis) and the measurement value, x, is plotted as the ordinate (y-axis) on a probability-grade scale for the abscissa. G(x) values arranged in order of magnitude from left to right form a straight line on probability-grade paper, when the sample lot contamination is normally distributed. Figure 4.4 shows this output.

The power of this graphical display is that it permits identification of values with significantly greater contamination than expected for that lot. Calculated statistics numerically indicate the average and dispersion of the distribution, but are not effective for identifying trends or anomalies. For instance, identification of an isolated area in a sample lot which is contaminated at levels significantly greater than the fitted Gaussian line are easily observable in the plot, but $\overline{x}$ + ks may still show acceptability. Upon further inspection and analysis, these graphical displays are used to show contamination level differences between areas or structures in a sample lot. The power of the fitted Gaussian graphical display is important in assessing significant variations in the contamination levels within sample lots.

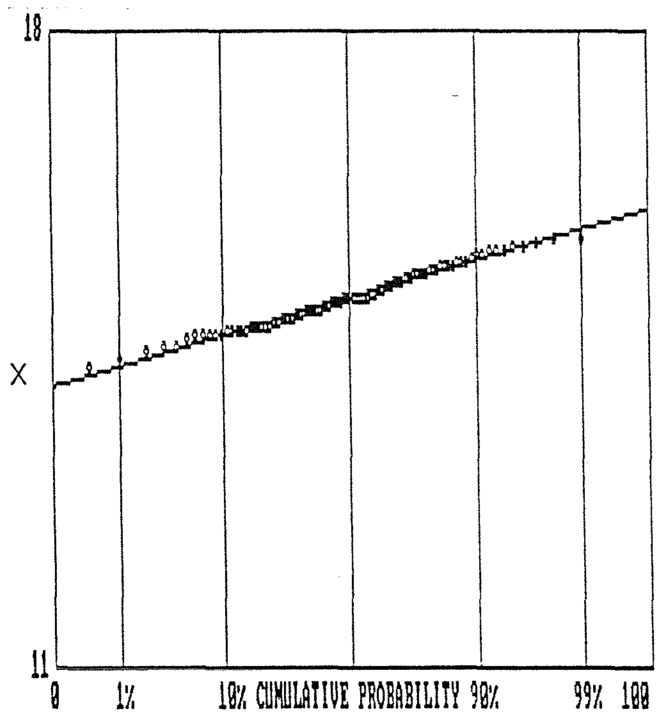

Figure 4.4 Gaussian cdf Plotted on Probability-Grade Paper

4.3.3 <u>Acceptance Criteria for an Uncontaminated Area</u>

Once the test statistic, $\overline{x}$ + ks, is calculated and the Gaussian cdf probability plot is generated, a decision is made as to the extent of contamination in the area. Is the area clean? Is part of the area contaminated? Is the entire area contaminated? Are additional measurements necessary to make a determination?

First, the Gaussian distribution will identify significant variations in the radiological measurements. The sample output, if it represents the entire area well, should approximate a straight line. Measurements made which represent radiological conditions in a separate population from the one assumed, are easily observable as severe deviations in the straight line. The location of these anomalous measurements can be determined and subsequent follow-up is applied.

Second, the test statistic, $\overline{x} + ks$, is calculated for the distribution. The criteria for acceptance are presented as a plan of action. The plan of action is:

1) Acceptance: If the test statistic ($\overline{x} + ks$) is less than or equal to the limit (U), accept the region as clean. (Any single value, x, less than 50% of the limit is considered the Characterization Level, which requires no further action. If any single measured value, x, exceeds 50% of the limit, reinspect that location and take a few additional samples in the immediate area for the analysis. This is the Reinspection Level. If any single measured value, x, exceeds 90% of the limit, investigate the source of occurrence. This is the Investigation Level. These proactive action levels were presented in section 3.1.)

2) Collect additional measurements: If the test statistic ($\overline{x}$ + ks) is greater than the limit (U), but $\bar{x}$ itself is less than U, independently resample and combine all measured values to determine if $\overline{x} + ks <= U$ for the combined set; if so, accept the region as clean. If not reject the region.

3) Rejection: If the test statistic ($\overline{x} + ks$) is greater than the limit (U) and $\bar{x} >= U$, reject the region. Investigate the source of occurrence.

5.0 ANALYTICAL TECHNIQUES

The statistical methods presented in Section 4.0 were used to judge whether an area is not contaminated, slightly contaminated, contaminated above acceptance limits, or whether additional investigation is required. For this particular survey, that judgement is based on one type of radiological measurement: ambient gamma exposure rate.

Analytical techniques used to acquire, evaluate, and interpret these radiological measurements are presented in detail in this section. These techniques include instrument calibration, determination of "ambient background" radiation, and computerized data analysis through inspection by variables.

5.1 Data Acquisition

In each designated 6-m square grid, ambient gamma exposure rate was measured. Each square grid was stepped-off from a local benchmark and marked with its coordinates. The exact location within that square grid where the measurement was made was left to the surveyor's judgement: it was to be the area that, in his judgement, was most likely to have retained the greatest amount of contamination in that square grid. This decision is based on discoloration, debris, crevices, or cracks in the soil; or a low settling spot for surface water runoff. The use of a predetermined grid with discretion for the exact location provides a uniform survey biased towards the high end of the distribution. Locations of noticeably greater exposure rates were reinspected. Reinspection of the data was required for this particular survey because of one outlier in Building T019 and variations in the NW Area distribution which caused the test statistic to exceed 5 μR/h, which according to Section 4.3.3 (2), calls for additional measurements to be collected.

5.2 Data Reduction Software Program

Each gamma exposure rate measurement value was input into SMART SPREADSHEET. This is an off-the-shelf computer software package which allows multiple computations to be performed on raw data values. Columns were established to calculate the surface ambient gamma exposure rate and its standard deviation in μR/h. Software was developed in a program language called Quick Basic by Microsoft to read data from a SMART file into a graphics program which plots the radiological measurements against the Gaussian cdf. For convenience, the distribution function, G(x) is plotted as the abscissa (probability grades), and x, the measurement value, is plotted as the ordinate (linear grades).

Input for data reduction of these measurements was:

1) Grid location, ex. (10,6)
2) Ambient Gamma Exposure Rate (counts in 1 min.; cpm);
3) Gamma survey instrument background (1 min.); and
4) Efficiency factor (μR/h/cpm).

Output for Gaussian plots of these measurements:

1) Ambient gamma exposure rate and standard deviation (μR/h).

5.3 Data Analysis

An arithmetic mean and standard deviation of the radiological measurement values is calculated for each data set. The test statistic, $\bar{x}$ + ks, based on a consumer's risk of acceptance of 0.10 at 10% defective, is also calculated for distributions being tested against an acceptance limit. The acceptance criteria presented in Section 4.3.3 is applied to each sampling distribution. Gamma exposure rate data is always handled differently than alpha/beta activity data because "background" is quite variable. The specifics are covered in detail in Section 5.4.

From the plot of measurement values vs. cumulative probability, the mean radiological value of the lot is the point on the ordinate axis where the fitted-distribution intersects the 50% cumulative probability. In test cases where an acceptance limit has been established for acceptably clean, a vertical line is plotted corresponding to the test statistic, $\overline{x}$ + ks. When an acceptance limit is applied to a test case, horizontal lines are displayed on the graph at 0 (zero), 50% of the acceptance limit (Reinspection), 90% of the acceptance limit (Investigation), and at the acceptance limit. The figures display the results on an expanded scale so that the variations in the data can be seen in detail.

5.4 Ambient Gamma Exposure Rate

Measurements of ambient gamma exposure rate were made by use of a 1 in. x 1 in. NaI scintillation crystal coupled to a Ludlum Model 2220 portable scaler, (Appendix A). This device was mounted on a tripod so that the sensitive crystal was 1 meter from the ground. The detector is nearly equally sensitive in all directions, i.e. 4-π geometry, and can show variations in exposure rate down to one-half of a μR/h, using the digital scaler for a 1-min. count time. Because of the natural variability of ambient radiation, however, a 3 to 5 μR/h exposure rate above "background" is considered the instrument sensitivity in practice. At this level, a surveyor would decide to collect additional measurements.

5.4.1 Instrument Calibration

This detector is calibrated quarterly by the calibration laboratory using Cs-137 as the calibration source. A voltage plateau is plotted and the voltage is set at a nominal 800 V. The detector is placed on a calibration range and readings taken at 5, 2, 1, 0.9, 0.5, 0.4, 0.3, and 0.2 mR/hr. A detector efficiency plot as a function of exposure rate is generated in this regard, (μR/h/cpm).

Because of an exposure rate-dependent effect and because our calibration range does not read less than 200 μR/h (0.2 mR/h), this instrument was cross-calibrated against a Reuter Stokes High Pressure Ion Chamber (HPIC). Count rates were converted to exposure rates by the relationship that about 215 cpm = 1 μR/h, at background exposure rates. This calibration was performed several times.

Instrument response was checked three times a day using a Ra-226 source. The source was placed 1 ft from the detector and counted for 1 min. If the scaler reading fell within ± 5% of the nominal value, then the instrument was qualified as operable for the day, under the calibration conditions previously described. Recalibration because of "instrument out of tolerance" was never necessary.

5.4.2 Data Acquisition and Reduction

Each location where a gamma measurement was made was identified on a map and in matrix notation. The gross number of counts recorded in 1 min. along with the matrix notation location was input into SMART SPREADSHEET. Columns were established to calculate the total exposure rate (μR/h) and its standard deviation according to equations 5-1 and 5-2. Gamma scintillations produced by a NaI detector were converted from gross counts to exposure rate (μR/h) by:

$$R = \frac{(C) * (EF)}{1 \text{ min.}} \qquad \text{(Eq. 5-1)}$$

where R = exposure rate (μR/h)
C = gross counts in 1 min.
EF = efficiency factor (0.0047 μR/h/cpm) based on cross calibration with HPIC.

The standard deviation of a single measurement then becomes by Eq. 4-3:

$$s = \frac{\sqrt{C} * (EF)}{1 \text{ min.}} \qquad \text{(Eq. 5-2)}$$

5.4.3 Data Analysis

Analysis and interpretation of gamma exposure rate data is a five step process:

1. Plot, in order of magnitude from left to right, total-gross exposure rates in μR/h against cumulative probability for three independent areas considered to be "natural background" at SSFL. These survey locations should be from areas where no radioactive material has ever been used, handled, stored, or disposed. These areas should be of similar geologic characteristics to those of the inspected areas. Calculate the average, standard deviation, and range for each distribution. These three distributions give the baseline for "natural" variability of exposure rate as a function of terrain at SSFL.

2. Plot total-gross exposure rates in μR/h against cumulative probability for each subject sampling lot. Calculate the average, standard deviation, and range for each distribution. Compare these statistics and probability distributions against "natural background" distributions.

3. Determine if there are any trends or perturbations indicated by the probability plots of each subject sampling lot which show a potentially contaminated area. If necessary, explain elevated measurements and/or trends in the distribution.

4. Determine whether the "natural background" distributions adequately represent "ambient background" for the tested areas. Determine if nuclear-related operations in the local area are influencing "ambient background" in the test-areas, or if the terrain is significantly influencing exposure rate results. If so, make corrections.

5. Subtract "natural background" from each test-area measurement and compare the results against acceptance criteria in Table 3.1 and Section 4.3.3. Use inspection by variables techniques to test for acceptance. Calculate the average, standard deviation, and test statistic, $\bar{x}$ + ks, for each test-area distribution. If "ambient background" in the test-areas exceeds "natural background," correct the data accordingly and retest.

The most critical step in the analysis of gamma exposure rate measurements is assessing what true "ambient background" radiation is for a test area. "Ambient background" accounts for three effects which result in the production of an electronic pulse of the instrument (a count), which under ideal measurement conditions would not occur:

1. "Natural background" radiation from the cosmos, and primordial radionuclides;

2. Secondary influence of gamma exposure rate due to nearby facilities which handle radioactive materials or radiation producing machines; and

3. Instrument noise.

These individual contributions to "ambient background" play havoc with data interpretation against acceptable limits because both the NRC and DOE criteria for acceptance for unrestricted use are given in μR/h above background, 5 and 20, respectively. First, during the survey we observed significant deviations in "natural background" radiation as a function of landscape geometry. For example, when the detector is placed near a large sandstone outcropping, the exposure rate may increase by almost 4 μR/h. This increase is due to primordial radionuclides in the sandstone, and a change in source geometry, from a planar 2π-steradian surface to a rocky 3π-steradian surface. "Natural background" is also different indoors and varies with construction materials. Second, the RMDF, which is near these test areas, significantly influences ambient background because of the radioactive materials stored there. Third, instrument noise is fairly uniform.

The best solution for evaluating the potential for or existence of residual contamination in an area where the radiation field varies naturally by swings as large as the acceptance limit, is to compare test-area total-gross exposure rates against "background" total-gross exposure rates. "Background" measurements were taken on flat and rugged terrain, with Chico Formation sandstone. These "natural background" measurements were not from areas as rugged as the NW Area, however.

Another component of "ambient background" must also be assessed: that contribution resulting from nearby operations using radioactive material or radiation-producing machines. These operations can significantly increase local area "ambient background." This is the case in several SSFL locations. If the test-area distribution is well-represented by a Gaussian at a uniformly greater value than the "natural background" distributions, then one of two conditions exist:

1. The area is uniformly contaminated; or

2. Contribution to ambient "background" from nearby facilities is elevating test-area "background."

This determination is made on a case by case basis. Because condition 1 is unlikely for these surveys, condition 2 is addressed. A correction for facility-influenced gamma "background" is made when a facility known to emit radiation is clearly visible from the test-area. An estimate for direct radiation and skyshine is made based on fence-line measurements and the median value of the test area distribution. This assessment is more of a qualitative analysis rather than a detailed analytical model.

Best corrections for "ambient background" radiation for this survey, then, fall into five categories:

1. "Natural background" inside a Butler-type building with concrete slab floor. Exposure rate is typically 6 to 7 μR/h. The best estimate of "background" for a typical facility is the median measurement value for that facility;

2. "Natural background" inside a small room constructed of cinder block (which contains primordial radioactivity). Exposure rate is variable depending on the size of the room and proximity of the wall to a measurement location. For close-wall measurements, 12 to 14 μR/h can be expected;

3. "Natural background" of a planar landscape composed of asphalt concrete. This is typical of equipment staging areas and storage yards. Exposure rates are not highly variable, unless a lot of large equipment items are stored there. Expect 13 to 15 μR/h;

4. "Natural background" of natural terrain at SSFL. Variability of the measurement values is strongly dependent on landscape geometry, ravines, and sandstone outcroppings. Expect 14 to 17 μR/h with a standard deviation of $\pm$ 1 μR/h; and

5. "Ambient background" which includes the variability of "natural background" plus that contribution from nearby radiation sources (e.g. RMDF). These effects are highly variable and depend on current operations (this can be largely time dependent), and measurement location. At locations considered here, this contribution could add an additional 5 to 15 μR/h above "natural background."

Once all the best corrections for "ambient background" have been made, resulting distributions are compared against the 5 μR/h above "background" acceptance limit. The test statistic, x + ks, is calculated for each distribution. Statistical acceptance criteria presented in section 4.3.3 apply.

5.4.4 Sensitivity of Gamma Exposure Rate Measurements

The purpose of performing these exposure rate measurements is to detect any significant quantity of gamma-emitting radionuclides. Operational history and surveys performed years ago show that the most probable radiological contaminant in these areas is Cs-137, and associated mixed-fission-products. Since Cs-137 is a gamma emitter, it is detectable with the NaI detector.

The sensitivity of these measurements, or rather, the amount of contamination which could be there and which would not be detected, is based on two possibilities:

1) A uniformly contaminated region of soil; a layer on the surface, or a layer several feet below the surface; or

2) A piece of contaminated debris located on the surface, or buried several feet below.

Our acceptance criteria specify that no soil activity exceeding 100 pCi/g-beta is acceptable for unrestricted use. In comparison, 10 μCi of Cs-137, total, is the limit for exempt quantity according to 10CFR30, Schedule B. If only Cs-137 were contained in the soil, 10 μCi of activity would be present in 100 kg of soil, or about 70,000 cm^2 of surface area, if the layer were 1 cm thick.

Natural ambient gamma "background" radiation is about 12-16 μR/h at 1 meter from the ground, so the radioactive material would have to produce an exposure rate of about 3 μR/h above background in order to detect it to such an extent that further investigation would commence. Table 5.1 shows theoretical exposure rates calculated for some uniformly contaminated soil and miscellaneous contaminated debris. The contaminant is assumed to be Cs-137. Condition (1) assumes a uniformly distributed layer of soil with 100 pCi/g Cs-137. Condition (2) assumes a point source of Cs-137 with total activity equal to 1 mCi.

Table 5.1 Exposure Rates of Cs-137 Contaminated Soil and Debris

(1) Contaminated Soil (100 pCi/g)	Exposure Rate (μR/h) 1 meter above surface	
Infinite Slab on the Surface		
0.3 meters thick	72	
1 meter thick	74	
Infinite Slab, 20 cm thick/10 cm thick		
at Surface	68	55
at 5 cm depth	32	25
at 10 cm depth	17	13
at 15 cm depth	9	7
at 30 cm depth	2	1
Rectangular Volume, 20 cm thick/10 cm thick		
1 square meter, surface	6.5	4.2
36 square meters, surface	47	34
(2) Contaminated Debris, (1 mCi total activity)		
at Surface	155	
at 15 cm depth	36	
at 30 cm depth	8	

For condition (1), 100 pCi/g Cs-137 layer of contaminated soil, these measurements would detect a surface layer greater than one cm thick, but would not detect a small thickness of soil (10 cm) buried much more than a half-foot from the surface. This is very good sensitivity, particularly since the likelihood of a thin layer of contaminated soil located more than 6 in. below the surface is small. For condition (2), contaminated debris, whose activity exceeded 1 mCi Cs-137 activity, could be seen if it wasn't buried much deeper than about a foot. 10 mCi could probably be seen down to 2 feet. The likelihood of buried or scattered debris occurring in these areas is very small. Concerning suspect activation products and their sensitivity levels, Co-60 is the most significant activation product. It is more easily detectable than Cs-137 because of higher energy gamma rays. Thus, this Cs-137 analysis gives the most conservative sensitivities for suspect contaminants.

5.5 Direct Beta Contamination Measurements

Direct beta contamination measurements were made "for indication" on an as-needed basis. These measurements were made with Ludlum model 44-9 beta probes coupled to Ludlum model 12 count-ratemeters. Measurements were required in one location of T019 where a gamma exposure rate measurement was greater than expected. A beta survey was also performed in the vault of T019 because of observed uniformly greater gamma exposure rates.

5.5.1 Instrument Calibration

Each beta detector was calibrated before use with Tc-99. Background levels were determined in an area of similar characteristics, known to be uncontaminated.

5.5.2 Data Acquisition and Reduction

Radioactivity measurements made "for indication" are reported as No Detectable Activity (NDA), or less than 20, 30, 40 counts per minute (cpm) above background, etc. A positive indication of beta contamination is a steady count rate above background (75-100 cpm). In cases where the count rate does not change from background, NDA is reported.

5.5.3 Data Analysis

Data analysis is not applicable to measurements made "for indication."

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6.0 PROCEDURES

The following radiological procedures were used in performing this survey.

6.1 Sample Selection Gridding

Four sample lots should be established, one for each of the subject test-areas. Superimpose 6-meter square grids on each surface to be radiologically characterized. Designate each square meter in matrix notation with location (1,1) being the northwestern-most square in a sample lot. From this northwestern-most location, mark a location off every 6 meters east, and south. Where it is not practical to make a measurement because of rock outcroppings or heavy equipment, step to the nearest clear area.

6.2 Calibration and Instrument Checks

Instruments are calibrated and checked every morning, noon, and evening for the duration of the project as follows.

Portable Ludlum 2220-ESG Survey Instruments coupled to a 1 in. x 1 in. NaI crystal:

1) Turn the instrument 'ON' and allow to warm up for 5 min.

2) Check high voltage (800V gamma).

3) Check threshold (400 gamma).

4) Set window in/out switch to "out."

5) Check battery (greater than 500).

6) Set range selector to 1, response to fast, and count time for ambient gamma exposure rate measurements to 1 min.

7) Take and record a 1 min. background count in an uncontaminated area which typifies the area to be surveyed. Verify that ambient background falls within ± 20% of daily-averaged background measurements.

8) Use a Ra-226 check source located 1 ft from the NaI detector to check operability of the gamma instrument. The count rate should not vary by more than ± 5% from the initially established standard. The gamma calibration efficiency factor is determined by comparison against a Reuter Stokes High Pressure Ion Chamber (HPIC).

6.3 Radiological Measurements

6.3.1 Ambient Gamma Exposure Rate Measurements

1) Mount the detector on a tripod which centers the detector 1 meter from the ground.

2) Set the count time to 1 min. and take a measurement at each applicable location for that length of time.

3) If any single reading exceeds about 400 cpm above normal readings, recount. Make sure all initial counts and following recounts are included with the data.

4) Record the location, total counts, background, and efficiency factor (μR/h/cpm).

5) Enter the data into SMART SPREADSHEET.

6) Take at least 30, 1-min. counts in an area of similar topography where no radioactive materials were ever handled, stored, or used. This is the background distribution. Enter data in SMART SPREADSHEET.

6.3.2 Beta Surface Activity Measurements

1) Using a Ludlum Model 12 count rate meter in connection with a Ludlum Model 44-9 pancake GM beta probe, survey various building features as appropriate The only areas requiring this type of investigation were: the NW corner of the high bay and the vault in Building T019.

2) Perform an instrument calibration check using a Tc-99 source.

3) Record the gross count rate in a generalized manner as NDA (No Detectable Activity) or less than 20 cpm, 30 cpm, 100 cpm, etc., as applicable.

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7.0 SURVEY RESULTS

A radiological survey of two facilities and two outdoor areas was performed using the survey plan previously described:

1. Building T019;
2. Building T013;
3. NW Area; and
4. T626 Storage Area.

Each inspected test-area was treated as a sample lot for analyzing and interpreting radiological data. Uniform 6-m square grids were established to measure ambient gamma exposure rates. Probability plots of these measurements show: 1) an outlier in Building T019 which was, upon reinspection, determined to be anomalous and insignificant; 2) well-fitted Gaussian distributions with no outliers or anomalies inside T013 and in the T626 Storage Yard; and 3) significant deviations from a Gaussian in the NW Area. Further analysis and interpretation were required for the NW Area because of these significant deviations. Analytical interpretation of gamma exposure rate measurements with corrections for significant changes in "ambient background," and follow-up beta surface activity measurements show that all areas are uncontaminated.

In this section, the format used for presenting data, analyzing probability plots, and interpreting results is presented first. Then the gamma exposure rate measurement results are presented according to this format. Each sampling lot is discussed separately.

7.1 Statistical Results Format

Gamma exposure rate data collected for this survey are displayed as Gaussian cumulative distribution functions in Figures 7.1 through 7.15. Figures 7.1 through 7.3 are distributions of gamma exposure rate measurements made at 3 independent SSFL locations to demonstrate the variability of "natural" background radiation. Figures 7.4, 7.6, 7.8, 7.10, 7.12, and 7.14 are distributions of gross-total gamma exposure rates for each test-area including a division of the NW Area measurements. Figures 7.5, 7.7, 7.9, 7.11, 7.13, and 7.15 are distributions of the same six data sets corrected for "ambient" background based on either the average of results presented in Figures 7.1 through 7.3, (i.e. the "natural background" data), or on location specific "ambient background." These figures show each measurement value, arranged in order of magnitude from left to right, and a straight line representing the derived fitted-Gaussian distribution.

The mean of each distribution is approximately that value of the fitted-Gaussian on the ordinate which corresponds to a 50% cumulative probability on the abscissa. The measurement value at 50% cumulative probability is the median. For a theoretical Gaussian, the median is equal to the mean. For a well-fitted Gaussian, the median is very close to the mean. One, two, and three standard deviations above the mean correspond to 84%, 97.7%, and 99.8% cumulative probability for a one-sided test, respectively. Inspection by variables is used to test only "background-corrected" data sets against the NRC acceptance limit of 5 μR/h. The value of k used in the inspection test is very nearly 1.5 for each case; thus, the Test Statistic (TS) line ($\bar{x}$ + ks) will run perpendicular to the abscissa corresponding to about a 93.3% cumulative probability. The Gaussian distribution line must pass below the intersection of the "TS" line (about 93%) and the horizontal line showing the acceptance limit at that point in order to accept the lot as being uncontaminated. "k" and thus the "TS" line increase as the number of samples in a lot decrease.

At the top left hand corner of each output is the data file name for the sample lot. For "uncorrected" data sets, 30 μR/h is normally used for convenience, as the maximum ordinate value. If measurements exceed 30 μR/h, then the greatest measurement value is the upper bound of the ordinate axis. In cases where the measurements have been corrected for "natural background," 5 μR/h (the NRC acceptance limit) is used as the maximum ordinate value. The lower bound of the ordinate is either the smallest measured value (minus background, if applicable) or the smallest value calculated for a Gaussian fit. Negative numbers result when the measured value is less than background. Cumulative probability (abscissa) is plotted in probability grades, i.e. the distance between any two successive points increases as the distance from the 50% cumulative probability line increases. If an acceptance limit is applicable, four horizontal lines extending across each plot show, from top to bottom, 100% of the test limit, 90% of the test limit (Investigation), 50% of the test limit (Reinspection), and zero; see Section 4.3.3.

In cases where an acceptance limit is not appropriate, for example, gamma exposure rate measurements not corrected for "natural background," the four horizontal lines are not shown. Furthermore, a test statistic is not calculated because we were not testing the data against an acceptance limit. Since the variability in naturally occurring ambient gamma exposure rates at SSFL is wide, background was not subtracted at first. In these cases, the mean is calculated and the shape of the distribution is observed to identify any areas of increased radioactivity. Then the shape of the curve is compared against three "background" distributions. Finally, "natural background" and contributions to "ambient background" are subtracted and inspection by variables techniques are applied to prove or disprove the hypothesis that the area is not contaminated.

7.2 Ambient Gamma Exposure Rates

Ambient gamma exposure rate measurements were made at 502 locations. Appendix C shows the data sets. Table 7.1 shows the computed statistics for each data set compared against data from three independent areas where no radioactive material was ever handled, used, or stored. These areas are considered "natural background" at SSFL. This type of comparison is necessary for two reasons: 1) to demonstrate variability of "natural background" gamma-radiation at SSFL; and 2) to estimate "natural background" at SSFL because the limits for unrestricted-use by which we use to demonstrate an "acceptable" area are based on above "background" criteria. So, unless we confidently know what "ambient background" is, (and this includes natural variability as well as facility construction vari-

Descriptive statistics presented in Table 7.1 show that average exposure rates calculated for indoor sample lots (Buildings T019 and T013) are considerably lower than outdoor "natural background" sample lots: 7 to 8 μR/h vs. 14 to 16 μR/h, respectively. This is a factor of 2 difference. The variability of indoor measurements, however, is greater than outdoor measurements; 1 μR/h vs. 0.5 μR/h, respectively. The T019 vault was handled as a separate data set because of its dissimilar construction and resultant affect on exposure rate (average of 12 μR/h). The average exposure rates calculated for the outdoor sample lots (NW Area and T626 Storage Area) agree with those measurements collected in the "natural background" areas; however, a noticeably lower average exposure rate was observed in the NW Area (smallest measurements) and T626 Storage Area. This bears further discussion. The NW Area measurements (247 total) show an expected average but a significant standard deviation of 3.38 μR/h. Upon observation of this distribution (Figure 7.8), there are clearly two Gaussian data-sets. The entire data-set was then divided by greatest half and least half of measurements, as seen in Table 7.1 This secondary analysis shows clearly the difference in exposure rate between natural terrain and asphalt concrete; 17.0 $\pm$ 3.05 μR/h corresponds to very rugged natural terrain plus an RMDF influence on "ambient background," 11.9 $\pm$ 0.98 μR/h corresponds to flat asphalt concrete. The T626 Storage Area measurements were also made on asphalt concrete and compare favorably with those previously mentioned. The variability of these measurements is greater because of scrap materials stored in the yard.

Although the mean exposure rates calculated for each test-area are about equal to or less than "natural background" values, significantly greater variation is observed. Greater variation is suspicious and before we incorrectly conclude that these test areas are uncontaminated, cumulative probability plots must be studied and compared against "natural background" distributions. Corrections for "ambient background" are made on a case by case basis.

Table 7.1 Natural Background Gamma Radiation at SSFL Compared to Survey Data

Location	No. of Measurements	Mean Exposure Rate (μR/h)	Expected Standard Deviation at the Mean (μR/h)*	Standard Deviation of the Distribution (μR/h)**	Range μR/h
Building T019 (1)	46	7.6	0.19	1.05	6.3
(2)	67	7.8	0.19	1.09	6.3
T019 Vault	10	12.4	0.24	0.88	2.9
Building T013	75	6.8	0.18	1.01	4.8
NW Area	247	14.4	0.26	3.38	18.5
NW Area (Greatest Measurements Corresponding to Natural Terrain)	120	17.0	0.28	3.05	14.1
NW Area (Smallest Measurements Corresponding to Asphalt Concrete)	127	11.9	0.23	0.98	4.4
T626 Storage Area	113	11.2	0.23	1.67	7.2
Background					
Building 309 Area (1/19/88)	36	15.6	0.27	0.82	3.4
Well #13 Road (Dirt) (4/29/88)	43	16.2	0.27	0.49	2.2
Incinerator Road (Dirt) (4/29/88)	35	14.0	0.25	0.36	1.4

* The expected standard deviation at the mean is calculated based on counting statistics, equation 4.2.

** The standard deviation of the data points accounts for dispersion in the measurements, equation 4.7.

(1) Initial measurements acquired throughout T019 facility.

(2) Includes 21 additional measurements acquired in high bay after analysis of initial data showed one outlier.

7.2.1 Non-Radiological Areas

Because the "natural background" gamma-radiation environment is quite variable at SSFL and because the limits for unrestricted use are based on limits above background, further demonstration of this natural variability is necessary. For comparison against the test-area measurements, three independent areas were surveyed, all in locations where no radioactive material was ever handled, used, stored, or disposed. All three areas are located on the eastern side of SSFL: (1) Area surrounding building 309 on Area I Road; (2) well #13 Road; and (3) Incinerator Road. Table 7.1 shows the results of these measurements. Unfortunately, these "natural background" areas are incongruous with the areas inspected for this report: 1) Building T019 and T013 measurements are indoors; 2) part of the NW Area and all of the T626 Storage Area is paved; and 3) the terrain of the NW Area is significantly more rugged. The only purpose these distributions serve is to show "natural" variability of gamma radiation at SSFL on natural terrain.

Figures 7.1 through 7.3 are probability plots of these three independent "background" areas. At least 30 measurements were made in each area on the same day. In the plots, a uniform background rate (unbiased by spatial effects), would appear as a straight line with a minimal slope. That slope would show that 1 standard deviation from the mean of values would be equivalent to the mean-value standard deviation (i.e. the square root of the counts of the mean multiplied by an appropriate efficiency factor). If this was the case, the values in columns 4 and 5 of Table 7.1 would be equivalent. Obviously, this ideal condition is impossible to achieve in terrain at SSFL. All three plots show model Gaussian distributions, but with greater variability than would be expected from unaffected measurements. Variability is greatest near Building 309.

Measurements from the area surrounding Building 309 show the most variability of all three background areas. This is attributed to large sandstone outcroppings in the area; the spatial dependency of each measurement is observable in this case. The variability of each distribution

Figure 7.1 Ambient Gamma Radiation at Area Surrounding Building 309
(Natural Background Distribution)

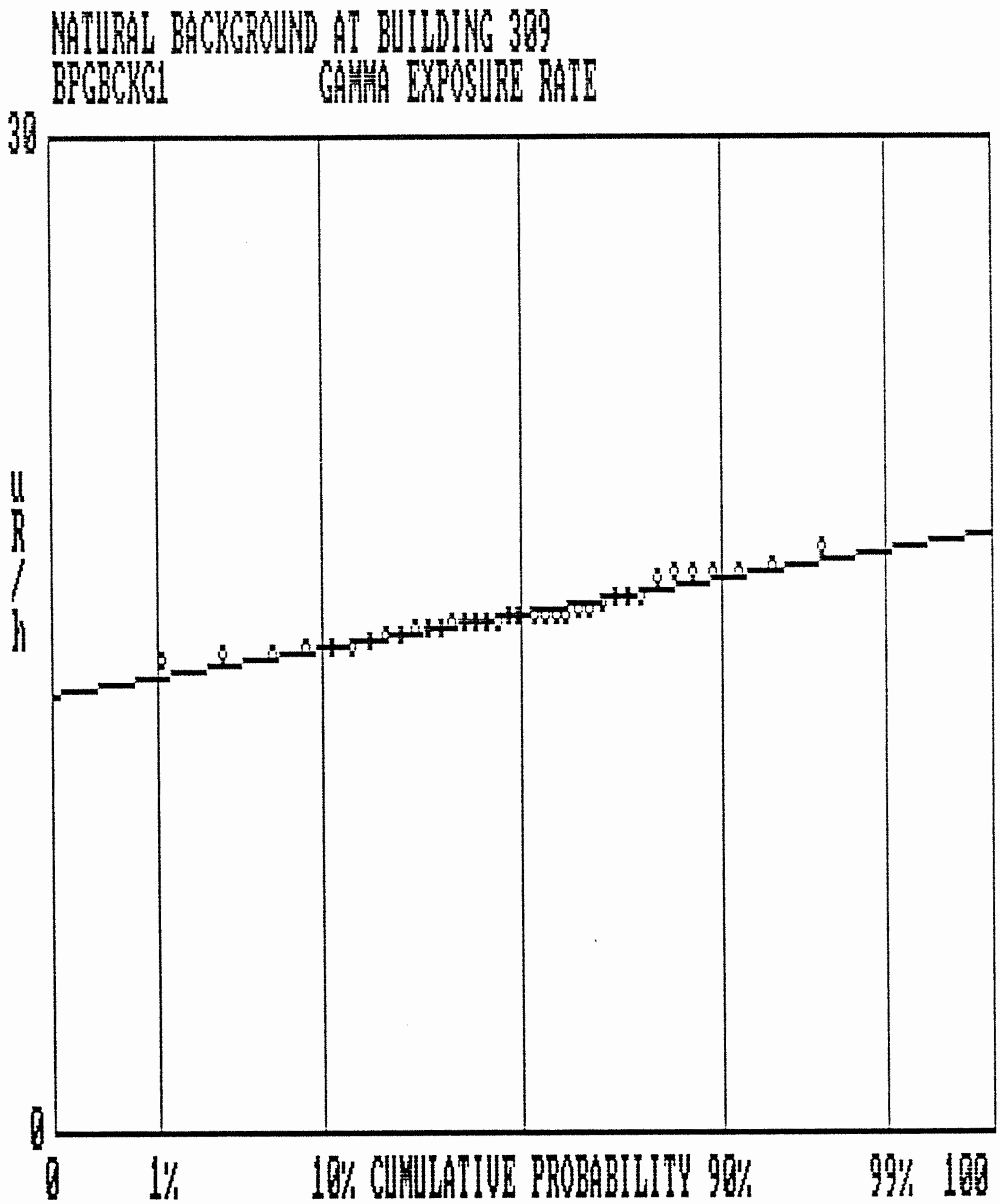


Figure 7.2 Ambient Gamma Radiation at Area Well #13 Road
(Natural Background Distribution)

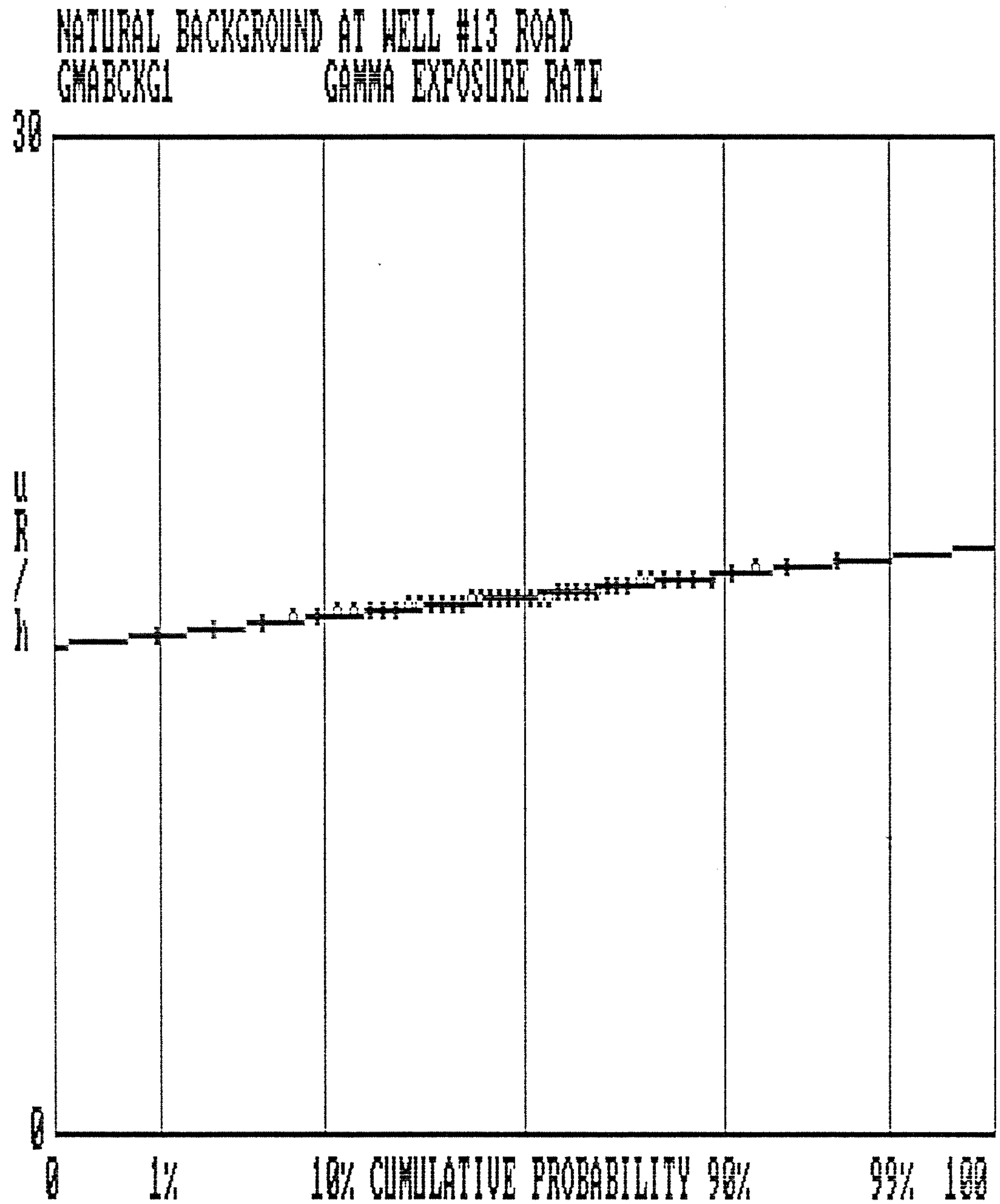
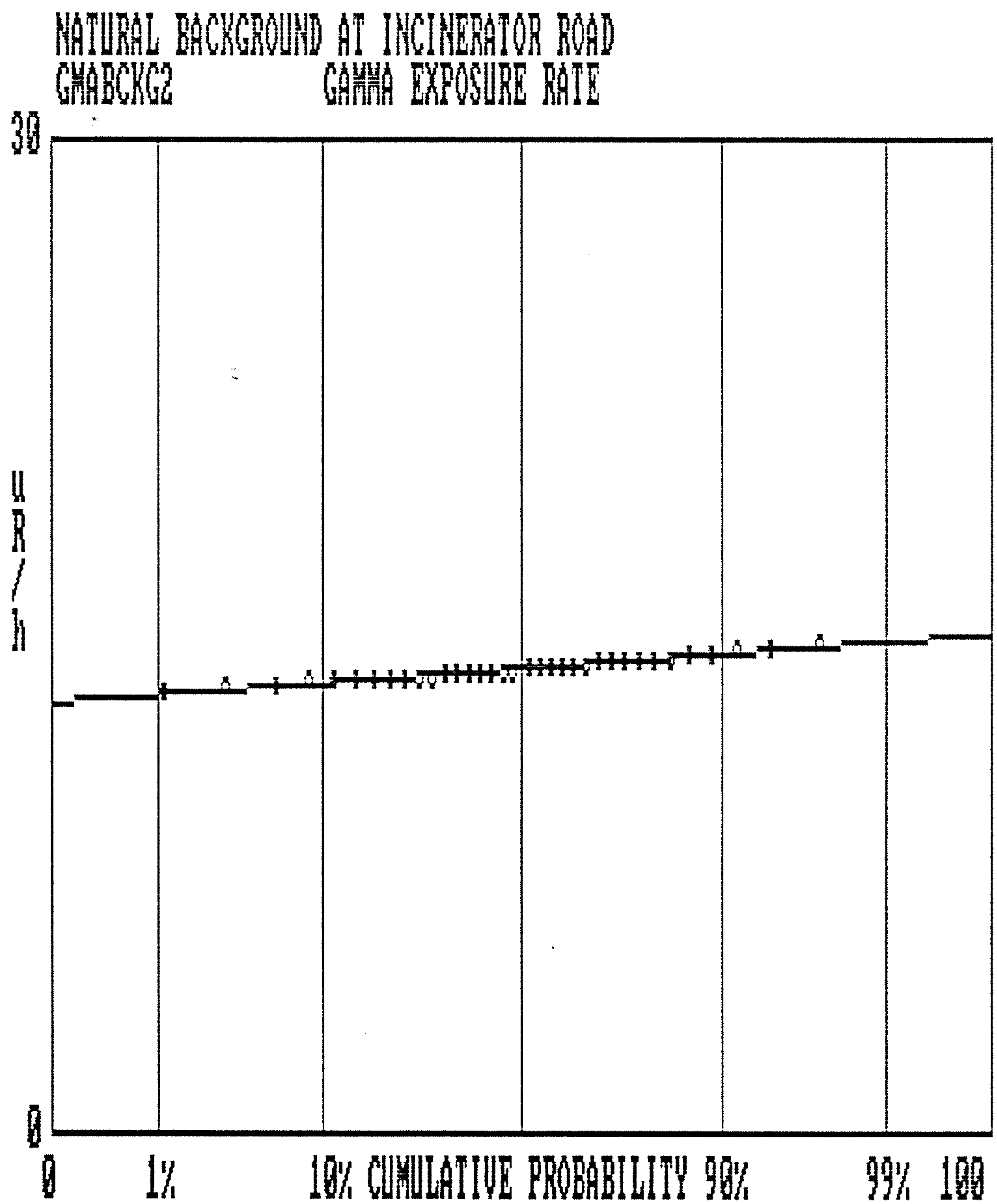


Figure 7.3 Ambient Gamma Radiation at Incinerator Road
(Natural Background Distribution)



depends on the number of measurements made directly against the rock versus the number made many feet from the rock. Also of importance here is the range of measurement values with a maximum of 3.4 μR/h. "Natural background" variability approaches the NRC limit.

This "natural background" analysis shows the great difficulty in assessing whether an area is contaminated based on the NRC acceptance limit of 5 μR/h above background. The DOE limit of 20 μR/h is more reasonable. Natural gamma radiation is significantly variable at SSFL. It is even more variable for natural terrain as rugged as the NW Area. We'll now compare this "natural" variability against the four test-areas presented in this report.

7.2.2 Building T019

Figure 7.4 shows the statistical distribution of gross-total gamma exposure rate measurements plotted against cumulative probability for the interior of Building T019. This test-area is indoors with a concrete floor and Butler-building sides and roof. Deviations from the Gaussian are due to changes in counting geometry, i.e. measurements made close to walls and equipment. These are normal expected deviations. One outlier exists at 12 μR/h, at 98.5% cumulative probability. This measurement was made in the northwest corner of the high bay. As shown in Table 7.1, 46 measurements were originally acquired in this facility. Because the outlier was observed, 21 additional measurements were taken in that area as part of our reinspection effort. These measurements are included in Figures 7.4 and 7.5. The combined set of 67 measurements show the area to be clean. The outlier is an anomalous reading. No trends indicating a contaminated area are observed.

Figure 7.5 shows the same data set, in which case a correction for "ambient background" was made uniformly to each measurement value. 7.75 μR/h was used for "background" subtraction, corresponding to the median value of gross-total measurements presented in Figure 7.4. Deviations

Figure 7.4 Total-Gross Ambient Gamma Exposure Rates
Inside Building T019

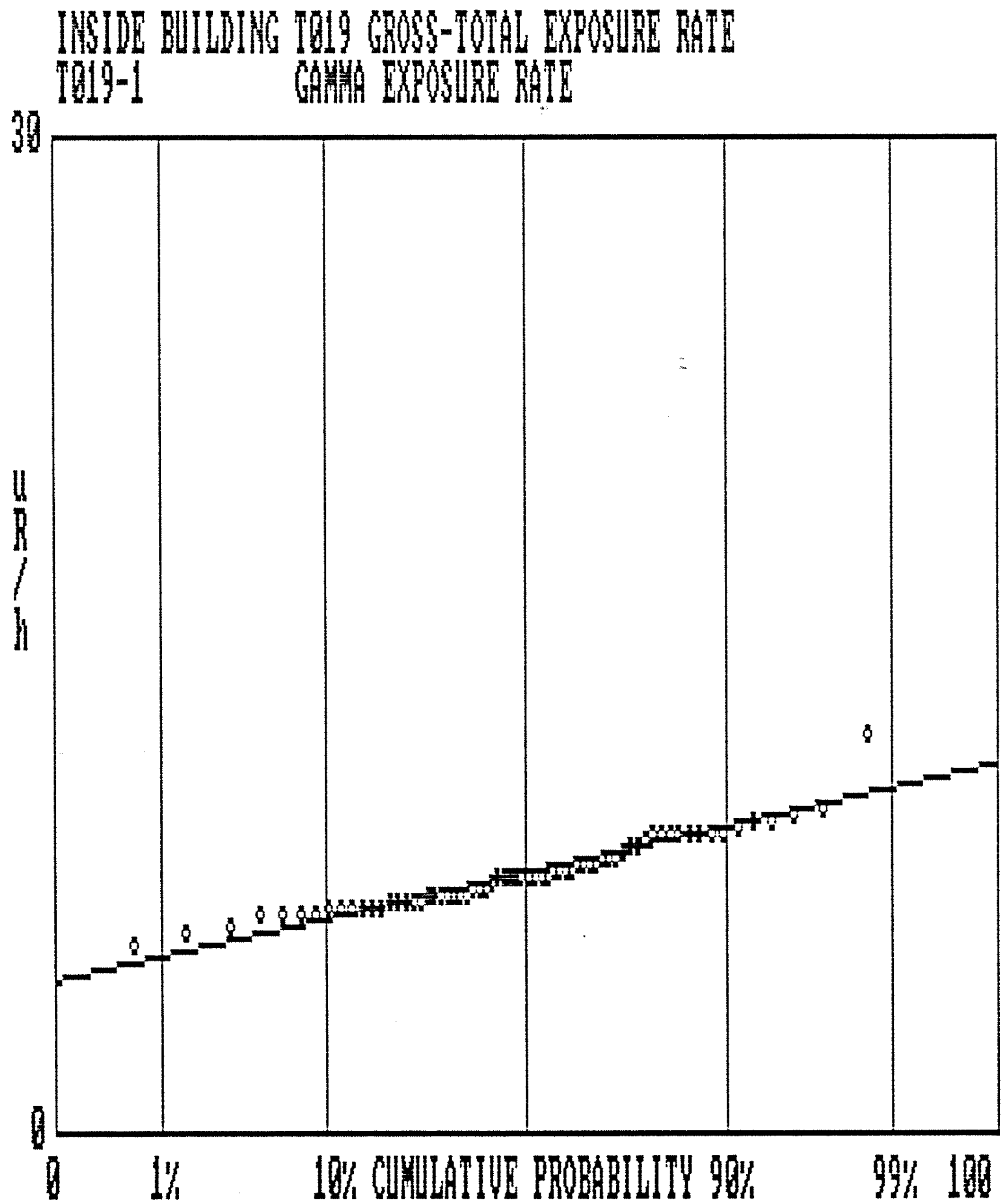
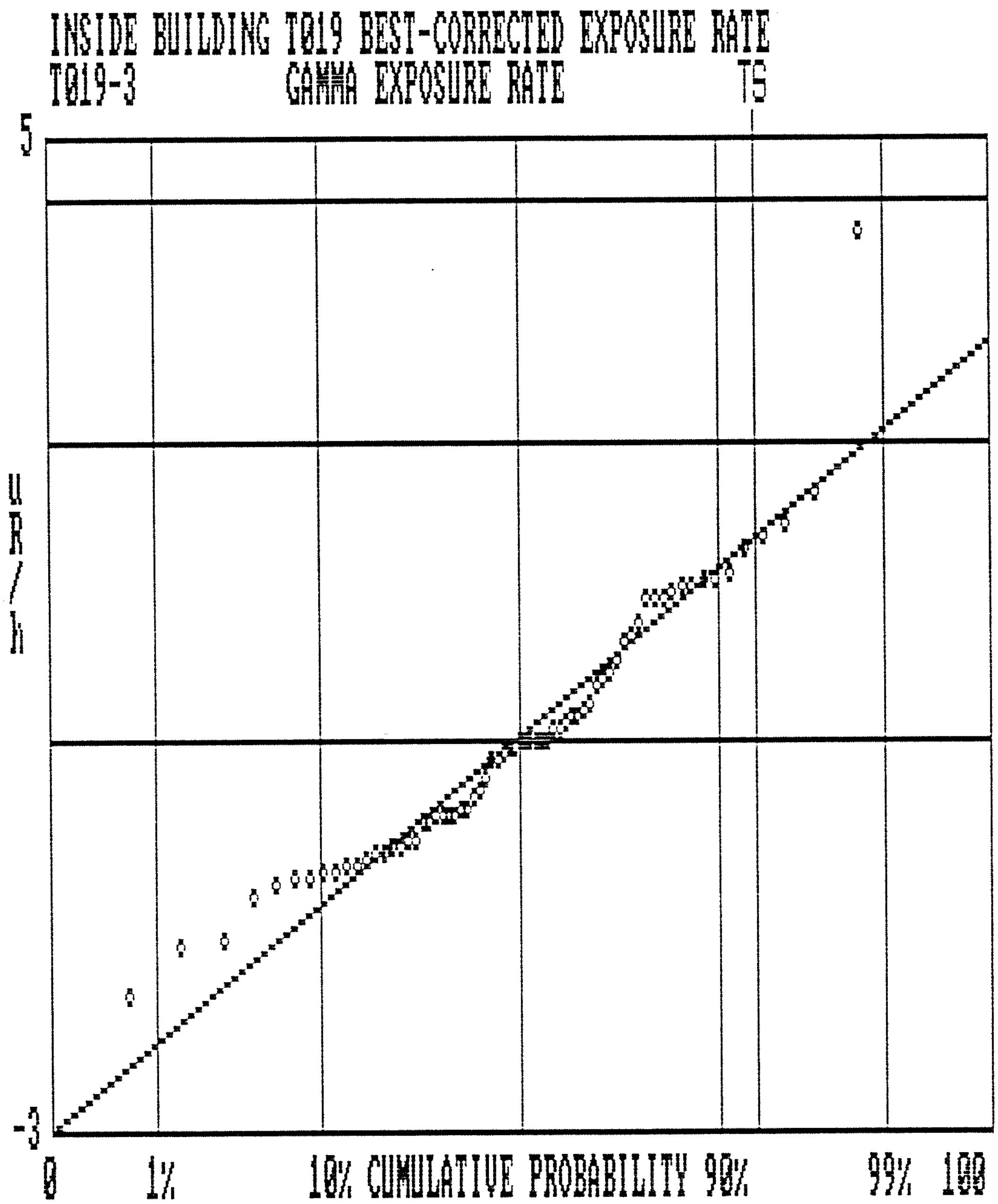


Figure 7.5 Background-Corrected Ambient Gamma Exposure Rates
Inside Building T019



observed in the measurements because of geometry changes are pronounced in this figure because the ordinate scale has been expanded. An average of 0.04 ± 1.09 μR/h is less than the 5 μR/h acceptance limit. The inspection test statistic, 1.69 μR/h, is less than the 5 μR/h limit. We accept this facility as uncontaminated by this inspection method. No further investigation is required.

The T019 vault was handled separately. Table 7.1 shows an elevated average exposure rate of 12.4 μR/h for the vault. This is attributed to primordial isotopes in the building materials. The vault is uncontaminated and no further investigation is required.

7.2.3 Building T013

Figure 7.6 shows the statistical distribution of gross-total gamma exposure rate measurements plotted against cumulative probability for the interior of Building T013. This test-area is indoors with a concrete floor and Butler-building sides and roof. The measurements follow a well-fitted Gaussian cdf. No trends or anomalies indicate a specific contaminated area. The distribution is similar to the three "background" distributions, except at a lower level.

Figure 7.7 shows the same data set, in which case a correction for "ambient background" was made uniformly to each measurement value. 7.04 μR/h was used for "background" subtraction, corresponding to the median value of gross-total measurements presented in Figure 7.6. An average of -0.19 ± 1.00 μR/h is less than the 5 μR/h acceptance limit and all action levels. The inspection test statistic, 1.32 μR/h, is less than the 5 μR/h limit. We accept this facility as uncontaminated by this inspection method. No further investigation is required.

Figure 7.6 Total-Gross Ambient Gamma Exposure Rates
Inside Building T013

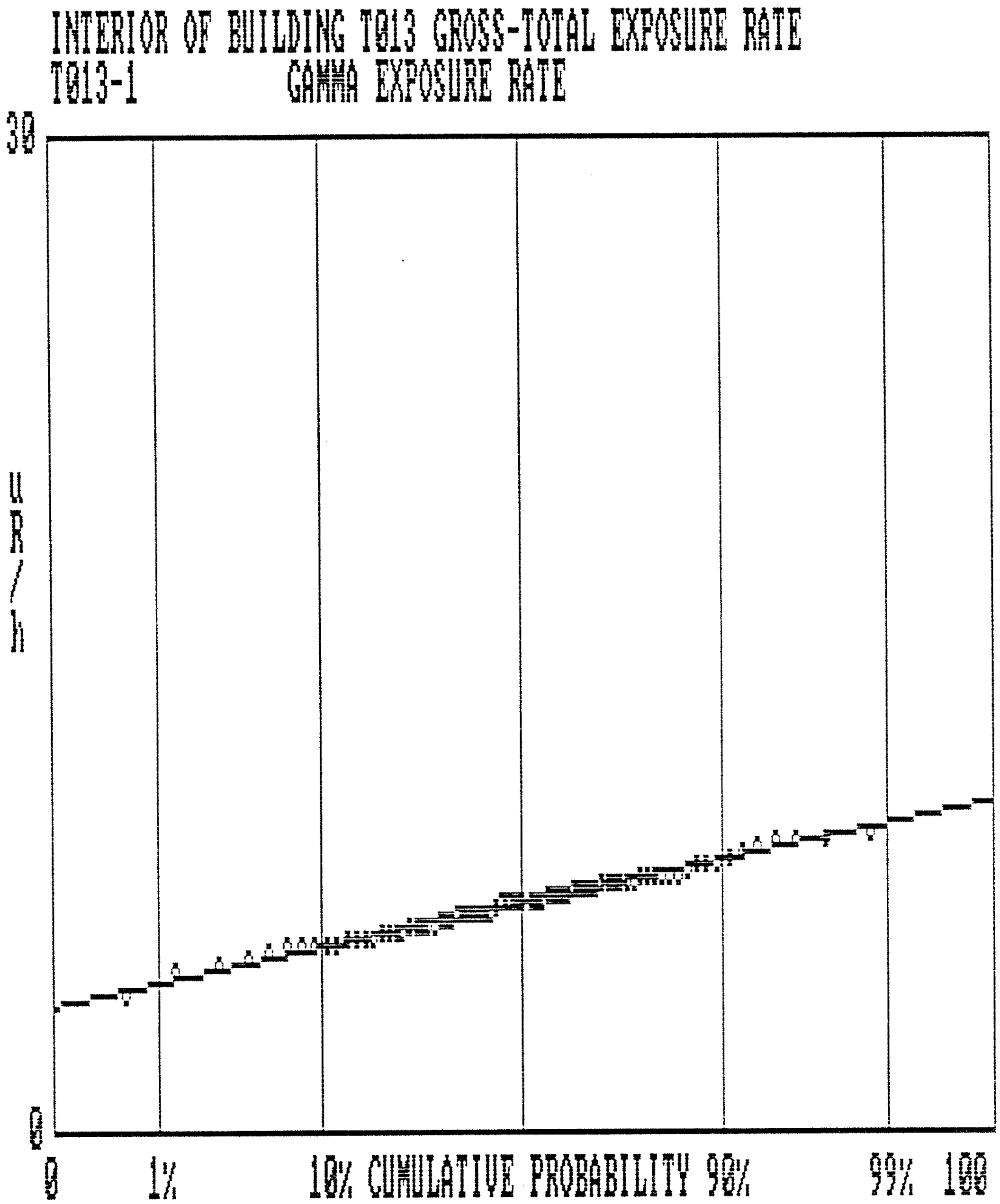
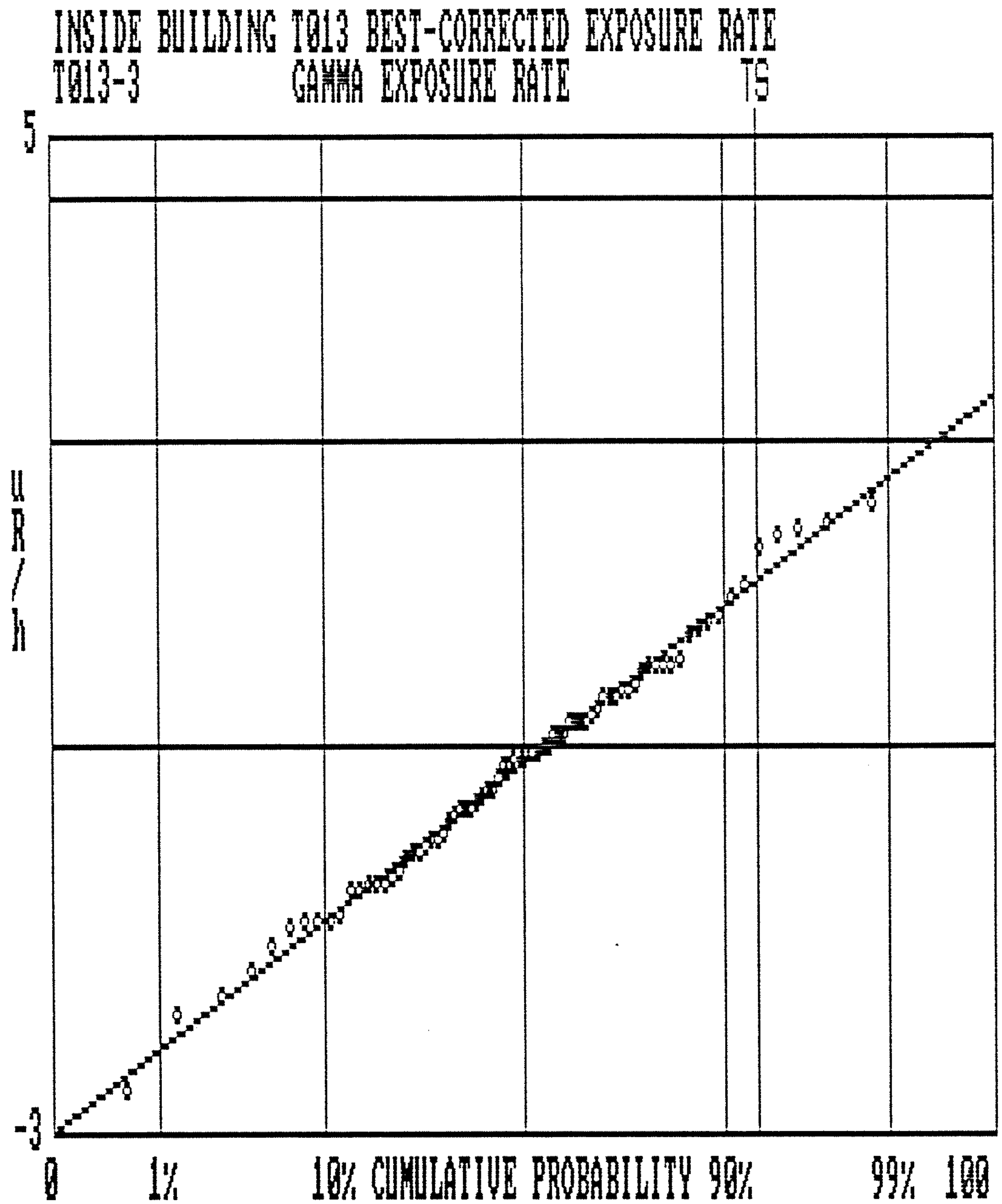


Figure 7.7 Background-Corrected Ambient Gamma Exposure Rates
Inside Building T013



7.2.4 NW Area

Figure 7.8 shows the statistical distribution of gross-total gamma exposure rate measurements plotted against cumulative probability for the entire NW Area. This test-area is very diverse in physical characteristics: half is rugged natural-terrain, half is asphalt concrete pavement. Furthermore, "ambient background" gamma radiation in the area is influenced by nearby RMDF nuclear operations. Since this RMDF effect is distance-dependent, these measurements are not from a uniform sampling lot. The obvious change in slope of the curve shows two sample lots -- and the power of this graphical display. A definite trend in exposure rate measurements is indicated in Figure 7.8. Further analysis and interpretation is required.

Figure 7.9 shows the same data set, in which case a correction for "natural background" was made uniformly to each measurement value. 15.30 μR/h was used for "background" subtraction, corresponding to the average of the three "natural background" measurements shown in Figures 7.1, 7.2 and 7.3, and Table 7.1. The change in slope is still evident and the large difference between the average and median reflect a poorly fitted Gaussian.

Deviations observed in the measurements because of variations in topography are slightly pronounced in this figure because the ordinate scale has been expanded. The power of inspection by variables is also demonstrated by this distribution. An average of -0.89 ± 3.38 is less than the 5 μR/h acceptance limit and all action levels, but the large standard deviation is suspicious. Although the inspection test statistic, 3.83 μR/h is less than the 5 μR/h limit, further reinspection and understanding of these measurements is required because of the large deviations observed in the measurements. Seven measurement values on the high end also need to be explained.

Figure 7.8 Total-Gross Ambient Gamma Exposure Rates in the NW Area (247 Measurements)

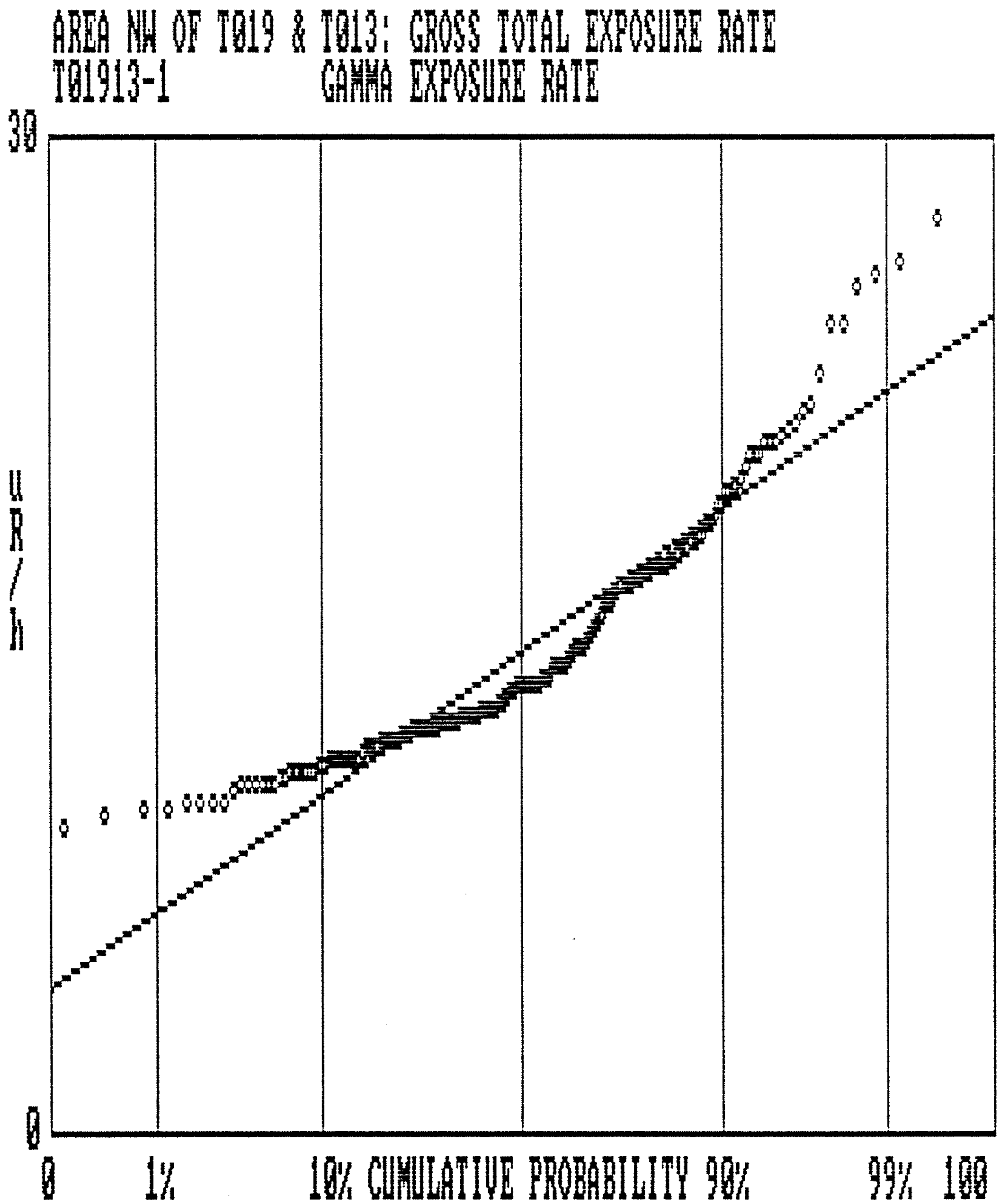
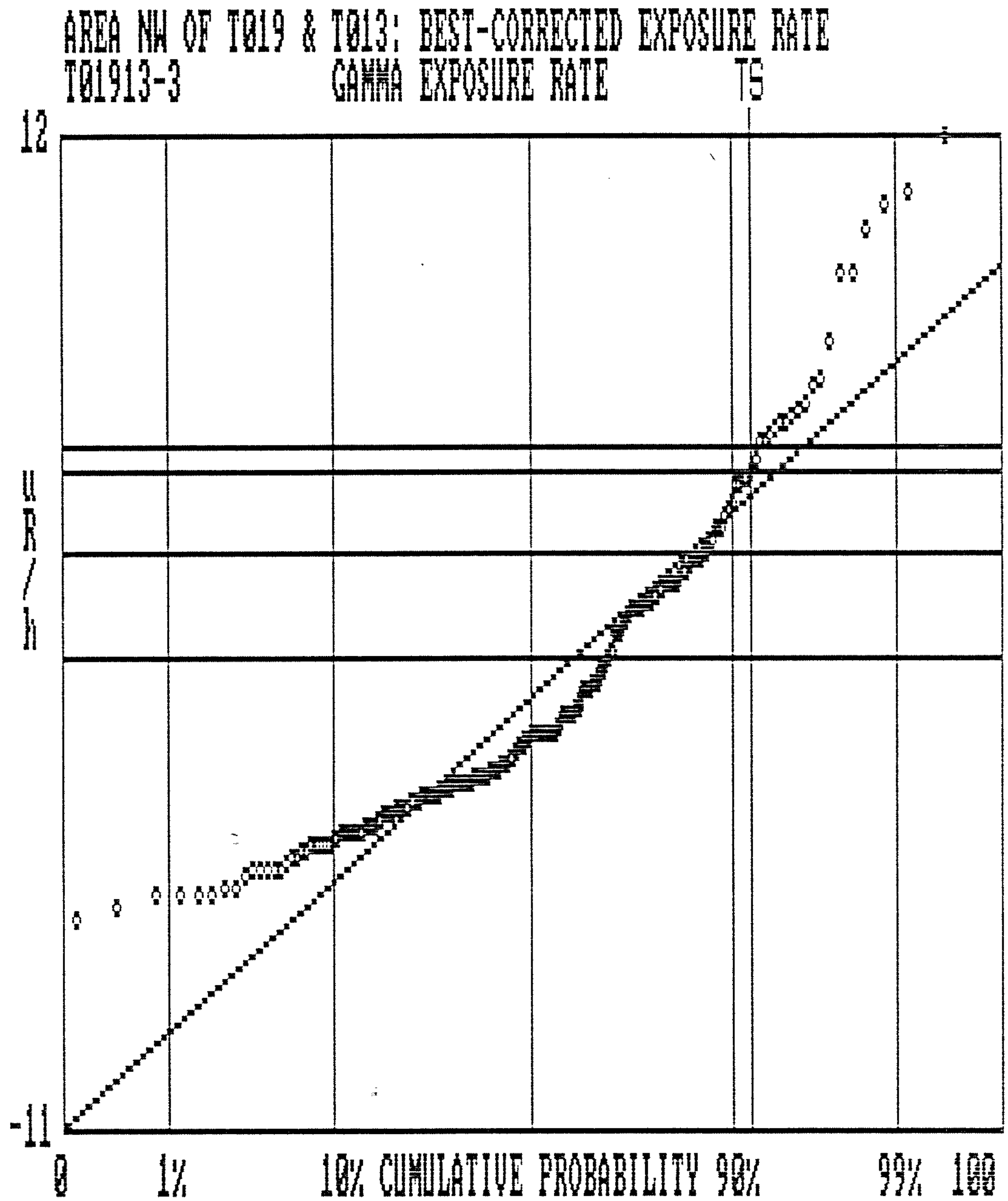


Figure 7.9 Background-Corrected Ambient Gamma Exposure Rates in the NW Area (247 Measurements)



7.2.5 Further Investigation of the NW Area

Figures 7.8 and 7.9 showed two incongruous Gaussian distributions for the NW Area and that several individual measurements appear to exceed our 50% Reinspection Level. The reason for this "appearance" is a function of what value is chosen for "ambient background." In the case of Figure 7.9, 15.3 μR/h was too low. As part of a reinspection effort, the distribution of measurements was divided at about 60% cumulative probability and treated independently, corresponding to the two Gaussian distributions. The greatest measurements (120) were analyzed separately from the least measurements (127). Figures 7.10 through 7.13 show the results of this reinspection and analysis.

Figure 7.10 shows the statistical distribution of gross-total gamma exposure rate measurements plotted against cumulative probability for the greatest measurements. The outliers at the low end (a straight line with 0 slope) is actually part of the lower-half measurements; they are insignificant. The distribution follows a fairly well-fit Gaussian with seven outliers at the high end. An average of 17.0 μR/h is about 2 μR/h higher than would be expected in natural terrain, and the deviations are more pronounced; this is attributed to significant changes in topography. Measurement locations of the seven outliers are in the area nearest the RMDF (about 300 ft from Building 075), used for storing radioactive materials. These increased readings are attributed to those operations. Appendix D.3 shows pictorially the locations from where the greatest measurements were collected. Out of coincidence, Appendix D.3 shows that the greatest measurements were collected from the natural terrain area and the eastern border near the RMDF; the least measurements were collected from the asphalt concrete equipment yard. Accepting the condition that the RMDF can increase local ambient background by as much as 3 to 5 μR/h, and that this effect is strongly dependent on location and landscape characteristics, these greater measurements are understood. No trends indicating a contaminated area are observed.

Figure 7.10 Greatest Total-Gross Ambient Gamma Exposure Rates in the NW Area (120 Measurements)

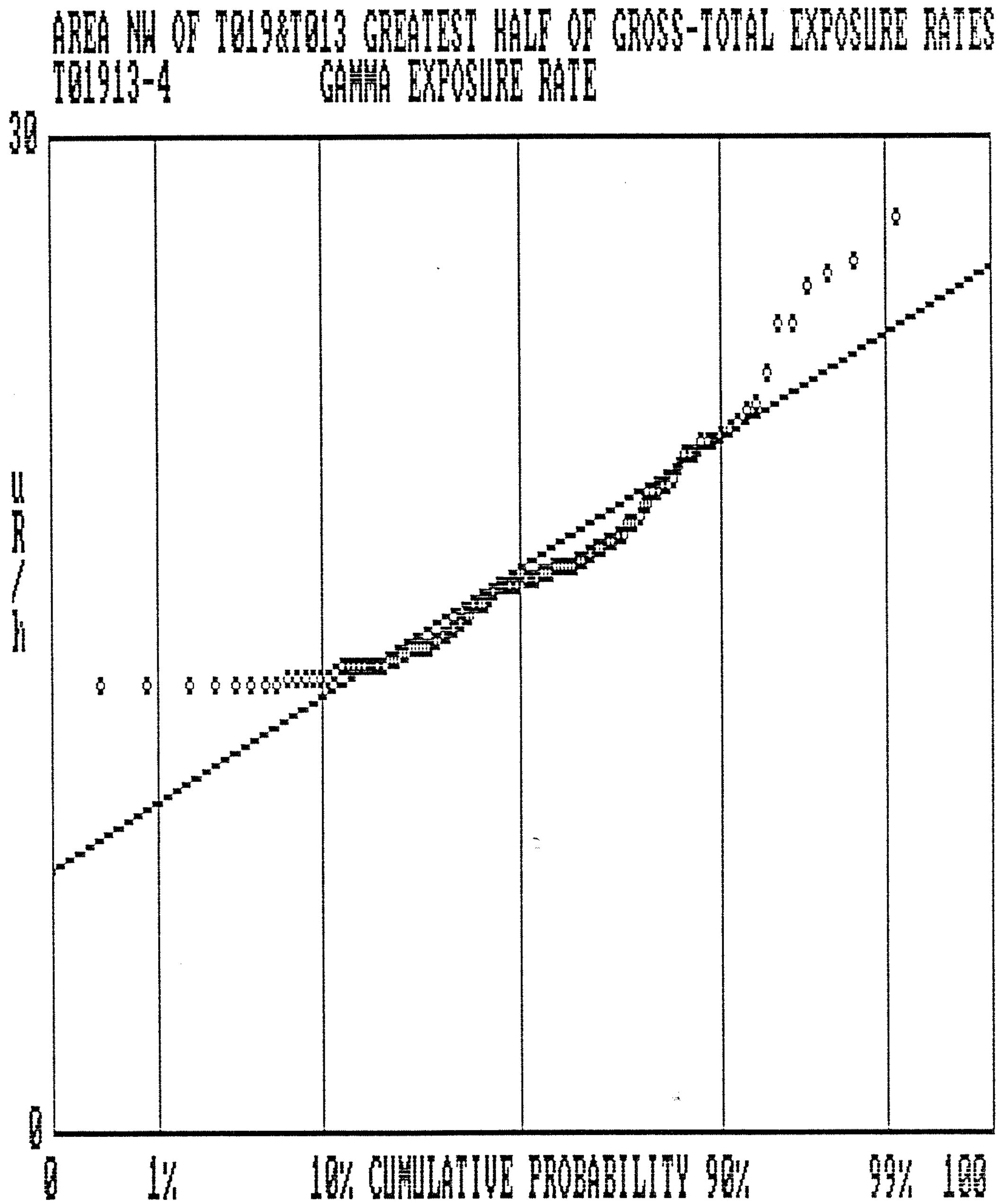


Figure 7.11 shows the same data set, in which case a correction for "ambient background" was made uniformly to each measurement value. 15.30 μR/h was used for "background" subtraction, corresponding to the average of the three "natural background" measurements presented earlier. This figure shows an average of 1.71 $\pm$ 3.05 μR/h and an inspection test statistic of 6.13 μR/h, which fails our acceptance tests. However, "ambient background" in this area is greater than "natural background" described, so a correction must be made based on RMDF gamma-radiation influence, severe topography changes, and major sandstone outcroppings. These factors probably add up to an additional 5 μR/h to "ambient background," and again this increase is highly location dependent; thus the large standard deviation of these measurements. By conservatively correcting these measurements by an additional 4 μR/h, the inspection test statistic becomes 2.4 μR/h and we conclude that this area is uncontaminated by this inspection method. Refer to Appendices C.6 and D.3 to observe the measurement values, locations, and topography of these greatest measurements.

Figure 7.12 shows the statistical distribution of gross-total gamma exposure rate measurements plotted against cumulative probability for the least measurements of the NW Area. This test-area is flat, asphalt concrete pavement. A well-fitted Gaussian distribution is presented with no outliers or significant deviations. This is a model sampling lot. An average of 11.9 $\pm$ 0.98 μR/h is slightly lower than our natural terrain, "natural background" distributions, and shows another geometry and material affect. No trends indicating a contaminated area are observed.

Figure 7.13 shows the same data set, in which case a correction for "ambient background" was made uniformly to each measurement value. Since the average exposure rate (11.9 μR/h) is 3.4 μR/h less than the "natural background" value of 15.3 μR/h, 12.2 μR/h was used for "background" subtraction, corresponding to the median of values presented in Figure 7.12. The median value is an unbiased estimator of the Gaussian mean for "ambient background" of a sample lot.

Figure 7.11 Greatest Background-Corrected Ambient Gamma Exposure Rate in the NW Area (120 Measurements)

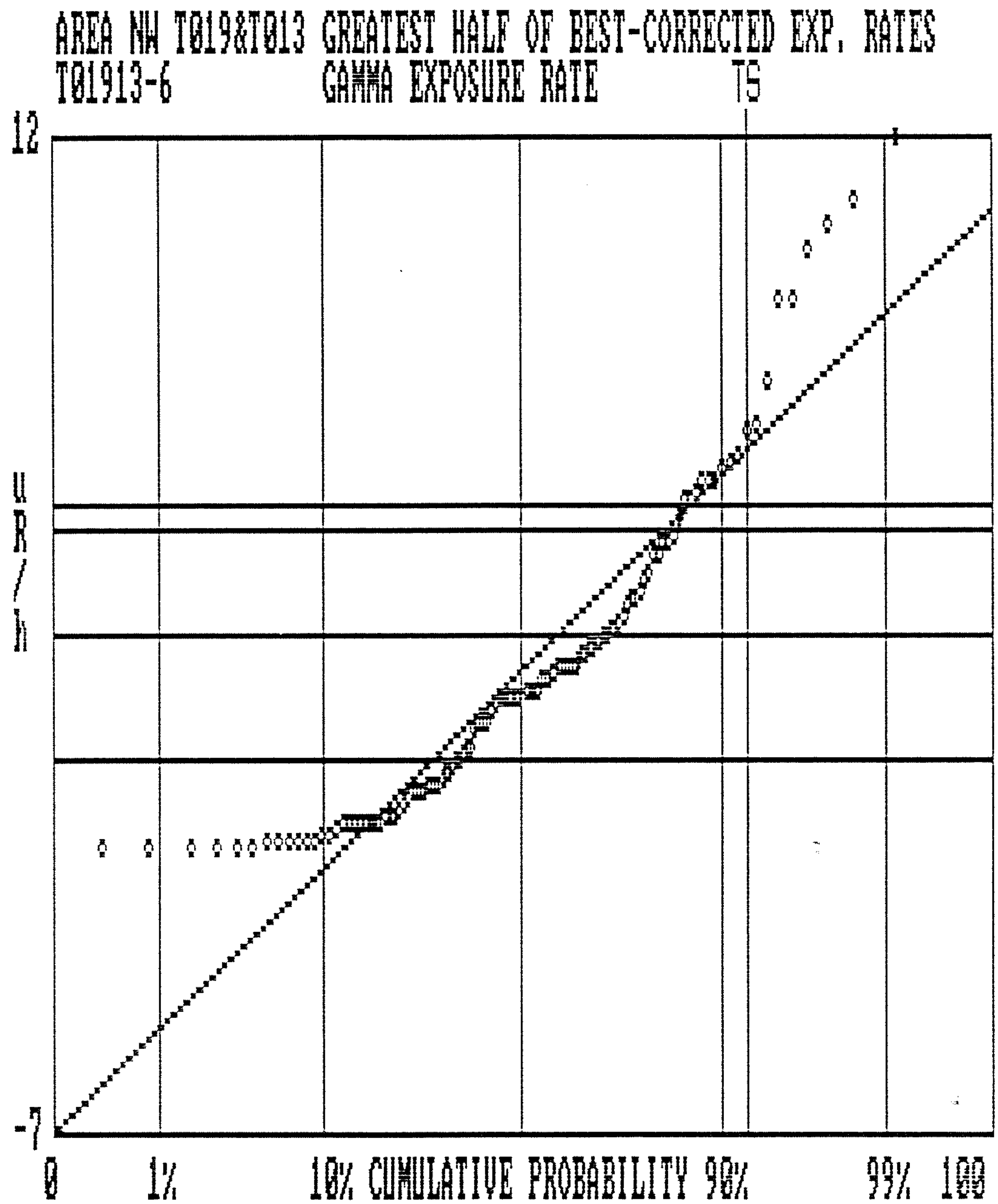


Figure 7.12 Least Total-Gross Ambient Gamma Exposure Rates in the NW Area (127 Measurements)

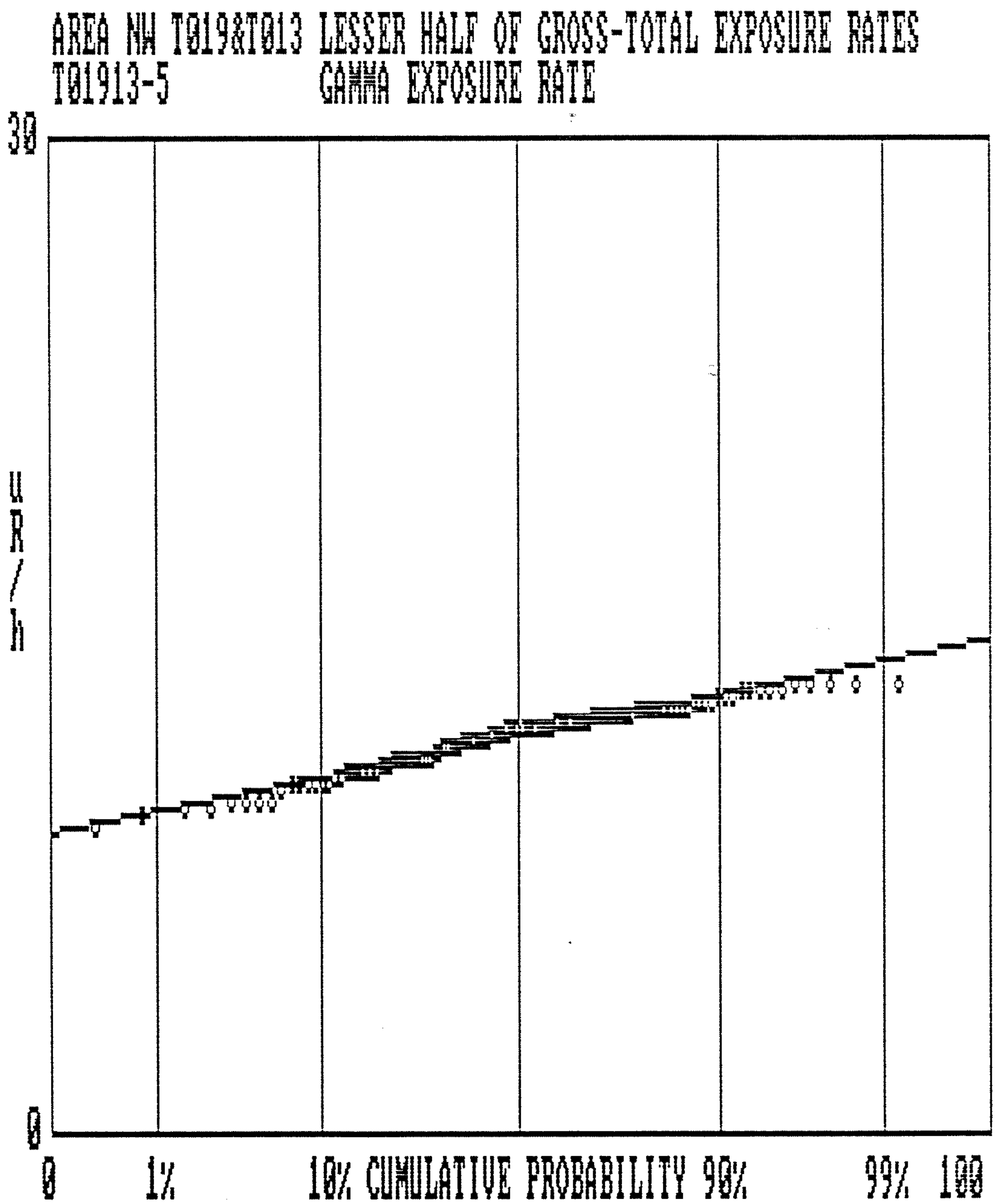
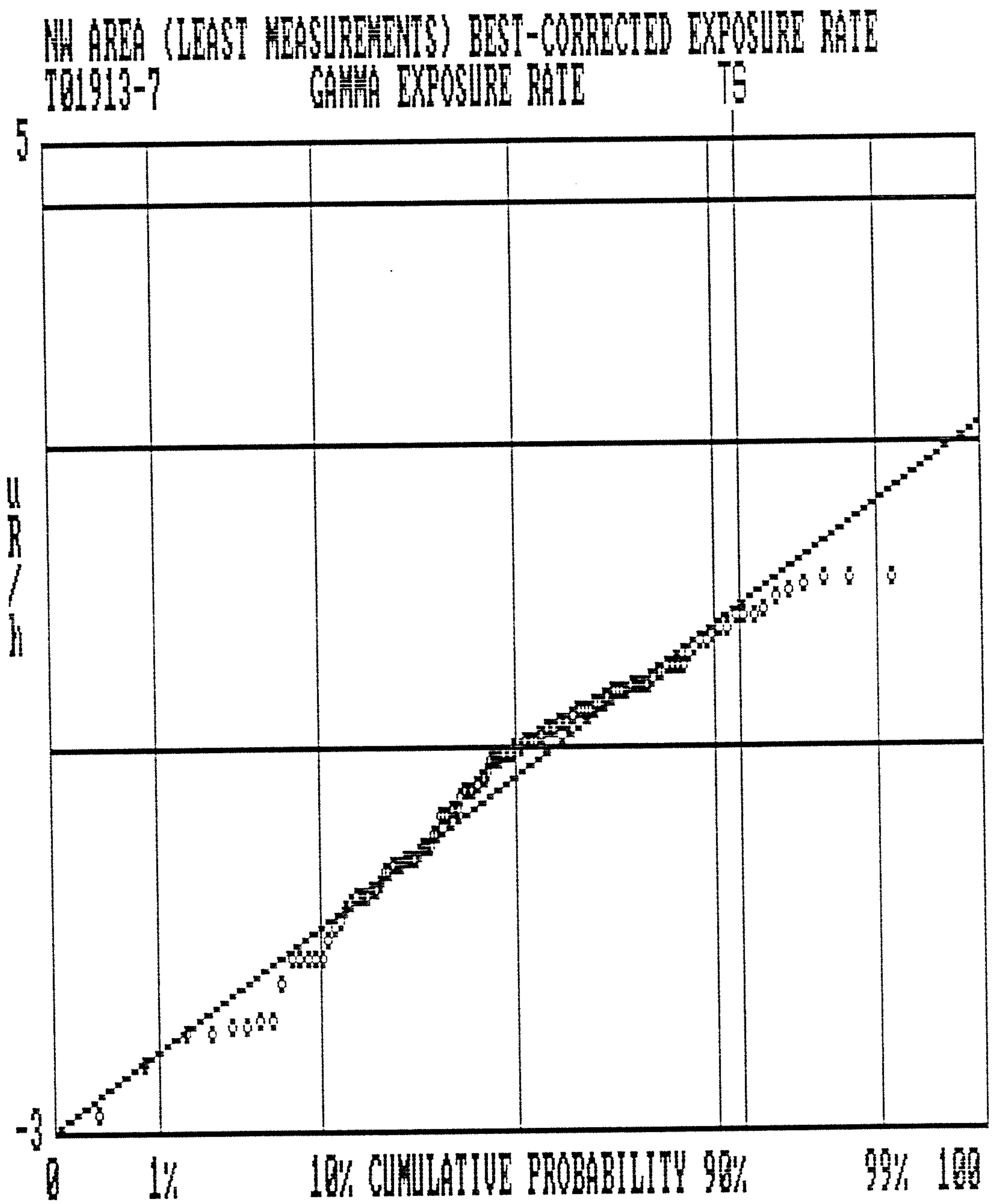


Figure 7.13 Least Background-Corrected Ambient Gamma Exposure Rates in the NW Area (127 Measurements)



Deviations observed in the measurements because of equipment and tanks in the yard are pronounced in this figure because the ordinate scale has been expanded. An average of 0.26 $\pm$ 1.38 μR/h and the inspection test statistic, 1.15 μR/h, are less than the 5 μR/h acceptance limit. We accept this area as uncontaminated by this inspection method. No further investigation is required.

7.2.6 T626 Storage Area

Figure 7.14 shows the statistical distribution of gross-total gamma exposure rate measurements plotted against cumulative probability for the T626 Storage Area. This test-area is asphalt concrete pavement surrounded by buildings and cluttered with salvageable parts, trailers, and equipment. An average of 11.2 $\pm$ 1.67 μR/h is equivalent to the paved portion of the NW Area, as expected for an uncontaminated area. No outliers or significant deviations exist. No trends indicating a contaminated area are observed.

Figure 7.15 shows the same data set, in which case a correction for "ambient background" was made uniformly to each measurement value. 1.2 μR/h was used for "background" subtraction, corresponding to the median value of gross-total measurements in Figure 7.14. The median value is an unbiased estimator for "ambient background." Deviations observed in the measurements because of equipment and nearby facilities are pronounced in this figure because the ordinate scale has been expanded. An average of 0.03 $\pm$ 1.67 μR/h and the inspection test statistic, 1.67 μR/h, are less than the 5 μR/h acceptance limit. Five data points exceed our 50% Reinspection Level. Four of five were made next to sandstone outcroppings; an increase of this magnitude was observed in natural terrain. The other measurement is anomalous. We accept this area as uncontaminated by this inspection method. No further investigation is required.

Figure 7.14 Total-Gross Ambient Gamma Exposure Rates at the Outside T626 Storage Area

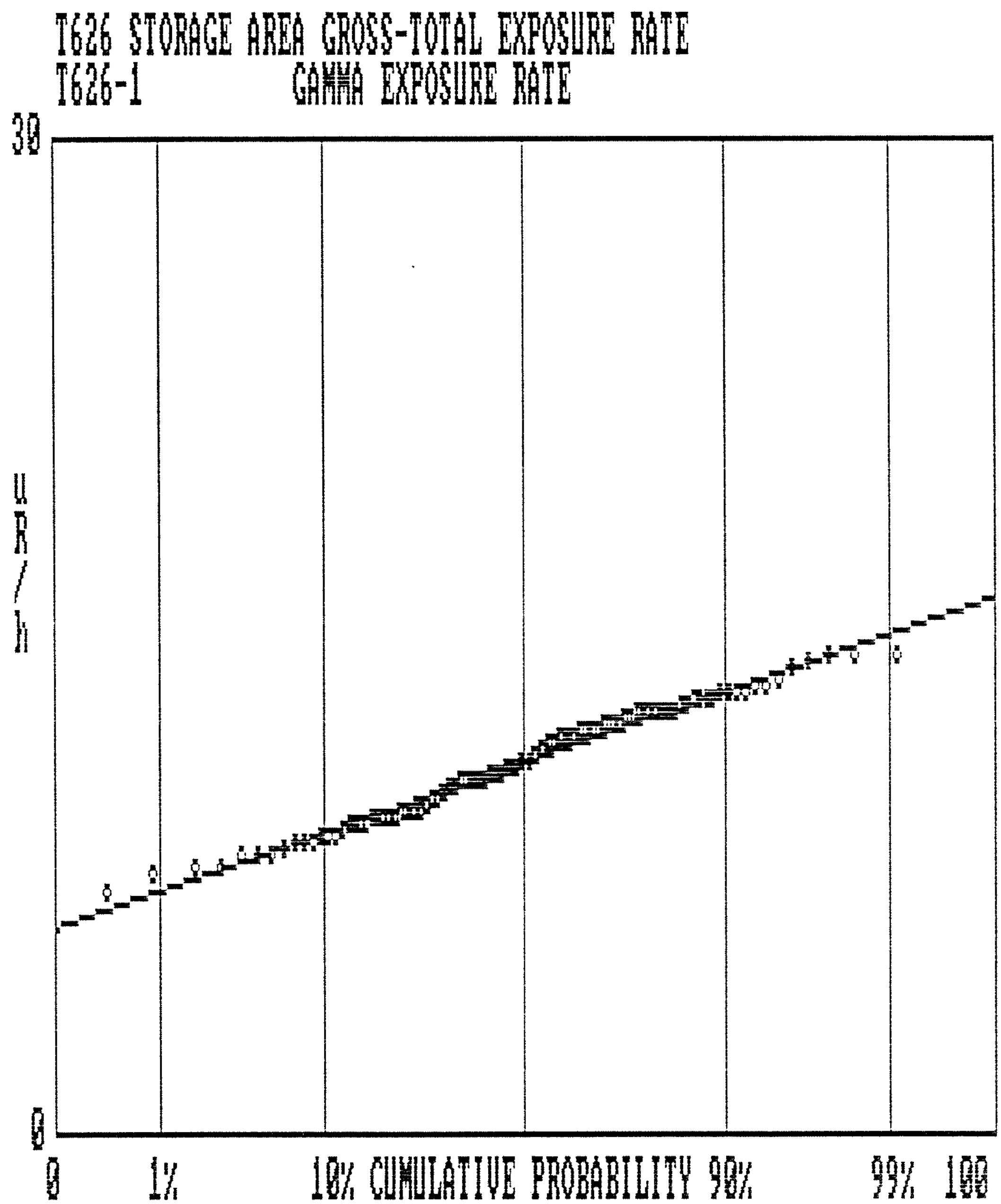
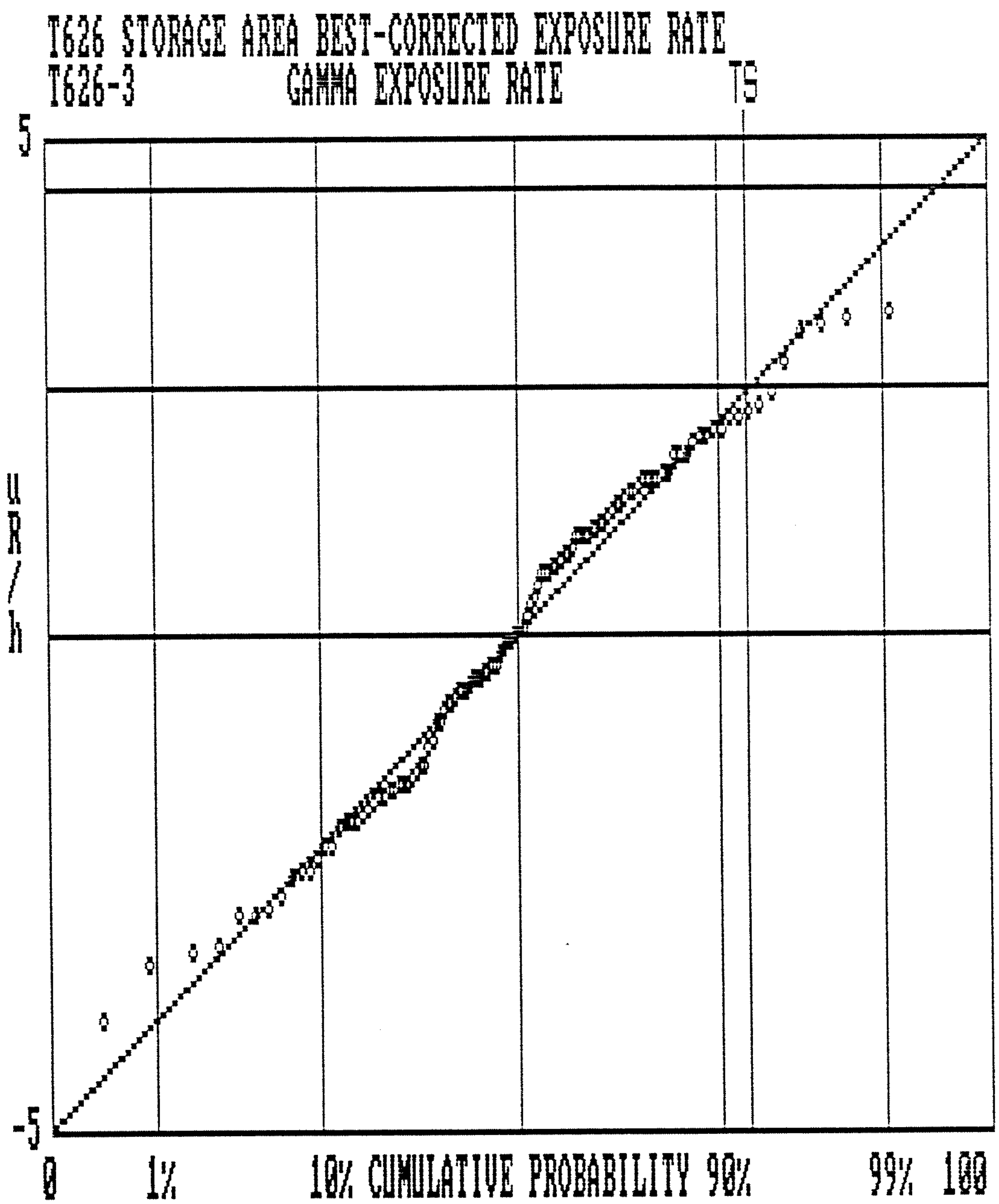


Figure 7.15 Background-Corrected Ambient Gamma Exposure Rates at the Outside T626 Storage Area



7.3 Surface Beta Activity Measurements

Surface beta activity measurements were performed "for indication" in T019's vault and northwest corner of the high bay. The vault floor was surveyed because of the capacity in which it was used -- storing nuclear fuel. The northwest corner of the high bay was surveyed because of an anomalous gamma exposure rate reading; that entire area (10 m^2) was surveyed with a pancake GM. In all cases, No Detectable Activity was observed.

7.4 Assessment of Radiological Condition

Analysis and interpretation of exposure rate measurements collected for this radiological survey became an exercise in assessing the variability of "ambient background" at SSFL, and the factors which influence these measurements. A culmination of various factors affected ambient exposure rate for this survey:

1) Indoor vs. Outdoor changes in "natural background;"
2) Significantly rugged natural terrain;
3) Asphalt concrete pavement;
4) Storage of large metal equipment items on-site; and
5) Nearby RMDF, where radioactive materials are stored.

Best-estimate corrections which account for these ambient variations were applied specifically to each sample lot. Outliers in each distribution were reinspected. Exposure rate mapping was performed (Appendix D.3) for the NW Area to show the RMDF influence and topography affects on exposure rate. Application of these corrections for "ambient background" and statistical analyses show that all sampled areas are acceptably clean. A summary of background-corrected statistics for these data sets is presented in Table 7.2. Note the comments after the table which explain the "ambient background" basis. All areas pass criteria for unrestricted use. We are confident that the sensitivity and sampling frequency of exposure rate measurements is sufficient for identifying suspect contamination even though the "noise" level was greater than usual.

Table 7.2 Summary of Gamma Exposure Rate Data Corrected for Background and Statistically Tested Against Acceptance Limits

Sample Lot	Ambient Background Value (μR/h)	Average Value (μR/h)	Standard Deviation (μR/h)	Maximum Value (μR/h)	Inspection Test Statistic (μR/h)	Acceptance Limit (μR/h)
Building T019	7.75 (1)	0.04	1.09	4.25	1.69	5
T019 Vault	12.35 (1)	0.07	0.88	0.96	N/A	5
Building T013	7.04 (1)	-0.19	1.00	1.96	1.32	5
NW Area (Greatest Measurements)*	15.30 (2)	1.71	3.05	12.31	6.13	5
	19.00 (2*)	-1.99	3.05	8.61	2.43	5
NW Area (Least Measurements)**	12.16 (3)	-0.26	0.98	1.38	1.15	5
T626 Storage Area	11.18 (3)	0.03	1.67	3.30	2.45	5

* Corresponds to measurements acquired between boundary fence-line and property-line in very rugged terrain.

** Corresponds to measurement acquired within the boundary fence-line on asphalt concrete pavement.

N/A Not Applicable - 10 measurements made "for indication."

(1) Ambient background based on median value of exposure rate measurements acquired in that test-area. These test-areas are indoors. Exposure rates vary with construction materials. For large rooms with concrete floors and metal siding, expect 7 to 8 μR/h background. For small rooms with cinder block walls, expect 12 to 13 μR/h background.

(2) Ambient background based on average "natural background" calculated from the three "background" distributions because topography is similar, yet the NW Area is more rugged.

(2*) "Natural background" contribution(2) plus RMDF direct radiation and skyshine contribution (estimated at 3 to 4 μR/h at 300 ft).

(3) Ambient background based on median value of exposure rate measurements acquired in that test-area. These test-areas are outdoors, on asphalt concrete pavement. "Natural background" is less here than in natural terrain.

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8.0 CONCLUSIONS

Buildings T019 and T013, an outdoor area northwest of the SNAP complex (Buildings T059, T019, T013, and T012), and a storage area west of Buildings T626 and T038 were inspected for radioactive contaminants. Gamma exposure rate measurements were made on a 6-m square sampling grid, according to the Site Survey Plan (Reference 4). Exposure rate measurements plotted against cumulative probability show that "ambient background" radiation from area to area can vary by as much as 12 μR/h. Exposure rate is dependent on local topography, natural landscape conditions, vicinity of large structures or equipment, building materials, and location relative to the RMDF where radioactive materials are stored in Building T075. The deviations observed in data collected for these inspected areas are attributed to ambient radiation conditions. This particular survey was an exercise in assessment of "ambient background." Results from these inspected areas were different from three control-group areas considered to be "natural background." The sample lot averages were in two cases, less than "natural background," and in two cases, greater than "natural background." The measurement variations observed in these sample lots were in all cases, significantly greater than "natural background." When proper adjustments are made to the data to account for "ambient background," the distributions show no trends indicating possible contamination. These locations pass as acceptably clean by our test criteria.

During performance of this particular survey, further reinspection and investigation were required and performed. First, one anomalous measurement was recorded in the northwest corner of the high bay at Building T019. Twenty-one additional gamma measurements were collected and a survey for beta activity was performed in that location. All repeated measurements show a purely anomalous measurement. Second, a few measurement outliers above the Gaussian were observed in outdoor locations nearest the RMDF and in direct line-of-site with Building T075. These increased values are attributed to direct radiation and skyshine. Third, a few measurement outliers above the Gaussian were observed in the T626 Storage Area. These are insignificant outliers and were regarded as anomalous because of topographical conditions. Finally, the process of adjusting for "ambient background" as a non-uniform occurrence as a function of measurement location was required and estimated.

Based on these statistical distributions of exposure rate measurements corrected for what we found to be "ambient background" in each sample lot, we conclude through inspection by variables, that all locations surveyed do not contain residual radioactivity. The boundary condition of this statistical test assumes a consumer's risk of acceptance of 0.1 at an LTPD of 10%. No further inspection is required in these locations.

9.0 REFERENCES

1. "Guidelines for Residual Radioactivity at FUSRAP and Remote SFMP Sites," U.S. DOE, March 5, 1985.

2. "Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Licenses for Byproduct, Source, or Special Nuclear Material," Annex B, USNRC License SNM-21, Docket 70-25, Issued to Energy Systems Group of Rockwell International, last revision June 5, 1984.

3. "State of California Guidelines for Decontaminating Facilities and Equipment Prior to Release for Unrestricted Use," DECON-1, Revised March 24, 1983.

4. "Radiological Survey Plan for SSFL," 154SRR000001, F. H. Badger and R. J. Tuttle, Rockwell International, September 25, 1985.

5. "Long Range Plan for Decommissioning Surplus Facilities at the Santa Susana Field Laboratories," N001TI000200, W.D. Kittinger, Rockwell International, September 30, 1983.

6. "Final Radiation Survey of the NMDF," N704SRR990027, J. A. Chapman, Rockwell International, December 19, 1986.

7. "Draft American National Standard Control of Radioactive Surface Contamination on Materials, Equipment, and Facilities to be Released for Uncontrolled Use," ANSI N13.12, August 1978, American National Standards Institute, Inc.

8. "Selected Techniques of Statistical Analysis," Statistical Research Group, Columbia University, McGraw-Hill Book Co., Inc., 1947.

9. "Some Theory of Sampling," W. E. Deming, Dover Publications, Inc., New York, 1950.

10. "Statistics in Research," B. Ostle and R. Mensing, The Iowa State University Press, 1979.

11. "Measurement and Detection of Radiation," N. Tsoulfanidis, Hemisphere Publishing Corp., Washington D.C., 1983.

12. "Standards for Protection Against Radiation," Title 10 Part 20, Code of Federal Regulations, January 1, 1985.

13. "Rocketdyne Division Environmental Monitoring and Facility Effluent Annual report Desoto and Santa Susana Field Laboratories Sites 1986," RI/RD87-133, J. D. Moore, Rockwell International, March 1987.

14. "Sampling Procedures and Tables for Inspection by Variables for Percent Defective," MIL-STD-414, June 11, 1957.

15. "Lower Limit of Detection and Statistically Significant Activity for Radiologic Measurements," IL from R. J. Tuttle to Radiation and Nuclear Safety, RI, June 24, 1986.

16. "Radiological Survey of Building T005," GEN-ZR-0003, J. A. Chapman, Rockwell International, February 1, 1988.

17. "Radiological Survey of the Sodium Disposal Facility - Building T886," GEN-ZR-0004, J. A. Chapman, Rockwell International, June 3, 1988.

18. "Radiological Survey of the Source and Special Nuclear Material Storage Vault - Building T064", GEN-ZR-0005, J. A. Chapman, Rocketdyne/Rockwell International, August, 1988.

19. "Radiological Survey of the Old Calibration Facility - Building T029", GEN-ZR-006, J. A. Chapman, Rocketdyne/Rockwell International, August, 1988

20. "Radiological Survey of Shipping/Receiving and Old Accelerator Area - Building T641 and T030", GEN-ZR-0007, J. A. Chapman, Rocketdyne/Rockwell International, August, 1988

21. "Radiological Survey of the Old ESG Salvage Yard, Rocketdyne Barrel Storage Yard, and New Salvage Yard (T583)", GEN-ZR-0008, J. A. Chapman, Rocketdyne/Rockwell International, August, 1988

22. "Radiological Survey of the T513 Parking Lot; Old R/A Laundry Area; Plot 333; and Areas Between the SRE-to-RMDF, and KEWB-to-RMDF", GEN-ZR-0009, J. A. Chapman, Rocketdyne/Rockwell International, September, 1988

23. "Evaluation of the Atomics International Nuclear Development Field Laboratory as a Location for Reactor Facilities", NAA-SR-7300, Atomics International, May 25, 1962

24. "Disposal or Onsite Storage of Thorium or Uranium Wastes from Past Operations", Federal Register Vol. 46, No. 205, October 31, 1981

APPENDIX A. DESCRIPTION OF NUCLEAR INSTRUMENTATION

During the radiological survey, direct radiation measurements were made by using portable instruments. Because sample collection was not necessary, analytical laboratory equipment was not required.

A Ludlum model 2220-ESG portable scaler/ratemeter was coupled to a Ludlum model 44-10 NaI gamma scintillator for detecting gamma radiation. The NaI (Tl) crystal is extremely sensitive to changes in gamma flux. The probe efficiency varies with exposure rate. At background ambient gamma exposure rates, the efficiency is about 215 cpm/μR/h. This determination was made by calibrating the 2220-ESG against a Reuter Stokes High-Pressure Ion Chamber (HPIC). The HPIC displays a digital readout every 3 to 4 seconds in μR/h.

A Ludlum model 12 count-ratemeter was coupled to a Ludlum model 44-9 pancake G-M beta probe to measure beta contamination. The probe active area is 20 cm^2. Instrument calibration is performed using Tc-99. This instrument is best suited "for indication" determinations.

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APPENDIX B. COPY OF DOE REPORT,

"GUIDELINES FOR RESIDUAL RADIOACTIVITY AT FUSRAP AND REMOTE SFMP SITES," March, 1985

MAR 6 '85 PM

Department of Energy
Richland Operations Office
P.O. Box 550
Richland, Washington 99352

MAR 05 1985

CORRESPONDENCE

Addressees

GUIDELINES FOR RESIDUAL RADIOACTIVITY AT FUSRAP AND REMOTE SFMP SITES

The attached guidelines, "U.S. Department of Energy Guidelines for Residual Radioactivity at Formerly Utilized Sites Remedial Action Program and Remote Surplus Facilities Management Program Sites," (January 1985) have been issued by the Division of Remedial Action Projects for implementation by FUSRAP and SFMP in order to establish authorized limits for remedial actions. While these Guidelines are specifically intended for "remote" SFMP sites (those located outside a major DOE R&D or production site), they should be taken into consideration when developing authorized limits for remedial actions on major DOE reservations. The guidelines provide specific authorized limits for residual radium and thorium radioisotopes in soil, for airborne radon decay products, for external gamma radiation, and for residual surface contamination levels on materials to be released for unrestricted use. These guidelines will be supplemented in the near future by a document providing the methodology and guidance to establish authorized limits for residual radioisotopes other than radium and thorium in soil at sites to be certified for unrestricted use. The supplement will provide further guidance on the philosophies, scenarios, and pathways to derive appropriate authorized limits for residual radionuclides and mixtures in soil. These guidelines are based on the International Commission on Radiation Protection (ICRP) philosophies and dose limits in ICRP reports 26 and 30 as interpreted in the draft revised DOE Order 5480.1A. These dose limits are 500 mrem/yr for an individual member of the public over a short period of time and an average of 100 mrem/yr over a lifetime.

The approval of authorized limits differing from the guidelines is described in Section D, last sentence of the attached document. If the urgency of field activity makes DRAP concurrence not cost effective, a copy of the approval and backup analysis should be furnished to DRAP as soon as possible, although not necessarily prior to beginning field activities. This does not remove the requirement for approval by SFMPO.

As a result of a recent court decision, the Environmental Protection Agency (EPA) has issued airborne radiation standards applicable to DOE facilities. These final standards, issued as revisions to 40 CFR 61, are:

- 25 mrem/yr-whole body
- 75 mrem/yr-organ
- waiver of these standards will be granted if DOE demonstrates that no individual would receive 100 mrem/yr continuous exposure whole body dose equivalent from all sources within 10 km radius, excluding natural background and medical procedures
- radon and radon daughters are excluded (these standards are covered in 40 CFR 192)

The attached guidelines were written to be consistent with the revision of the DOE Order 5480.1A now in draft at Headquarters and have received the concurrence of the Public Safety Division, Office of Operational Safety. The guidelines will be included in the SFMP Program Plan beginning with the next revision (for FY 1986-1990).

Please refer any questions to Paul F. X. Dunigan, Jr. (FTS 444-6667), of my staff.

Clarence E. Miller, Jr.

Clarence E. Miller, Jr., Director
Surplus Facilities Management
Program Office

SFMPO:PFXD

Attachment:
As stated

cc: R. N. Coy, UNC
E. G. DeLaney, NE-24, HQ

U.S. DEPARTMENT OF ENERGY GUIDELINES FOR RESIDUAL RADIOACTIVITY AT FORMERLY UTILIZED SITES REMEDIAL ACTION PROGRAM AND REMOTE SURPLUS FACILITIES MANAGEMENT PROGRAM SITES

(February 1985)

A. INTRODUCTION

This document presents U.S. Department of Energy (DOE) radiological protection guidelines for cleanup of residual radioactive materials and management of the resulting wastes and residues. It is applicable to sites identified by the Formerly Utilized Sites Remedial Action Program (FUSRAP) and remote sites identified by the Surplus Facilities Management Program (SFMP).* The topics covered are basic dose limits, guidelines and authorized limits for allowable levels of residual radioactivity, and requirements for control of the radioactive wastes and residues.

Protocols for identification, characterization, and designation of FUSRAP sites for remedial action; for implementation of the remedial action; and for certification of a FUSRAP site for release for unrestricted use are given in a separate document (U.S. Dept. Energy 1984). More detailed information on applications of the guidelines presented herein, including procedures for deriving site-specific guidelines for allowable levels of residual radioactivity from basic dose limits, is contained in a supplementary document--referred to herein as the "supplement" (U.S. Dept. Energy 1985).

"Residual radioactivity" includes: (1) residual concentrations of radionuclides in soil material,** (2) concentrations of airborne radon decay products, (3) external gamma radiation level, and (4) surface contamination. A "basic dose limit" is a prescribed standard from which limits for quantities that can be monitored and controlled are derived; it is specified in terms of the effective dose equivalent as defined by the International Commission on Radiological Protection (ICRP 1977, 1978). Basic dose limits are used explicitly for deriving guidelines for residual concentrations of radionuclides in soil material, except for thorium and radium. Guidelines for

*A remote SFMP site is one that is excess to DOE programmatic needs and is located outside a major operating DOE research and development or production area.

**The term "soil material" refers to all material below grade level after remedial action is completed.

residual concentrations of thorium and radium and for the other three quantities (airborne radon decay products, external gamma radiation level, and surface contamination) are based on existing radiological protection standards (U.S. Environ. Prot. Agency 1983; U.S. Nucl. Reg. Comm. 1982). These standards are assumed to be consistent with basic dose limits within the uncertainty of derivations of levels of residual radioactivity from basic limits.

A "guideline" for residual radioactivity is a level of residual radioactivity that is acceptable if the use of the site is to be unrestricted. Guidelines for residual radioactivity presented herein are of two kinds: (1) generic, site-independent guidelines taken from existing radiation protection standards, and (2) site-specific guidelines derived from basic dose limits using site-specific models and data. Generic guideline values are presented in this document. Procedures and data for deriving site-specific guideline values are given in the supplement.

An "authorized limit" is a level of residual radioactivity that must not be exceeded if the remedial action is to be considered completed. Under normal circumstances, expected to occur at most sites, authorized limits are set equal to guideline values for residual radioactivity that are acceptable if use of the site is not be restricted. If the authorized limit is set higher than the guideline, restrictions and controls must be established for use of the site. Exceptional circumstances for which authorized limits might differ from guideline values are specified in Sections D and F. The restrictions and controls that must be placed on the site if authorized limits are set higher than guidelines are described in Section E.

DOE policy requires that all exposures to radiation be limited to levels that are as low as reasonably achievable (ALARA). Implementation of ALARA policy is specified as procedures to be applied after authorized limits have been set. For sites to be released for unrestricted use, the intent is to reduce residual radioactivity to levels that are as far below authorized limits as reasonable considering technical, economic, and social factors. At sites where the residual radioactivity is not reduced to levels that permit release for unrestricted use, ALARA policy is implemented by establishing controls to reduce exposure to ALARA levels. Procedures for implementing ALARA policy are described in the supplement. ALARA policies, procedures, and actions must be documented and filed as a permanent record upon completion of remedial action at a site.

B. BASIC DOSE LIMITS

The basic limit for the annual radiation dose received by an individual member of the general public is 500 mrem/yr for a period of exposure not to exceed 5 years and an average of 100 mrem/yr over a lifetime. The committed effective dose equivalent, as defined in ICRP Publication 26 (ICRP 1977) and calculated by dosimetry models described in ICRP Publication 30 (ICRP 1978), shall be used for determining the dose.

C. GUIDELINES FOR RESIDUAL RADIOACTIVITY

C.1 Residual Radionuclides in Soil Material

Residual concentrations of radionuclides in soil material shall be specified as above-background concentrations averaged over an area of 100 m^2. If the concentration in any area is found to exceed the average by a factor greater than 3, guidelines for local concentrations shall also be applicable. These "hot spot" guidelines depend on the extent of the elevated local concentrations and are given in the supplement.

The generic guidelines specified below are for concentrations of individual radionuclides occurring alone. If mixtures of radionuclides are present, the concentrations of individual radionuclides shall be reduced so that the dose for the mixture would not exceed the basic dose limit. Explicit formulas for calculating residual concentration guidelines for mixtures are given in the supplement.

The generic guidelines for residual concentrations of Th-232, Th-230, Ra-228, and Ra-226 are:

- 5 pCi/g, averaged over the first 15 cm of soil below the surface

- 15 pCi/g, averaged over 15-cm-thick layers of soil more than 15 cm below the surface

The guidelines for residual concentrations in soil material of all other radionuclides shall be derived from basic dose limits by means of an environmental pathway analysis using site-specific data. Procedures for deriving these guidelines are given in the supplement.

C.2 Airborne Radon Decay Products

Generic guidelines for concentrations of airborne radon decay products shall apply to existing occupied or habitable structures on private property that are intended for unrestricted use; structures that will be demolished or buried are excluded. The applicable generic guideline (40 CFR 192) is: In any occupied or habitable building, the objective of remedial action shall be, and reasonable effort shall be made to achieve, an annual average (or equivalent) radon decay product concentration (including background) not to exceed 0.02 WL.* In any case, the radon decay product concentration (including background) shall not exceed 0.03 WL. Remedial actions are not required in order to comply with this guideline when there is reasonable assurance that residual radioactive materials are not the cause.

C.3. External Gamma Radiation

The level of gamma radiation at any location on a site to be released for unrestricted use, whether inside an occupied building or habitable structure or outdoors, shall not exceed the background level by more than 20 μR/h.

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*A working level (WL) is any combination of short-lived radon decay products in one liter of air that will result in the ultimate emission of 1.3×10^5 MeV of potential alpha energy.

C.4 Surface Contamination

The following generic guidelines, adapted from standards of the U.S. Nuclear Regulatory Commission (1982), are applicable only to existing structures and equipment that will not be demolished and buried. They apply to both interior and exterior surfaces. If a building is demolished and buried, the guidelines in Section C.1 are applicable to the resulting contamination in the ground.

	Allowable Total Residual Surface Contamination (dpm/100 cm^2)†1		
Radionuclides†2	Average†3,†4	Maximum†4,†5	Removable†6
Transuranics, Ra-226, Ra-228, Th-230, Th-228, Pa-231, Ac-227, I-125, I-129	100	300	20
Th-Natural, Th-232, Sr-90, Ra-223, Ra-224, U-232, I-126, I-131, I-133	1,000	3,000	200
U-Natural, U-235, U-238, and associated decay products	5,000α	15,000α	1,000α
Beta-gamma emitters (radionuclides with decay modes other than alpha emission or spontaneous fission) except Sr-90 and others noted above	5,000β-γ	15,000β-γ	1,000β-γ

†1 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 measured by an appropriate detector for background, efficiency, and geometric factors associated with the instrumentation.

†2 Where surface contamination by both alpha- and beta-gamma-emitting radionuclides exists, the limits established for alpha- and beta-gamma-emitting radionuclides should apply independently.

†3 Measurements of average contamination should not be averaged over an area of more than 1 m^2. For objects of less surface area, the average should be derived for each such object.

†4 The average and maximum dose rates associated with surface contamination resulting from beta-gamma emitters should not exceed 0.2 mrad/h and 1.0 mrad/h, respectively, at 1 cm.

†5 The maximum contamination level applies to an area of not more than 100 cm^2.

†6 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 measuring the amount of radioactive material on the wipe with an appropriate instrument of known efficiency. When removable contamination on objects of surface area less than 100 cm^2 is determined, the activity per unit area should be based on the actual area and the entire surface should be wiped. The numbers in this column are maximum amounts.

D. AUTHORIZED LIMITS FOR RESIDUAL RADIOACTIVITY

The remedial action shall not be considered complete unless the residual radioactivity is below authorized limits. Authorized limits shall be set equal to guidelines for residual radioactivity unless: (1) exceptions specified in Section F of this document are applicable, in which case an authorized limit may be set above the guideline value for the specific location or condition to which the exception is applicable; or (2) on the basis of site-specific data not used in establishing the guidelines, it can be clearly established that limits below the guidelines are reasonable and can be achieved without appreciable increase in cost of the remedial action. Authorized limits that differ from guidelines must be justified and established on a site-specific basis, with documentation that must be filed as a permanent record upon completion of remedial action at a site. Authorized limits differing from the guidelines must be approved by the Director, Oak Ridge Technical Services Division, for FUSRAP and by the Director, Richland Surplus Facilities Management Program Office, for remote SFMP--with concurrence by the Director of Remedial Action Projects for both programs.

E. CONTROL OF RESIDUAL RADIOACTIVITY AT FUSRAP AND REMOTE SFMP SITES

Residual radioactivity above the guidelines at FUSRAP and remote SFMP sites must be managed in accordance with applicable DOE Orders. The DOE Order 5480.1A requires compliance with applicable federal, state, and local environmental protection standards.

The operational and control requirements specified in the following DOE Orders shall apply to both interim storage and long-term management.

a. 5440.1B, Implementation of the National Environmental Policy Act

b. 5480.1A, Environmental Protection, Safety, and Health Protection Program for DOE Operations

c. 5480.2, Hazardous and Radioactive Mixed Waste Management

d. 5480.4, Environmental Protection, Safety, and Health Protection Standards

e. 5482.1A, Environmental, Safety, and Health Appraisal Program

f. 5483.1, Occupational Safety and Health Program for Government-Owned Contractor-Operated Facilities

g. 5484.1, Environmental Protection, Safety, and Health Protection Information Reporting Requirements

h. 5484.2, Unusual Occurrence Reporting System

i. 5820.2, Radioactive Waste Management

E.1 Interim Storage

a. Control and stabilization features shall be designed to ensure, to the extent reasonably achievable, an effective life of 50 years and, in any case, at least 25 years.

b. Above-background Rn-222 concentrations in the atmosphere above facility surfaces or openings shall not exceed: (1) 100 pCi/L at any given point, (2) an annual average concentration of 30 pCi/L over the facility site, and (3) an annual average concentration of 3 pCi/L at or above any location outside the facility site (DOE Order 5480.1A, Attachment XI-1).

c. Concentrations of radionuclides in the groundwater or quantities of residual radioactive materials shall not exceed existing federal, state, or local standards.

d. Access to a site should be controlled and misuse of onsite material contaminated by residual radioactivity should be prevented through appropriate administrative controls and physical barriers--active and passive controls as described by the U.S. Environmental Protection Agency (1983--p. 595). These control features should be designed to ensure, to the extent reasonable, an effective life of at least 25 years. The federal government shall have title to the property.

E.2 <u>Long-Term Management</u>

a. Control and stabilization features shall be designed to ensure, to the extent reasonably achievable, an effective life of 1,000 years and, in any case, at least 200 years.

b. Control and stabilization features shall be designed to ensure that Rn-222 emanation to the atmosphere from the waste shall not: (1) exceed an annual average release rate of 20 $pCi/m^2/s$, and (2) increase the annual average Rn-222 concentration at or above any location outside the boundary of the contaminated area by more than 0.5 pCi/L. Field verification of emanation rates is not required.

c. Prior to placement of any potentially biodegradable contaminated wastes in a long-term management facility, such wastes shall be properly conditioned to ensure that (1) the generation and escape of biogenic gases will not cause the requirement in paragraph b of this section (E.2) to be exceeded, and (2) biodegradation within the facility will not result in premature structural failure in violation of the requirements in paragraph a of this section (E.2).

d. Groundwater shall be protected in accordance with 40 CFR 192.20(a)(2) and 192.20(a)(3), as applicable to FUSRAP and remote SFMP sites.

e. Access to a site should be controlled and misuse of onsite material contaminated by residual radioactivity should be prevented through appropriate administrative controls and physical barriers--active and passive controls as described by the U.S. Environmental Protection Agency (1983--p. 595). These controls should be designed to be effective to the extent reasonable for at least 200 years. The federal government shall have title to the property.

F. EXCEPTIONS

Exceptions to the requirement that authorized limits be set equal to the guidelines may be made on the basis of an analysis of site-specific aspects of a designated site that were not taken into account in deriving the guidelines. Exceptions require approvals as stated in Section D. Specific situations that warrant exceptions are:

a. Where remedial actions would pose a clear and present risk of injury to workers or members of the general public, notwithstanding reasonable measures to avoid or reduce risk.

b. Where remedial actions--even after all reasonable mitigative measures have been taken--would produce environmental harm that is clearly excessive compared to the health benefits to persons living on or near affected sites, now or in the future. A clear excess of environmental harm is harm that is long-term, manifest, and grossly disproportionate to health benefits that may reasonably be anticipated.

c. Where the cost of remedial actions for contaminated soil is unreasonably high relative to long-term benefits and where the residual radioactive materials do not pose a clear present or future risk after taking necessary control measures. The likelihood that buildings will be erected or that people will spend long periods of time at such a site should be considered in evaluating this risk. Remedial actions will generally not be necessary where only minor quantities of residual radioactive materials are involved or where residual radioactive materials occur in an inaccessible location at which site-specific factors limit their hazard and from which they are costly or difficult to remove. Examples are residual radioactive materials under hard-surface public roads and sidewalks, around public sewer lines, or in fence-post foundations. In order to invoke this exception, a site-specific analysis must be provided to establish that it would not cause an individual to receive a radiation dose in excess of the basic dose limits stated in Section B, and a statement specifying the residual radioactivity must be included in the appropriate state and local records.

d. Where the cost of cleanup of a contaminated building is clearly unreasonably high relative to the benefits. Factors that shall be included in this judgment are the anticipated period of occupancy, the incremental radiation level that would be effected by remedial action, the residual useful lifetime of the building, the potential for future construction at the site, and the applicability of remedial actions that would be less costly than removal of the residual radioactive materials. A statement specifying the residual radioactivity must be included in the appropriate state and local records.

e. Where there is no feasible remedial action.

G. SOURCES

Limit or Guideline	Source
Basic Dose Limits	
Dosimetry Model and Dose Limits	International Commission on Radiological Protection (1977, 1978)
Guidelines for Residual Radioactivity	
Residual Radionuclides in Soil Material	40 CFR 192
Airborne Radon Decay Products	40 CFR 192
External Gamma Radiation	40 CFR 192
Surface Contamination	U.S. Nuclear Regulatory Commission (1982)
Control of Radioactive Wastes and Residues	
Interim Storage	DOE Order 5480.1A
Long-Term Management	DOE Order 5480.1A; 40 CFR 192

H. REFERENCES

International Commission on Radiological Protection. 1977. Recommendations of the International Commission on Radiological Protection (Adopted January 17, 1977). ICRP Publication 26. Pergamon Press, Oxford. [As modified by "Statement from the 1978 Stockholm Meeting of the ICRP." Annals of the ICRP, Vol. 2, No. 1, 1978.]

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U.S. Environmental Protection Agency. 1983. Standards for Remedial Actions at Inactive Uranium Processing Sites; Final Rule (40 CFR Part 192). Fed. Regist. 48(3):590-604 (January 5, 1983).

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U.S. Department of Energy. 1985. Supplement to U.S. Department of Energy Guidelines for Residual Radioactivity at Formerly Utilized Sites Remedial Action Program and Remote Surplus Facilities Management Program Sites. A Manual for Implementing Residual Radioactivity Guidelines. Prepared by Argonne National Laboratory, Los Alamos National Laboratory, Oak Ridge National Laboratory, and Pacific Northwest Laboratory for the U.S. Department of Energy. (In preparation.)

U.S. Nuclear Regulatory Commission. 1982. Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Licenses for Byproduct, Source, or Special Nuclear Material. Division of Fuel Cycle and Material Safety, Washington, DC. July 1982. [See also: U.S. Atomic Energy Commission. 1974. Regulatory Guide 1.86. Termination of Operating Licenses for Nuclear Reactors. Table I.]

APPENDIX C. RADIOLOGICAL SURVEY DATA

Building T019 Sorted by Location

C.1

T019.WS SORTED BY LOCATION

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	STD DEV
	1-5	2591	12.00	0.24
	1-9	1697	7.86	0.19
	1-11	1868	8.65	0.20
	1-12	1732	8.02	0.19
	3-1	1452	6.73	0.18
	3-3	1531	7.09	0.18
	3-4	1471	6.81	0.18
	3-5	1478	6.85	0.18
	3-9	1932	8.95	0.20
	3-11	1503	6.96	0.18
	4-7	1485	6.88	0.18
	5-1	1681	7.79	0.19
	5-4	1673	7.75	0.19
	5-7	1533	7.10	0.18
	6-3	1703	7.89	0.19
	6-6	1424	6.60	0.17
	6-8	1576	7.30	0.18
	6-9	1852	8.58	0.20
	6-11	1680	7.78	0.19
	7-1	1486	6.88	0.18
	8-1	1710	7.92	0.19
	8-3	1609	7.45	0.19
	8-5	1448	6.71	0.18
	8-5	1313	6.08	0.17
	9-1	1728	8.00	0.19
	9-2	1670	7.74	0.19
	9-3	1430	6.62	0.18
	9-6	1397	6.47	0.17
	9-11	1226	5.68	0.16
	10-1	1645	7.62	0.19
	10-3	1546	7.16	0.18
	10-5	1449	6.71	0.18
	10-9	1936	8.97	0.20
	11-1	1744	8.08	0.19
	11-2	1645	7.62	0.19
	11-3A	1555	7.20	0.18
	11-3	1539	7.13	0.18
	11-4	1541	7.14	0.18
	11-7	2018	9.35	0.21
	11-11	1667	7.72	0.19
	12-2	1679	7.78	0.19
	12-3	1653	7.66	0.19
	12-5A	1558	7.22	0.18
	12-5	1540	7.13	0.18
	12-9	1960	9.08	0.21
	12-12	1960	9.08	0.21
REINSPECT	7-7	1931	8.94	0.20
REINSPECT	7-7	1949	9.03	0.20
REINSPECT	7-7	1950	9.03	0.20
REINSPECT	7-7	1942	9.00	0.20
REINSPECT	7-7	1885	8.73	0.20
REINSPECT	1-11	2038	9.44	0.21
REINSPECT	1-11	2121	9.82	0.21
REINSPECT	1-10	2064	9.56	0.21
REINSPECT	1-9	1979	9.17	0.21

T019.WS SORTED BY LOCATION

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	STD DEV
REINSPECT	1-7	1827	8.46	0.20
REINSPECT	1-7	1776	8.23	0.20
REINSPECT	1-5	1455	6.74	0.18
REINSPECT	1-5	1475	6.83	0.18
REINSPECT	1-5	1328	6.15	0.17
REINSPECT	1-5	1504	6.97	0.18
REINSPECT	1-5	1725	7.99	0.19
REINSPECT	1-5	1787	8.28	0.20
REINSPECT	1-5	1793	8.31	0.20
REINSPECT	1-5	1678	7.77	0.19
REINSPECT	1-5	1434	6.64	0.18
REINSPECT	1-5	1594	7.38	0.18
	NO. OF MEASUREMENTS		67	
	AVERAGE/SQRT(SUMSQ)		7.79	1.56
	STD. DEV.		1.09	
	MAXIMUM		12.00	
	MINIMUM		5.68	
	RANGE		6.32	
VAULT	1	2250	10.42	0.22
VAULT	2	2666	12.35	0.24
VAULT	3	2874	13.31	0.25
VAULT	4	2859	13.24	0.25
VAULT	5	2629	12.18	0.24
VAULT	6	2537	11.75	0.23
VAULT	7	2797	12.96	0.24
VAULT	8	2611	12.09	0.24
VAULT	9	2763	12.80	0.24
VAULT	10	2825	13.09	0.25
	AVERAGE/SQRT(SUMSQ)		12.42	0.76
	STD. DEV. OF VALUES		0.88	
	MAXIMUM		13.31	
	MINIMUM		10.42	
	RANGE		2.89	

Building T019 Sorted by Exposure Rate

C.2

T019.WS SORTED BY EXPOSURE RATE

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	STD DEV
	1-5	2591	12.00	0.24
REINSPECT	1-11	2121	9.82	0.21
REINSPECT	1-10	2064	9.56	0.21
REINSPECT	1-11	2038	9.44	0.21
	11-7	2018	9.35	0.21
REINSPECT	1-9	1979	9.17	0.21
	12-9	1960	9.08	0.21
	12-12	1960	9.08	0.21
REINSPECT	7-7	1950	9.03	0.20
REINSPECT	7-7	1949	9.03	0.20
REINSPECT	7-7	1942	9.00	0.20
	10-9	1936	8.97	0.20
	3-9	1932	8.95	0.20
REINSPECT	7-7	1931	8.94	0.20
REINSPECT	7-7	1885	8.73	0.20
	1-11	1868	8.65	0.20
	6-9	1852	8.58	0.20
REINSPECT	1-7	1827	8.46	0.20
REINSPECT	1-5	1793	8.31	0.20
REINSPECT	1-5	1787	8.28	0.20
REINSPECT	1-7	1776	8.23	0.20
	11-1	1744	8.08	0.19
	1-12	1732	8.02	0.19
	9-1	1728	8.00	0.19
REINSPECT	1-5	1725	7.99	0.19
	8-1	1710	7.92	0.19
	6-3	1703	7.89	0.19
	1-9	1697	7.86	0.19
	5-1	1681	7.79	0.19
	6-11	1680	7.78	0.19
	12-2	1679	7.78	0.19
REINSPECT	1-5	1678	7.77	0.19
	5-4	1673	7.75	0.19
	9-2	1670	7.74	0.19
	11-11	1667	7.72	0.19
	12-3	1653	7.66	0.19
	11-2	1645	7.62	0.19
	10-1	1645	7.62	0.19
	8-3	1609	7.45	0.19
REINSPECT	1-5	1594	7.38	0.18
	6-8	1576	7.30	0.18
	12-5A	1558	7.22	0.18
	11-3A	1555	7.20	0.18
	10-3	1546	7.16	0.18
	11-4	1541	7.14	0.18
	12-5	1540	7.13	0.18
	11-3	1539	7.13	0.18
	5-7	1533	7.10	0.18
	3-3	1531	7.09	0.18
REINSPECT	1-5	1504	6.97	0.18
	3-11	1503	6.96	0.18
	7-1	1486	6.88	0.18
	4-7	1485	6.88	0.18
	3-5	1478	6.85	0.18
REINSPECT	1-5	1475	6.83	0.18

T019.WS

SORTED BY EXPOSURE RATE

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	STD DEV
	3-4	1471	6.81	0.18
REINSPECT	1-5	1455	6.74	0.18
	3-1	1452	6.73	0.18
	10-5	1449	6.71	0.18
	8-5	1448	6.71	0.18
REINSPECT	1-5	1434	6.64	0.18
	9-3	1430	6.62	0.18
	6-6	1424	6.60	0.17
	9-6	1397	6.47	0.17
REINSPECT	1-5	1328	6.15	0.17
	8-5	1313	6.08	0.17
	9-11	1226	5.68	0.16
	NO. OF MEASUREMENTS		67	
	AVERAGE/SQRT(SUMSQ)		7.79	1.56
	STD. DEV.		1.09	
	MAXIMUM		12.00	
	MINIMUM		5.68	
	RANGE		6.32	
VAULT	3	2874	13.31	0.25
VAULT	4	2859	13.24	0.25
VAULT	10	2825	13.09	0.25
VAULT	7	2797	12.96	0.24
VAULT	9	2763	12.80	0.24
VAULT	2	2666	12.35	0.24
VAULT	5	2629	12.18	0.24
VAULT	8	2611	12.09	0.24
VAULT	6	2537	11.75	0.23
VAULT	1	2250	10.42	0.22
	AVERAGE/SQRT(SUMSQ)		12.42	0.76
	STD. DEV. OF VALUES		0.88	
	MAXIMUM		13.31	
	MINIMUM		10.42	
	RANGE		2.89	

Building T013 Sorted by Location

C.3

T013.WS

SORTED BY LOCATION

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	STD DEV
	1-3	1534	7.11	0.18
	1-4	1408	6.52	0.17
	1-6	1607	7.44	0.19
	1-7	1719	7.96	0.19
	1-8	1273	5.90	0.17
	1-9	1077	4.99	0.15
	1-10	1117	5.17	0.15
	1-11	1384	6.41	0.17
	1-13	1331	6.17	0.17
	1-15	1205	5.58	0.16
	2-8A	1502	6.96	0.18
	2-8	1211	5.61	0.16
	2-9A	1337	6.19	0.17
	2-9	1157	5.36	0.16
	3-3	1276	5.91	0.17
	3-5	1330	6.16	0.17
	3-7	1751	8.11	0.19
	3-8	1505	6.97	0.18
	3-9	1351	6.26	0.17
	3-10	1041	4.82	0.15
	3-14	909	4.21	0.14
	4-8	1538	7.12	0.18
	5-3	1483	6.87	0.18
	5-5	1401	6.49	0.17
	5-7	1874	8.68	0.20
	5-8	1561	7.23	0.18
	5-9	1206	5.59	0.16
	5-10	1314	6.09	0.17
	5-11	1264	5.85	0.16
	5-13	1197	5.54	0.16
	5-15	1298	6.01	0.17
	6-3	1431	6.63	0.18
	6-5	1942	9.00	0.20
	6-7	1804	8.36	0.20
	6-8A	1659	7.68	0.19
	6-8	1486	6.88	0.18
	6-9A	1672	7.74	0.19
	6-9	1499	6.94	0.18
	6-10	1609	7.45	0.19
	7-7	1662	7.70	0.19
	7-11	1391	6.44	0.17
	7-13	1585	7.34	0.18
	7-15	1559	7.22	0.18
	8-4	1494	6.92	0.18
	8-5	1888	8.75	0.20
	8-10	1520	7.04	0.18
	8-11	1518	7.03	0.18
	8-13	1506	6.98	0.18
	8-15	1362	6.31	0.17
	9-4	1647	7.63	0.19
	9-6	1563	7.24	0.18
	9-8	1457	6.75	0.18
	9-9	1284	5.95	0.17
	10-7	1661	7.69	0.19
	10-9	1271	5.89	0.17

T013.WS SORTED BY LOCATION

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	uR/h STD DEV
	10-10	1263	5.85	0.16
	10-11	1403	6.50	0.17
	10-13	1433	6.64	0.18
	11-4	1628	7.54	0.19
	11-5	1611	7.46	0.19
	11-6	1657	7.68	0.19
	11-8A	1779	8.24	0.20
	11-8	1723	7.98	0.19
	14-3	1738	8.05	0.19
	14-4	1416	6.56	0.17
	14-5	1539	7.13	0.18
	14-6	1607	7.44	0.19
	14-7	1566	7.25	0.18
	14-8	1556	7.21	0.18
	14-9	1433	6.64	0.18
	14-10	1205	5.58	0.16
	14-15	1348	6.24	0.17
	15-1	1898	8.79	0.20
	15-3	1914	8.87	0.20
	15-4	1619	7.50	0.19
	AVERAGE/SQRT(SUMSQ)		6.85	1.54
	STD. DEV. OF VALUES		1.01	

Building T013 Sorted by Exposure Rate

T013.WS — SORTED BY EXPOSURE RATE

C.4

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	uR/h STD DEV
	6-5	1942	9.00	0.20
C.4	15-3	1914	8.87	0.20
	15-1	1898	8.79	0.20
	8-5	1888	8.75	0.20
	5-7	1874	8.68	0.20
	6-7	1804	8.36	0.20
	11-8A	1779	8.24	0.20
	3-7	1751	8.11	0.19
	14-3	1738	8.05	0.19
	11-8	1723	7.98	0.19
	1-7	1719	7.96	0.19
	6-9A	1672	7.74	0.19
	7-7	1662	7.70	0.19
	10-7	1661	7.69	0.19
	6-8A	1659	7.68	0.19
	11-6	1657	7.68	0.19
	9-4	1647	7.63	0.19
	11-4	1628	7.54	0.19
	15-4	1619	7.50	0.19
	11-5	1611	7.46	0.19
	6-10	1609	7.45	0.19
	14-6	1607	7.44	0.19
	1-6	1607	7.44	0.19
	7-13	1585	7.34	0.18
	14-7	1566	7.25	0.18
	9-6	1563	7.24	0.18
	5-8	1561	7.23	0.18
	7-15	1559	7.22	0.18
	14-8	1556	7.21	0.18
	14-5	1539	7.13	0.18
	4-8	1538	7.12	0.18
	1-3	1534	7.11	0.18
	8-10	1520	7.04	0.18
	8-11	1518	7.03	0.18
	8-13	1506	6.98	0.18
	3-8	1505	6.97	0.18
	2-8A	1502	6.96	0.18
	6-9	1499	6.94	0.18
	8-4	1494	6.92	0.18
	6-8	1486	6.88	0.18
	5-3	1483	6.87	0.18
	9-8	1457	6.75	0.18
	10-13	1433	6.64	0.18
	14-9	1433	6.64	0.18
	6-3	1431	6.63	0.18
	14-4	1416	6.56	0.17
	1-4	1408	6.52	0.17
	10-11	1403	6.50	0.17
	5-5	1401	6.49	0.17
	7-11	1391	6.44	0.17
	1-11	1384	6.41	0.17
	8-15	1362	6.31	0.17
	3-9	1351	6.26	0.17
	14-15	1348	6.24	0.17
	2-9A	1337	6.19	0.17

T013.WS SORTED BY EXPOSURE RATE

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	uR/h STD DEV
	1-13	1331	6.17	0.17
	3-5	1330	6.16	0.17
	5-10	1314	6.09	0.17
	5-15	1298	6.01	0.17
	9-9	1284	5.95	0.17
	3-3	1276	5.91	0.17
	1-8	1273	5.90	0.17
	10-9	1271	5.89	0.17
	5-11	1264	5.85	0.16
	10-10	1263	5.85	0.16
	2-8	1211	5.61	0.16
	5-9	1206	5.59	0.16
	14-10	1205	5.58	0.16
	1-15	1205	5.58	0.16
	5-13	1197	5.54	0.16
	2-9	1157	5.36	0.16
	1-10	1117	5.17	0.15
	1-9	1077	4.99	0.15
	3-10	1041	4.82	0.15
	3-14	909	4.21	0.14
	MAXIMUM		9.00	
	MINIMUM		4.21	
	RANGE		4.78	

Northwest Area Sorted by Location

C.5

T01913.WS SORTED BY LOCATION

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	STD DEV
	3-15	3802	17.61	0.29
	4-15	3986	18.46	0.29
	4-25	3637	16.85	0.28
	2-15	3653	16.92	0.28
	5-25	3637	16.85	0.28
	5-33	3671	17.00	0.28
	5-38	3778	17.50	0.28
	5-44	3961	18.35	0.29
	6-6	3551	16.45	0.28
	6-7	3553	16.46	0.28
	6-8	3545	16.42	0.28
	6-9	3688	17.08	0.28
	6-10	3758	17.41	0.28
	6-11	3721	17.24	0.28
	6-25	3444	15.95	0.27
	6-29	3494	16.18	0.27
	6-30	3737	17.31	0.28
	6-32	3738	17.31	0.28
	6-38	3860	17.88	0.29
	6-44	4229	19.59	0.30
	7-5	3553	16.46	0.28
	7-12	3804	17.62	0.29
	7-13	3904	18.08	0.29
	7-14	3440	15.93	0.27
	7-17	3567	16.52	0.28
	7-19	3588	16.62	0.28
	7-21	3537	16.38	0.28
	7-23	3591	16.63	0.28
	7-25	3455	16.00	0.27
	7-30	3687	17.08	0.28
	7-32	3649	16.90	0.28
	7-35	3828	17.73	0.29
	7-36	3698	17.13	0.28
	7-38	3821	17.70	0.29
	7-44	4319	20.01	0.30
	8-4	3585	16.61	0.28
	8-5	3551	16.45	0.28
	8-15	3428	15.88	0.27
	8-27	3678	17.04	0.28
	8-38	3866	17.91	0.29
	8-44	4229	19.59	0.30
	9-3	3586	16.61	0.28
	9-38	3841	17.79	0.29
	9-44	4182	19.37	0.30
	9-46	4745	21.98	0.32
	9-49	4705	21.79	0.32
	10-3	3586	16.61	0.28
	10-8	3020	13.99	0.25
	10-9	2915	13.50	0.25
	10-39	3553	16.46	0.28
	10-41	4022	18.63	0.29
	10-49	4180	19.36	0.30
	11-7	2934	13.59	0.25
	11-8	2814	13.03	0.25
	11-9	2871	13.30	0.25

T01913.WS SORTED BY LOCATION

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	STD DEV
	11-12	2747	12.72	0.24
	11-13	2918	13.52	0.25
	11-14	3016	13.97	0.25
	11-15	3022	14.00	0.25
	11-16	2965	13.73	0.25
	11-17	3222	14.92	0.26
	11-18	3172	14.69	0.26
	11-19	3307	15.32	0.27
	11-21	3158	14.63	0.26
	11-22	3080	14.27	0.26
	11-23	3146	14.57	0.26
	11-25	3236	14.99	0.26
	11-26	3174	14.70	0.26
	11-27	3148	14.58	0.26
	11-28	3301	15.29	0.27
	11-29	3190	14.78	0.26
	11-31	3233	14.98	0.26
	11-44	4101	19.00	0.30
	11-50	4498	20.83	0.31
	11-51	4492	20.81	0.31
	12-8	2785	12.90	0.24
	12-9	2561	11.86	0.23
	12-10	2598	12.03	0.24
	12-11	2684	12.43	0.24
	12-16	2545	11.79	0.23
	12-17	2805	12.99	0.25
	12-18	2629	12.18	0.24
	12-19	2697	12.49	0.24
	12-20	2677	12.40	0.24
	12-21	2683	12.43	0.24
	12-22	2543	11.78	0.23
	12-23	2771	12.84	0.24
	12-24	2734	12.66	0.24
	12-25	2668	12.36	0.24
	12-26	2757	12.77	0.24
	12-27	2719	12.59	0.24
	12-28	2818	13.05	0.25
	12-29	2887	13.37	0.25
	12-33	2968	13.75	0.25
	12-34	2856	13.23	0.25
	12-35	2924	13.54	0.25
	12-36	3015	13.97	0.25
	12-37	3019	13.98	0.25
	12-38	3010	13.94	0.25
	12-40	3112	14.41	0.26
	12-41	3156	14.62	0.26
	12-42	3136	14.53	0.26
	12-43	3050	14.13	0.26
	12-45	3195	14.80	0.26
	12-46	3978	18.43	0.29
	12-47	4432	20.53	0.31
	12-49	5262	24.37	0.34
	12-50	4596	21.29	0.31
	12-51	5960	27.61	0.36
	12-52	5685	26.33	0.35

T01913.WS SORTED BY LOCATION

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	STD DEV
	13-7	2907	13.47	0.25
	13-10	2718	12.59	0.24
	13-14	2717	12.59	0.24
	13-15	2659	12.32	0.24
	13-16	2654	12.29	0.24
	13-17	2595	12.02	0.24
	13-18	2601	12.05	0.24
	13-20	2420	11.21	0.23
	13-21	2628	12.17	0.24
	13-23	2829	13.10	0.25
	13-24	2804	12.99	0.25
	13-25	2759	12.78	0.24
	13-26	2720	12.60	0.24
	13-27	2900	13.43	0.25
	13-30	2855	13.22	0.25
	13-31	2834	13.13	0.25
	13-32	2925	13.55	0.25
	13-33	2937	13.60	0.25
	13-34	2927	13.56	0.25
	13-35	2920	13.53	0.25
	13-36	3018	13.98	0.25
	13-37	3060	14.17	0.26
	13-38	3062	14.18	0.26
	13-39	2944	13.64	0.25
	13-40	3022	14.00	0.25
	13-41	3281	15.20	0.27
	13-43	3261	15.10	0.26
	13-44	3510	16.26	0.27
	13-47	4069	18.85	0.30
	13-48	4535	21.01	0.31
	13-49	4925	22.81	0.33
	13-53	5262	24.37	0.34
	13-54	5485	25.41	0.34
	14-7	2668	12.36	0.24
	14-10	2055	9.52	0.21
	14-13	2446	11.33	0.23
	14-14	2627	12.17	0.24
	14-20	2626	12.16	0.24
	14-21	2251	10.43	0.22
	14-30	2855	13.22	0.25
	14-31	2434	11.27	0.23
	14-32	2925	13.55	0.25
	14-33	2937	13.60	0.25
	14-35	2937	13.60	0.25
	14-36	2927	13.56	0.25
	14-39	2920	13.53	0.25
	14-39	3018	13.98	0.25
	15-7	2663	12.34	0.24
	15-10	2110	9.77	0.21
	15-12	2684	12.43	0.24
	15-13	2713	12.57	0.24
	15-14	2693	12.47	0.24
	15-20	1975	9.15	0.21
	15-21	2301	10.66	0.22
	15-50	4494	20.82	0.31

T01913.WS SORTED BY LOCATION

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	STD DEV
	16-7	2663	12.34	0.24
	16-8	2110	9.77	0.21
	16-10	2684	12.43	0.24
	16-12	2713	12.57	0.24
	16-13	2693	12.47	0.24
	16-14	2536	11.75	0.23
	16-16	2612	12.10	0.24
	16-17	2544	11.78	0.23
	16-18	2340	10.84	0.22
	16-19	2418	11.20	0.23
	16-20	2126	9.85	0.21
	16-21	2616	12.12	0.24
	16-22	2628	12.17	0.24
	16-23	2412	11.17	0.23
	16-24	2208	10.23	0.22
	16-25	2140	9.91	0.21
	16-29	2364	10.95	0.23
	16-30	2581	11.96	0.24
	16-31	2449	11.34	0.23
	16-32	2401	11.12	0.23
	16-33	2406	11.14	0.23
	16-34	2501	11.58	0.23
	16-35	2646	12.26	0.24
	16-36	2762	12.79	0.24
	16-38	2735	12.67	0.24
	16-39	2628	12.17	0.24
	16-40	2933	13.59	0.25
	16-42	3441	15.94	0.27
	16-43	3355	15.54	0.27
	16-44	3684	17.06	0.28
	16-49	4419	20.47	0.31
	17-13	2598	12.03	0.24
	17-14	2466	11.42	0.23
	17-15	2636	12.21	0.24
	17-16	2702	12.52	0.24
	17-17	2734	12.66	0.24
	17-18	2355	10.91	0.22
	17-19	2414	11.18	0.23
	17-20	2511	11.63	0.23
	17-21	2723	12.61	0.24
	17-22	2652	12.28	0.24
	17-23	2140	9.91	0.21
	17-24	2249	10.42	0.22
	17-25	2376	11.01	0.23
	17-28	2467	11.43	0.23
	17-29	2127	9.85	0.21
	17-30	2362	10.94	0.23
	17-31	2360	10.93	0.23
	17-32	2446	11.33	0.23
	17-33	2313	10.71	0.22
	17-34	2613	12.10	0.24
	17-35	2765	12.81	0.24
	17-36	2558	11.85	0.23
	17-38	2613	12.10	0.24
	17-39	2765	12.81	0.24

T01913.WS SORTED BY LOCATION

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	STD DEV
	17-40	2558	11.85	0.23
	17-45	3355	15.54	0.27
	17-46	3684	17.06	0.28
	17-47	4419	20.47	0.31
	17-49	4559	21.12	0.31
	18-15	2251	10.43	0.22
	18-16	2500	11.58	0.23
	18-17	2569	11.90	0.23
	18-18	2645	12.25	0.24
	18-19	2698	12.50	0.24
	18-22	2734	12.66	0.24
	18-23	2425	11.23	0.23
	18-24	2357	10.92	0.22
	18-25	2249	10.42	0.22
	18-28	2276	10.54	0.22
	18-49	4257	19.72	0.30
	19-16	2734	12.66	0.24
	19-17	2330	10.79	0.22
	19-18	2543	11.78	0.23
	19-19	2412	11.17	0.23
	19-22	2515	11.65	0.23
	19-23	2425	11.23	0.23
	19-24	2249	10.42	0.22
	19-25	2506	11.61	0.23
	19-26	2511	11.63	0.23
	19-27	2652	12.28	0.24
	12-54	5597	25.93	0.35
	AVERAGE/SQRT(SUMSQ)		14.36	4.05
	STD. DEV. OF VALUES		3.38	

Northwest Area Sorted by Exposure Rate

T01913.WS SORTED BY EXPOSURE RATE

C.6

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	uR/h STD DEV
	12-51	5960	27.61	0.36
	12-52	5685	26.33	0.35
	12-54	5597	25.93	0.35
	13-54	5485	25.41	0.34
	12-49	5262	24.37	0.34
	13-53	5262	24.37	0.34
	13-49	4925	22.81	0.33
	9-46	4745	21.98	0.32
	9-49	4705	21.79	0.32
	12-50	4596	21.29	0.31
	17-49	4559	21.12	0.31
	13-48	4535	21.01	0.31
	11-50	4498	20.83	0.31
	15-50	4494	20.82	0.31
	11-51	4492	20.81	0.31
	12-47	4432	20.53	0.31
	16-49	4419	20.47	0.31
	17-47	4419	20.47	0.31
	7-44	4319	20.01	0.30
	18-49	4257	19.72	0.30
	8-44	4229	19.59	0.30
	6-44	4229	19.59	0.30
	9-44	4182	19.37	0.30
	10-49	4180	19.36	0.30
	11-44	4101	19.00	0.30
	13-47	4069	18.85	0.30
	10-41	4022	18.63	0.29
	4-15	3986	18.46	0.29
	12-46	3978	18.43	0.29
	5-44	3961	18.35	0.29
	7-13	3904	18.08	0.29
	8-38	3866	17.91	0.29
	6-38	3860	17.88	0.29
	9-38	3841	17.79	0.29
	7-35	3828	17.73	0.29
	7-38	3821	17.70	0.29
	7-12	3804	17.62	0.29
	3-15	3802	17.61	0.29
	5-38	3778	17.50	0.28
	6-10	3758	17.41	0.28
	6-32	3738	17.31	0.28
	6-30	3737	17.31	0.28
	6-11	3721	17.24	0.28
	7-36	3698	17.13	0.28
	6-9	3688	17.08	0.28
	7-30	3687	17.08	0.28
	16-44	3684	17.06	0.28
	17-46	3684	17.06	0.28
	8-27	3678	17.04	0.28
	5-33	3671	17.00	0.28
	2-15	3653	16.92	0.28
	7-32	3649	16.90	0.28
	5-25	3637	16.85	0.28
	4-25	3637	16.85	0.28
	7-23	3591	16.63	0.28

T01913.WS SORTED BY EXPOSURE RATE

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	uR/h STD DEV
	7-19	3588	16.62	0.28
	10-3	3586	16.61	0.28
	9-3	3586	16.61	0.28
	8-4	3585	16.61	0.28
	7-17	3567	16.52	0.28
	6-7	3553	16.46	0.28
	10-39	3553	16.46	0.28
	7-5	3553	16.46	0.28
	6-6	3551	16.45	0.28
	8-5	3551	16.45	0.28
	6-8	3545	16.42	0.28
	7-21	3537	16.38	0.28
	13-44	3510	16.26	0.27
	6-29	3494	16.18	0.27
	7-25	3455	16.00	0.27
	6-25	3444	15.95	0.27
	16-42	3441	15.94	0.27
	7-14	3440	15.93	0.27
	8-15	3428	15.88	0.27
	16-43	3355	15.54	0.27
	17-45	3355	15.54	0.27
	11-19	3307	15.32	0.27
	11-28	3301	15.29	0.27
	13-41	3281	15.20	0.27
	13-43	3261	15.10	0.26
	11-25	3236	14.99	0.26
	11-31	3233	14.98	0.26
	11-17	3222	14.92	0.26
	12-45	3195	14.80	0.26
	11-29	3190	14.78	0.26
	11-26	3174	14.70	0.26
	11-18	3172	14.69	0.26
	11-21	3158	14.63	0.26
	12-41	3156	14.62	0.26
	11-27	3148	14.58	0.26
	11-23	3146	14.57	0.26
	12-42	3136	14.53	0.26
	12-40	3112	14.41	0.26
	11-22	3080	14.27	0.26
	13-38	3062	14.18	0.26
	13-37	3060	14.17	0.26
	12-43	3050	14.13	0.26
	13-40	3022	14.00	0.25
	11-15	3022	14.00	0.25
	10-8	3020	13.99	0.25
	12-37	3019	13.98	0.25
	13-36	3018	13.98	0.25
	14-39	3018	13.98	0.25
	11-14	3016	13.97	0.25
	12-36	3015	13.97	0.25
	12-38	3010	13.94	0.25
	12-33	2968	13.75	0.25
	11-16	2965	13.73	0.25
	13-39	2944	13.64	0.25
	13-33	2937	13.60	0.25

T01913.WS SORTED BY EXPOSURE RATE

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	uR/h STD DEV
	14-33	2937	13.60	0.25
	14-35	2937	13.60	0.25
	11-7	2934	13.59	0.25
	16-40	2933	13.59	0.25
	13-34	2927	13.56	0.25
	14-36	2927	13.56	0.25
	13-32	2925	13.55	0.25
	14-32	2925	13.55	0.25
	12-35	2924	13.54	0.25
	13-35	2920	13.53	0.25
	14-39	2920	13.53	0.25
	11-13	2918	13.52	0.25
	10-9	2915	13.50	0.25
	13-7	2907	13.47	0.25
	13-27	2900	13.43	0.25
	12-29	2887	13.37	0.25
	11-9	2871	13.30	0.25
	12-34	2856	13.23	0.25
	14-30	2855	13.22	0.25
	13-30	2855	13.22	0.25
	13-31	2834	13.13	0.25
	13-23	2829	13.10	0.25
	12-28	2818	13.05	0.25
	11-8	2814	13.03	0.25
	12-17	2805	12.99	0.25
	13-24	2804	12.99	0.25
	12-8	2785	12.90	0.24
	12-23	2771	12.84	0.24
	17-35	2765	12.81	0.24
	17-39	2765	12.81	0.24
	16-36	2762	12.79	0.24
	13-25	2759	12.78	0.24
	12-26	2757	12.77	0.24
	11-12	2747	12.72	0.24
	16-38	2735	12.67	0.24
	17-17	2734	12.66	0.24
	12-24	2734	12.66	0.24
	18-22	2734	12.66	0.24
	19-16	2734	12.66	0.24
	17-21	2723	12.61	0.24
	13-26	2720	12.60	0.24
	12-27	2719	12.59	0.24
	13-10	2718	12.59	0.24
	13-14	2717	12.59	0.24
	15-13	2713	12.57	0.24
	16-12	2713	12.57	0.24
	17-16	2702	12.52	0.24
	18-19	2698	12.50	0.24
	12-19	2697	12.49	0.24
	15-14	2693	12.47	0.24
	16-13	2693	12.47	0.24
	15-12	2684	12.43	0.24
	16-10	2684	12.43	0.24
	12-11	2684	12.43	0.24
	12-21	2683	12.43	0.24

T01913.WS SORTED BY EXPOSURE RATE

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	STD DEV
	12-20	2677	12.40	0.24
	12-25	2668	12.36	0.24
	14-7	2668	12.36	0.24
	16-7	2663	12.34	0.24
	15-7	2663	12.34	0.24
	13-15	2659	12.32	0.24
	13-16	2654	12.29	0.24
	17-22	2652	12.28	0.24
	19-27	2652	12.28	0.24
	16-35	2646	12.26	0.24
	18-18	2645	12.25	0.24
	17-15	2636	12.21	0.24
	12-18	2629	12.18	0.24
	16-39	2628	12.17	0.24
	16-22	2628	12.17	0.24
	13-21	2628	12.17	0.24
	14-14	2627	12.17	0.24
	14-20	2626	12.16	0.24
	16-21	2616	12.12	0.24
	17-34	2613	12.10	0.24
	17-38	2613	12.10	0.24
	16-16	2612	12.10	0.24
	13-18	2601	12.05	0.24
	17-13	2598	12.03	0.24
	12-10	2598	12.03	0.24
	13-17	2595	12.02	0.24
	16-30	2581	11.96	0.24
	18-17	2569	11.90	0.23
	12-9	2561	11.86	0.23
	17-36	2558	11.85	0.23
	17-40	2558	11.85	0.23
	12-16	2545	11.79	0.23
	16-17	2544	11.78	0.23
	12-22	2543	11.78	0.23
	19-18	2543	11.78	0.23
	16-14	2536	11.75	0.23
	19-22	2515	11.65	0.23
	17-20	2511	11.63	0.23
	19-26	2511	11.63	0.23
	19-25	2506	11.61	0.23
	16-34	2501	11.58	0.23
	18-16	2500	11.58	0.23
	17-28	2467	11.43	0.23
	17-14	2466	11.42	0.23
	16-31	2449	11.34	0.23
	17-32	2446	11.33	0.23
	14-13	2446	11.33	0.23
	14-31	2434	11.27	0.23
	18-23	2425	11.23	0.23
	19-23	2425	11.23	0.23
	13-20	2420	11.21	0.23
	16-19	2418	11.20	0.23
	17-19	2414	11.18	0.23
	16-23	2412	11.17	0.23
	19-19	2412	11.17	0.23

T01913.WS SORTED BY EXPOSURE RATE

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	STD DEV
	16-33	2406	11.14	0.23
	16-32	2401	11.12	0.23
	17-25	2376	11.01	0.23
	16-29	2364	10.95	0.23
	17-30	2362	10.94	0.23
	17-31	2360	10.93	0.23
	18-24	2357	10.92	0.22
	17-18	2355	10.91	0.22
	16-18	2340	10.84	0.22
	19-17	2330	10.79	0.22
	17-33	2313	10.71	0.22
	15-21	2301	10.66	0.22
	18-28	2276	10.54	0.22
	14-21	2251	10.43	0.22
	18-15	2251	10.43	0.22
	18-25	2249	10.42	0.22
	19-24	2249	10.42	0.22
	17-24	2249	10.42	0.22
	16-24	2208	10.23	0.22
	17-23	2140	9.91	0.21
	16-25	2140	9.91	0.21
	17-29	2127	9.85	0.21
	16-20	2126	9.85	0.21
	16-8	2110	9.77	0.21
	15-10	2110	9.77	0.21
	14-10	2055	9.52	0.21
	15-20	1975	9.15	0.21
	MAXIMUM		27.61	
	MINIMUM		9.15	
	RANGE		18.46	

T626 Storage Area Sorted by Location

C.7

T626.WS SORTED BY LOCATION

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	STD DEV
AREA 1	1-2	2273	10.53	0.22
AREA 1	1-3	2504	11.60	0.23
AREA 1	1-3	2717	12.59	0.24
AREA 1	1-4	2573	11.92	0.23
AREA 1	2-1	2467	11.43	0.23
AREA 1	2-3	2616	12.12	0.24
AREA 1	2-5	1997	9.25	0.21
AREA 1	3-1	2059	9.54	0.21
AREA 1	3-2	2120	9.82	0.21
AREA 1	3-2	2385	11.05	0.23
AREA 1	3-4	2584	11.97	0.24
AREA 1	3-5	2390	11.07	0.23
AREA 1	4-1	2757	12.77	0.24
AREA 1	4-2	2630	12.18	0.24
AREA 1	4-3	2587	11.98	0.24
AREA 1	4-4	2771	12.84	0.24
AREA 1	4-5	2357	10.92	0.22
AREA 1	4-5	2425	11.23	0.23
AREA 2	1-1	2093	9.69	0.21
AREA 2	1-1	1706	7.90	0.19
AREA 2	1-4	1820	8.43	0.20
AREA 2	1-5	1903	8.81	0.20
AREA 2	1-7	2020	9.36	0.21
AREA 2	1-11	1959	9.07	0.21
AREA 2	1-13	2016	9.34	0.21
AREA 2	2-1	2525	11.70	0.23
AREA 2	2-4	1961	9.08	0.21
AREA 2	2-8	2346	10.87	0.22
AREA 2	4-4	2288	10.60	0.22
AREA 2	4-11	2415	11.19	0.23
AREA 2	5-3	2669	12.36	0.24
AREA 2	5-13	2356	10.91	0.22
AREA 2	6-6	2574	11.92	0.24
AREA 2	6-8	2408	11.15	0.23
AREA 2	6-10	2440	11.30	0.23
AREA 2	6-12	2328	10.78	0.22
AREA 2	7-3	2651	12.28	0.24
AREA 2	7-4	2560	11.86	0.23
AREA 2	7-9	2319	10.74	0.22
AREA 2	7-11	2296	10.64	0.22
AREA 2	7-13	2319	10.74	0.22
AREA 2	8-6	2562	11.87	0.23
AREA 2	8-9	2317	10.73	0.22
AREA 2	8-9	1905	8.82	0.20
AREA 2	8-10	2236	10.36	0.22
AREA 2	8-11	2347	10.87	0.22
AREA 2	8-13	2263	10.48	0.22
AREA 2	9-4	2681	12.42	0.24
AREA 2	9-7	2230	10.33	0.22
AREA 2	10-6	2754	12.76	0.24
AREA 2	10-7	2296	10.64	0.22
AREA 2	11-5	2685	12.44	0.24
AREA 2	11-6	2943	13.63	0.25
AREA 2	12-3	1937	8.97	0.20
AREA 2	12-4	2075	9.61	0.21

T626.WS SORTED BY LOCATION

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	STD DEV
AREA 2	13-7	2139	9.91	0.21
AREA 2	13-8	2700	12.51	0.24
AREA 2	13-8	2637	12.21	0.24
AREA 2	14-3	2273	10.53	0.22
AREA 2	14-6	2599	12.04	0.24
AREA 2	14-8	2637	12.21	0.24
AREA 2	14-8	2596	12.02	0.24
AREA 2	14-9	2733	12.66	0.24
AREA 3	1-1	3126	14.48	0.26
AREA 3	1-2	3101	14.36	0.26
AREA 3	1-3	3020	13.99	0.25
AREA 3	1-4	2915	13.50	0.25
AREA 3	1-5	2339	10.83	0.22
AREA 3	1-6	2032	9.41	0.21
AREA 3	1-8	1729	8.01	0.19
AREA 3	2-3	2738	12.68	0.24
AREA 3	2-5	2299	10.65	0.22
AREA 3	2-6	2047	9.48	0.21
AREA 3	2-8	1579	7.31	0.18
AREA 3	3-3	2869	13.29	0.25
AREA 3	3-7	2020	9.36	0.21
AREA 3	4-3	2754	12.76	0.24
AREA 3	4-5	2558	11.85	0.23
AREA 3	4-6	2075	9.61	0.21
AREA 3	5-3	2846	13.18	0.25
AREA 3	5-8	1744	8.08	0.19
AREA 3	6-6	2192	10.15	0.22
AREA 3	6-7	2115	9.80	0.21
AREA 3	7-4	2864	13.27	0.25
AREA 3	7-5	2733	12.66	0.24
AREA 3	7-8	1898	8.79	0.20
AREA 3	8-5	2849	13.20	0.25
AREA 3	8-6	2133	9.88	0.21
AREA 3	9-4	2906	13.46	0.25
AREA 3	9-7	2103	9.74	0.21
AREA 3	9-8	1821	8.43	0.20
AREA 3	10-4	2755	12.76	0.24
AREA 3	10-5	3080	14.27	0.26
AREA 3	10-6	2082	9.64	0.21
AREA 3	11-4	2631	12.19	0.24
AREA 3	11-8	1808	8.37	0.20
AREA 3	12-4	2667	12.35	0.24
AREA 3	12-5	3114	14.42	0.26
AREA 3	12-6	2083	9.65	0.21
AREA 3	12-7	2100	9.73	0.21
AREA 3	13-4	2808	13.01	0.25
AREA 3	14-4	2702	12.52	0.24
AREA 3	14-5	2180	10.10	0.22
AREA 3	14-6	2403	11.13	0.23
AREA 3	14-8	1860	8.62	0.20
AREA 3	15-4	2766	12.81	0.24
AREA 3	15-5	2654	12.29	0.24
AREA 3	15-6	2818	13.05	0.25
AREA 3	15-7	2481	11.49	0.23
AREA 3	15-9	2805	12.99	0.25

T626.WS SORTED BY LOCATION

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	uR/h STD DEV
AREA 3	16-8	2887	13.37	0.25
AREA 3	17-8	2888	13.38	0.25
AREA 3	18-8	2833	13.12	0.25
AVERAGE / SQRT(SUM OF SQUARES)			11.21	2.42
STANDARD DEVIATION OF VALUES			1.67	

T626 Storage Area Sorted by Exposure Rate

T626.WS SORTED BY EXPOSURE RATE

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	uR/h STD DEV
AREA 3	1-1	3126	14.48	0.26
C.8 AREA 3	12-5	3114	14.42	0.26
AREA 3	1-2	3101	14.36	0.26
AREA 3	10-5	3080	14.27	0.26
AREA 3	1-3	3020	13.99	0.25
AREA 2	11-6	2943	13.63	0.25
AREA 3	1-4	2915	13.50	0.25
AREA 3	9-4	2906	13.46	0.25
AREA 3	17-8	2888	13.38	0.25
AREA 3	16-8	2887	13.37	0.25
AREA 3	3-3	2869	13.29	0.25
AREA 3	7-4	2864	13.27	0.25
AREA 3	8-5	2849	13.20	0.25
AREA 3	5-3	2846	13.18	0.25
AREA 3	18-8	2833	13.12	0.25
AREA 3	15-6	2818	13.05	0.25
AREA 3	13-4	2808	13.01	0.25
AREA 3	15-9	2805	12.99	0.25
AREA 1	4-4	2771	12.84	0.24
AREA 3	15-4	2766	12.81	0.24
AREA 1	4-1	2757	12.77	0.24
AREA 3	10-4	2755	12.76	0.24
AREA 2	10-6	2754	12.76	0.24
AREA 3	4-3	2754	12.76	0.24
AREA 3	2-3	2738	12.68	0.24
AREA 2	14-9	2733	12.66	0.24
AREA 3	7-5	2733	12.66	0.24
AREA 1	1-3	2717	12.59	0.24
AREA 3	14-4	2702	12.52	0.24
AREA 2	13-8	2700	12.51	0.24
AREA 2	11-5	2685	12.44	0.24
AREA 2	9-4	2681	12.42	0.24
AREA 2	5-3	2669	12.36	0.24
AREA 3	12-4	2667	12.35	0.24
AREA 3	15-5	2654	12.29	0.24
AREA 2	7-3	2651	12.28	0.24
AREA 2	13-8	2637	12.21	0.24
AREA 2	14-8	2637	12.21	0.24
AREA 3	11-4	2631	12.19	0.24
AREA 1	4-2	2630	12.18	0.24
AREA 1	2-3	2616	12.12	0.24
AREA 2	14-6	2599	12.04	0.24
AREA 2	14-8	2596	12.02	0.24
AREA 1	4-3	2587	11.98	0.24
AREA 1	3-4	2584	11.97	0.24
AREA 2	6-6	2574	11.92	0.24
AREA 1	1-4	2573	11.92	0.23
AREA 2	8-6	2562	11.87	0.23
AREA 2	7-4	2560	11.86	0.23
AREA 3	4-5	2558	11.85	0.23
AREA 2	2-1	2525	11.70	0.23
AREA 1	1-3	2504	11.60	0.23
AREA 3	15-7	2481	11.49	0.23
AREA 1	2-1	2467	11.43	0.23
AREA 2	6-10	2440	11.30	0.23

T626.WS SORTED BY EXPOSURE RATE

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	uR/h STD DEV
AREA 1	4-5	2425	11.23	0.23
AREA 2	4-11	2415	11.19	0.23
AREA 2	6-8	2408	11.15	0.23
AREA 3	14-6	2403	11.13	0.23
AREA 1	3-5	2390	11.07	0.23
AREA 1	3-2	2385	11.05	0.23
AREA 1	4-5	2357	10.92	0.22
AREA 2	5-13	2356	10.91	0.22
AREA 2	8-11	2347	10.87	0.22
AREA 2	2-8	2346	10.87	0.22
AREA 3	1-5	2339	10.83	0.22
AREA 2	6-12	2328	10.78	0.22
AREA 2	7-9	2319	10.74	0.22
AREA 2	7-13	2319	10.74	0.22
AREA 2	8-9	2317	10.73	0.22
AREA 3	2-5	2299	10.65	0.22
AREA 2	7-11	2296	10.64	0.22
AREA 2	10-7	2296	10.64	0.22
AREA 2	4-4	2288	10.60	0.22
AREA 1	1-2	2273	10.53	0.22
AREA 2	14-3	2273	10.53	0.22
AREA 2	8-13	2263	10.48	0.22
AREA 2	8-10	2236	10.36	0.22
AREA 2	9-7	2230	10.33	0.22
AREA 3	6-6	2192	10.15	0.22
AREA 3	14-5	2180	10.10	0.22
AREA 2	13-7	2139	9.91	0.21
AREA 3	8-6	2133	9.88	0.21
AREA 1	3-2	2120	9.82	0.21
AREA 3	6-7	2115	9.80	0.21
AREA 3	9-7	2103	9.74	0.21
AREA 3	12-7	2100	9.73	0.21
AREA 2	1-1	2093	9.69	0.21
AREA 3	12-6	2083	9.65	0.21
AREA 3	10-6	2082	9.64	0.21
AREA 2	12-4	2075	9.61	0.21
AREA 3	4-6	2075	9.61	0.21
AREA 1	3-1	2059	9.54	0.21
AREA 3	2-6	2047	9.48	0.21
AREA 3	1-6	2032	9.41	0.21
AREA 2	1-7	2020	9.36	0.21
AREA 3	3-7	2020	9.36	0.21
AREA 2	1-13	2016	9.34	0.21
AREA 1	2-5	1997	9.25	0.21
AREA 2	2-4	1961	9.08	0.21
AREA 2	1-11	1959	9.07	0.21
AREA 2	12-3	1937	8.97	0.20
AREA 2	8-9	1905	8.82	0.20
AREA 2	1-5	1903	8.81	0.20
AREA 3	7-8	1898	8.79	0.20
AREA 3	14-8	1860	8.62	0.20
AREA 3	9-8	1821	8.43	0.20
AREA 2	1-4	1820	8.43	0.20
AREA 3	11-8	1808	8.37	0.20
AREA 3	5-8	1744	8.08	0.19

T626.WS SORTED BY EXPOSURE RATE

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	uR/h STD DEV
AREA 3	1-8	1729	8.01	0.19
AREA 2	1-1	1706	7.90	0.19
AREA 3	2-8	1579	7.31	0.18

NUMBER OF MEASUREMENTS	113
MAXIMUM	14.48
MINIMUM	7.31
RANGE	7.17

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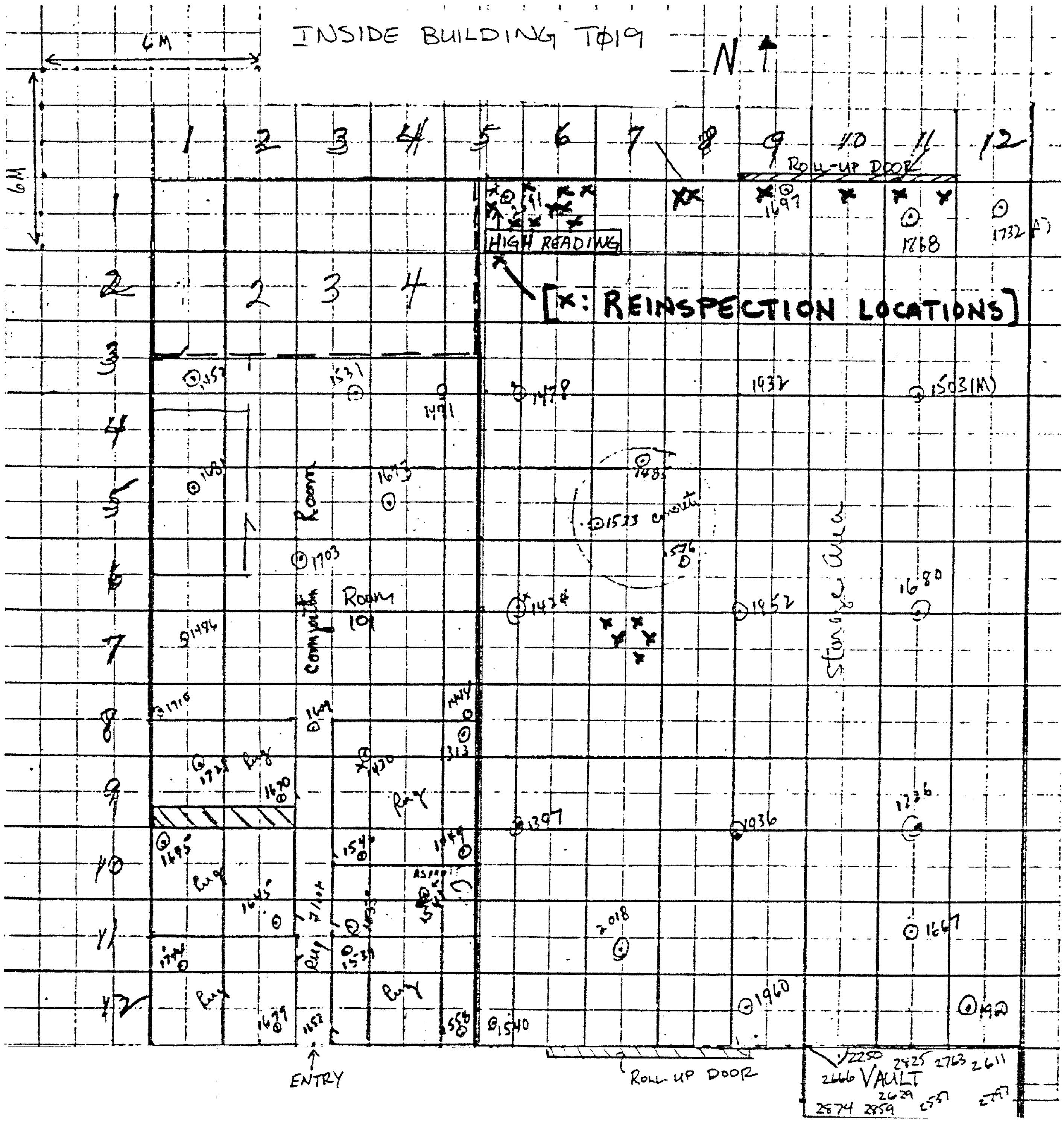
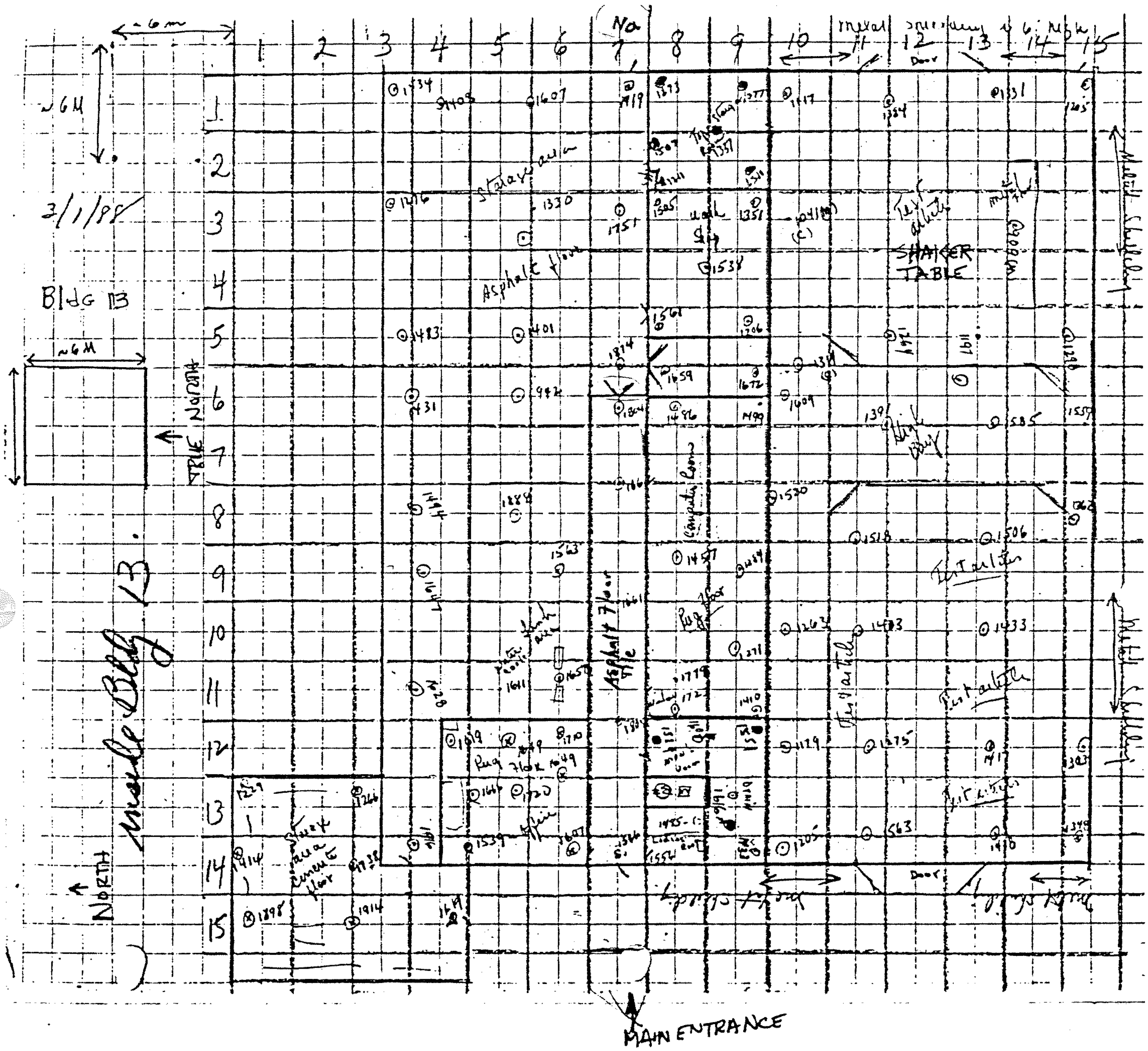
APPENDIX D. SURVEYOR'S MAPS USED DURING RADIOLOGICAL SURVEY

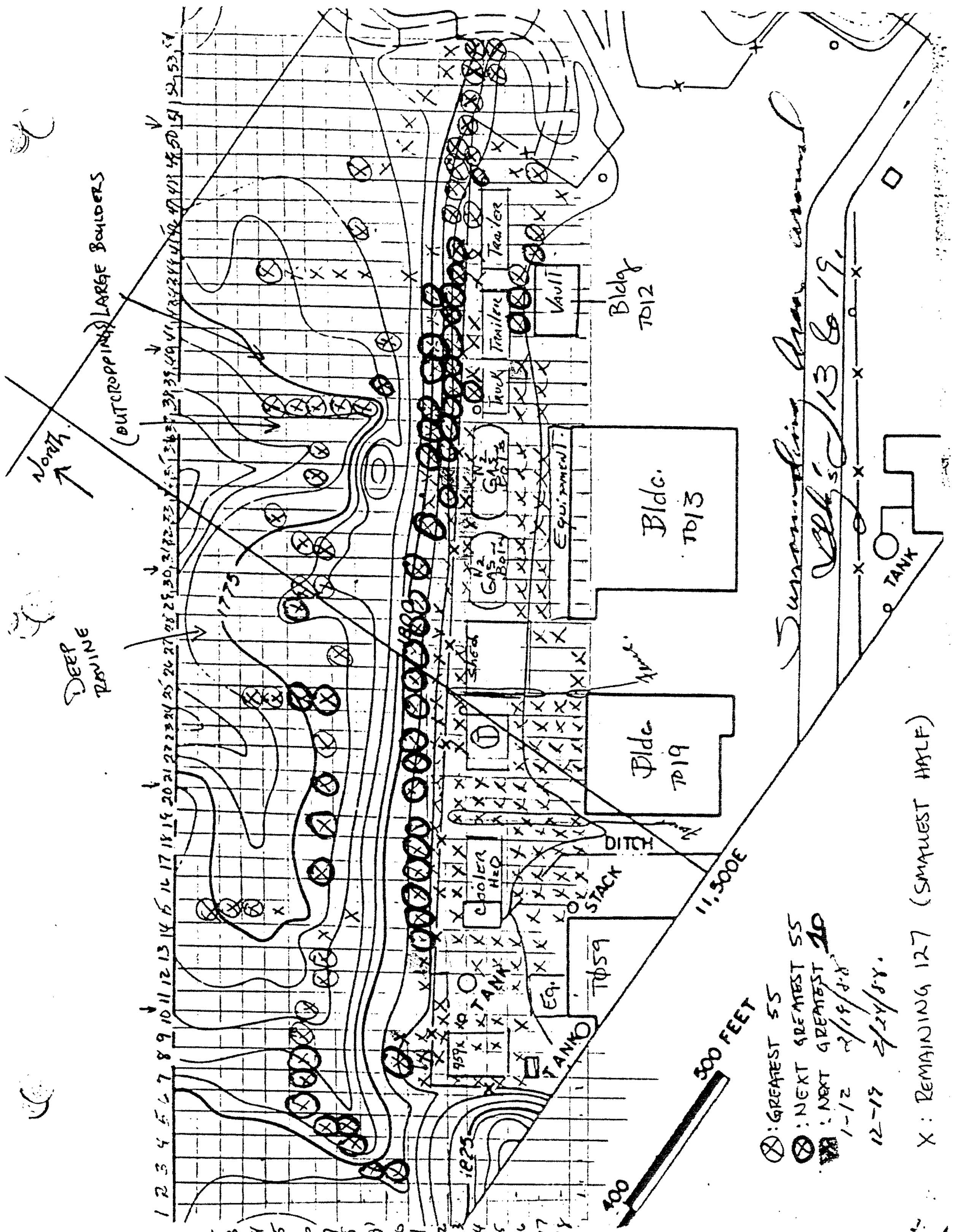
D.1 Building T019



D.2 Building T013

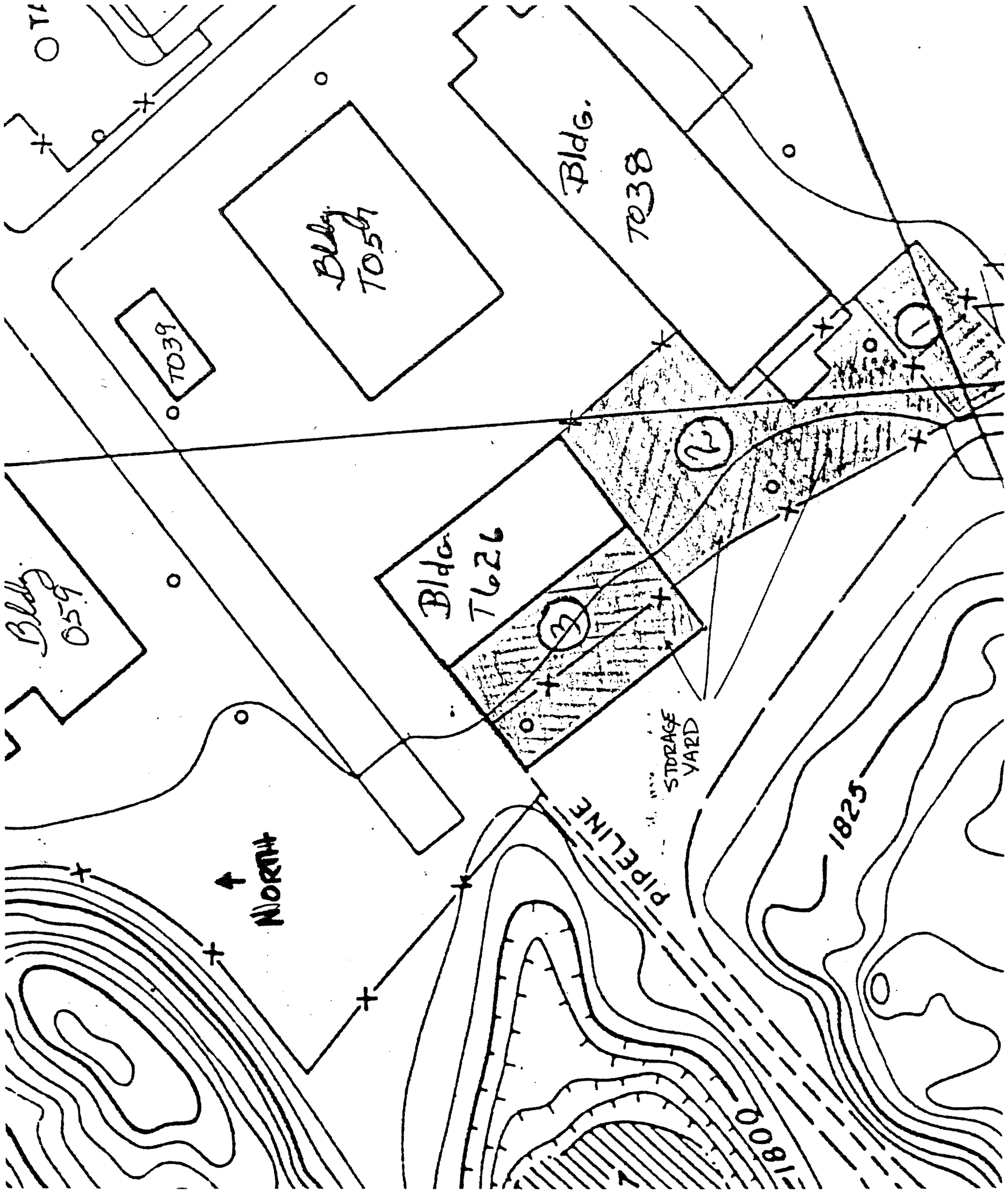


D.3

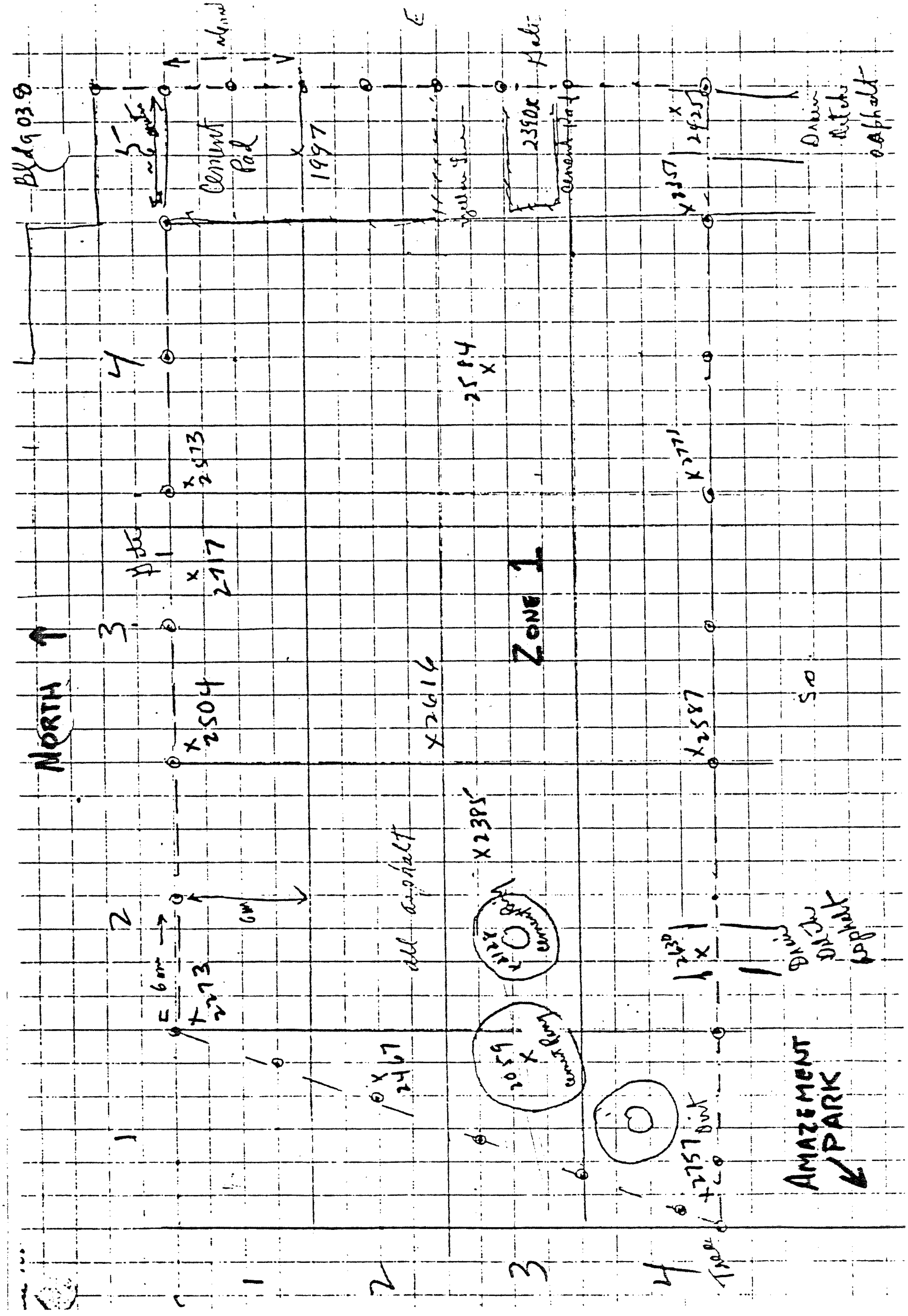


Northwest Area

D.4

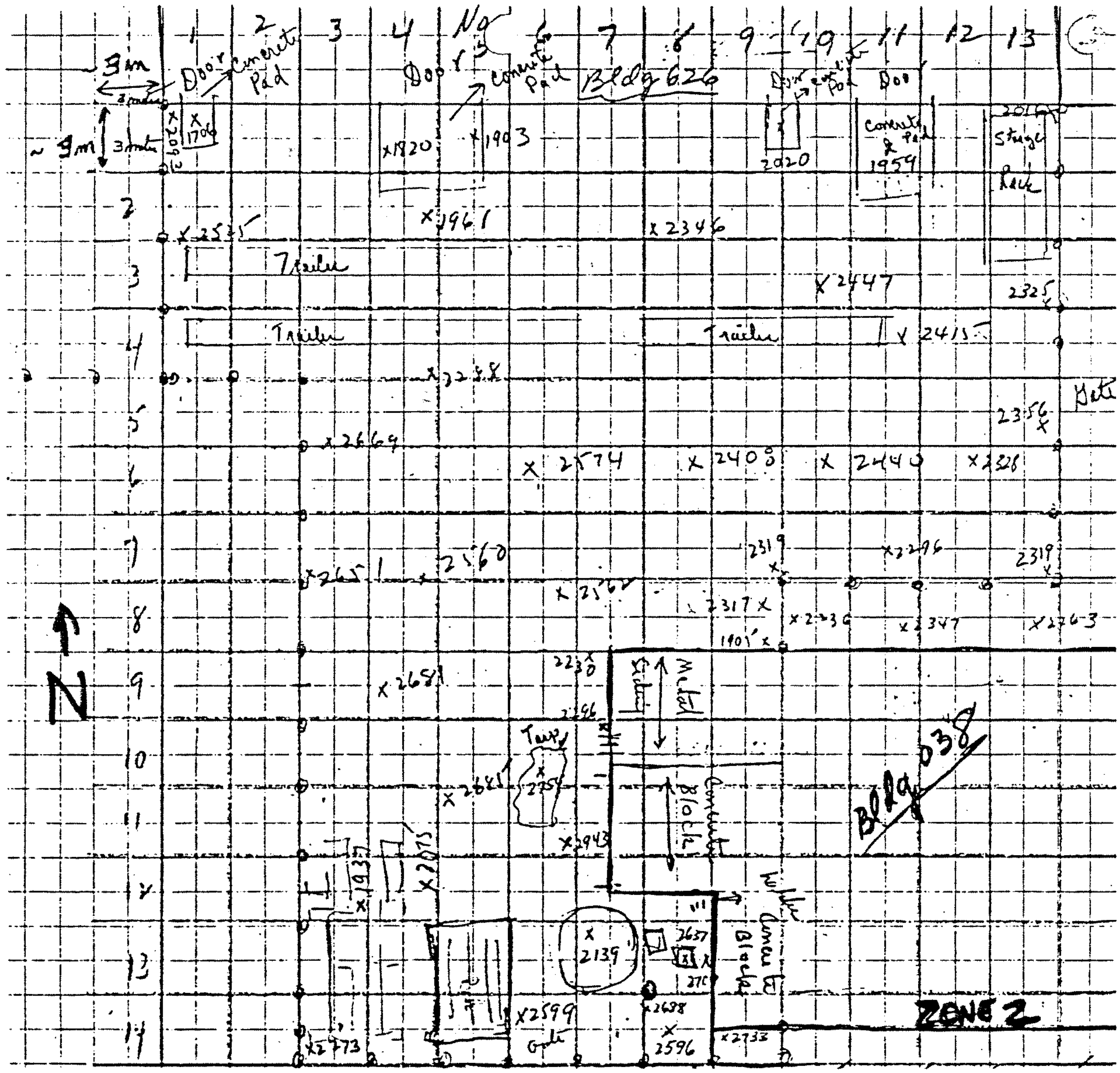


T626 Storage Area (Zones 1, 2, and 3)



T626 Storage Area (Zone 1)

T626 Storage Area (Zone 2)



T626 Storage Area (Zone 3)