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TITLE: "Radiological Survey of the ESG Salvage Yard (Old), Rocketdyne Barrel Storage Yard, and New Salvage Yard (T583)"

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ABSTRACT

A radiological survey was performed in three SSFL areas used for storing salvageable materials, parts, barrels, drums, or shipping containers: 1) the Old Energy Systems Group (ESG) Salvage Yard; 2) Rocketdyne Barrel Storage/Conservation Yard; and 3) New Salvage Yard (T583). These areas have supported research and development work at SSFL since the 1950s. The first two areas mentioned were used extensively during the 1960s to late 1970s time frame in support of predominantly nuclear-related work for the AEC and ERDA. Although controls were instituted to prevent storage of radioactively contaminated materials in these two areas, some contamination incidents are thought to have occurred. When the nuclear-related projects came to an end around 1977, these two yards were cleaned and surveyed. All non-radioactive scrap was moved to T583, which is currently in use. The presence of residual radioactive material in these areas is not likely; however, because the practices in effect several years ago and historical operating events are not well known, this radiological survey was performed. The purpose of this survey is to determine if any residual radioactive contamination was left behind from these storage operations to such an extent that further surveying or decontamination is warranted.

All combined, a five-acre area was inspected. Ambient gamma exposure rate measurements were performed on a 6-m square plot plan. Soil samples required by the Site Survey Plan (Reference 4) were collected and analyzed. Additional soil samples were collected and analyzed because radioactivity was indicated by exposure rate measurements.

Results of this survey and analyses show that, with one exception, all three storage areas are "clean" of radioactive contaminants. Gamma exposure rate distributions are equivalent to natural "background" at SSFL-with one exception. All soil samples collected and analyzed as required by the Survey Plan indicate nothing above naturally-occurring primordial activity. No further investigation is required - these areas are "clean."

Further investigation _is_ required in one localized area; the southwest corner of Rocketdyne's Barrel Storage Yard. This area is a mud puddle resulting from rainwater runoff from the site. Cs-137 was found in concentrations slightly exceeding the 100 pCi/g - beta unrestricted-use limit. The extent of contamination has been estimated, but is not well known. This small amount of contamination is not a health hazard; however, further inspection is required.

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1.0 INTRODUCTION

Three areas located in Area IV of Rockwell International's Santa Susana Field Laboratories (SSFL) were surveyed and analyzed for residual radioactive material. All of these areas have been used for storing excess salvageable materials and scrap components, some of which may have been contaminated with radioactive material. These natural-terrain areas include the Old Energy System's Group (ESG) Salvage Yard, Rocketdyne's Barrel Storage Yard, and the New Salvage Yard (T583). Each area was inspected for radioactivity to determine whether any radioactive material has been accidentally left behind, 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 5.4.5, 5.4.6, and 5.4.7).

Located in Ventura County, California, Area IV of Rockwell International's SSFL has been used to develop and test nuclear powered reactors; fabricate reactor-grade nuclear fuels; and reprocess spent nuclear fuels. These programs were funded by the AEC, ERDA, and DOE. Many of these government-sponsored nuclear-related programs have ended, and the facilities that supported these programs have been reassigned and modified for other non-nuclear DOE programs. During various construction, dismantling, and refurbishing phases of the facilities which supported these programs, excess salvageable materials were kept primarily in an area designated the Old ESG Salvage Yard. This natural-terrain yard was active from about 1952 to 1977. Because of the large amount of materials excessed during that time frame, the size of the original ESG Salvage Yard spread out to surrounding areas. Part of this growth expanded into the Rocketdyne Barrel Storage Yard, immediately south of the ESG Salvage Yard. The Rocketdyne Barrel Storage Yard (also known as the Conservation Yard) was predominately used by Rocketdyne for storing excess material from 1957 to 1969. Although not operated as a radiologically-controlled facility, these areas were surveyed for contamination on a regular basis. No deliberate dumping or placing of radioactive materials in these areas ever occurred. Because extremely regimented radiological controls were not instituted, however, contaminated items were found on occasion during performance of routine radiation surveys.

Two restructuring phases of these two yards took place to better accommodate storage needs. First, in 1969 the Rocketdyne Barrel Storage Yard was converted to a material storage area for Plant Services, who then in 1986 relinquished control to Transportation. Shipping trailers and casks are currently stored there. Second, in 1977, during which time the major nuclear-related programs were winding down, salvageable materials were moved from the Old ESG Salvage Yard to the New Salvage Yard (T583) or transported off-site. The Old ESG Salvage Yard is now completely free of debris. The new fenced-in Salvage Yard is currently in use. During these restructuring phases, radiation surveys were performed on materials and the general area. No contaminated items were moved to T583. Although some minor radiological problems are known to have occurred, spills were cleaned and the affected areas returned to their natural condition.

A few locations were suspect of residual contamination: northwest corner of the Rocketdyne Barrel Yard; and drainage gullies from the SRE pond. Because the extent of suspect contamination is unknown, and because no records exist to document the radiological condition of these areas, a radiological survey was performed.

As part of the DOE SSFL Site Survey (Reference 4, sections 5.4.5, 5.4.6 and 5.4.7), a radiation survey was performed in these areas where radioactive material may have been kept 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 radioactive materials handled at the production facilities: mixed fission products, and activation products. If radioactive contamination was indicated during performance of the gamma measurements, samples were collected and analyzed for radioactivity.

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.

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. Energy Systems Group (ESG) Salvage Yard (old) (section 5.4.5);
2. Rocketdyne Barrel Storage Yard (section 5.4.6);
3. New Salvage Yard, T583 (section 5.4.7).

These 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. SSFL 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.

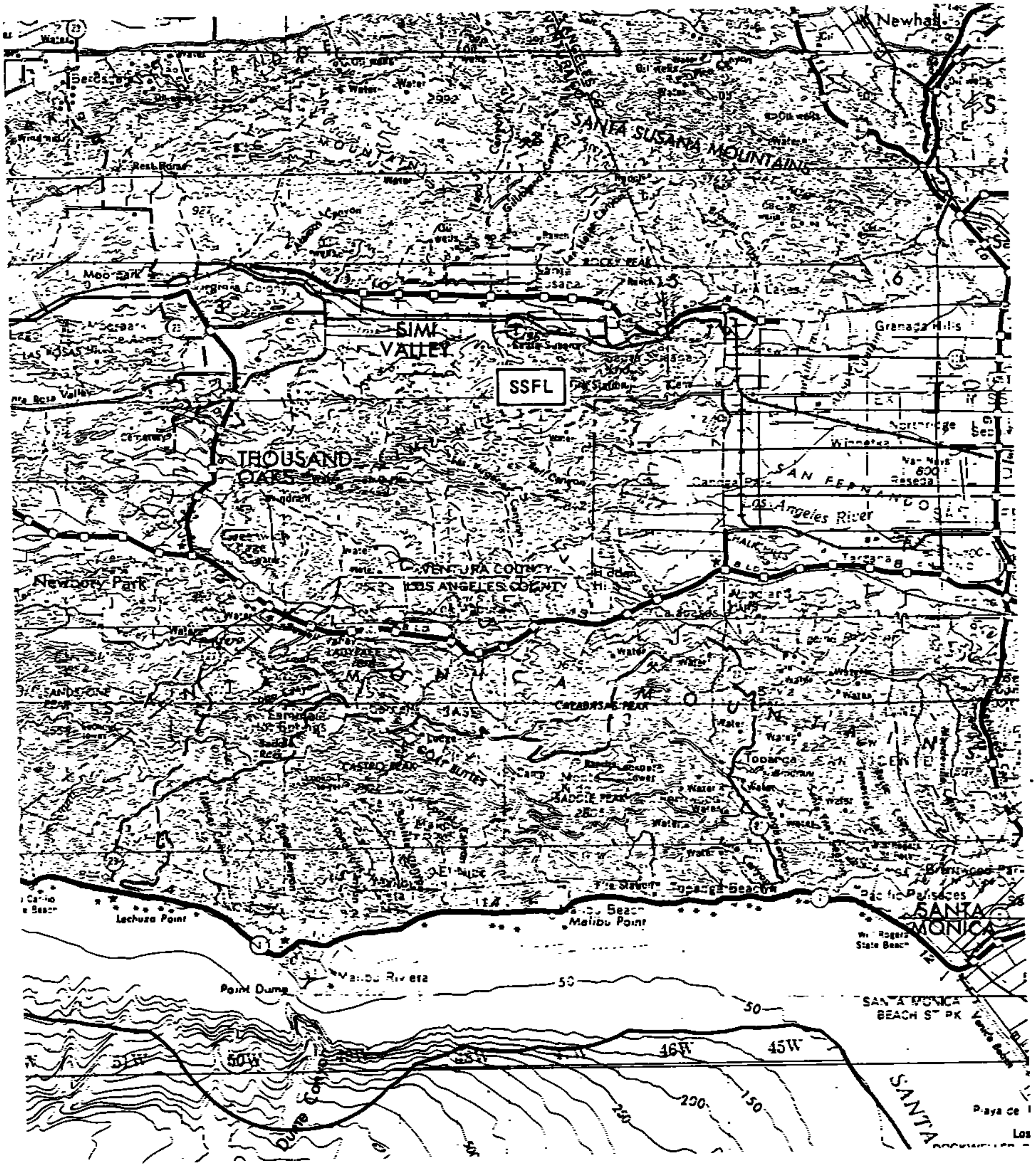
The three areas covered in this report are located in the western portion of SSFL, which is referred to as Area IV. Figure 2.3 is a plot plan of Area IV showing the locations of the subject areas. The Old ESG Salvage Yard, which is currently used as the fuel oil tank farm, is located on the government-optioned land, whereas the New Salvage Yard (T583) and the area identified as the Rocketdyne Barrel Storage Yard are located on Rockwell-owned land.

2.2 Area Characteristics and Site Topography

The terrain throughout most of these areas is uneven due to rock outcroppings. Because of this condition, the field survey data was broken down and collected by zones (1 through 10) as shown in Figure 2.4. The site is located on an irregular plateau in a mountainous area of recent geological age sprinkled with outcroppings above the more level patches. Outcroppings of Chico sandstone formation are numerous.

Figure 2.1 Map of Los Angeles Area

Figure 2.2 Map of Neighboring SSFL Communities



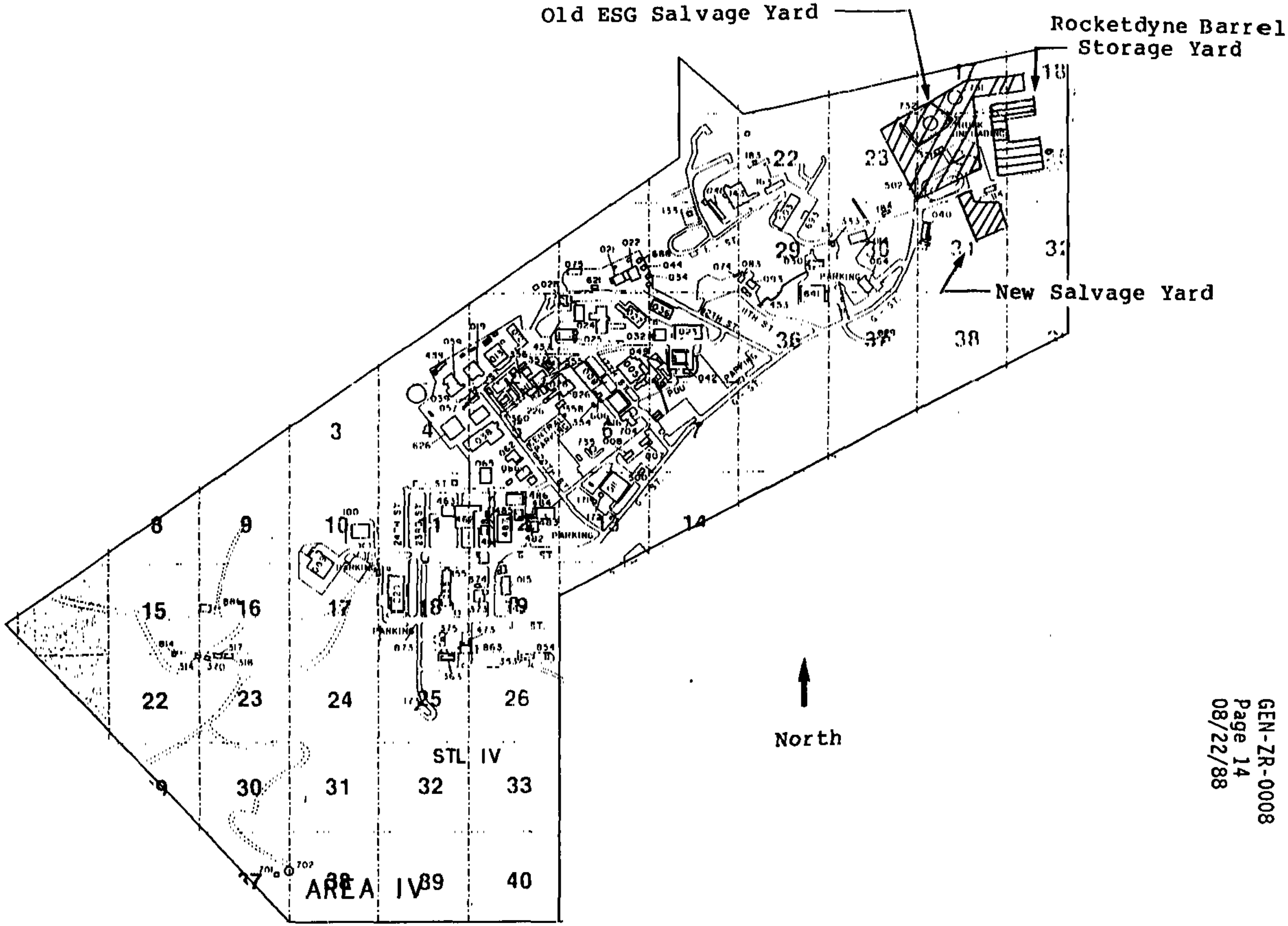
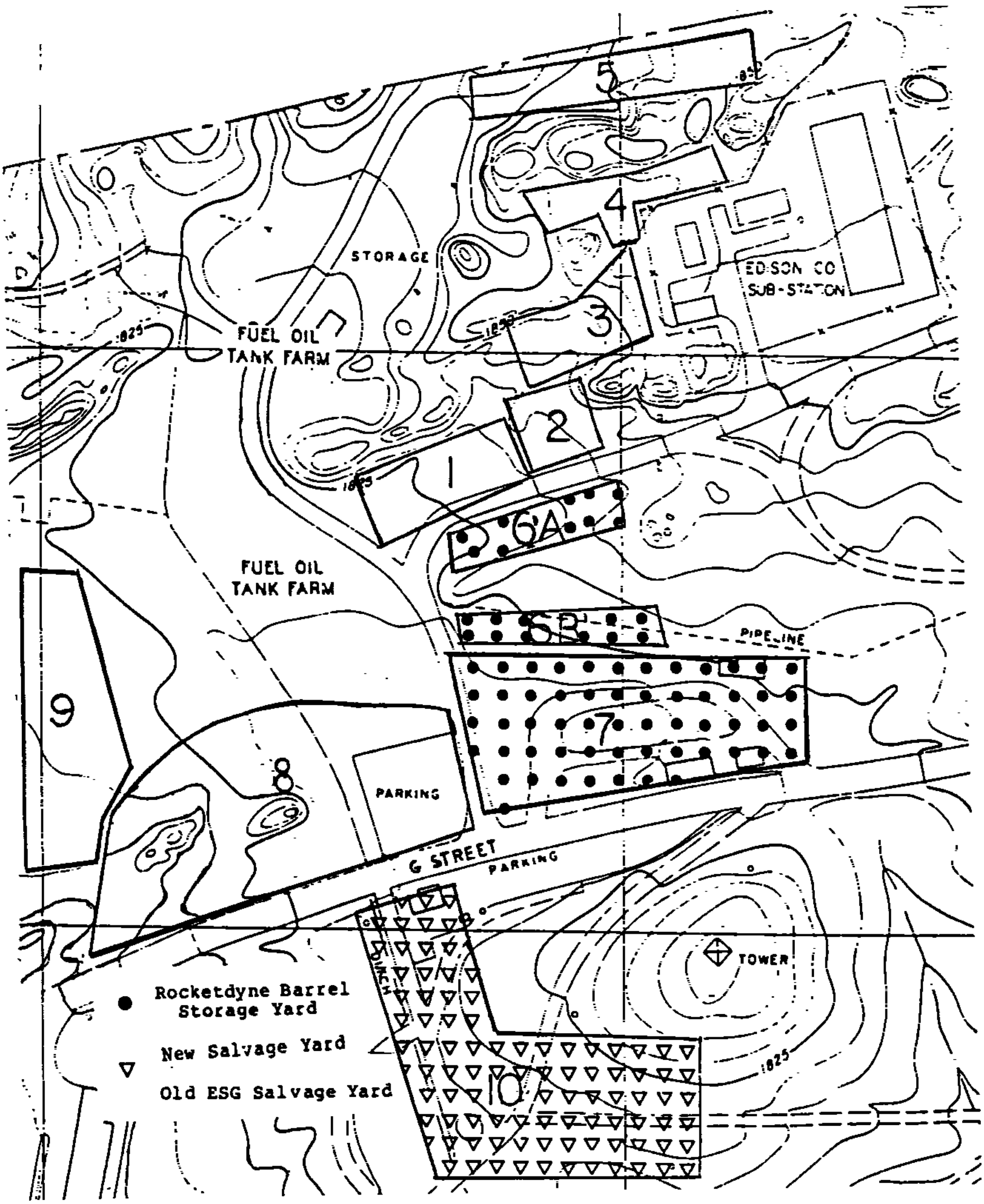


Figure 2.3 SSFL Layout, Showing Locations of the Old ESG Salvage Yard, Rocketdyne Barrel Storage Yard, and New Salvage Yard (T583)

Figure 2.4 Area Topography Map



The general slope of the area 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 property into the Bell Canyon drainage occurs only after controlled effluent hold-up and sampling.

The Old ESG Salvage Yard is marked in Figure 2.4 as zones 1, 2, 3, 4, 5, 8, and 9; and now includes two fuel-oil tanks. This area encompasses upward of 110,000 ft^2 (3 acres). The area is loaded with sandstone outcroppings; thus, the segmented survey zones. Most of the area is natural-terrain, free of debris, not fenced, and is not currently used for any purpose.

The Rocketdyne Barrel Storage Yard (also known as the Rocketdyne Conservation Yard) is marked as zones 6A, 6B, and 7 in Figure 2.4. It encompasses about 40,000 ft^2 (1 acre). This flat area is partially paved, gravel, and dirt, and is not fenced in. This area, in contrast to the Old Salvage Yard, is flat and was much easier to grid and survey. This area is currently used as a storage location for shipping trailers.

The New Salvage Yard is marked as zone 10 in Figure 2.4. It encompasses about 24,000 ft^2 (about 0.5 acres). This well-controlled, fenced-in area is in limited use today for storing salvageable items. A paved road off "G" Street allows access to this area. The area is relatively flat covered with loose dirt and weeds, and cluttered with material. A surface drainage gully running near the west boundary line of T583 used to drain water pumped from the old Sodium Reactor Experiment (SRE) catch pond in area 773. Surface water run-off (primarily rain water) from the SRE flowed down-hill to the catch pond. This volume of water was then pumped through a series of surface drainage gullies to the SSFL-controlled Delta pond. One of the gullies ran west of T583. Because several radioactive spills occurred at the SRE, radioactive contamination is slightly suspect in this series of drainage gullies.

2.3 Area Utilization and Present Radiological Condition

The area shown in Figure 2.4 as the current fuel oil tank farm, and zones 5, 8, and 9, were occupied by the Atomics International Conservation and Salvage Yard during the 1952-1977 time frame. The area served as an impound area for excess salvageable materials for reuse at the site, or for eventual disposal to a salvage contractor. Radiation monitoring of the area was performed on a regularly scheduled basis.

In January 1977, remaining materials in this yard were relocated to the New Salvage Yard (T583) site south of "G" Street, (identified in Figure 2.4 as zone 10). Prior to the relocation, a thorough radiation survey of the entire area was conducted, and construction of the initial phase of the fuel oil tank farm was started. A second fuel oil storage tank was added in 1982 and the area was fenced. This enclosed tank farm area is not included in this survey.

Zones 6A, 6B, and 7 were initially used by Rocketdyne as a conservation (barrel storage) yard for excess material and equipment. This use of the area extended from 1957 to 1969. In 1970, the conservation function was relocated to the Canoga site, and the Plant Services organization took over the area as a material hold area. This use continued until 1986, when it was converted to a parking area for trailers and other transportation vehicles. Only zone 7 is used as a parking area; 6A and 6B are no longer in use.

The remaining zones 1, 2, 3, and 4, were expansion areas of the ESG Salvage Yard. Figure 2.5 is an aerial photo taken of the area in 1963 showing various material stored in the Old ESG Salvage Yard and Rocketdyne Barrel/Conservation Yard. In this photo, most of the material is concentrated in zones 1 through 5, and 7 (Figure 2.7). Zones 6A, 6B, 8, and 9 appear to be empty of debris in this photo. Also in 1963, it is clear from the photo that the New Salvage Yard had not yet been established.

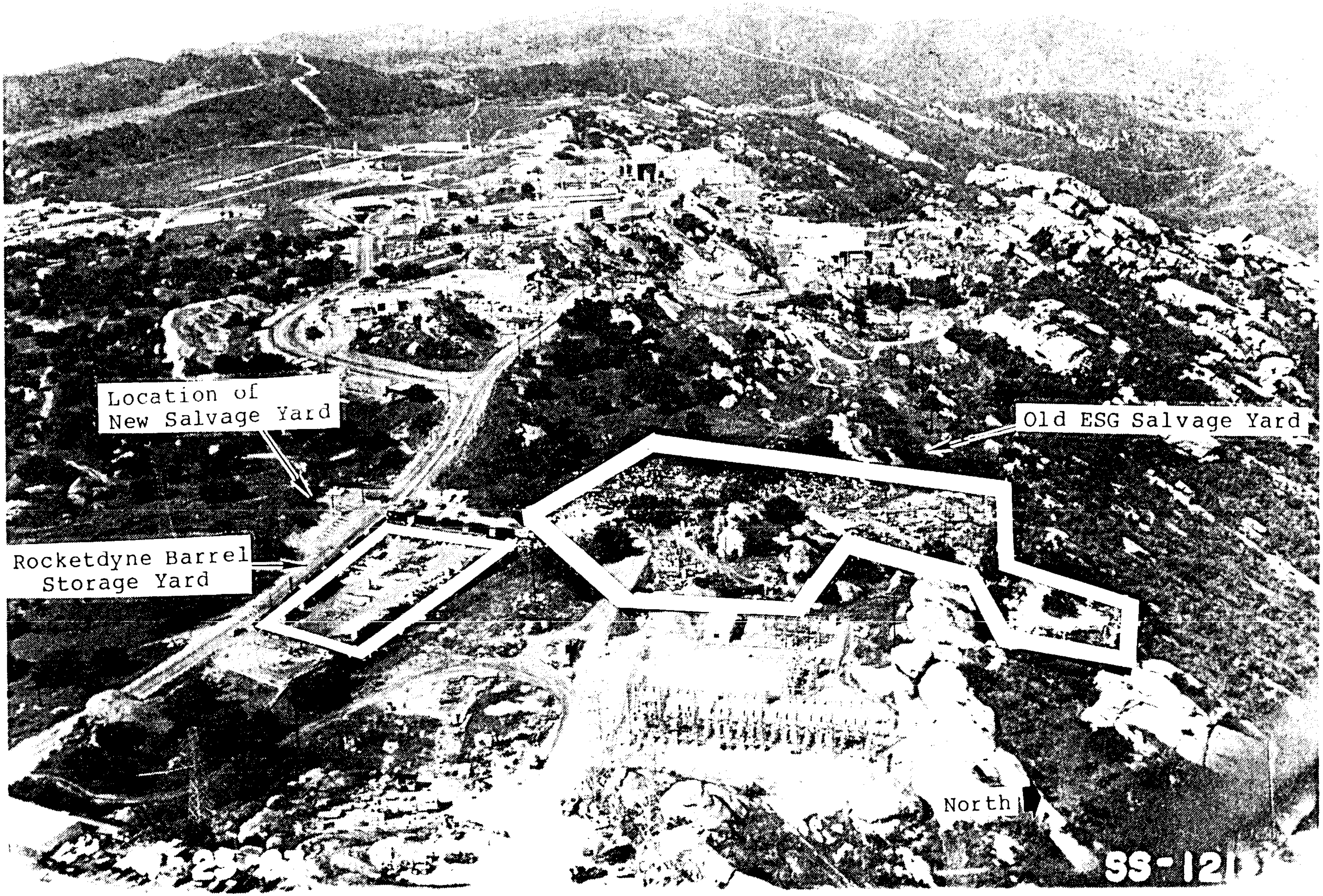


Figure 2.5 Aerial Photo Showing Old ESG Salvage Yard, Rocketdyne Barrel/Conservation Yard, and the Site of T583

During routine radiological inspections of the Old ESG Salvage Yard in the 1960s and 1970s, some radioactive items were found. These items were contaminated with either mixed fission products (MFP) or uranium. When all the debris and salvageable items were removed from this area, a radiation survey was performed to ensure that no radioactive material had been left behind. Currently the area is thought to be free of radioactive material.

It is believed that a spill of mixed-fission-product-contaminated liquid occurred at the Rocketdyne Barrel/Conservation Yard. The details of this incident are unknown. Previous routine surveys of this area showed a small location on the southwest corner of the lot which read above ambient gamma background. This location was further investigated by the survey team.

At the New Salvage Yard (T583), established in 1977, controls were instituted to ensure that no radioactive material or radioactively contaminated materials were stored there. Because of these controls and because few major nuclear-related projects have occurred in this recent time frame, residual radioactive material existing on the premises is unlikely. Residual radioactive material in the SRE drainage gully was slightly suspect.

3.0 SURVEY SCOPE

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

1. Old ESG Salvage Yard (Reference 4, Section 5.4.5)

   . Survey the surface from "G" Street north to the oil tanks, and east (north-east) to the electrical substation.

   . Survey the surface east of the oil tanks and all relatively level areas to north-facing banks.

2. Rocketdyne Barrel Storage Yard (Reference 4, Section 5.4.6)

   . Survey the surface from northern edge of outcropping south to "G" Street.

   . If indicated, sample subsurface northwest corner (40 ft x 40 ft).

3. New Salvage Yard - T583 (Reference 4, Section 5.4.7)

   . Survey surface.

   . Subsurface (2 ft deep), if indicated, in north-south drainage ditch on both sides of "G" Street and approximately 60 ft each direction.

These areas are shown in Figure 2.4., a topography map; and Figure 2.5, an aerial photograph.

Gamma exposure rate measurements were made at 438 locations in the combined areas: 279 (Old ESG Salvage Yard); 96 (Rocketdyne Barrel Storage Yard); and 63 (New Salvage Yard). Soil samples were collected and analyzed as required by the Survey Plan or determined appropriate because of elevated gamma exposure rates. Three soil samples were collected in the northwest-area of the Rocketdyne Barrel Storage Yard as required by the plan; soil samples were collected in the SRE drainage ditch near T583 as required by the plan; and three soil samples were collected in the southwest-corner of the RD Barrel Yard as determined appropriate by the survey. Ambient gamma exposure rates are reported in micro-roentgens per hour (μR/h). Radionuclide activity concentrations and gross alpha/beta activity in soil is reported in picocuries per gram (pCi/g).

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.

Limits for soil and water radioactivity concentrations are applicable on an as-required basis. The limits used here for alpha contamination in soil, are based on Ra-226 (Reference 1). No effort was made to sum the concentrations of these individual radionuclides and calculate the dose for the mixture so as to show that it does not exceed the basic dose limit. The 100 pCi/g-beta limit applies for Cs-137 and Sr-90. Cs-137 was found in above "background" concentrations. Sr-90, which accompanies Cs-137, was not specifically analyzed during this survey.

Table 3.1 Maximum Acceptable Contamination Limits

Criteria	Alpha	Beta
Ambient Gamma Exposure Rate*	5 μR/h above background	
Soil Activity Concentration**	21 pCi/g 31 pCi/g	100 pCi/g
Water Activity Concentration***	$1x10^{-4}$ μCi/ml	$1x10^{-5}$ 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.

** The alpha activity concentration limit for Ra-226 is 5 pCi/g (Reference 1) plus that contribution from naturally occurring radioactivity, (about 16 pCi/g from Reference 17, p. 93) averaged over the first 15 cm of soil below the surface. At a depth greater than 15 cm below the surface, 15 pCi/g averaged over 15-cm-thick layers of soil plus "background" is the limit. 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 during the survey. These are proactive action levels initiated when the surveyor detects radiation according to the following criteria:

1. <u>Characterization Level</u> - 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 storage yard was treated as a single sample lot for characterization and interpretation. Within each area, however, zones were established to ease the gridding procedure. The areas, as demonstrated by the topography map, are cluttered with sandstone outcroppings. Figure 3.1 shows the survey sampling lot plan. This figure shows the various zones set up for each sample lot.

6-m square grids were superimposed over the terrain. One ambient gamma exposure rate measurement was made in each 36-m^2 cell. Location (1,1) was the northwestern-most grid in each zone. Each measurement location was marked by zone (1, 2, 3, 4, 5, 6A, 6B, 7, 8, 9, or 10) and its corresponding two figure Cartesian coordinate indicating the location in meters from a local benchmark. The sampling inspection plan used was based upon a uniform 6-meter square grid superimposed on a uniform inspection area. Radiological conditions and physical surroundings were similar in all areas.

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 µR/h. The measurement location and exposure rate were recorded in tabular form. 438 1-min. measurements were acquired over the total area.

3.4 Surface Soil Samples

Soil sampling was required by the site survey plan (Reference 4) only if gamma exposure rate measurements indicated possible radioactivity. As mentioned at the beginning of this section, two areas of soil were suspect of residual radioactivity: 1) northwest corner of the RD Barrel Storage Yard; and 2) the SRE drainage gully which runs west of and adjacent to T583. Although no positive indication of contamination was found by gamma exposure rate measurements taken in these locations, a few soil samples were collected. Elevated exposure rates were observed in the southwest corner of the RD Barrel Storage Yard; soil samples were collected and analyzed. Figure 7.12 shows these soil sampling locations.

Each soil sample location was identified and marked on the sample bag. Each sample was transferred to a bread pan for drying in an oven. When dry, each sample was stirred, then split into a 450-ml sample and a 2-g sample. Each 450-ml sample was placed in a Marinelli beaker for counting by gamma spectrometry. Each 2-g sample was ground with a mortar and pestle, placed in a 2-in diameter aluminum planchet, and then counted for gross alpha/beta activity for 30 min.

3.5 Goals and Limitations of Survey Scope

These salvage yards and excess material storage areas cover a large territory, almost 5 acres. Certain areas have been used for many years and were used quite vigorously in the 1960s and 1970s. Limited inventory controls were used during the active periods to ensure that only truly salvageable materials were brought here. However, radiation controls were well-known and were, for the most part, complied with. Radioactive materials and radioactively contaminated equipment were prohibited from the area. Radiation surveys were performed regularly to ensure compliance with this policy. Even with the controls, some contaminated items and debris were discovered on occasion. It is believed that a small radioactive material spill occurred from either a shipping cask or drum. This is not documented. A thorough radiation survey was performed when each area was cleaned-out. No radioactivity was found then. Radioactivity is not suspect now. 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. It is unlikely that any subsurface (greater than a foot) debris is presently on site; the area was never a dumping ground or landfill. Subsurface transport of contaminants is also considered negligible.

Because of the large area surveyed, exposure rates were measured once in every 36 m^2. Although this may not appear to be a very thorough sampling plan, it is sufficient for two reasons:

1) gamma measurements made on a 6-m square would detect Cs-137 at 100 pCi/g (the 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 graphical representations of cumulative distribution functions will identify trends, anomalies, outliers, and perturbations in the radiation levels.

We are thus 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

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 activities took place in this area.

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, $(x = \overline{x} = m)$. 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:

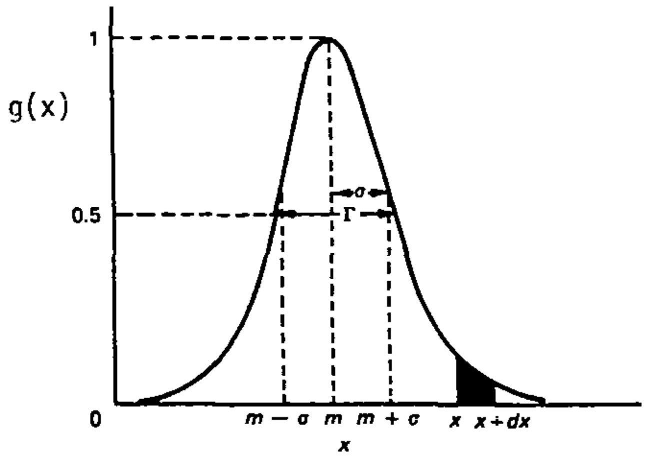


Figure 4.1 The Gaussian Probability Density Function

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:

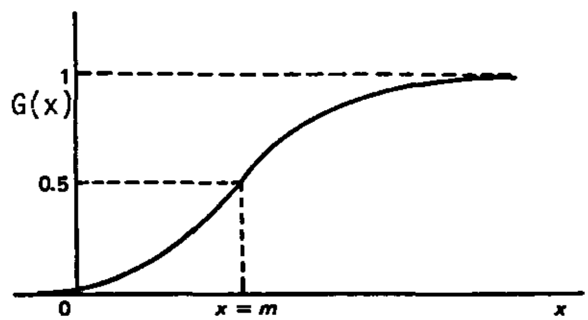


Figure 4.2 The Gaussian Cumulative Distribution Function

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, $\overline{x} + ks$, is compared to the acceptance limit U, where:

$\overline{x}$ = 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:

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

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

The standard deviation, s is given by:

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

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.

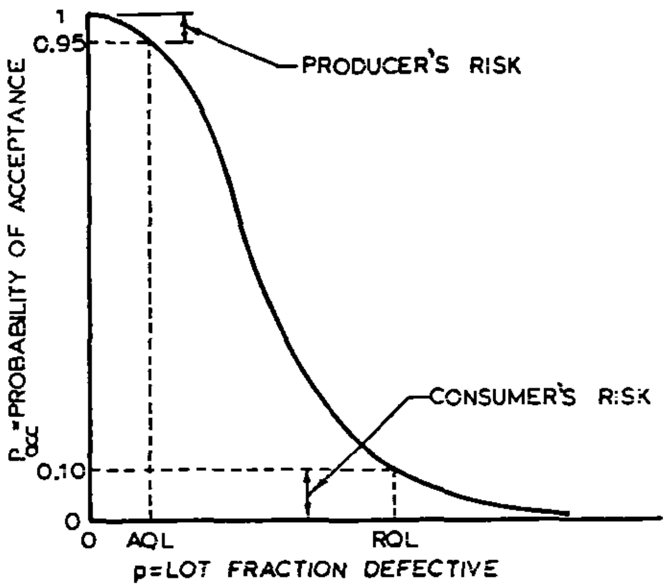


Figure 4.3 Operating Characteristics Curve

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):

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

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_β 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.

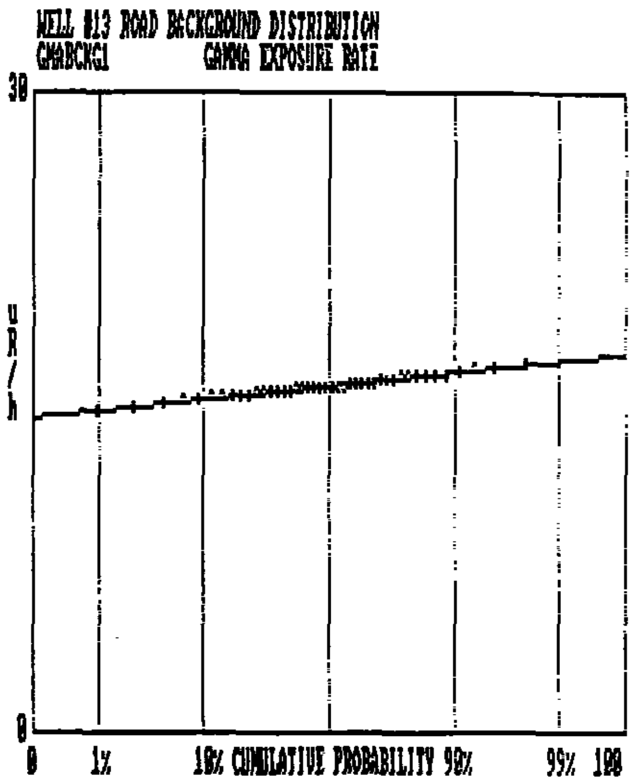


Figure 4.4 Gaussian cdf Plotted on Probability-Grade Paper

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.

4.3.3 Acceptance Criteria for an Uncontaminated Area

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 $\overline{x}$ 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 $\overline{x}$ >= 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 several radiological measurements:

1) Ambient gamma exposure rate;
2) Gross alpha/beta activity in soil samples; and
3) The presence and quantity of gamma emitters in soil samples (these include primordial, cosmogenic, and fission and activation products).

Analytical techniques used to acquire, evaluate, and interpret these radiological measurements are presented in detail in this section. These techniques include instrument calibration corrections, alpha absorption corrections in soil samples, evaluation of computer-generated gamma spectrometry output, determination of "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. 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 or radionuclide concentrations were always reinspected. In this case, soil samples were collected and analyzed for gross alpha/beta activity, and gamma emitters.

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. Z1 (10,6) (Z = Zone; either 1, 2, 3, 4, 5, 6A, 6B, 7, 8, 9, or 10), grid location 10,6.
2) Ambient Gamma Exposure Rate (counts in 1 min.; cpm); and
3) Gamma survey instrument background (1 min.), and 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 each distribution. The acceptance criteria presented in Section 4.3.3 is applied to each sampling distribution.

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

Both the NRC and DOE criteria for acceptance as unrestricted use are given in μR/h above background, 5 and 20, respectively. 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.

The best solution for evaluating the potential 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 total-gross exposure rates in different areas.

The Old Salvage Yard, Barrel Yard, and T583 distributions of ambient exposure rate measurements are compared against three independent sampling areas of similar geologic characteristics. In these other areas, no radioactive materials were ever used, handled, stored, or disposed. These distributions represent "natural ambient gamma radiation" levels in this SSFL location. "Background" measurements were taken on flat and rugged terrain, with Chico Formation sandstone, similar to conditions of the areas surveyed.

These distributions make no corrections for "background"; the total-gross gamma exposure rate is considered. Then, in order to compare this survey data against acceptance limits "above background," the average of the "true background" areas is used as our best estimate for background radiation at SSFL. Using this value, we correct the survey data and compare the resulting "background corrected" distributions against the acceptance limit of 5 μR/h above background. Inspection by variables techniques are used to judge whether the lots are acceptably clean; the test statistic, $\overline{X}$ + ks is calculated.

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 10CFR20, Appendix C. If only Cs-137 were contained in the soil, this 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.

The ambient gamma background radiation is about 10-15 μR/h at 1 meter from the ground, so the source material would have to produce an exposure rate of at least 5 μR/h 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 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 below the surface more than 6 in. is small. For condition (2), contaminated debris, whose activity exceeded 1 mCi Cs-137 activity could be seen if it wasn't buried any deeper than a foot. 10 mCi could probably be seen down to 2 feet. As mentioned earlier, the likelihood of buried debris in these areas is very small.

5.5 Surface Soil

A 2-lb surface soil sample was collected in certain areas. The sample was dried in an oven after large chunks and rocks were removed. The sample was homogenized, then split into 450-ml and 2-g samples. The 2-g sample was crushed using a mortar and pestle, then placed in an aluminum planchet for alpha/beta counting. The 450-ml sample was placed in a Marinelli beaker for gamma spectrometry.

5.5.1 Gross Alpha/Beta Analysis

Once the 2-g sample was finely ground and placed on a 2-in. aluminum planchet, it was placed on the sample loading magazine of the Canberra proportional alpha/beta counter, (Appendix A.2). Each sample was spread uniformly over the entire area of the planchet.

5.5.1.1 Instrument Calibration

When counting soil samples for radioactivity, it is very important that the geometry from sample to sample remain constant. Proper corrections must be made for detector background, and efficiency. Before any of the soil samples were analyzed, a precise determination was made of the background, the degree of alpha/beta absorption in soil, and the detector efficiency.

Detector background for "false positive" alpha/beta counts was determined by using processed sea sand. All primordial radioactive isotopes have been removed from this silica material. A 2-g sample was placed on a planchet and counted at least 10 times for 30 min. each to determine the alpha and beta background count rates. The average background determined for this instrument was 4.5 ± 1.8 alpha counts in 30 min. and 53.4 ± 11.1 beta counts in 30 min.

Alpha efficiency (detector plus self-absorption) was determined by using a 2-g soil sample spiked with 93% enriched uranium. The standard was spiked with 40 pCi/g-alpha activity. Natural primordial radioactivity in the standard contributed an additional 25.85 pCi/g-alpha activity. The total alpha activity in the soil was therefore 65.85 pCi/g. By counting the standard several times for 30 min. each, an alpha efficiency factor of 32.45 $\pm$ 3.7 pCi/g·cpm was calculated.

Beta efficiency was determined by using a 2-g KCl beta standard. At 0.00117% abundant, K-40 produces 1750 beta disintegrations per minute per 2-g sample of KCl. By counting the standard several times for 30 min. each, a beta efficiency factor of 1.44 pCi/g·cpm was calculated.

The efficiency factor calculations and background measurements were used throughout the duration of the analysis. An NBS traceable Th-230 calibration source was used twice daily as a check source. If, on a day to day basis, the check source alpha/beta count deviated by $\pm$ 5% of the nominal value, the instrument would be checked and recalibrated using the soil standards. This recalibration was never necessary.

5.5.1.2 Data Reduction and Analysis

Gross alpha/beta counts were collected for each soil sample, 30 min. each. Gross activities in pCi/g were calculated using the backgrounds and efficiency factors mentioned in Section 5.5.1.1. This radioactivity concentration calculation is given by the following expression:

$$A_C = \frac{C - B}{30\ \text{min.}}\ EF \qquad (\text{pCi/g}) \qquad \text{(Eq. 5-3)}$$

where A_C = Activity Concentration (pCi/g)
C = Gross Counts (alpha or beta)
B = Background Counts (alpha or beta)
EF = Efficiency Factor (32.45 alpha - pCi/g·cpm)
(1.44 beta - pCi/g·cpm)
30 min. = Count Time

The standard deviation of this measurement is:

$$s = \frac{\sqrt{C + B}}{30 \text{ min.}} (EF) \qquad (pCi/g) \qquad (Eq.\ 5\text{-}4)$$

Results are presented in a tabular format.

5.5.2 Gamma Spectrometry

Each 450-ml soil sample was placed in a Marinelli beaker and counted for 30 min. on a Canberra Series 80 gamma spectrometer, described in Appendix A.1. This instrument measures U-238, U-235, Th-232 and K-40 radioactivity, all of which are naturally occurring. It will also detect characteristic fission and activation products such as Cs-137, Co-60, and Eu-152.

5.5.2.1 Instrument Calibration

The instrument is calibrated routinely for energy and efficiency using a Marinelli Beaker Standard Source (MBSS), described in Appendix A.1. This calibration process is performed over a wide energy range: Cd-109 (88.03 keV), Co-57 (122.06 keV), Ce-139 (165,85 keV), Hg-203 (661.65 keV), Y-88 (898.02), Co-60 (1173.21 and 1332.47 keV), Y-88 (1836.04 keV). The multichannel analyzer automatically fits efficiency and energy-to-channel number curves for energies which are not present in the calibration spectrum. These calibrations are performed in accordance with the procedures prescribed by the Canberra Operator's Manual. The library of isotopes is presented in Appendix C.

It is particularly important when performing gamma spectrometry analysis, that the sample geometry be identical to the standard geometry. Efficiency is a function of geometry, and varies significantly in this case.

5.5.2.2 Data Reduction and Analysis

The multi-channel analyzer is programmable; for any unknown sample, it will calculate the activity in μCi of any isotope it identifies corresponding to the signature library listed in Appendix C. The percent error in activity is also calculated based on the number of counts collected under the peak. Although the machine is quite good, a great deal of prudence must be used when evaluating the output.

A computer-based spreadsheet was established to calculate U-238 and Th-232 activity concentrations. This determination is made based on the activities of their daughter products. While it will not detect chemically purified U-238, due to the long half-life of its daughter U-234, it will detect chemically purified thorium. These decay schemes are shown in Figure 5.1. With each sample, the mass was entered, along with the calculated activities of the isotopes, and corresponding energies shown in Table 5.2.

Corrections to MCA calculated activities were made in two cases. First, because of peak overlap at 185-186 keV from Ra-226 and U-235, an estimate of each isotope had to be derived. Assuming that Ra-226 is in equilibrium with U-238 and that U-235 is 0.7% by weight of U-238, it can be shown that the true Ra-226 activity is equal to the Ra-226 MCA calculated activity multiplied by 0.5525. The true U-235 activity is then equal to the U-235 MCA calculated activity multiplied by 0.446. If enriched uranium is present in the sample, these corrected values will show up as large deviations.

Figure 5.1 Naturally Occurring Thorium and Uranium Decay Chains
(From "Radiological Health Handbook," Revised Edition
U.S. Department of Health, Education and Welfare, 1970)

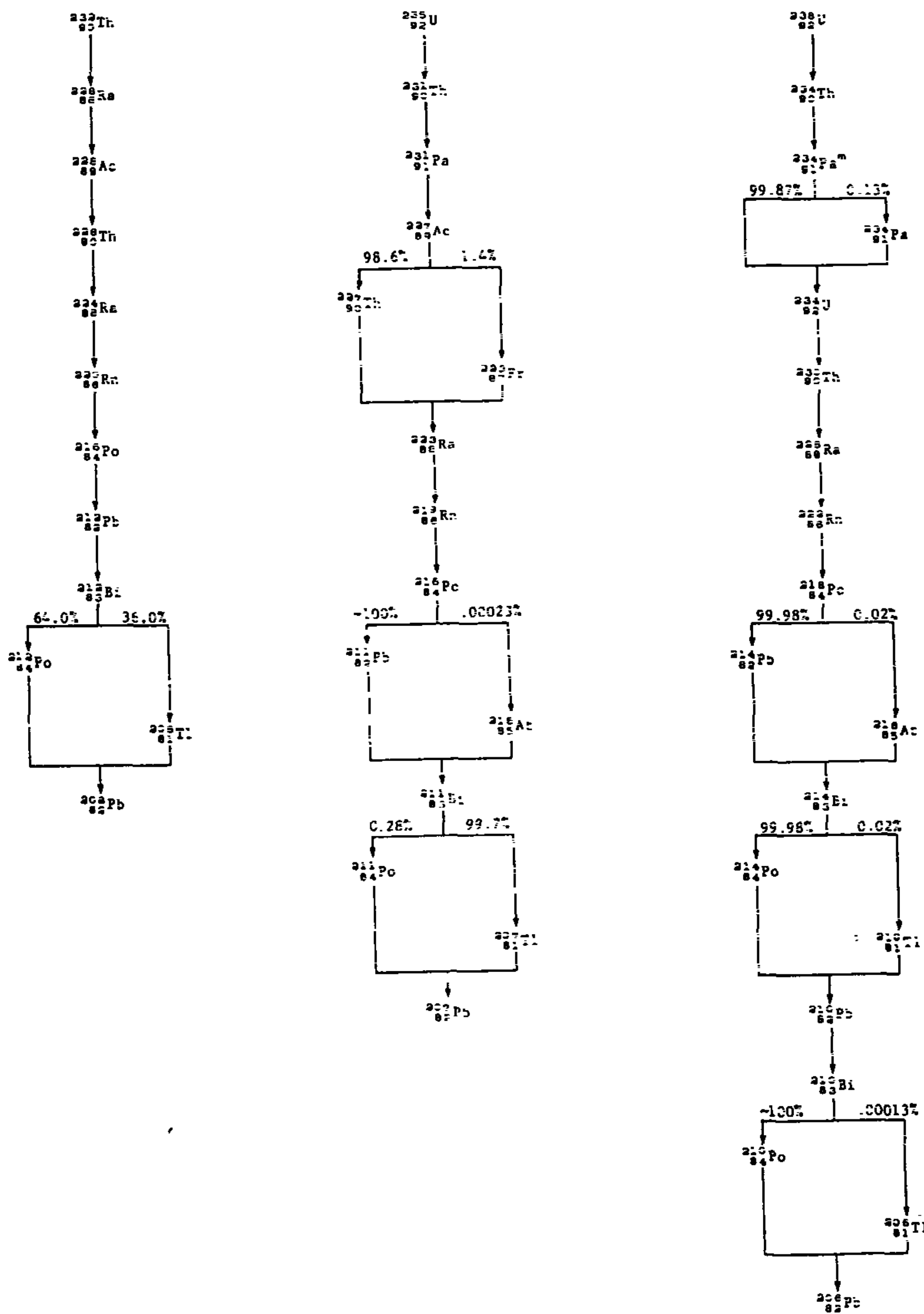


Table 5.2 Probable Gamma Energies for Determining Soil Radioactivity

U-238 Chain (Primordial)	Th-232 Chain (Primordial)
Th-234 (93 keV)*	Ac-228 (908 keV)
Ra-226 (186 keV)**	Ac-228 (338 keV)
Pb-214 (295 keV)	Ac-228 (960 keV)
Pb-214 (352 keV)	Th-228 (84 keV)*
Bi-214 (609 keV)	Ra-224 (241 keV)***
Bi-214 (1120 keV)*	Pb-212 (239 keV)***
Bi-214 (1764 keV)*	Pb-212 (300 keV)*
	Bi-212 (727 keV)*
	Bi-212 (1620 keV)*
	Tl-208 (511 keV)*
	Tl-208 (583 keV)
	Tl-208 (860 keV)*
U-235 Chain (Primordial)	**Fission Products**
U-235 (93 keV)*	Cs-137 (661 keV)
U-235 (185.6 keV)**	
U-235 (205.2 keV)*	
K-40 (Primordial)	**Activation Products**
K-40 (1460 keV)	Eu-152 (several energies)
	Co-60 (1117 keV)
	(1332 keV)
Be-7 (Cosmogenic)	
Be-7 (478 keV)****	

* Not evident because of low gamma yield (rarely seen)
** Peak overlaps from Ra-226 and U-235
*** Peak overlaps from Ra-224 and Pb-212
**** Formed in atmosphere - not normally found in soil

Estimates of radionuclide content in each sample were derived based on corrections for:

1) Multi-Channel Analyzer (MCA) output; and
2) Daughter Product decay for U-238, and Th-232.

Second, because of peak overlap at 239-240 keV from Ra-224 and Pb-212, estimates for true activity had to be derived. The true Pb-212 activity is equal to the MCA calculated activity multiplied by 0.91. Since Ra-224 and Pb-212 are in equilibrium, their activities are equal.

U-238 activity is calculated by:

$$A_{U-238} = \frac{\sum_{i=1}^{n} A_i}{n} \quad (pCi/g) \qquad \text{(Eq. 5-5)}$$

where A_i = all non-zero MCA calculated and corrected activities from U-238 daughter products listed in Table 5.2. (All daughters in equilibrium, branching ratios equal 100%)

n = number of non-zero activity values

pCi/g = appropriate conversion factors and sample mass used to obtain this unit.

Th-232 activity is calculated by:

$$A_{Th-232} = \frac{\sum_{i=1}^{n} A_i}{n} + \frac{\sum_{1}^{3} A_{Tl-208}}{3 * 0.36} \quad (pCi/g) \qquad \text{(Eq. 5-6)}$$

where A_i = all non-zero calculated and corrected activities from Th-232 daughter products listed in Table 5.2 (all daughters in equilibrium, branching ratios equal 100%)

n = number of non-zero activity values

A_{Tl-208} = Three identifiable gamma energies from Tl-208 (in equilibrium, branching ratio from Bi-212 is 36%).

Because only a few soil samples were collected based on gamma indication of radioactivity, statistical analyses is not appropriate. Soil samples were taken "for indication" of contaminants. Results are presented in tabular format.

6.0 PROCEDURES

The following radiological procedures were used in performing this survey.

6.1 Sample Selection Gridding

Divide each survey into appropriate zones based on topography. A zone should be a relatively flat area that is easily distinguished and convenient for gridding. 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 zone. From this northwestern-most location, mark a location off every 6 meters east, and south. Where it is not convenient to make a measurement because of rock outcroppings, 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).

Gas-flow Proportional:

1) Equipment is to be left in the 'ON' position at all times.

2) Before the analysis is run, using uncontaminated planchets, take ten 30-min. background counts of processed sea sand. Take and record 30-min. counts of known alpha and beta soil standards to obtain an efficiency calibration.

3) Use a Th-230 check source daily to ensure that the alpha/-beta count rates do not vary by more than ± 5% from the initially established standard.

Gamma Spectrometer:

1) Check to make sure that the MCA has been calibrated for energy and efficiency.

2) If machine is not calibrated, refer to user's manual for proper calibration of device.

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

4) Enter the data into SMART SPREADSHEET.

5) 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 Measurements of Gross Alpha/Beta Activity

1) After homogenizing a dried, 2-lb soil sample, take a few grams and place in a mortar. Using a pestle, grind the sample until a fine powder results. All big chunks should be removed, or broken down.

2) Take a 2 in. aluminum planchet, then place a 2-g soil sample evenly about its surface.

3) Place, in order of sampling location, each sample in the proportional counter sample magazine. Count each for 30 min.

4) Record the date, location and number of alpha and beta counts. Enter data with calibration numbers into SMART SPREADSHEET.

5) Count the Th-230 check source to ensure that the calibration efficiency and background factors are still applicable (alpha: 241120 ± 12056 dpm, beta: 59977 ± 2999 dpm).

6.3.3 Gamma Spectrometry Measurements

1) After homogenizing a dried, 2-lb soil sample, take a 450-ml sample which has no large chunks, and place it in a Marinelli beaker. The soil should lay flat, 1 1/2 in. from the top of the beaker.

2) Place the beaker over the calibrated high purity germanium (HPGE) detector and collect counts for 30 min. Use the MCA to qualify and quantify radioactive material in the sample.

3) Evaluate and correct MCA calculated activities and reduce to units of pCi/g. Enter data into SMART SPREADSHEET.

7.0 SURVEY RESULTS

The radiological survey of ESG's Old Salvage Yard, Rocketdyne's Barrel/Conservation Yard, and the New Salvage Yard (T583) was performed using the Survey Plan previously described. Each area was treated as a sample lot for analyzing and interpreting radiological data. The Old Salvage Yard was subdivided into 7 zones, the Barrel Storage Yard into 3 zones, and T583 into 1 zone. Uniform 6-m square grids were established to measure ambient gamma exposure rates. Soil samples were required by the survey plan in certain suspect areas; no radioactivity above naturally-occurring concentration was detected in these areas. Exposure rate measurements above "background" were observed in the southwest corner of the RD Barrel Yard. Three soil samples collected there show Cs-137 contamination at an average activity concentration of 81 pCi/g. This small area needs further attention, even though it is not a hazard. Analytical interpretation of gamma exposure rate measurements show that all three yards are uncontaminated, except for the small area mentioned above.

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. Similarly, soil sampling results are presented for each sampling lot. Then a final assessment of current radiological condition is made.

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 7.11. 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. Figures 7.4, 7.6, and 7.8 are distributions of gross-total gamma exposure rates for the three storage yards under study. Figures 7.5, 7.7, and 7.9 are distributions of the same three data sets corrected for "natural" background based on the average of the results presented in Figures 7.1 through 7.3. Figure 7.10 is a probability plot of the sum of all gross-total exposure rate data collected in all three storage yards. Figure 7.11 is the same graph corrected for natural "background" radiation. 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 on the ordinate which corresponds to a 50% cumulative probability on the abscissa. One, two, and three standard deviations above the mean corresponds 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 "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.

In cases where an acceptance limit is not appropriate, for example, gamma exposure rate measurements not corrected for "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, "background" is subtracted and inspection by variables techniques are applied to prove or disprove the hypothesis that the area is not contaminated.

Soil sample results are displayed in tabular format. Probability plots are not meaningful unless at least 30 data points are plotted.

7.2 Ambient Gamma Exposure Rates

Four hundred thirty-eight ambient gamma exposure rate measurements were made over all three areas. Appendix D shows the data sets. Table 7.1 shows the 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." This type of comparison is necessary for two reasons: 1) to demonstrate variability of "background" gamma-radiation at SSFL; and 2) to estimate "true" 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 "background" is, the area under study may be found incorrectly acceptable if the background used was too high, or incorrectly unacceptable if the background used was too low.

The descriptive statistics presented in Table 7.1 show that the average exposure rates calculated for each location, including the "background" locations, are all within one standard deviation of each other. We may incorrectly conclude the tested areas are free of contamination based only on a comparison of the averages. Further observation of the statistics

Table 7.1 Ambient Gamma Radiation at SSFL Compared to Survey Data

Location	No. of Measurements	Average Exposure Rate (μR/h)	Standard Deviation of the Mean (μR/h)*	Standard Deviation of the Distribution (μR/h)**	Range μR/h
Old ESG Salvage Yard	279	14.7	0.26	0.84	6.3
Rocketdyne Barrel Storage Yard	96	13.5	0.25	1.73	17.0
New Salvage Yard (T583)	63	13.5	0.25	1.46	5.4
Total - Sum	438	14.3	0.26	1.32	18.1
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 standard deviation of 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.

show that the tested area standard deviations and ranges are greater than those for our "background" data. A range of 17.0 μR/h for the RD Barrel Storage Yard indicates a potential problem area. Before any judgments can be made about the existence of residual contamination in these tested areas, cumulative probability plots must be studied and compared against "background" distributions.

7.2.1 Non-Radiological Areas

Because the 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 tested 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.

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 be fit such 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 variance 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 topography of these locations is somewhat similar to that of the test areas. The Old Salvage Yard, however, is scattered with numerous sandstone outcroppings. The New Salvage Yard is packed with large metal scrap pieces which also affect ambient background. The variability of each 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. "Background" variability approaches the NRC limit.

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

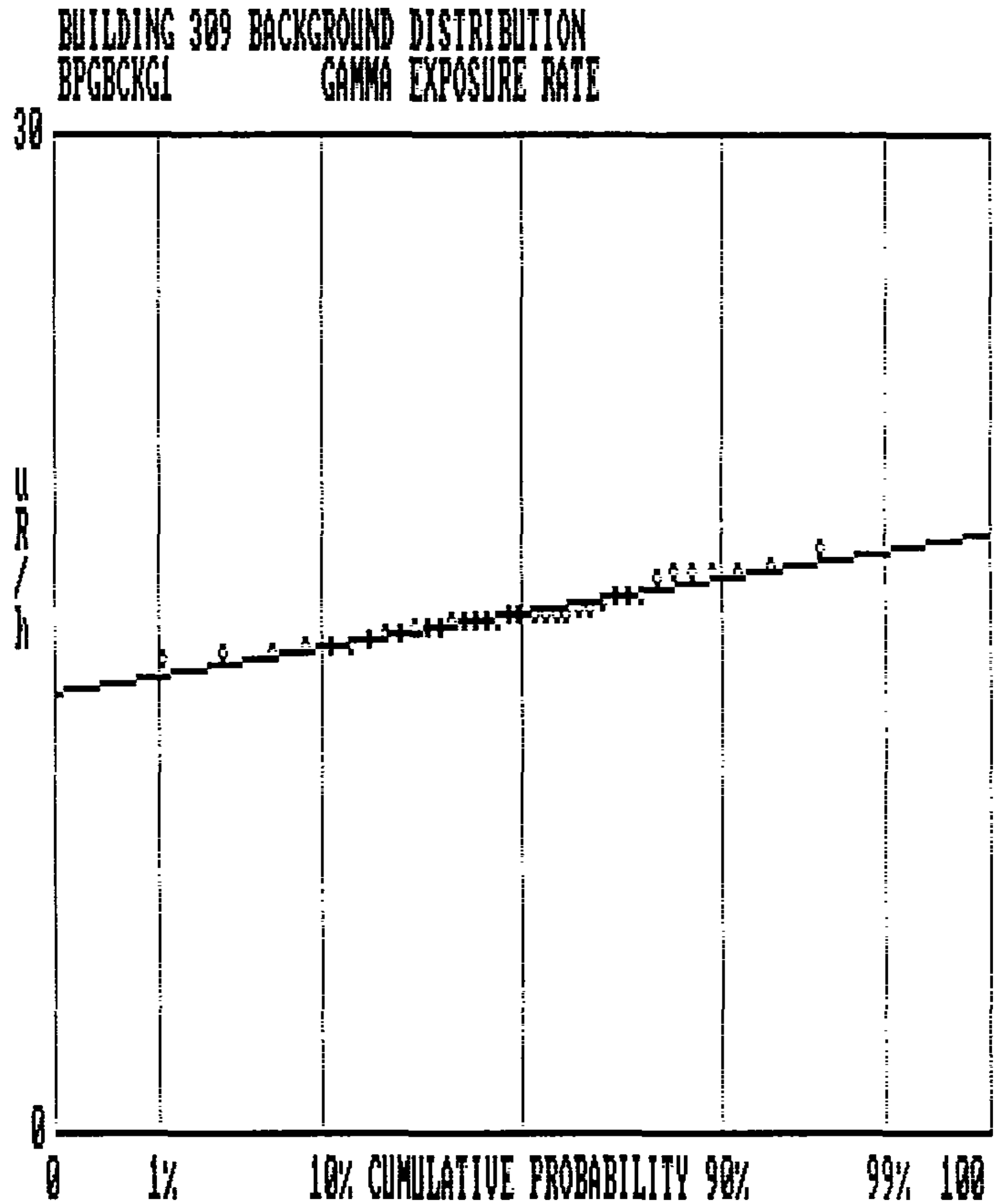


Figure 7.2 Ambient Gamma Radiation at Area Well #13 Road
(Background Distribution)

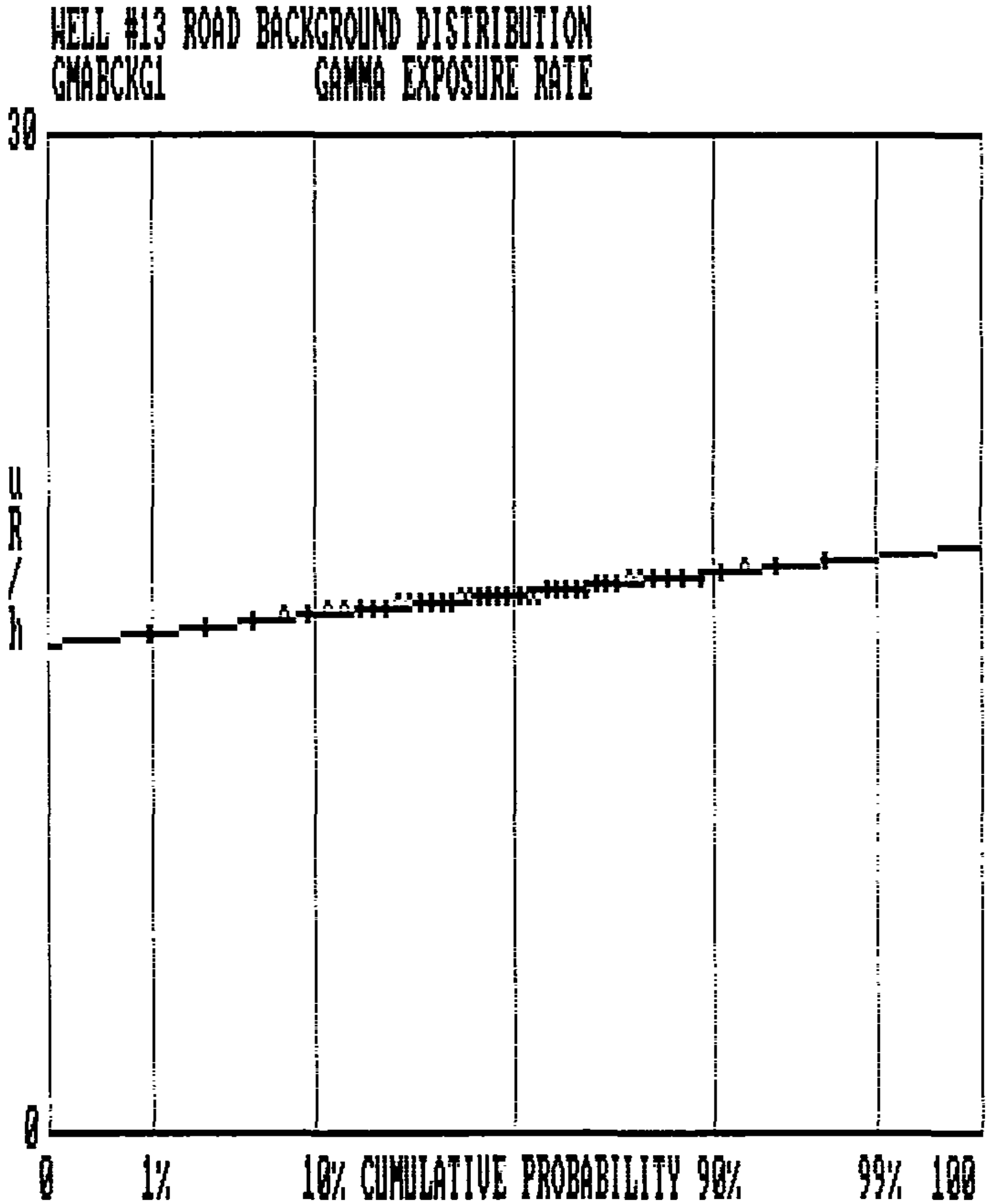
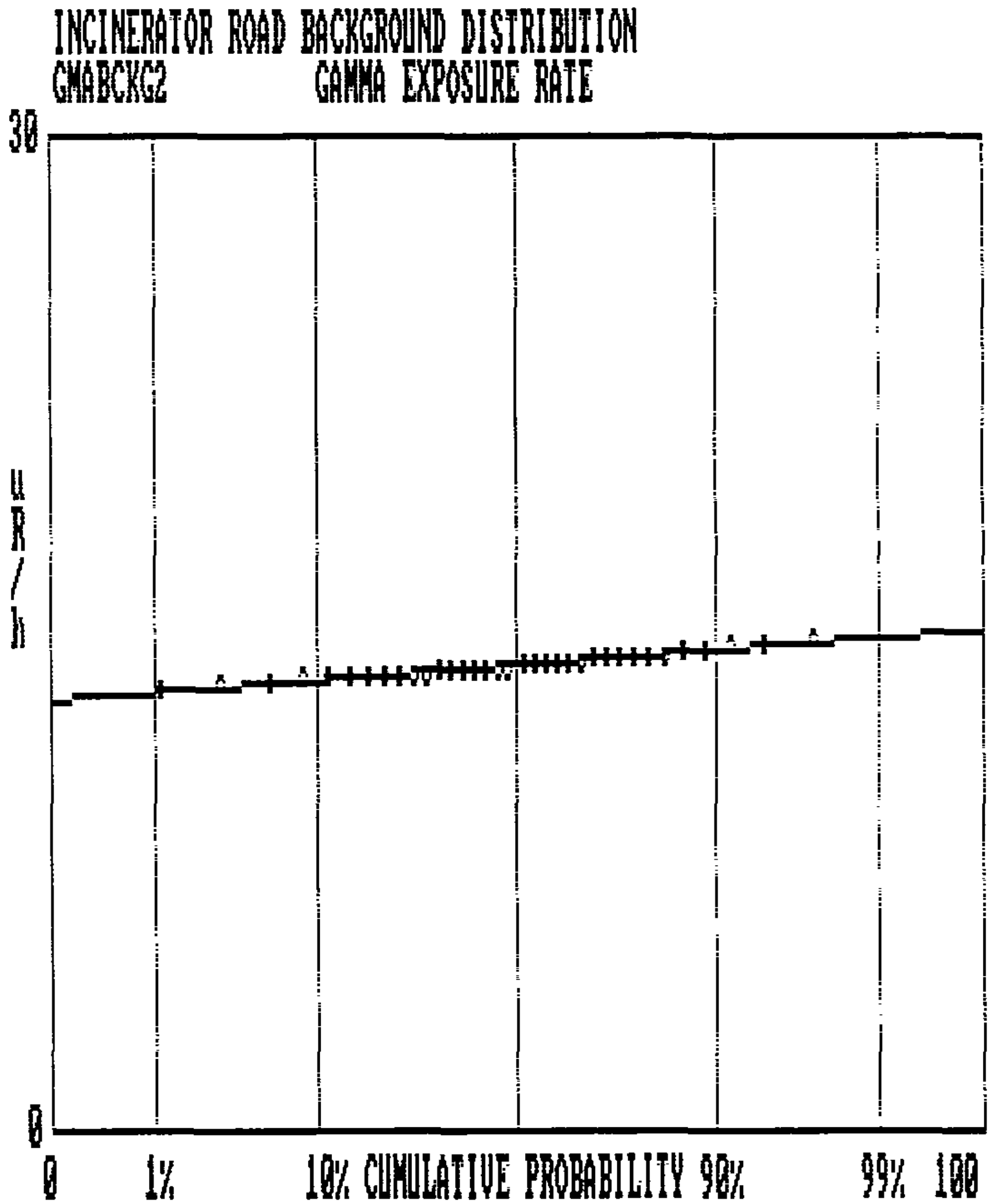


Figure 7.3 Ambient Gamma Radiation at Incinerator Road (Background Distribution)



This "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. Ambient radiation is significantly variable at SSFL. We'll now compare this "natural" variability against the three test areas presented in this report.

7.2.2 Old ESG Salvage Yard

Figure 7.4 shows the statistical distribution of gross-total gamma exposure rate measurements plotted against cumulative probability for the Old ESG Salvage Yard. The terrain of this yard was the most rugged of all three test areas, yet the distribution shows a remarkably well-fitted Gaussian. Three data points shown as deviations from the Gaussian at the high and low ends are anomalous and do not indicate a trend, or a contaminated area not sufficiently investigated. The range of 6.3 μR/h observed for this data set demonstrates significant spatial effects due to sandstone outcroppings.

Figure 7.5 shows the same data set, in which case a correction for natural "background" was made uniformly to each measurement value. 15.3 μR/h was used for "background" subtraction; this value is the average of the average exposure rates calculated for the three background data sets (Figure 7.1, 7.2, and 7.3) An average of -0.55 ± 0.849 μR/h is less than the 5 μR/h acceptance limit. The test statistic, 0.625 μR/h, is less than the 50% reinspection level. Further investigation of the two points at the reinspection level (50%) show nothing significant. We accept the area as "clean" by this inspection method.

7.2.3 Rocketdyne Barrel Storage Yard

Figure 7.6 shows the statistical distribution of gross-total gamma exposure rate measurements plotted against cumulative probability for the Rocketdyne Barrel Storage Yard. The terrain of this area is flat and was paved many years ago. Except for a significant outlier, the survey data follows a representative Gaussian. The fitted-Gaussian line is subsequently

Figure 7.4 Total-Gross Ambient Gamma Exposure Rates at the Old ESG Salvage Yard

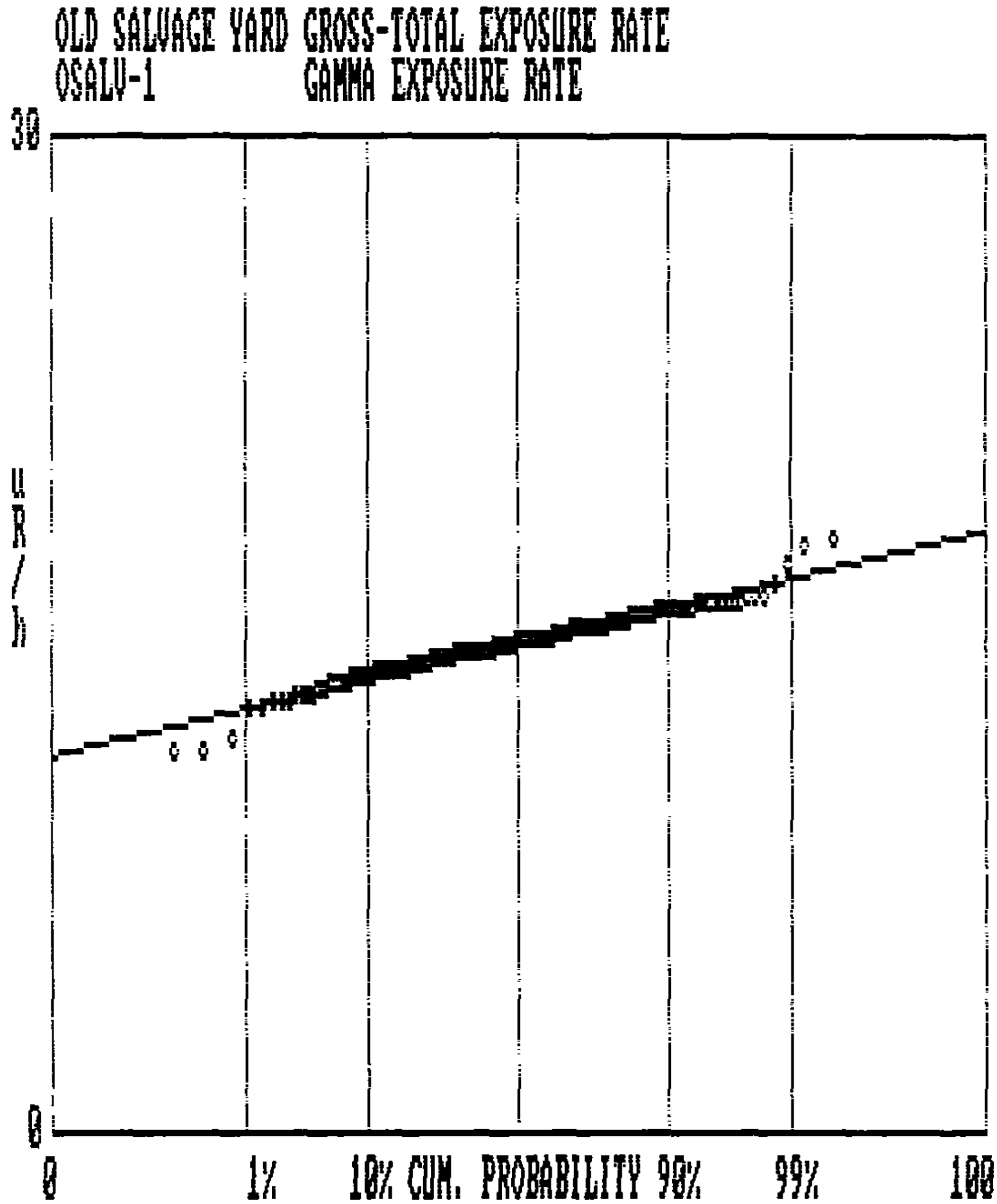
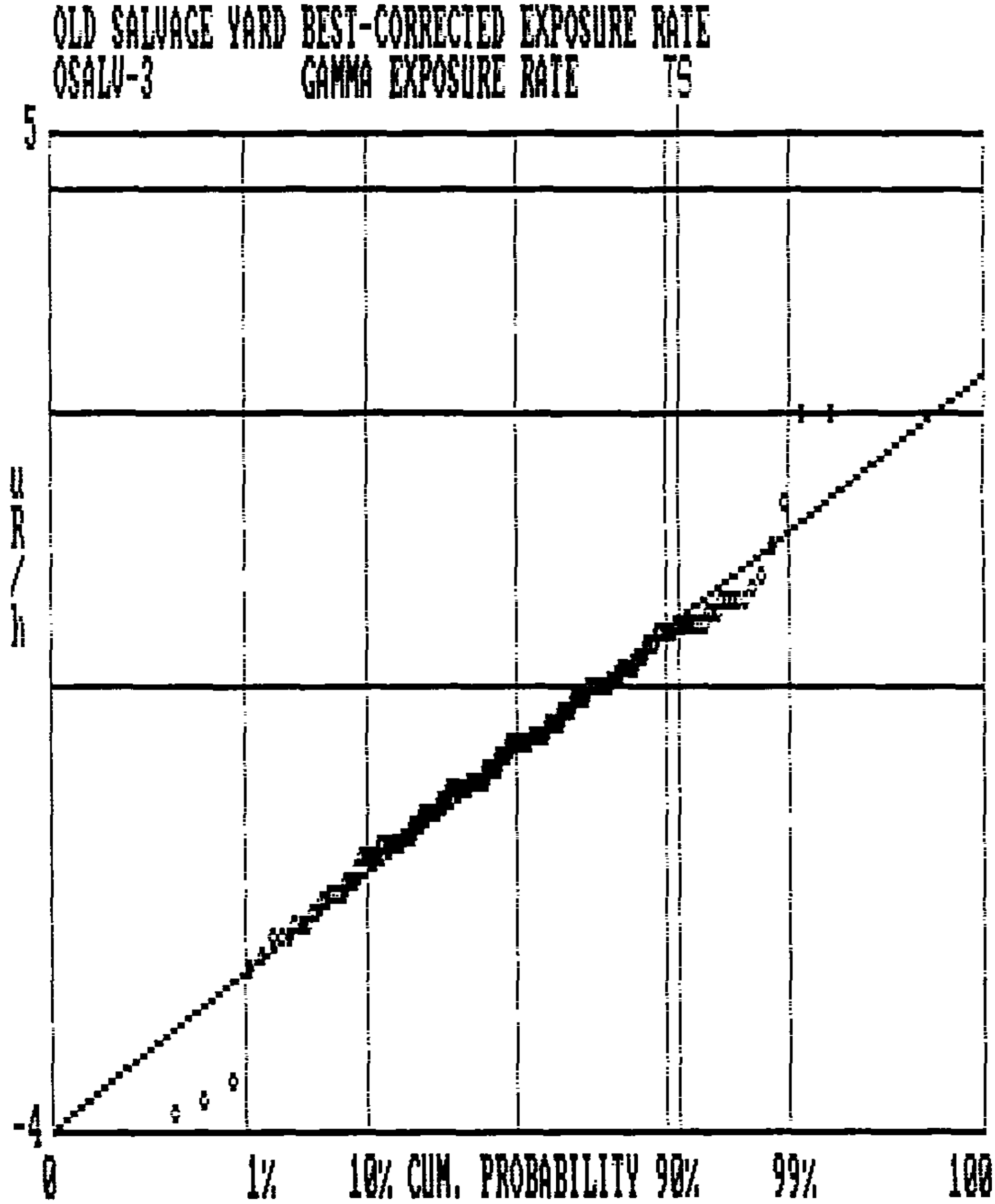


Figure 7.5 Background-Corrected Ambient Gamma Exposure Rates at the Old ESG Salvage Yard



skewed with a larger slope to account for the single outlier. This distribution suggests that further investigation is required in the location where the 27.9 μR/h measurement was acquired; soil samples were collected and analyzed in this location.

Figure 7.7 shows the same data set corrected for natural SSFL "background" and compared against the 5 μR/h acceptance limit. An average of -1.74 ± 1.73 μR/h and the test statistic, 0.809 μR/h show that the area passes NRC criteria for acceptably clean. However, the single outlier still requires further explanation. Additional gamma measurements were taken at that location and combined with the remaining data as shown in Figure 7.7. The vicinity and quantity of contamination is small. Soil samples were taken in this area, results of which are presented in Section 7.3.2.

7.2.4 New Salvage Yard (T583)

Figure 7.8 shows the statistical distribution of gross-total gamma exposure rate measurements plotted against cumulative probability for the New Salvage Yard (T583). The terrain in this area is dirt, but the yard is scattered with large metal equipment items and scrap metal. These metal pieces, because of scatter and absorption, affected ambient gamma radiation. This effect is distinguishable on the distribution at the 20% cumulative probability line. The measurements don't follow a representative Gaussian because of these spatial, scatter, and absorption effects, yet there are no indications of potential contaminated areas.

Figure 7.9 shows the same data set corrected for natural SSFL "background" and compared against the 5 μR/h acceptance limit. The deviations observed in the measurements because of this metal-effect are expanded in this figure because the ordinate scale has been expanded. An average of -1.78 ± 1.4 μR/h and the test statistic, -0.10 μR/h show that the area passes NRC criteria for acceptably clean. No further inspection or investigation is required.

Figure 7.6 Total-Gross Ambient Gamma Exposure Rates at the Rocketdyne Barrel Storage Yard

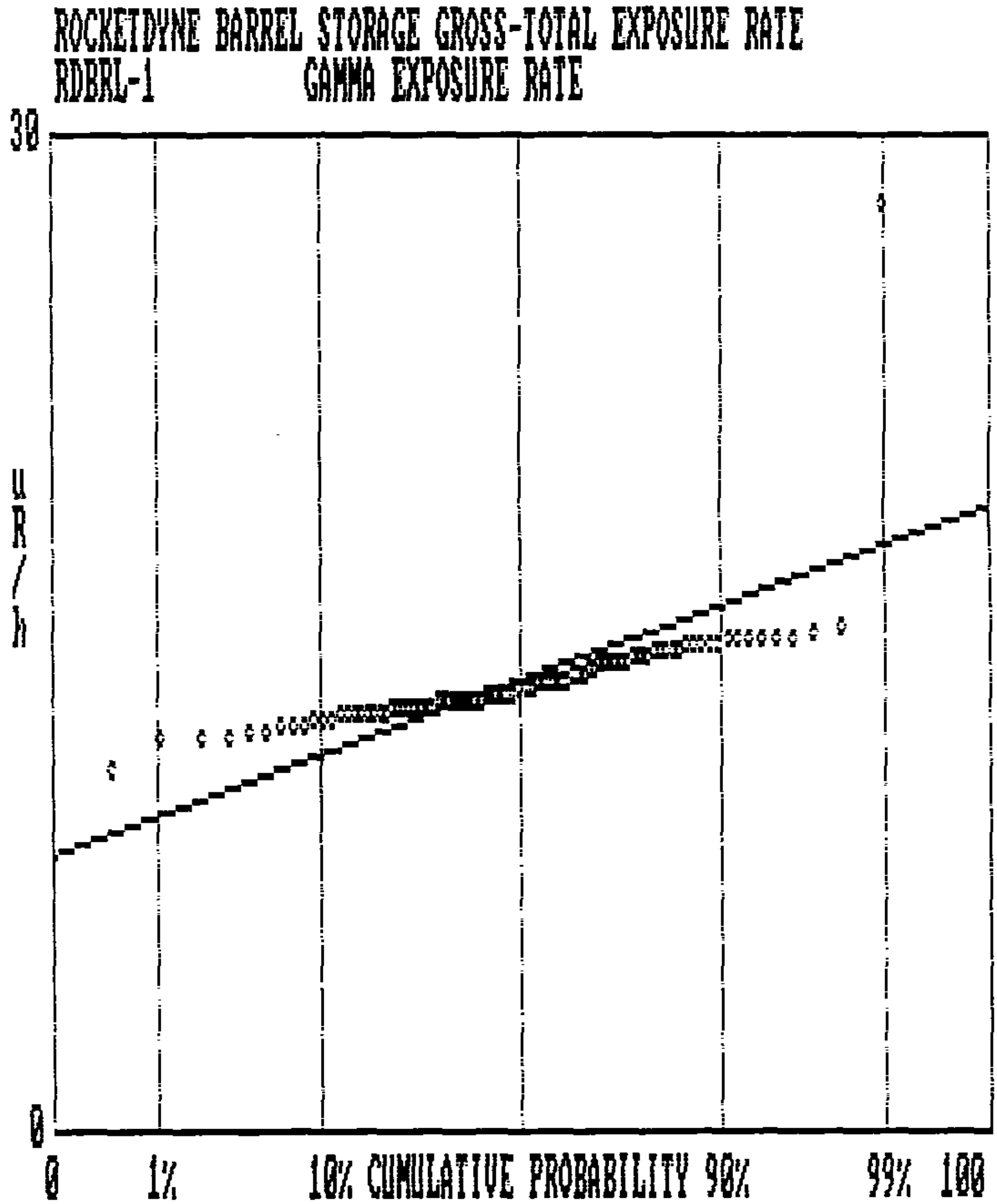


Figure 7.7 Background-Corrected Ambient Gamma Exposure Rates at the Rocketdyne Barrel Storage Yard

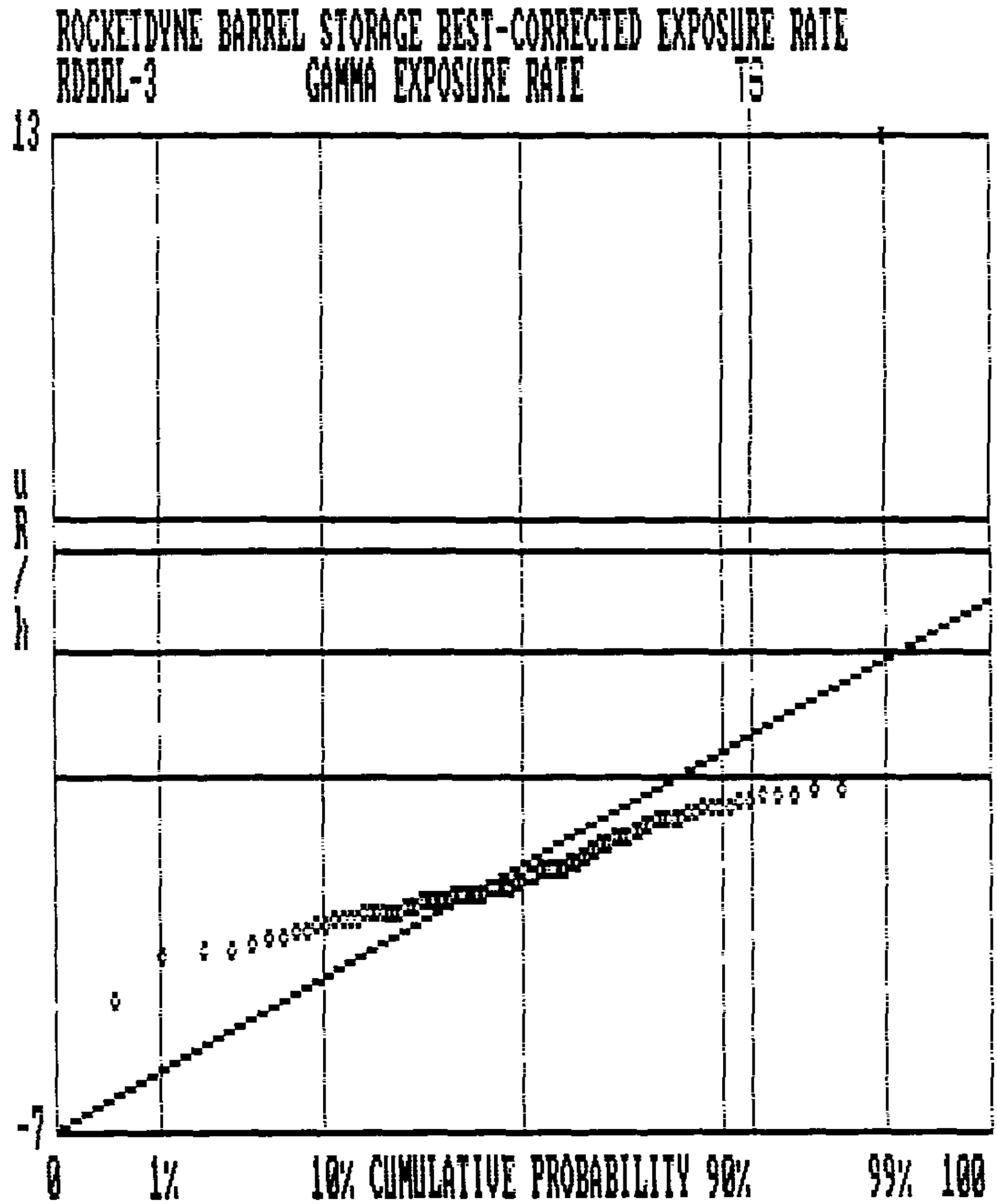


Figure 7.8 Total-Gross Ambient Gamma Exposure Rates at the New Salvage Yard (T583)

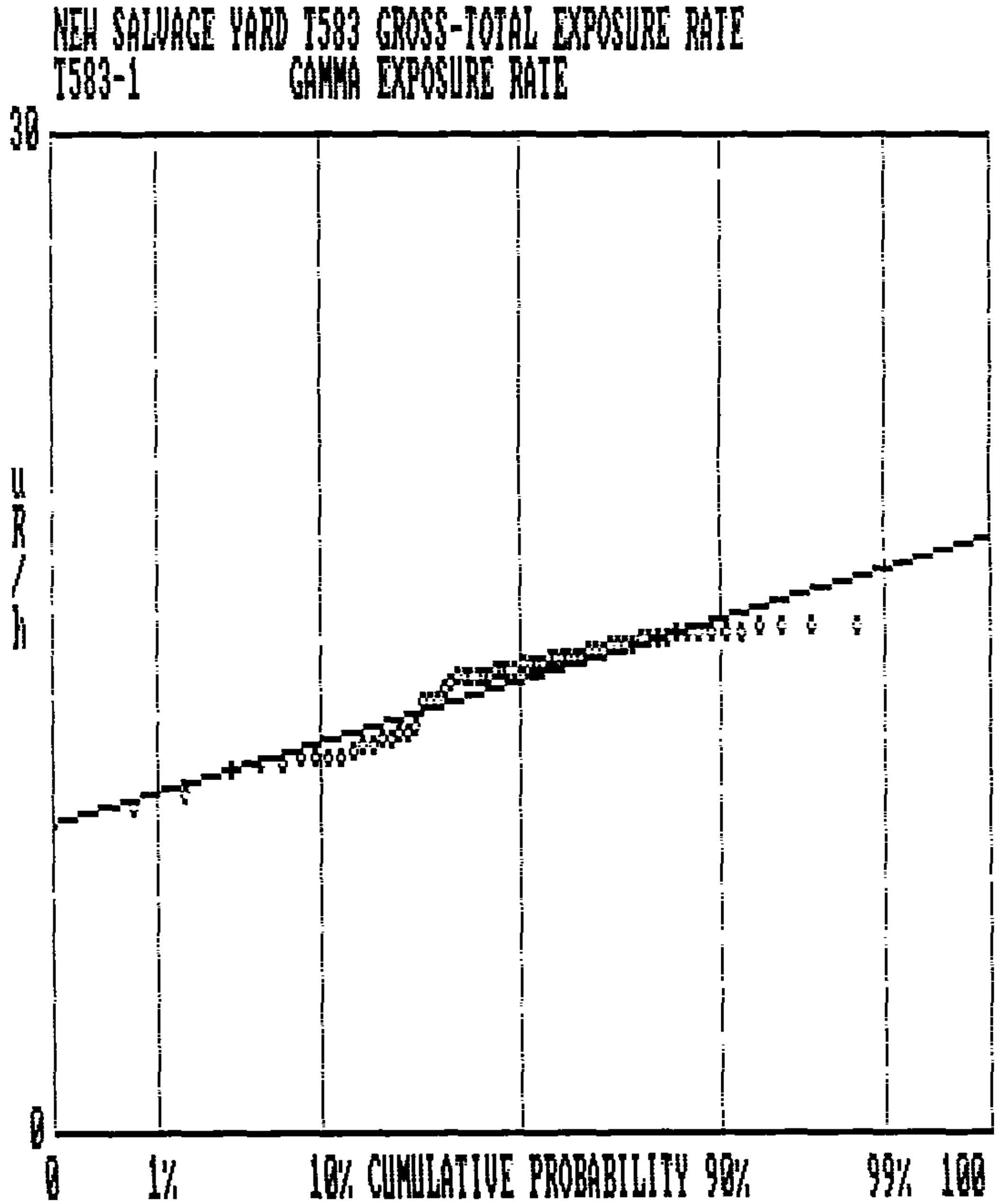
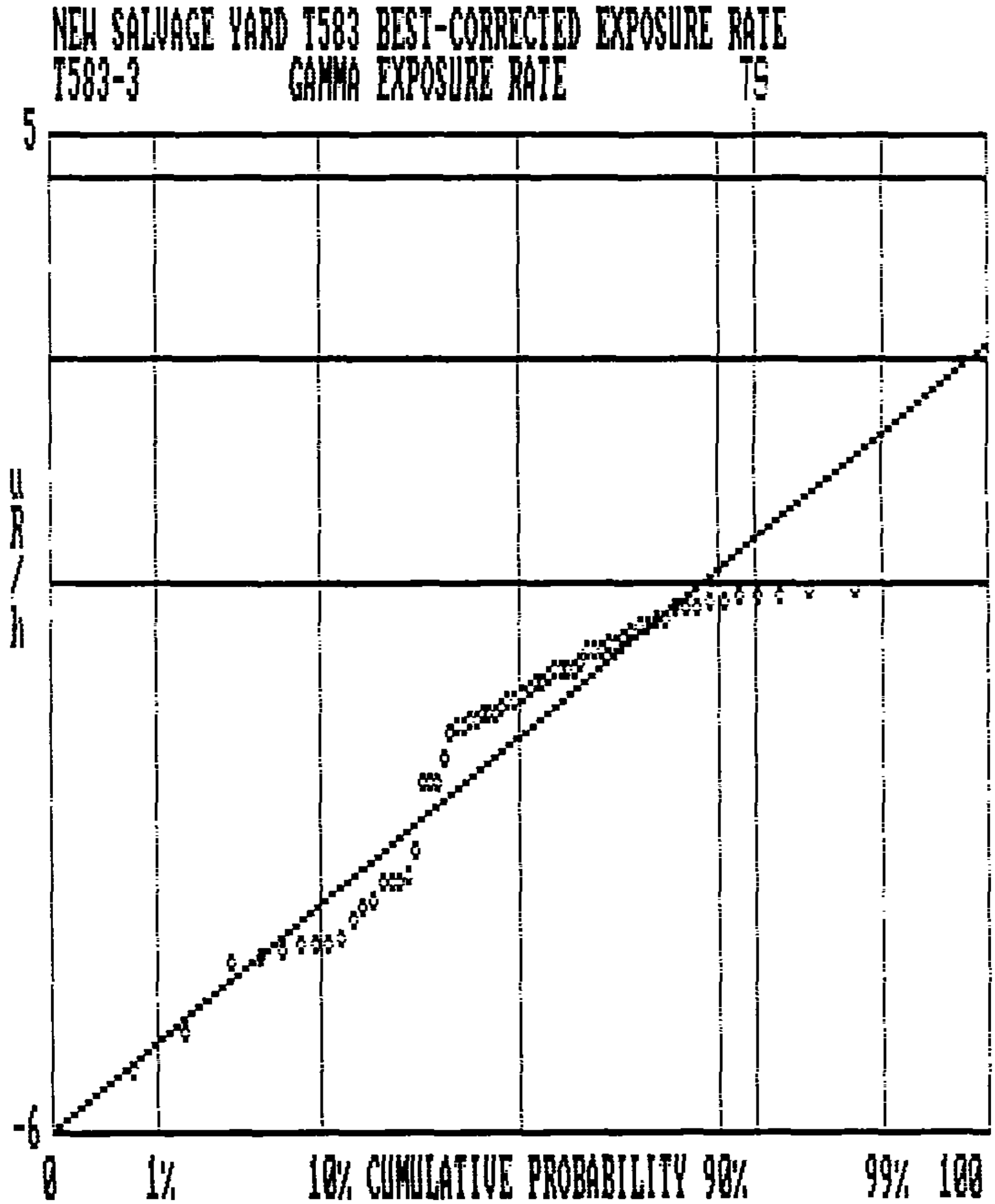


Figure 7.9 Background-Corrected Ambient Gamma Exposure Rates at the New Salvage Yard (T583)



7.2.5 Combination of All Three Storage Yards

Figure 7.10 shows the statistical distribution of gross-total gamma exposure rate measurements plotted against cumulative probability for the 438 total measurements made in all three storage yards. The figure shows a Gaussian with that single outlier in the Barrel Storage Yard. The next greatest five points are from unrelated areas in the Old Salvage Yard; they are anomalous measurements.

Figure 7.11 shows the "background-corrected" data with an average of -0.99 ± 1.32 μR/h and test statistic of 0.816. No trends are evident and the test statistic is less than our 50% reinspection level. We accept all areas, with one exception, as "clean" based on this investigation method.

7.3 Soil Sample Results

Soil sampling and analysis was required by the site survey plan in certain suspect areas. Sampling was also required on one occasion as part of an investigation effort as to the occurrence of an exposure rate measurement 3 times greater than background. It was beyond the scope of this survey to collect and analyze enough soil samples to show statistically meaningful results. Soil analysis was "for indication."

7.3.1 Old ESG Salvage Yard

No abnormally high exposure rate measurements were observed in this location which required further radiologic investigation. The northwest corner of the Rocketdyne Barrel Storage Yard was originally suspect. This suspect area was actually located in the southwest corner of Zone 1 of the Old ESG Salvage Yard sample lot, see Figure 7.12. A trash dumpster, broken bottles, and some junk were scattered about. Three surface soil samples were collected in suspicious locations where soil was discolored. Table 7.2 shows the results of these analyses and that nothing above primordial radioactivity is present.

Figure 7.10 Total-Gross Ambient Gamma Exposure Rates Combined Over All Three Storage Yards

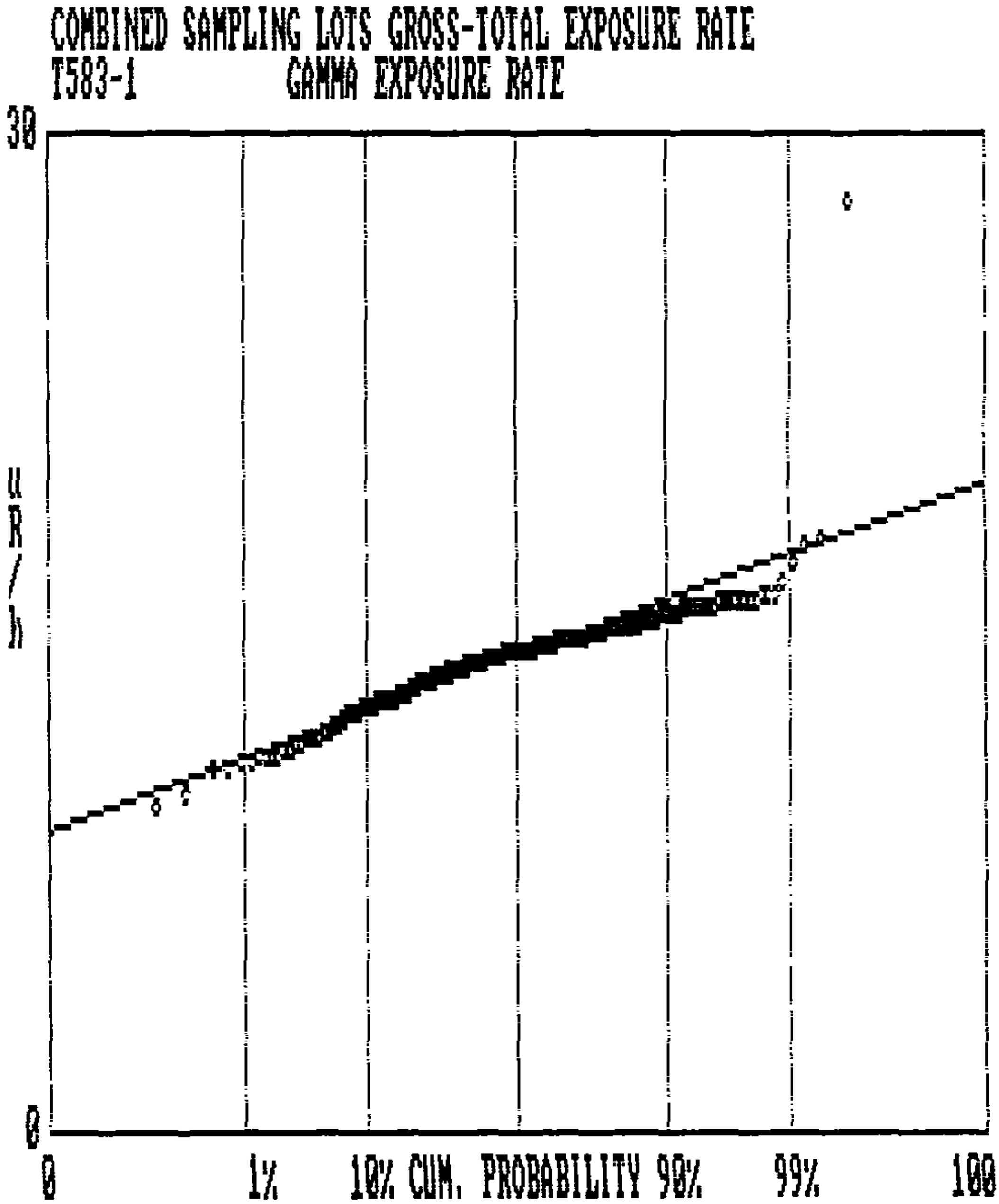
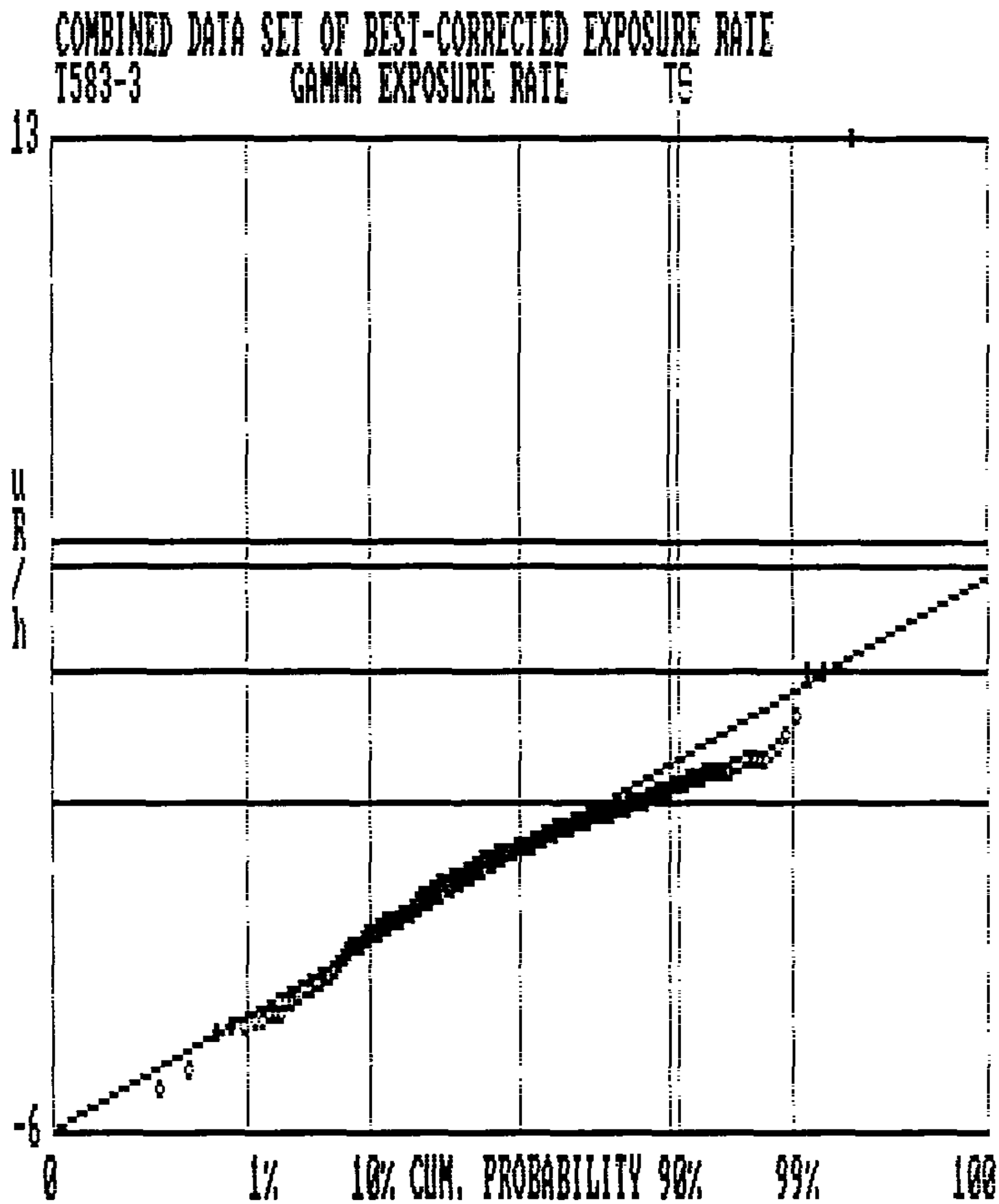


Figure 7.11 Background-Corrected Ambient Gamma Exposure Rates Combined Over All Three Storage Yards



7.3.2 Rocketdyne Barrel Storage Yard

One gamma exposure rate measurement taken at the southwest corner of Zone 7 is an outlier in Figures 7.6 and 7.7. The value is about 3 times ambient "background." Three soil samples collected from the dirt in this area were analyzed. Table 7.2 shows the results of these analyses. The soil is contaminated, on average greater than the 50% reinspection level of 50 pCi/g-beta. The greatest value, 132 pCi/g of Cs-137 exceeds the acceptance limit of 100 pCi/g-beta. These soil samples were collected from spots where the exposure rate was greatest. Figure 7.12 shows where these soil samples were taken from. This particular location is a low spot in the yard. The area is a mud puddle in the spring. Any contaminants spilled in the yard over the years has probably washed down to this mud puddle. The contamination level is not hazardous. Slight contamination may extend to about a 20 ft by 20 ft area, although it is thought to be less than six inches deep. This has not been confirmed; further investigation is necessary. A most conservative estimate of the total Cs-137 activity in the puddle assumes 20 ft x 20 ft x 0.5 ft volume, at 1.4 g/cm^3 density and 50 pCi/g (the average of the hottest spots was 81 pCi/g). This would yield 400 μCi as an upper limit in 200 cubic feet of dirt. The acceptance limit for unrestricted use is 100 pCi/g-beta (total), including Sr-90 and other beta emitters. A better investigation is required to determine the extent of contamination and Sr-90 contribution.

7.3.3 New Salvage Yard (T583)

No abnormally high exposure rate measurements were observed which required further radiologic investigation. However, as mentioned in the site survey plan, the gully running west of T583 was suspect. This gully used to drain the SRE pond to SSFL's retention ponds. Five samples were collected along the gully at depths down to 2 feet. Table 7.2 shows the results. Nothing above primordial radioactivity is present.

Table 7.2 Soil Sample Results

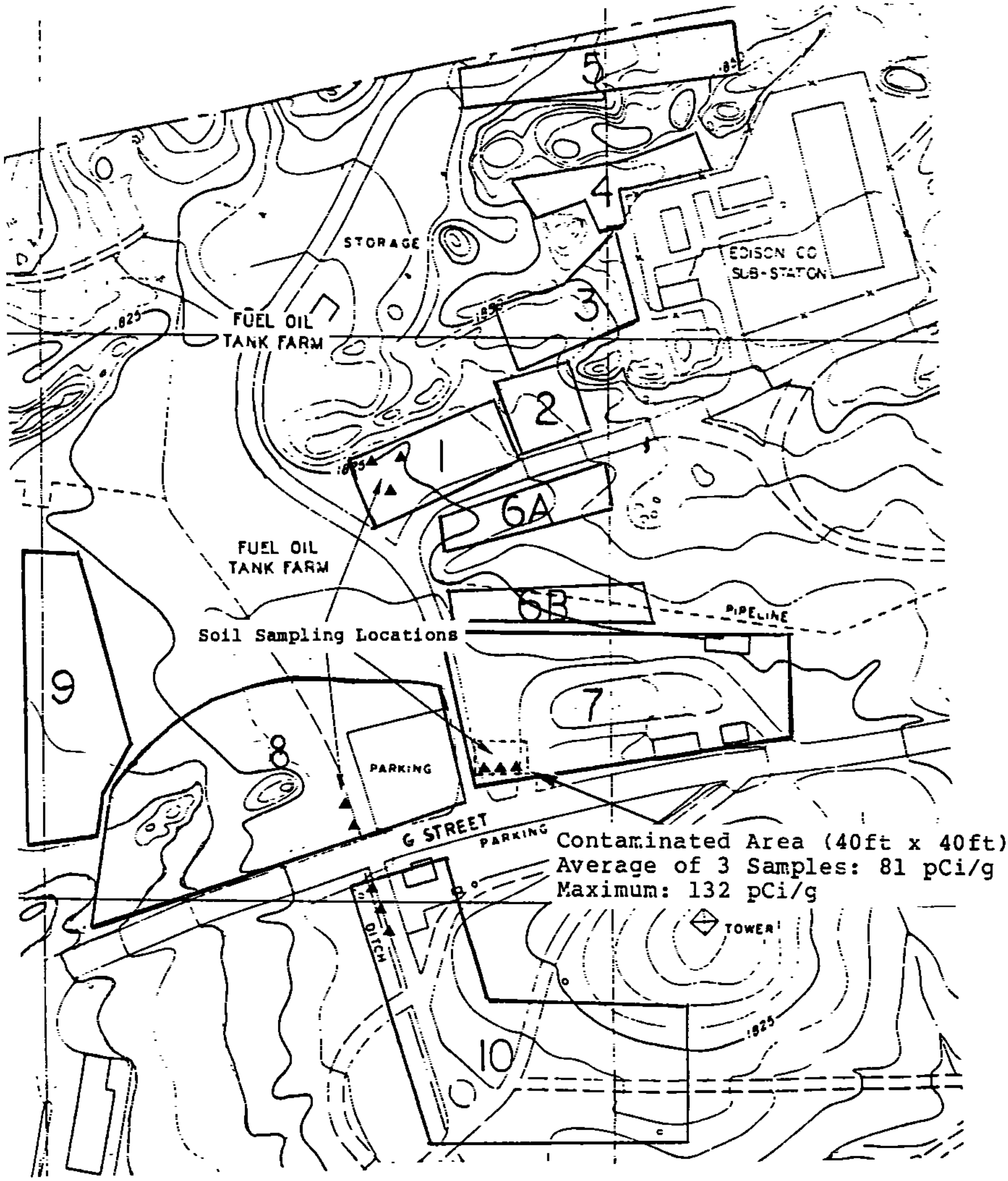
Location	Average Radioactivity Concentration (pCi/g)					
	Alpha	Beta	U-238	Th-232	K-40	Cs-137
Southwest Corner of Zone 1, Old Salvage Yard*	19.8 ±2.7	25.37 ±1.77	1.01 ±0.27	1.19 ±0.68	18.78 ±0.93	NDA
Southwest Corner of Zone 7, RD Barrel Storage Yard **	15.2 ±4.9	69.2 ±37.2	0.82 ±0.11	0.97 ±0.52	17.97 ±1.42	81.38 + ±45.20
SRE Drainage Gully, West of T583 *	N/M	N/M	0.87 ±0.99	0.76 ±0.26	21.99 ±1.26	0.18 ±0.029
For Comparison, Burn Pit ***	15.8 ±5.7	23.5 ±2.5	0.98 ±0.18	1.25 ±0.20	20.7 ±2.89	0.34 ±0.25

* Required by the Site Survey Plan
** Required because gamma exposure rate measurements exceeded the 50% Reinspection Level.
*** The Burn Pit results show naturally occurring background radioactive at SSFL (Reference 17).

N/M: Not Measured
NDA: No Detectable Activity

+ Maximum Value of 3 samples was 132 pCi/g.

Figure 7.12 Soil Sampling Locations



7.4 Assessment of Radiological Condition

Results of this radiological survey show that only a small area has residual radioactivity. Interpretation of ambient gamma exposure rate data show that all three sample lots are acceptably clean. A summary of background-corrected statistics of this data is presented in Table 7.3. In all cases, the inspection test statistic is less than 50% of the acceptance limit (reinspection level). We are confident that the sensitivity and sampling frequency of exposure rate measurements is sufficient for identifying suspect contamination.

Observation of the Gaussian distributions shows that one outlier exceeds our investigation level. Soil samples were collected in this location (southwest area of Zone 7) and analyzed. Analyses show that the soil is contaminated with Cs-137 and most likely, other mixed fission products. This mud puddle area, no more than 20-ft square, is a settling spot for area runoff water. The soil concentrations are not hazardous. Further investigation is required.

Soil samples collected and analyzed as specified by the Site Survey Plan, (Reference 4), show no detectable activity above background. Results compare favorably to the extensive Sodium Burn Facility soil analysis and investigation (Reference 17), which better defined primordial radioactivity at SSFL.

Table 7.3 Summary of Gamma Exposure Rate Data Corrected for Background and Statistically Tested Against Acceptance Limits

Sample Lot	Number of Locations	Average Value (μR/h)	Standard Deviation (μR/h)	Maximum Value (μR/h)	Inspection Test Statistic (μR/h)	Acceptance Limit (μR/h)
Old ESG Salvage Yard	279	-0.55	0.849	2.5	0.625*	5
Rocketdyne Barrel Storage Yard	96	-1.74	1.73	12.6	0.809*	5
New Salvage Yard (T583)	63	-1.78	1.46	-0.10	0.443*	5
Total-Sum	438	-0.99	1.32	12.6	0.816*	5

* All areas pass as acceptably clean.

8.0 CONCLUSIONS

The Old ESG Salvage Yard, Rocketdyne Barrel Storage/Conservation Yard, and New Salvage Yard were inspected for radioactive contaminants. Gamma exposure rate measurements, and limited soil sample collection and analysis were required by the Site Survey Plan (Reference 4). Performance of this radiological survey satisfies the plan. Gamma exposure rate measurements plotted against cumulative probability show a single spot which exceeds our 90% investigation level. This high exposure rate location was further investigated. A small area was found to be slightly contaminated.

Based on these statistical distributions of exposure rate measurements corrected for what we believe represents "natural background" at SSFL, we conclude through inspection by variables, that all three storage yards are clean of residual radioactive contamination. The boundary condition of this statistical test assumes a consumer's risk of acceptance of 0.1 at an LTPD of 10%. However, a contaminated mud puddle was discovered on the southwest corner of the Rocketdyne Barrel Storage Yard. Soil samples collected, as required by the survey plan and the survey results, show no radioactive contaminants except for that location. These soil samples were collected in suspect areas: 1) An area in the Old Salvage Yard where a radioactivity spill is thought to have occurred; and 2) a gully which drained water from the SRE pond to SSFL retention ponds.

The one small area found radioactively contaminated is in the southwest corner of the Rocketdyne Barrel Storage Yard (Zone 7) about 50 ft north of "G" Street. The surface area is no greater than 400 ft^2 at a depth thought, but not confirmed, to be less than 6 in. This location is a local low spot for the surrounding area; rainwater collects there and forms a mud puddle. The surrounding area is old pavement. We suspect that at one time a small radioactive spill occurred somewhere in the yard. Since rainwater drains form the yard to this mud puddle, contaminants are probably concentrated there. Exposure rate measurements were 3 times background. Cs-137 was detected in 3 of 3 soil samples with activity concentrations of 132, 67, and 45 pCi/g. These results are from the most contaminated locations. Sr-90, which normally accompanies Cs-137, is probably present here, but was not specifically measured and analyzed. The unrestricted-use beta acceptance limit for soil is 100 pCi/g; one measurement of Cs-137 alone exceeds the limit. Further investigation is required to measure specifically the extent of contamination. Assuming as an upper limit, a uniformly contaminated area (400 ft^2) at a 6-in depth at 50 pCi/g, total Cs-137 in the area may approach 400 μCi. The area is not hazardous to health.

Except for the mud puddle area mentioned above, all three storage areas are considered clean of radioactivity. No further investigation is required in that regard. Further investigation and remedial action is required in the mud puddle.

9.0 REFERENCES

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19. "Radiological Survey of the old Calibration Facility - Building T029", GEN-ZR-0006, 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

APPENDIX A. DESCRIPTION OF NUCLEAR INSTRUMENTATION

During the radiological survey, soil samples and miscellaneous crud items were analyzed for radioactivity content by one or more of the following nuclear instrumentation systems.

A.1 Gamma Spectrometry Analyzer

Gamma spectrometry of selected samples including all soil samples was performed with a Canberra Industries, Inc. Series 80 Multichannel Analyzer (MCA). The MCA is coupled to a planar high purity germanium (HPGe) radiation detector having about a 10% relative sensitivity (relative to the sensitivity of a 3 in. x 3 in. NaI detector for cesium-137 gamma radiation), and a photopeak resolution capability of about 2.5 keV (FWHM) for the higher energy line of cobalt-60. The Series 80 MCA used for soil analyses has a 8192 channel memory capacity with a 1E+06 counts per channel capacity. Functional operation options include integral, net area, strip, and energy calibration, all used for spectrum analysis. The Series 80 was calibrated both for gamma energy and for nuclide quantification with a Marinelli Beaker Standard Source (MBSS) as specified in document ANSI/IEEE Std 680-1978, "IEEE Standard Techniques for Determination of Germanium Semiconductor Detector Gamma-Ray Efficiency Using a Standard Marinelli (Reentrant) Beaker Geometry." All soil samples analyzed by gamma spectrometry were presented to the detector with the same geometric configuration as the MBSS.

A.2 Gross Alpha/Beta Automatic Proportional Counter

Soil samples and smear wipe test samples, where appropriate, were analyzed for gross alpha and gross beta radioactivity with a Canberra Industries Model 2201 Ultra Low Level Counting System. Model 2201 consists of a highly efficient gas-flow sample detector operating in the proportional gas amplification region. The system detects radiation in a 2π geometry using P-10 gas (90% methane, 10% argon). A cosmic-ray detector provides coincidence event cancellation to reduce instrument background. The two detectors operate in an anticoincidence mode to reduce the count rate due to cosmic-ray events. When cosmic-ray or background events occur, the input circuit to the count integrator is gated off and the simultaneous event is discarded. Thus, only true alpha and/or beta radiation events are recorded. The detectors are coupled through dual Model 2006A preamplifiers to a Model 2015A system amplifier then through a Model 2209A coincidence analyzer to the alpha or beta event scaling unit. The Series 2201 has a sample capacity of 99 samples contained in a magazine designed to accept sample planchets having a 2-inch diameter. Calibration of the sample detector for alpha and for beta radiation on smear-wipes is done with NBS traceable certified thorium-230 (alpha) and technicium-99 (beta) radiation sources having a configuration essentially equivalent to that of the smear wipes. Calibration for soil counting involves the use of an NBS traceable U-235 spiked soil standard for alpha radiation; KCl for beta radiation; and nutrient-depleted sea sand for detector background measurements.

A.3 Portable Instruments

A Ludlum model 2220 portable scalar/ratemeter coupled to a gamma probe was used during the course of this survey. The 2220 has a six decade LCD readout; combination four decade linear and log rate meter; adjustable HV threshold, and window positions, with readouts on digital display; audio provided by unimorph speaker with pitch change in relation to count rate; and preset electronic timer.

A Ludlum model 44-10 NaI gamma scintillator was used for detecting gamma radiation. The NaI (Tl) crystal is extremely sensitive to changes in gamma flux. The efficiency of the probe coupled to the 2220 for Cs-137 gamma rays is about 215 cpm/μR/h. Because of limitations with the Cs-137 calibration range and because of fluctuations in ambient background radiation, this instrument was calibrated against a Reuter Stokes High-Pressure Ion Chamber (HPIC). The HPIC displays a digital readout every 3 to 4 seconds in μR/h.

APPENDIX B. COPY OF DOE REPORT,

"GUIDELINES FOR RESIDUAL RADIOACTIVITY AT

FUSRAP AND REMOTE SFMP SITES," March, 1985

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

MAR 0 5 1985

RECEIVED
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:

02067RL

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- 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

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

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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.

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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.

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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 Long-Term Management

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.

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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.

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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.]

International Commission on Radiological Protection. 1978. Limits for Intakes of Radionuclides by Workers. A Report of Committee 2 of the International Commission on Radiological Protection. Adopted by the Commission in July 1978. ICRP Publication 30. Part 1 (and Supplement), Part 2 (and Supplement), Part 3 (and Supplements A and B), and Index. Pergamon Press, Oxford.

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).

U.S. Department of Energy. 1984. Formerly Utilized Sites Remedial Action Program. Summary Protocol: Identification - Characterization - Designation - Remedial Action - Certification. Office of Nuclear Energy, Office of Terminal Waste Disposal and Remedial Action, Division of Remedial Action Projects. April 1984.

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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.]

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APPENDIX C. GAMMA SPECTROMETRY RADIONUCLIDE GAMMA-SIGNATURE LIBRARY

Isotope Energy (keV)	Half-Life % Yield								
1. Zr-95	64.40 D								
724.0	44%	756.6	55%						
2. Nb-95	35.15 D								
765.7	99%								
3. Ru-103	39.35 D								
497.0	86%	610.0	5%						
4. Sb-125	0.1011E04 D								
176.2	6%	428.0	29%	463.5	10%	606.7	5%	636.1	11%
5. I-131	8.04 D								
284.2	6%	364.5	81%	636.9	7%				
6. Cs-134	752.63 D								
563.2	8%	569.2	15%	604.6	98%	795.7	85%	801.7	9%
7. Cs-136	12.98 D								
66.8	12%	86.2	6%	153.1	7%	176.5	14%	273.5	13%
340.5	47%	818.5	100%	1048.0	80%	1235.2	20%		
8. Cs-137	0.1095E05 D								
661.6	85%								
9. Ba-140	12.80 D								
162.5	5%	537.3	20%						
10. La-140	1.68 D								
328.7	18%	487.0	43%	815.7	22%	867.8	5%	925.0	6%
1596.0	95%								
11. Ce-141	32.50 D								
36.0	8%	145.1	48%						
12. Ce-144	284.19 D								
133.5	11%								
13. Cr-51	27.70 D								
320.0	9%								
14. Mn-54	312.19 D								
834.7	100%								
15. Fe-59	45.10 D								
1099.1	56%	1291.5	43%						

Isotope Energy (keV)	Half-Life % Yield								
16. Co-58	70.78 D								
511.0	30%	810.7	99%						
17. Co-60	0.1924E04 D								
1173.1	100%	1332.5	100%						
18. Zn-65	243.80 D								
511.0	3%	1115.5	51%						
19. Rh-102	0.1054E04 D								
418.2	10%	475.0	93%	628.0	6%	631.0	56%	697.0	45%
766.7	33%	1046.5	33%	1112.6	17%				
20. Rh-102M	206.00D								
475.0	44%	511.0	23%						
21. Sb-124	60.20 D								
602.6	98%	645.7	7%	722.7	12%	1691.0	50%	2091.1	6%
22. Be-07	53.40 D								
477.5	10%								
23. Na-22	949.00 D								
511.0	180%	1274.5	100%						
24. K-040	0.46E12 D								
1460.7	11%								
25. Ra-226	0.584E06 D								
186.0	3%								
26. Pb-214	0.02 D								
74.7 6%	77.0 11%	241.8	7%	295.1	19%	352.0	37%		
27. Bi-214	0.01 D								
609.2	46%	1120.2	15%	1238.0	6%	1764.5	15%		
28. Ra-224	3.66 D								
241.0	4%								
29. Pb-212	0.44 D								
74.7	9%	77.0	18%	87.1	6%	238.5	43%		
30. Bi-212	0.04 D								
727.1	12%	1620.5	3%						

	Isotope Energy (keV)	Half-Life % Yield								
31.	Tl-208	0.00 D								
	277.3	6%	510.6	22%	583.0	86%	860.5	12%		
32.	Ac-228	0.25 D								
	338.3	12%	911.0	29%	964.5	5%	968.8	17%		
33.	Th-234	24.10 D								
	63.2	4%	92.3	2%	92.7	3%				
34.	U-232	0.263E05 D								
	269.0	4%								
35.	U-235	0.26E12 D								
	93.3	2%	143.7	11%	163.3	5%	185.6	54%	205.2	5%
36.	Am-241	0.158E06 D								
	59.5	36%								
37.	Np-237	0.7817E09 D								
	29.0	9%	86.1	13%						
38.	Pu-242	0.1409E09 D								
	44.5	3%								
39.	Am-243	0.2699E07 D								
	74.6	66%								
40.	Np-239	2.35 D								
	99.5	15%	103.6	24%	106.0	23%	117.6	8%	228.1	11%
	277.5	14%								
41.	Al-26	0.2612E10 D								
	511.0	164%	1808.6	100%						
42.	Nb-94	0.7409E07 D								
	702.5	100%	871.0	100%						
43.	Ag-108M	0.4635E05 D								
	79.5	7%	433.6	90%	614.3	90%	722.9	90%		
44.	Cd-109	453.00 D								
	88.0	3%								
45.	Ba-133	0.3906E04 D								
	81.0	33%	276.2	7%	302.6	19%	355.8	62%	383.6	9%

Isotope Energy (keV)	Half-Life % Yield								
46. Eu-148	54.00 D								
413.8	11%	414.0	7%	550.1	99%	553.1	17%	571.8	9%
611.2	19%	629.8	71%	725.6	12%	1034.0	8%		
47. Eu-152	0.4636E04 D								
121.7	29%	244.6	8%	344.2	27%	778.8	13%	964.0	14%
1085.7	10%	1112.0	13%	1408.0	21%				
48. Eu-154	0.3102E04 D								
123.0	40%	248.0	7%	723.2	20%	873.1	11%	996.2	11%
1004.7	18%	1274.7	35%						
49. Eu-155	0.181E04 D								
86.3	33%	105.2	22%						
50. Tb-158	0.5475E05 D								
79.5	11%	181.8	9%	780.1	9%	944.1	43%	962.1	20%
51. Pt-193	0.1825E05 D								
63.2	24%	64.8	44%	73.5	15%				
52. Co-57	270.00 D								
122.0	86%	136.3	11%						
53. Sr-85	64.73 D								
513.9	99%								
54. Y-88	106.60 D								
898.0	94%	1836.0	99%						
55. Sn-113	115.10 D								
391.6	64%								
56. Ce-139	137.50 D								
165.7	80%								
57. Hg-203	46.59 D								
72.8	6%	279.1	81%						
58. Ta-182	115.00 D								
67.7	41%	100.1	14%	152.4	7%	222.0	7%	1121.2	35%
1189.0	16%	1221.4	27%	1230.9	11%				

APPENDIX D. RADIOLOGICAL SURVEY DATA

OSALVYRD.WS SORTED BY LOCATION

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	STD DEV
O SALV 1	3-1	2996	13.9	0.25
O SALV 1	8-2	2972	13.8	0.25
O SALV 1	15-3	2909	13.5	0.25
O SALV 1	3-6	3138	14.5	0.26
O SALV 1	6-8	2991	13.9	0.25
O SALV 1	10-9	2992	13.9	0.25
O SALV 1	15-9	2999	13.9	0.25
O SALV 1	9-15	3216	14.9	0.26
O SALV 1	9-15	3260	15.1	0.26
O SALV 1	2-17	3192	14.8	0.26
O SALV 1	2-17	3283	15.2	0.27
O SALV 1	15-18	2967	13.7	0.25
O SALV 1	10-20	2870	13.3	0.25
O SALV 1	18-23	3133	14.5	0.26
O SALV 1	2-22	3066	14.2	0.26
O SALV 1	2-27	3170	14.7	0.26
O SALV 1	10-29	3237	15.0	0.26
O SALV 1	17-28	3191	14.8	0.26
O SALV 1	4-33	3423	15.9	0.27
O SALV 1	9-34	3334	15.4	0.27
O SALV 1	16-35	3440	15.9	0.27
O SALV 1	2-37	3416	15.8	0.27
O SALV 1	7-39	3427	15.9	0.27
O SALV 1	14-41	3478	16.1	0.27
O SALV 1	5-45	3416	15.8	0.27
O SALV 1	11-46	3224	14.9	0.26
O SALV 1	18-44	3662	17.0	0.28
O SALV 1	3-50	3348	15.5	0.27
O SALV 1	11-51	3415	15.8	0.27
O SALV 1	15-51	3357	15.5	0.27
O SALV 1	18-54	3307	15.3	0.27
O SALV 2	3-3	3291	15.2	0.27
O SALV 2	3-9	3278	15.2	0.27
O SALV 2	6-5	3419	15.8	0.27
O SALV 2	6-10	3341	15.5	0.27
O SALV 2	11-2	3314	15.4	0.27
O SALV 2	11-5	3427	15.9	0.27
O SALV 2	15-4	3290	15.2	0.27
O SALV 2	15-9	3399	15.7	0.27
O SALV 2	17-7	3377	15.6	0.27
O SALV 2	19-2	3245	15.0	0.26
O SALV 2	20-5	3283	15.2	0.27
O SALV 2	21-9	3278	15.2	0.27
O SALV 2	24-6	3358	15.6	0.27
O SALV 2	24-11	3380	15.7	0.27
O SALV 2	25-8	3337	15.5	0.27
O SALV 2	26-1	3239	15.0	0.26
O SALV 2	28-9	3374	15.6	0.27
O SALV 3	1-6	3368	15.6	0.27
O SALV 3	1-14	3442	15.9	0.27
O SALV 3	2-20	3329	15.4	0.27
O SALV 3	1-27	3471	16.1	0.27
O SALV 3	2-38	3370	15.6	0.27
O SALV 3	3-3	3320	15.4	0.27
O SALV 3	3-33	3396	15.7	0.27

OSALVYRD.WS SORTED BY LOCATION

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	STD DEV
O SALV 3	4-9	3461	16.0	0.27
O SALV 3	6-1	3207	14.9	0.26
O SALV 3	7-12	3317	15.4	0.27
O SALV 3	7-15	3326	15.4	0.27
O SALV 3	7-23	3396	15.7	0.27
O SALV 3	8-19	3394	15.7	0.27
O SALV 3	8-20	3394	15.7	0.27
O SALV 3	8-30	3226	14.9	0.26
O SALV 3	8-38	3199	14.8	0.26
O SALV 3	9-24	2473	11.5	0.23
O SALV 3	9-47	2991	13.9	0.25
O SALV 3	11-47	3415	15.8	0.27
O SALV 3	12-20	3270	15.1	0.26
O SALV 3	13-27	3290	15.2	0.27
O SALV 3	13-31	3075	14.2	0.26
O SALV 3	13-38	3241	15.0	0.26
O SALV 3	14-22	3128	14.5	0.26
O SALV 3	14-34	3290	15.2	0.27
O SALV 3	15-47	3415	15.8	0.27
O SALV 3	16-17	3218	14.9	0.26
O SALV 3	19-20	3346	15.5	0.27
O SALV 3	21-21	3439	15.9	0.27
O SALV 3	24-20	3425	15.9	0.27
O SALV 3	2-6	3328	15.4	0.27
O SALV 4	1-36	3827	17.7	0.29
O SALV 4	1-63	3564	16.5	0.28
O SALV 4	1-72	3837	17.8	0.29
O SALV 4	2-49	3395	15.7	0.27
O SALV 4	2-58	3197	14.8	0.26
O SALV 4	4-41	3223	14.9	0.26
O SALV 4	4-50	3189	14.8	0.26
O SALV 4	4-59	3224	14.9	0.26
O SALV 4	4-67	3142	14.6	0.26
O SALV 4	4-73	3461	16.0	0.27
O SALV 4	5-9	3503	16.2	0.27
O SALV 4	5-27	3289	15.2	0.27
O SALV 4	7-1	3458	16.0	0.27
O SALV 4	7-9	3212	14.9	0.26
O SALV 4	7-18	3228	15.0	0.26
O SALV 4	7-27	3251	15.1	0.26
O SALV 4	7-34	3102	14.4	0.26
O SALV 4	7-47	3170	14.7	0.26
O SALV 4	7-55	2985	13.8	0.25
O SALV 4	8-63	3180	14.7	0.26
O SALV 4	9-61	3119	14.4	0.26
O SALV 4	9-68	3110	14.4	0.26
O SALV 4	10-38	3176	14.7	0.26
O SALV 4	10-43	3195	14.8	0.26
O SALV 4	11-12	3010	13.9	0.25
O SALV 4	12-27	3153	14.6	0.26
O SALV 4	12-33	3102	14.4	0.26
O SALV 4	12-48	3052	14.1	0.26
O SALV 4	12-59	3033	14.0	0.26
O SALV 4	12-64	3009	13.9	0.25
O SALV 4	14-21	3151	14.6	0.26

OSALVYRD.WS SORTED BY LOCATION

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	STD DEV
O SALV 4	15-38	3185	14.8	0.26
O SALV 4	15-50	3075	14.2	0.26
O SALV 4	15-60	2879	13.3	0.25
O SALV 4	15-68	2920	13.5	0.25
O SALV 4	15-78	3012	14.0	0.25
O SALV 4	23-15	3329	15.4	0.27
O SALV 4	23-21	3338	15.5	0.27
O SALV 4	23-27	3348	15.5	0.27
O SALV 4	18-27	3403	15.8	0.27
O SALV 4	29-27	3029	14.0	0.25
O SALV 4	29-21	3091	14.3	0.26
O SALV 4	29-15	3091	14.3	0.26
O SALV 4	37-15	3095	14.3	0.26
O SALV 4	37-21	2974	13.8	0.25
O SALV 4	37-33	3103	14.4	0.26
O SALV 4	37-39	2910	13.5	0.25
O SALV 4	37-45	2843	13.2	0.25
O SALV 4	37-51	2909	13.5	0.25
O SALV 4	37-57	3089	14.3	0.26
O SALV 5	1-1	2766	12.8	0.24
O SALV 5	2-1	2542	11.8	0.23
O SALV 5	3-1	3082	14.3	0.26
O SALV 5	4-1	3342	15.5	0.27
O SALV 5	5-1	3197	14.8	0.26
O SALV 5	5-2	3257	15.1	0.26
O SALV 5	4-2	3217	14.9	0.26
O SALV 5	3-2	3137	14.5	0.26
O SALV 5	2-2	2492	11.5	0.23
O SALV 5	1-2	2911	13.5	0.25
O SALV 5	1-3	3121	14.5	0.26
O SALV 5	2-3	2923	13.5	0.25
O SALV 5	3-3	2931	13.6	0.25
O SALV 5	4-3	3160	14.6	0.26
O SALV 5	5-3	3081	14.3	0.26
O SALV 5	6-3	3111	14.4	0.26
O SALV 5	6-4	2832	13.1	0.25
O SALV 5	5-4	2762	12.8	0.24
O SALV 5	4-4	2816	13.0	0.25
O SALV 5	3-4	3114	14.4	0.26
O SALV 5	2-4	2966	13.7	0.25
O SALV 5	1-4	3146	14.6	0.26
O SALV 5	1-5	3136	14.5	0.26
O SALV 5	2-5	3034	14.1	0.26
O SALV 5	3-5	2991	13.9	0.25
O SALV 5	4-5	2973	13.8	0.25
O SALV 5	5-5	2874	13.3	0.25
O SALV 5	6-5	2963	13.7	0.25
O SALV 5	7-5	2915	13.5	0.25
O SALV 5	7-6	3066	14.2	0.26
O SALV 5	6-6	3106	14.4	0.26
O SALV 5	5-6	3062	14.2	0.26
O SALV 5	4-6	3049	14.1	0.26
O SALV 5	3-6	3110	14.4	0.26
O SALV 5	2-6	3274	15.2	0.27
O SALV 5	1-6	3059	14.2	0.26

OSALVYRD.WS SORTED BY LOCATION

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	STD DEV
O SALV 5	1-7	3309	15.3	0.27
O SALV 5	2-7	3287	15.2	0.27
O SALV 5	3-7	3280	15.2	0.27
O SALV 5	4-7	3290	15.2	0.27
O SALV 5	5-7	3176	14.7	0.26
O SALV 5	6-7	3292	15.2	0.27
O SALV 5	7-7	3104	14.4	0.26
O SALV 5	7-8	3081	14.3	0.26
O SALV 5	7-11	3146	14.6	0.26
O SALV 5	7-15	3342	15.5	0.27
O SALV 5	1-8	3308	15.3	0.27
O SALV 5	3-9	3299	15.3	0.27
O SALV 5	2-9	3292	15.2	0.27
O SALV 5	3-8	3395	15.7	0.27
O SALV 8	1-6	3005	13.9	0.25
O SALV 8	1-7	2988	13.8	0.25
O SALV 8	1-8	3185	14.8	0.26
O SALV 8	1-8	3165	14.7	0.26
O SALV 8	2-4	2814	13.0	0.25
O SALV 8	2-5	3031	14.0	0.26
O SALV 8	2-5	3244	15.0	0.26
O SALV 8	2-6	3260	15.1	0.26
O SALV 8	2-7	3191	14.8	0.26
O SALV 8	2-8	3105	14.4	0.26
O SALV 8	2-9	2987	13.8	0.25
O SALV 8	2-9	3093	14.3	0.26
O SALV 8	3-1	3113	14.4	0.26
O SALV 8	3-2	2967	13.7	0.25
O SALV 8	3-3	2930	13.6	0.25
O SALV 8	3-3	3207	14.9	0.26
O SALV 8	3-4	3002	13.9	0.25
O SALV 8	3-5	3233	15.0	0.26
O SALV 8	3-6	3288	15.2	0.27
O SALV 8	3-6	3130	14.5	0.26
O SALV 8	3-7	3244	15.0	0.26
O SALV 8	3-7	3234	15.0	0.26
O SALV 8	3-7	3054	14.1	0.26
O SALV 8	3-7	2999	13.9	0.25
O SALV 8	3-8	2981	13.8	0.25
O SALV 8	3-8	2853	13.2	0.25
O SALV 8	3-8	2811	13.0	0.25
O SALV 8	3-9	2833	13.1	0.25
O SALV 8	3-9	2965	13.7	0.25
O SALV 8	3-9	3012	14.0	0.25
O SALV 8	3-10	3120	14.5	0.26
O SALV 8	3-10	3116	14.4	0.26
O SALV 8	4-1	3267	15.1	0.26
O SALV 8	4-2	3237	15.0	0.26
O SALV 8	4-3	3141	14.5	0.26
O SALV 8	4-4	3208	14.9	0.26
O SALV 8	4-6	3191	14.8	0.26
O SALV 8	4-6	3165	14.7	0.26
O SALV 8	4-7	3204	14.8	0.26
O SALV 8	4-8	3182	14.7	0.26
O SALV 8	4-8	3052	14.1	0.26

OSALVYRD.WS SORTED BY LOCATION

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	STD DEV
O SALV 8	4-8	3189	14.8	0.26
O SALV 8	4-8	3040	14.1	0.26
O SALV 8	4-9	3059	14.2	0.26
O SALV 8	4-9	3195	14.8	0.26
O SALV 8	4-9	3217	14.9	0.26
O SALV 8	4-10	3233	15.0	0.26
O SALV 8	5-1	3163	14.7	0.26
O SALV 8	5-2	3203	14.8	0.26
O SALV 8	5-3	3287	15.2	0.27
O SALV 8	5-4	3244	15.0	0.26
O SALV 8	5-5	3266	15.1	0.26
O SALV 8	5-5	3203	14.8	0.26
O SALV 8	5-5	3289	15.2	0.27
O SALV 8	5-6	3283	15.2	0.27
O SALV 8	5-6	3288	15.2	0.27
O SALV 8	5-7	3241	15.0	0.26
O SALV 8	6-2	3267	15.1	0.26
O SALV 8	6-2	3169	14.7	0.26
O SALV 8	6-3	3237	15.0	0.26
O SALV 8	6-3	3203	14.8	0.26
O SALV 8	6-4	3141	14.5	0.26
O SALV 9	6-11	3299	15.3	0.27
O SALV 9	6-12	3465	16.0	0.27
O SALV 9	6-13	3134	14.5	0.26
O SALV 9	7-13	3179	14.7	0.26
O SALV 9	7-12	3303	15.3	0.27
O SALV 9	7-11	3273	15.2	0.26
O SALV 9	7-10	3380	15.7	0.27
O SALV 9	8-11	3186	14.8	0.26
O SALV 9	8-12	3065	14.2	0.26
O SALV 9	8-13	3160	14.6	0.26
O SALV 9	9-13	3087	14.3	0.26
O SALV 9	9-12	3100	14.4	0.26
O SALV 9	9-11	3113	14.4	0.26
O SALV 9	10-8	3249	15.0	0.26
O SALV 9	10-9	3111	14.4	0.26
O SALV 9	10-10	3105	14.4	0.26
O SALV 9	10-11	3197	14.8	0.26
O SALV 9	10-12	3120	14.5	0.26
O SALV 9	10-13	3057	14.2	0.26
O SALV 9	11-13	3029	14.0	0.25
O SALV 9	11-12	3050	14.1	0.26
O SALV 9	11-11	3023	14.0	0.25
O SALV 9	11-10	3127	14.5	0.26
O SALV 9	11-9	3077	14.3	0.26
O SALV 9	11-8	2998	13.9	0.25
O SALV 9	12-11	3047	14.1	0.26
O SALV 9	12-12	2954	13.7	0.25
O SALV 9	12-13	3189	14.8	0.26
O SALV 9	12-14	3103	14.4	0.26
O SALV 9	13-13	3104	14.4	0.26
O SALV 9	13-14	3171	14.7	0.26
O SALV 9	14-14	3127	14.5	0.26
O SALV 9	14-13	3287	15.2	0.27
O SALV 9	9-14	3169	14.7	0.26

OSALVYRD.WS SORTED BY LOCATION

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	STD DEV
O SALV 9	9-15	3103	14.4	0.26
O SALV 9	10-15	3189	14.8	0.26
O SALV 9	10-14	2954	13.7	0.25
O SALV 9	11-14	3116	14.4	0.26

Old ESG Salvage Yard Sorted by Exposure Rate

OSALVYRD.WS SORTED BY EXPOSURE RATE

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	STD DEV
O SALV 4	1-72	3837	17.8	0.29
O SALV 4	1-36	3827	17.7	0.29
O SALV 1	18-44	3662	17.0	0.28
O SALV 4	1-63	3564	16.5	0.28
O SALV 4	5-9	3503	16.2	0.27
O SALV 1	14-41	3478	16.1	0.27
O SALV 3	1-27	3471	16.1	0.27
O SALV 9	6-12	3465	16.0	0.27
O SALV 3	4-9	3461	16.0	0.27
O SALV 4	4-73	3461	16.0	0.27
O SALV 4	7-1	3458	16.0	0.27
O SALV 3	1-14	3442	15.9	0.27
O SALV 1	16-35	3440	15.9	0.27
O SALV 3	21-21	3439	15.9	0.27
O SALV 1	7-39	3427	15.9	0.27
O SALV 2	11-5	3427	15.9	0.27
O SALV 3	24-20	3425	15.9	0.27
O SALV 1	4-33	3423	15.9	0.27
O SALV 2	6-5	3419	15.8	0.27
O SALV 1	2-37	3416	15.8	0.27
O SALV 1	5-45	3416	15.8	0.27
O SALV 1	11-51	3415	15.8	0.27
O SALV 3	11-47	3415	15.8	0.27
O SALV 3	15-47	3415	15.8	0.27
O SALV 4	18-27	3403	15.8	0.27
O SALV 2	15-9	3399	15.7	0.27
O SALV 3	3-33	3396	15.7	0.27
O SALV 3	7-23	3396	15.7	0.27
O SALV 4	2-49	3395	15.7	0.27
O SALV 5	3-8	3395	15.7	0.27
O SALV 3	8-19	3394	15.7	0.27
O SALV 3	8-20	3394	15.7	0.27
O SALV 2	24-11	3380	15.7	0.27
O SALV 9	7-10	3380	15.7	0.27
O SALV 2	17-7	3377	15.6	0.27
O SALV 2	28-9	3374	15.6	0.27
O SALV 3	2-38	3370	15.6	0.27
O SALV 3	1-6	3368	15.6	0.27
O SALV 2	24-6	3358	15.6	0.27
O SALV 1	15-51	3357	15.5	0.27
O SALV 1	3-50	3348	15.5	0.27
O SALV 4	23-27	3348	15.5	0.27
O SALV 3	19-20	3346	15.5	0.27
O SALV 5	4-1	3342	15.5	0.27
O SALV 5	7-15	3342	15.5	0.27
O SALV 2	6-10	3341	15.5	0.27
O SALV 4	23-21	3338	15.5	0.27
O SALV 2	25-8	3337	15.5	0.27
O SALV 1	9-34	3334	15.4	0.27
O SALV 3	2-20	3329	15.4	0.27
O SALV 4	23-15	3329	15.4	0.27
O SALV 3	2-6	3328	15.4	0.27
O SALV 3	7-15	3326	15.4	0.27
O SALV 3	3-3	3320	15.4	0.27
O SALV 3	7-12	3317	15.4	0.27

OSALVYRD.WS SORTED BY EXPOSURE RATE

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	STD DEV
O SALV 2	11-2	3314	15.4	0.27
O SALV 5	1-7	3309	15.3	0.27
O SALV 5	1-8	3308	15.3	0.27
O SALV 1	18-54	3307	15.3	0.27
O SALV 9	7-12	3303	15.3	0.27
O SALV 5	3-9	3299	15.3	0.27
O SALV 9	6-11	3299	15.3	0.27
O SALV 5	6-7	3292	15.2	0.27
O SALV 5	2-9	3292	15.2	0.27
O SALV 2	3-3	3291	15.2	0.27
O SALV 3	13-27	3290	15.2	0.27
O SALV 3	14-34	3290	15.2	0.27
O SALV 2	15-4	3290	15.2	0.27
O SALV 5	4-7	3290	15.2	0.27
O SALV 4	5-27	3289	15.2	0.27
O SALV 8	5-5	3289	15.2	0.27
O SALV 8	3-6	3288	15.2	0.27
O SALV 8	5-6	3288	15.2	0.27
O SALV 5	2-7	3287	15.2	0.27
O SALV 8	5-3	3287	15.2	0.27
O SALV 9	14-13	3287	15.2	0.27
O SALV 1	2-17	3283	15.2	0.27
O SALV 2	20-5	3283	15.2	0.27
O SALV 8	5-6	3283	15.2	0.27
O SALV 5	3-7	3280	15.2	0.27
O SALV 2	3-9	3278	15.2	0.27
O SALV 2	21-9	3278	15.2	0.27
O SALV 5	2-6	3274	15.2	0.27
O SALV 9	7-11	3273	15.2	0.26
O SALV 3	12-20	3270	15.1	0.26
O SALV 8	4-1	3267	15.1	0.26
O SALV 8	6-2	3267	15.1	0.26
O SALV 8	5-5	3266	15.1	0.26
O SALV 1	9-15	3260	15.1	0.26
O SALV 8	2-6	3260	15.1	0.26
O SALV 5	5-2	3257	15.1	0.26
O SALV 4	7-27	3251	15.1	0.26
O SALV 9	10-8	3249	15.0	0.26
O SALV 2	19-2	3245	15.0	0.26
O SALV 8	2-5	3244	15.0	0.26
O SALV 8	3-7	3244	15.0	0.26
O SALV 8	5-4	3244	15.0	0.26
O SALV 3	13-38	3241	15.0	0.26
O SALV 8	5-7	3241	15.0	0.26
O SALV 2	26-1	3239	15.0	0.26
O SALV 1	10-29	3237	15.0	0.26
O SALV 8	4-2	3237	15.0	0.26
O SALV 8	6-3	3237	15.0	0.26
O SALV 8	3-7	3234	15.0	0.26
O SALV 8	3-5	3233	15.0	0.26
O SALV 8	4-10	3233	15.0	0.26
O SALV 4	7-18	3228	15.0	0.26
O SALV 3	8-30	3226	14.9	0.26
O SALV 1	11-46	3224	14.9	0.26
O SALV 4	4-59	3224	14.9	0.26

OSALVYRD.WS SORTED BY EXPOSURE RATE

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	STD DEV
O SALV 4	4-41	3223	14.9	0.26
O SALV 3	16-17	3218	14.9	0.26
O SALV 5	4-2	3217	14.9	0.26
O SALV 8	4-9	3217	14.9	0.26
O SALV 1	9-15	3216	14.9	0.26
O SALV 4	7-9	3212	14.9	0.26
O SALV 8	4-4	3208	14.9	0.26
O SALV 3	6-1	3207	14.9	0.26
O SALV 8	3-3	3207	14.9	0.26
O SALV 8	4-7	3204	14.8	0.26
O SALV 8	5-2	3203	14.8	0.26
O SALV 8	5-5	3203	14.8	0.26
O SALV 8	6-3	3203	14.8	0.26
O SALV 3	8-38	3199	14.8	0.26
O SALV 5	5-1	3197	14.8	0.26
O SALV 4	2-58	3197	14.8	0.26
O SALV 9	10-11	3197	14.8	0.26
O SALV 8	4-9	3195	14.8	0.26
O SALV 4	10-43	3195	14.8	0.26
O SALV 1	2-17	3192	14.8	0.26
O SALV 8	2-7	3191	14.8	0.26
O SALV 8	4-6	3191	14.8	0.26
O SALV 1	17-28	3191	14.8	0.26
O SALV 4	4-50	3189	14.8	0.26
O SALV 8	4-8	3189	14.8	0.26
O SALV 9	12-13	3189	14.8	0.26
O SALV 9	10-15	3189	14.8	0.26
O SALV 9	8-11	3186	14.8	0.26
O SALV 4	15-38	3185	14.8	0.26
O SALV 8	1-8	3185	14.8	0.26
O SALV 8	4-8	3182	14.7	0.26
O SALV 4	8-63	3180	14.7	0.26
O SALV 9	7-13	3179	14.7	0.26
O SALV 5	5-7	3176	14.7	0.26
O SALV 4	10-38	3176	14.7	0.26
O SALV 9	13-14	3171	14.7	0.26
O SALV 1	2-27	3170	14.7	0.26
O SALV 4	7-47	3170	14.7	0.26
O SALV 8	6-2	3169	14.7	0.26
O SALV 9	9-14	3169	14.7	0.26
O SALV 8	1-8	3165	14.7	0.26
O SALV 8	4-6	3165	14.7	0.26
O SALV 8	5-1	3163	14.7	0.26
O SALV 5	4-3	3160	14.6	0.26
O SALV 9	8-13	3160	14.6	0.26
O SALV 4	12-27	3153	14.6	0.26
O SALV 4	14-21	3151	14.6	0.26
O SALV 5	7-11	3146	14.6	0.26
O SALV 5	1-4	3146	14.6	0.26
O SALV 4	4-67	3142	14.6	0.26
O SALV 8	4-3	3141	14.5	0.26
O SALV 8	6-4	3141	14.5	0.26
O SALV 1	3-6	3138	14.5	0.26
O SALV 5	3-2	3137	14.5	0.26
O SALV 5	1-5	3136	14.5	0.26

OSALVYRD.WS SORTED BY EXPOSURE RATE

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	STD DEV
O SALV 9	6-13	3134	14.5	0.26
O SALV 1	18-23	3133	14.5	0.26
O SALV 8	3-6	3130	14.5	0.26
O SALV 3	14-22	3128	14.5	0.26
O SALV 9	11-10	3127	14.5	0.26
O SALV 9	14-14	3127	14.5	0.26
O SALV 5	1-3	3121	14.5	0.26
O SALV 8	3-10	3120	14.5	0.26
O SALV 9	10-12	3120	14.5	0.26
O SALV 4	9-61	3119	14.4	0.26
O SALV 8	3-10	3116	14.4	0.26
O SALV 9	11-14	3116	14.4	0.26
O SALV 5	3-4	3114	14.4	0.26
O SALV 8	3-1	3113	14.4	0.26
O SALV 9	9-11	3113	14.4	0.26
O SALV 5	6-3	3111	14.4	0.26
O SALV 9	10-9	3111	14.4	0.26
O SALV 5	3-6	3110	14.4	0.26
O SALV 4	9-68	3110	14.4	0.26
O SALV 5	6-6	3106	14.4	0.26
O SALV 8	2-8	3105	14.4	0.26
O SALV 9	10-10	3105	14.4	0.26
O SALV 5	7-7	3104	14.4	0.26
O SALV 9	13-13	3104	14.4	0.26
O SALV 4	37-33	3103	14.4	0.26
O SALV 9	12-14	3103	14.4	0.26
O SALV 9	9-15	3103	14.4	0.26
O SALV 4	7-34	3102	14.4	0.26
O SALV 4	12-33	3102	14.4	0.26
O SALV 9	9-12	3100	14.4	0.26
O SALV 4	37-15	3095	14.3	0.26
O SALV 8	2-9	3093	14.3	0.26
O SALV 4	29-21	3091	14.3	0.26
O SALV 4	29-15	3091	14.3	0.26
O SALV 4	37-57	3089	14.3	0.26
O SALV 9	9-13	3087	14.3	0.26
O SALV 5	3-1	3082	14.3	0.26
O SALV 5	7-8	3081	14.3	0.26
O SALV 5	5-3	3081	14.3	0.26
O SALV 9	11-9	3077	14.3	0.26
O SALV 3	13-31	3075	14.2	0.26
O SALV 4	15-50	3075	14.2	0.26
O SALV 5	7-6	3066	14.2	0.26
O SALV 1	2-22	3066	14.2	0.26
O SALV 9	8-12	3065	14.2	0.26
O SALV 5	5-6	3062	14.2	0.26
O SALV 5	1-6	3059	14.2	0.26
O SALV 8	4-9	3059	14.2	0.26
O SALV 9	10-13	3057	14.2	0.26
O SALV 8	3-7	3054	14.1	0.26
O SALV 8	4-8	3052	14.1	0.26
O SALV 4	12-48	3052	14.1	0.26
O SALV 9	11-12	3050	14.1	0.26
O SALV 5	4-6	3049	14.1	0.26
O SALV 9	12-11	3047	14.1	0.26

OSALVYRD.WS SORTED BY EXPOSURE RATE

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	STD DEV
O SALV 8	4-8	3040	14.1	0.26
O SALV 5	2-5	3034	14.1	0.26
O SALV 4	12-59	3033	14.0	0.26
O SALV 8	2-5	3031	14.0	0.26
O SALV 9	11-13	3029	14.0	0.25
O SALV 4	29-27	3029	14.0	0.25
O SALV 9	11-11	3023	14.0	0.25
O SALV 8	3-9	3012	14.0	0.25
O SALV 4	15-78	3012	14.0	0.25
O SALV 4	11-12	3010	13.9	0.25
O SALV 4	12-64	3009	13.9	0.25
O SALV 8	1-6	3005	13.9	0.25
O SALV 8	3-4	3002	13.9	0.25
O SALV 1	15-9	2999	13.9	0.25
O SALV 8	3-7	2999	13.9	0.25
O SALV 9	11-8	2998	13.9	0.25
O SALV 1	3-1	2996	13.9	0.25
O SALV 1	10-9	2992	13.9	0.25
O SALV 5	3-5	2991	13.9	0.25
O SALV 3	9-47	2991	13.9	0.25
O SALV 1	6-8	2991	13.9	0.25
O SALV 8	1-7	2988	13.8	0.25
O SALV 8	2-9	2987	13.8	0.25
O SALV 4	7-55	2985	13.8	0.25
O SALV 8	3-8	2981	13.8	0.25
O SALV 4	37-21	2974	13.8	0.25
O SALV 5	4-5	2973	13.8	0.25
O SALV 1	8-2	2972	13.8	0.25
O SALV 1	15-18	2967	13.7	0.25
O SALV 8	3-2	2967	13.7	0.25
O SALV 5	2-4	2966	13.7	0.25
O SALV 8	3-9	2965	13.7	0.25
O SALV 5	6-5	2963	13.7	0.25
O SALV 9	12-12	2954	13.7	0.25
O SALV 9	10-14	2954	13.7	0.25
O SALV 5	3-3	2931	13.6	0.25
O SALV 8	3-3	2930	13.6	0.25
O SALV 5	2-3	2923	13.5	0.25
O SALV 4	15-68	2920	13.5	0.25
O SALV 5	7-5	2915	13.5	0.25
O SALV 5	1-2	2911	13.5	0.25
O SALV 4	37-39	2910	13.5	0.25
O SALV 4	37-51	2909	13.5	0.25
O SALV 1	15-3	2909	13.5	0.25
O SALV 4	15-60	2879	13.3	0.25
O SALV 5	5-5	2874	13.3	0.25
O SALV 1	10-20	2870	13.3	0.25
O SALV 8	3-8	2853	13.2	0.25
O SALV 4	37-45	2843	13.2	0.25
O SALV 8	3-9	2833	13.1	0.25
O SALV 5	6-4	2832	13.1	0.25
O SALV 5	4-4	2816	13.0	0.25
O SALV 8	2-4	2814	13.0	0.25
O SALV 8	3-8	2811	13.0	0.25
O SALV 5	1-1	2766	12.8	0.24

OSALVYRD.WS SORTED BY EXPOSURE RATE

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	uR/h STD DEV
O SALV 5	5-4	2762	12.8	0.24
O SALV 5	2-1	2542	11.8	0.23
O SALV 5	2-2	2492	11.5	0.23
O SALV 3	9-24	2473	11.5	0.23

RDBRLS.WS SORTED BY LOCATION

ROOM NUMBER		GRID NAME	GAMMA TOTAL	uR/h TOTAL	STD DEV
RDBRLS	6A	1-6	3211	14.87	0.26
RDBRLS	6A	1-5	3213	14.88	0.26
RDBRLS	6A	1-4	3153	14.60	0.26
RDBRLS	6A	1-3	3121	14.46	0.26
RDBRLS	6A	1-2	3016	13.97	0.25
RDBRLS	6A	1-1	2563	11.87	0.23
RDBRLS	6A	1-1	3090	14.31	0.26
RDBRLS	6B	1-1	3060	14.17	0.26
RDBRLS	6B	1-2	3023	14.00	0.25
RDBRLS	6B	1-3	3091	14.32	0.26
RDBRLS	6B	1-4	3145	14.57	0.26
RDBRLS	6B	1-5	3189	14.77	0.26
RDBRLS	6B	1-6	3164	14.66	0.26
RDBRLS	7	1-1	3116	14.43	0.26
RDBRLS	7	1-2	2902	13.44	0.25
RDBRLS	7	1-3	2997	13.88	0.25
RDBRLS	7	1-4	2813	13.03	0.25
RDBRLS	7	1-5	2844	13.17	0.25
RDBRLS	7	1-6	2945	13.64	0.25
RDBRLS	7	1-7	3046	14.11	0.26
RDBRLS	7	1-8	3021	13.99	0.25
RDBRLS	7	1-9	3116	14.43	0.26
RDBRLS	7	1-10	3181	14.73	0.26
RDBRLS	7	1-11	3208	14.86	0.26
RDBRLS	7	1-12	3029	14.03	0.25
RDBRLS	7	1-13	2953	13.68	0.25
RDBRLS	7	1-14	2553	11.83	0.23
RDBRLS	7	2-1	3121	14.46	0.26
RDBRLS	7	2-2	2982	13.81	0.25
RDBRLS	7	2-3	2915	13.50	0.25
RDBRLS	7	2-4	2878	13.33	0.25
RDBRLS	7	2-5	2775	12.85	0.24
RDBRLS	7	2-6	2805	12.99	0.25
RDBRLS	7	2-7	2710	12.55	0.24
RDBRLS	7	2-8	2583	11.96	0.24
RDBRLS	7	2-9	2530	11.72	0.23
RDBRLS	7	2-10	2673	12.38	0.24
RDBRLS	7	2-11	2804	12.99	0.25
RDBRLS	7	2-12	2916	13.51	0.25
RDBRLS	7	2-13	2821	13.07	0.25
RDBRLS	7	2-14	2346	10.87	0.22
RDBRLS	7	3-1	3067	14.21	0.26
RDBRLS	7	3-2	2940	13.62	0.25
RDBRLS	7	3-3	2776	12.86	0.24
RDBRLS	7	3-4	2818	13.05	0.25
RDBRLS	7	3-5	2729	12.64	0.24
RDBRLS	7	3-6	2638	12.22	0.24
RDBRLS	7	3-7	2639	12.22	0.24
RDBRLS	7	3-8	2614	12.11	0.24
RDBRLS	7	3-9	2607	12.08	0.24
RDBRLS	7	3-10	2685	12.44	0.24
RDBRLS	7	3-11	2665	12.34	0.24
RDBRLS	7	3-12	2793	12.94	0.24
RDBRLS	7	3-13	2814	13.03	0.25
RDBRLS	7	3-14	2755	12.76	0.24

RDBRLS.WS SORTED BY LOCATION

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	STD DEV
RDBRLS 7	4-1	3172	14.69	0.26
RDBRLS 7	4-2	3128	14.49	0.26
RDBRLS 7	4-4	2833	13.12	0.25
RDBRLS 7	4-5	2841	13.16	0.25
RDBRLS 7	4-6	2795	12.95	0.24
RDBRLS 7	4-7	2763	12.80	0.24
RDBRLS 7	4-8	2718	12.59	0.24
RDBRLS 7	4-9	2706	12.53	0.24
RDBRLS 7	4-10	2825	13.09	0.25
RDBRLS 7	4-11	2747	12.72	0.24
RDBRLS 7	4-12	2717	12.59	0.24
RDBRLS 7	4-13	2884	13.36	0.25
RDBRLS 7	4-14	2767	12.82	0.24
RDBRLS 7	5-1	3035	14.06	0.26
RDBRLS 7	5-2	3212	14.88	0.26
RDBRLS 7	5-3	6023	27.90	0.36
RDBRLS 7	5-4	3050	14.13	0.26
RDBRLS 7	5-5	2770	12.83	0.24
RDBRLS 7	5-6	2745	12.71	0.24
RDBRLS 7	5-7	2715	12.58	0.24
RDBRLS 7	5-8	2733	12.66	0.24
RDBRLS 7	5-9	2716	12.58	0.24
RDBRLS 7	5-10	2702	12.52	0.24
RDBRLS 7	5-11	2804	12.99	0.25
RDBRLS 7	5-12	2735	12.67	0.24
RDBRLS 7	5-13	2800	12.97	0.25
RDBRLS 7	5-14	2768	12.82	0.24
RDBRLS 7	6-1	3244	15.03	0.26
RDBRLS 7	6-2	3263	15.11	0.26
RDBRLS 7	6-3	3169	14.68	0.26
RDBRLS 7	6-4	2860	13.25	0.25
RDBRLS 7	6-5	2904	13.45	0.25
RDBRLS 7	6-6	2869	13.29	0.25
RDBRLS 7	6-7	2962	13.72	0.25
RDBRLS 7	6-8	2918	13.52	0.25
RDBRLS 7	6-9	2775	12.85	0.24
RDBRLS 7	6-10	2912	13.49	0.25
RDBRLS 7	6-11	2840	13.15	0.25
RDBRLS 7	6-12	2821	13.07	0.25
RDBRLS 7	6-13	2918	13.52	0.25
RDBRLS 7	6-14	2934	13.59	0.25

Rocketdyne Barrel Storage Yard Sorted by Exposure Rate

RDBRLS.WS SORTED BY EXPOSURE RATE

ROOM NUMBER		GRID NAME	GAMMA TOTAL	uR/h TOTAL	STD DEV
RDBRLS	7	5-3	6023	27.90	0.36
RDBRLS	7	6-2	3263	15.11	0.26
RDBRLS	7	6-1	3244	15.03	0.26
RDBRLS	6A	1-5	3213	14.88	0.26
RDBRLS	7	5-2	3212	14.88	0.26
RDBRLS	6A	1-6	3211	14.87	0.26
RDBRLS	7	1-11	3208	14.86	0.26
RDBRLS	6B	1-5	3189	14.77	0.26
RDBRLS	7	1-10	3181	14.73	0.26
RDBRLS	7	4-1	3172	14.69	0.26
RDBRLS	7	6-3	3169	14.68	0.26
RDBRLS	6B	1-6	3164	14.66	0.26
RDBRLS	6A	1-4	3153	14.60	0.26
RDBRLS	6B	1-4	3145	14.57	0.26
RDBRLS	7	4-2	3128	14.49	0.26
RDBRLS	7	2-1	3121	14.46	0.26
RDBRLS	6A	1-3	3121	14.46	0.26
RDBRLS	7	1-9	3116	14.43	0.26
RDBRLS	7	1-1	3116	14.43	0.26
RDBRLS	6B	1-3	3091	14.32	0.26
RDBRLS	6A	1-1	3090	14.31	0.26
RDBRLS	7	3-1	3067	14.21	0.26
RDBRLS	6B	1-1	3060	14.17	0.26
RDBRLS	7	5-4	3050	14.13	0.26
RDBRLS	7	1-7	3046	14.11	0.26
RDBRLS	7	5-1	3035	14.06	0.26
RDBRLS	7	1-12	3029	14.03	0.25
RDBRLS	6B	1-2	3023	14.00	0.25
RDBRLS	7	1-8	3021	13.99	0.25
RDBRLS	6A	1-2	3016	13.97	0.25
RDBRLS	7	1-3	2997	13.88	0.25
RDBRLS	7	2-2	2982	13.81	0.25
RDBRLS	7	6-7	2962	13.72	0.25
RDBRLS	7	1-13	2953	13.68	0.25
RDBRLS	7	1-6	2945	13.64	0.25
RDBRLS	7	3-2	2940	13.62	0.25
RDBRLS	7	6-14	2934	13.59	0.25
RDBRLS	7	6-8	2918	13.52	0.25
RDBRLS	7	6-13	2918	13.52	0.25
RDBRLS	7	2-12	2916	13.51	0.25
RDBRLS	7	2-3	2915	13.50	0.25
RDBRLS	7	6-10	2912	13.49	0.25
RDBRLS	7	6-5	2904	13.45	0.25
RDBRLS	7	1-2	2902	13.44	0.25
RDBRLS	7	4-13	2884	13.36	0.25
RDBRLS	7	2-4	2878	13.33	0.25
RDBRLS	7	6-6	2869	13.29	0.25
RDBRLS	7	6-4	2860	13.25	0.25
RDBRLS	7	1-5	2844	13.17	0.25
RDBRLS	7	4-5	2841	13.16	0.25
RDBRLS	7	6-11	2840	13.15	0.25
RDBRLS	7	4-4	2833	13.12	0.25
RDBRLS	7	4-10	2825	13.09	0.25
RDBRLS	7	6-12	2821	13.07	0.25
RDBRLS	7	2-13	2821	13.07	0.25

RDBRLS.WS SORTED BY EXPOSURE RATE

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	STD DEV
RDBRLS 7	3-4	2818	13.05	0.25
RDBRLS 7	3-13	2814	13.03	0.25
RDBRLS 7	1-4	2813	13.03	0.25
RDBRLS 7	2-6	2805	12.99	0.25
RDBRLS 7	5-11	2804	12.99	0.25
RDBRLS 7	2-11	2804	12.99	0.25
RDBRLS 7	5-13	2800	12.97	0.25
RDBRLS 7	4-6	2795	12.95	0.24
RDBRLS 7	3-12	2793	12.94	0.24
RDBRLS 7	3-3	2776	12.86	0.24
RDBRLS 7	2-5	2775	12.85	0.24
RDBRLS 7	6-9	2775	12.85	0.24
RDBRLS 7	5-5	2770	12.83	0.24
RDBRLS 7	5-14	2768	12.82	0.24
RDBRLS 7	4-14	2767	12.82	0.24
RDBRLS 7	4-7	2763	12.80	0.24
RDBRLS 7	3-14	2755	12.76	0.24
RDBRLS 7	4-11	2747	12.72	0.24
RDBRLS 7	5-6	2745	12.71	0.24
RDBRLS 7	5-12	2735	12.67	0.24
RDBRLS 7	5-8	2733	12.66	0.24
RDBRLS 7	3-5	2729	12.64	0.24
RDBRLS 7	4-8	2718	12.59	0.24
RDBRLS 7	4-12	2717	12.59	0.24
RDBRLS 7	5-9	2716	12.58	0.24
RDBRLS 7	5-7	2715	12.58	0.24
RDBRLS 7	2-7	2710	12.55	0.24
RDBRLS 7	4-9	2706	12.53	0.24
RDBRLS 7	5-10	2702	12.52	0.24
RDBRLS 7	3-10	2685	12.44	0.24
RDBRLS 7	2-10	2673	12.38	0.24
RDBRLS 7	3-11	2665	12.34	0.24
RDBRLS 7	3-7	2639	12.22	0.24
RDBRLS 7	3-6	2638	12.22	0.24
RDBRLS 7	3-8	2614	12.11	0.24
RDBRLS 7	3-9	2607	12.08	0.24
RDBRLS 7	2-8	2583	11.96	0.24
RDBRLS 6A	1-1	2563	11.87	0.23
RDBRLS 7	1-14	2553	11.83	0.23
RDBRLS 7	2-9	2530	11.72	0.23
RDBRLS 7	2-14	2346	10.87	0.22

New Salvage Yard (T583) Sorted by Location

T583.WS SORTED BY LOCATION

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	STD DEV
T583	-1,2	2974	13.78	0.25
	1-1	2808	13.01	0.25
	1-2	2802	12.98	0.25
	1-3	3052	14.14	0.26
	1-4	3121	14.46	0.26
	1-5	3256	15.08	0.26
	2-1	3199	14.82	0.26
	2-2	2996	13.88	0.25
	2-3	3235	14.98	0.26
	2-5	3281	15.20	0.27
	2-5	3270	15.15	0.26
	2-6	3248	15.04	0.26
	2-6	3167	14.67	0.26
	3-2	3243	15.02	0.26
	3-2	2941	13.62	0.25
	3-3	2978	13.79	0.25
	3-4	3199	14.82	0.26
	3-6	3021	13.99	0.25
	3-6	3092	14.32	0.26
	4-2	3226	14.94	0.26
	4-3	3077	14.25	0.26
	4-3	3071	14.22	0.26
	4-3	3049	14.12	0.26
	4-4	2997	13.88	0.25
	4-4	3236	14.99	0.26
	4-5	2973	13.77	0.25
	4-6	2942	13.63	0.25
	5-2	2960	13.71	0.25
	5-3	2957	13.70	0.25
	5-4	2413	11.18	0.23
	5-4	2198	10.18	0.22
	5-5	2412	11.17	0.23
	5-6	2434	11.27	0.23
	5-7	2861	13.25	0.25
	5-8	2573	11.92	0.23
	6-2	3036	14.06	0.26
	6-3	2933	13.59	0.25
	6-4	3071	14.22	0.26
	6-5	2379	11.02	0.23
	6-5	3139	14.54	0.26
	6-6	2520	11.67	0.23
	6-7	2579	11.95	0.24
	6-8	2366	10.96	0.23
	6-9	2503	11.59	0.23
	6-10	2415	11.19	0.23
	6-11	2397	11.10	0.23
	6-12	2802	12.98	0.25
	7-3	3139	14.54	0.26
	7-3	2642	12.24	0.24
	7-4	3083	14.28	0.26
	7-5	2987	13.84	0.25
	7-6	3058	14.16	0.26
	7-7	2116	9.80	0.21
	7-7	3266	15.13	0.26
	7-9	2566	11.89	0.23

T583.WS SORTED BY LOCATION

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	STD DEV
	7-10	2562	11.87	0.23
	7-11	2469	11.44	0.23
	7-12	3190	14.78	0.26
	8-7	3266	15.13	0.26
	8-8	3190	14.78	0.26
	8-9	3126	14.48	0.26
	8-10	3124	14.47	0.26
	8-11	3154	14.61	0.26

New Salvage Yard (T583) Sorted by Exposure Rate

T583.WS SORTED BY EXPOSURE RATE

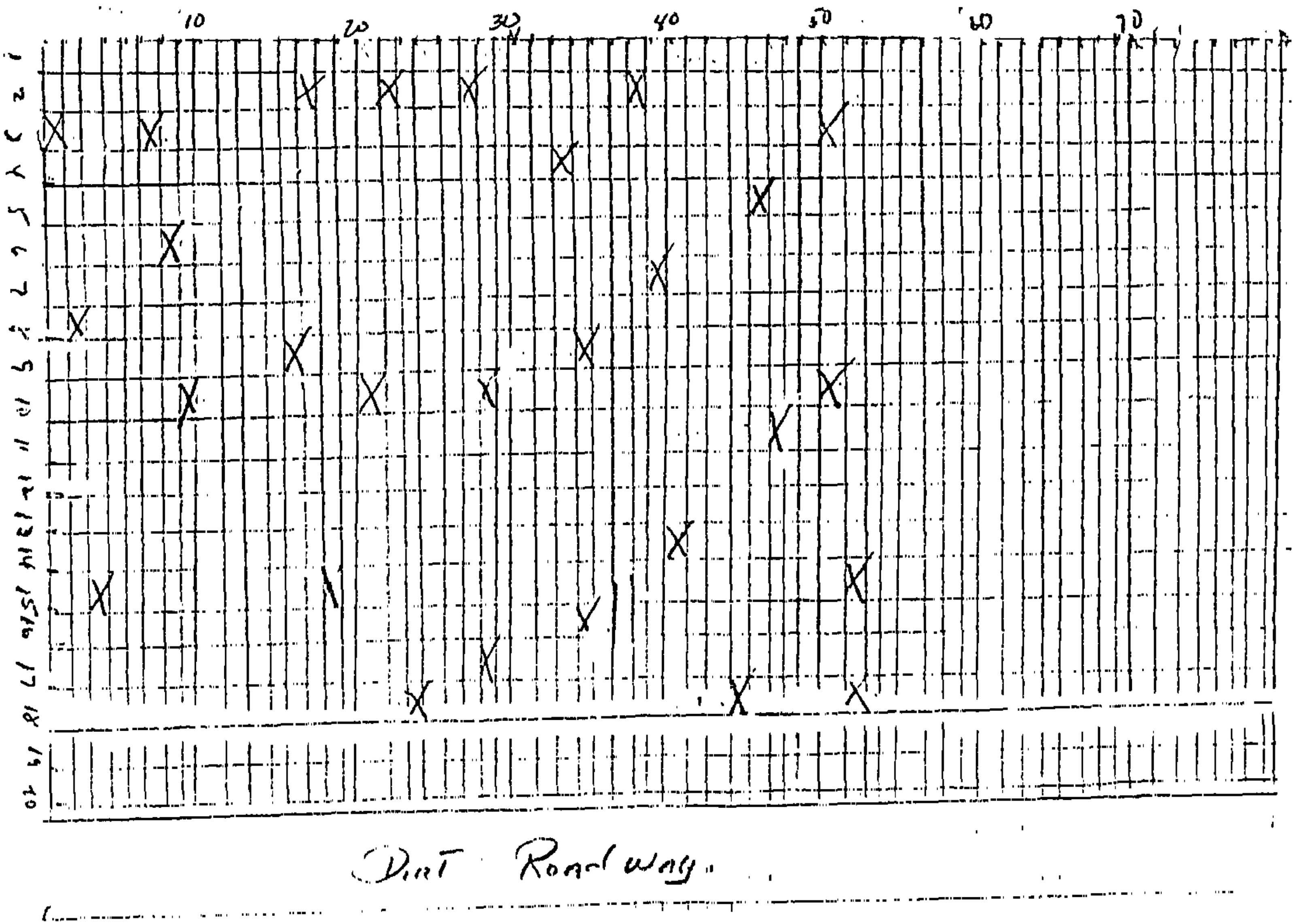
ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	STD DEV
	2-5	3281	15.20	0.27
	2-5	3270	15.15	0.26
	7-7	3266	15.13	0.26
	8-7	3266	15.13	0.26
	1-5	3256	15.08	0.26
	2-6	3248	15.04	0.26
	3-2	3243	15.02	0.26
	4-4	3236	14.99	0.26
	2-3	3235	14.98	0.26
	4-2	3226	14.94	0.26
	2-1	3199	14.82	0.26
	3-4	3199	14.82	0.26
	7-12	3190	14.78	0.26
	8-8	3190	14.78	0.26
	2-6	3167	14.67	0.26
	8-11	3154	14.61	0.26
	6-5	3139	14.54	0.26
	7-3	3139	14.54	0.26
	8-9	3126	14.48	0.26
	8-10	3124	14.47	0.26
	1-4	3121	14.46	0.26
	3-6	3092	14.32	0.26
	7-4	3083	14.28	0.26
	4-3	3077	14.25	0.26
	6-4	3071	14.22	0.26
	4-3	3071	14.22	0.26
	7-6	3058	14.16	0.26
	1-3	3052	14.14	0.26
	4-3	3049	14.12	0.26
	6-2	3036	14.06	0.26
	3-6	3021	13.99	0.25
	4-4	2997	13.88	0.25
	2-2	2996	13.88	0.25
	7-5	2987	13.84	0.25
	3-3	2978	13.79	0.25
	-1,2	2974	13.78	0.25
	4-5	2973	13.77	0.25
	5-2	2960	13.71	0.25
	5-3	2957	13.70	0.25
	4-6	2942	13.63	0.25
	3-2	2941	13.62	0.25
	6-3	2933	13.59	0.25
	5-7	2861	13.25	0.25
	1-1	2808	13.01	0.25
	6-12	2802	12.98	0.25
	1-2	2802	12.98	0.25
	7-3	2642	12.24	0.24
	6-7	2579	11.95	0.24
	5-8	2573	11.92	0.23
	7-9	2566	11.89	0.23
	7-10	2562	11.87	0.23
	6-6	2520	11.67	0.23
	6-9	2503	11.59	0.23
	7-11	2469	11.44	0.23
	5-6	2434	11.27	0.23

T583.WS SORTED BY EXPOSURE RATE

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	STD DEV
	6-10	2415	11.19	0.23
	5-4	2413	11.18	0.23
	5-5	2412	11.17	0.23
	6-11	2397	11.10	0.23
	6-5	2379	11.02	0.23
	6-8	2366	10.96	0.23
	5-4	2198	10.18	0.22
	7-7	2116	9.80	0.21

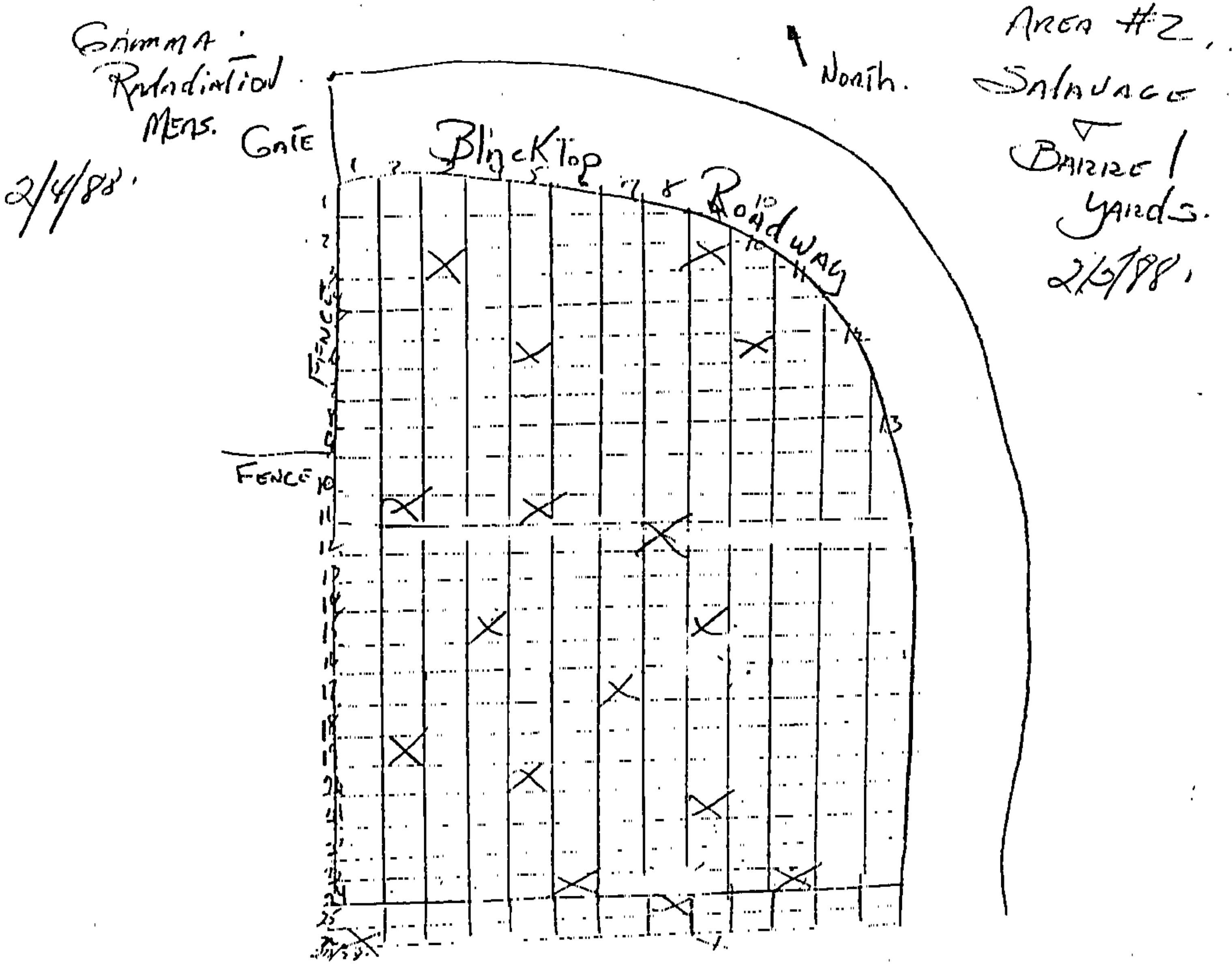
APPENDIX E. SURVEYOR'S MAPS OF EACH ZONE

Salvage Yard / 2/4/88.
Sand.
Area 1.

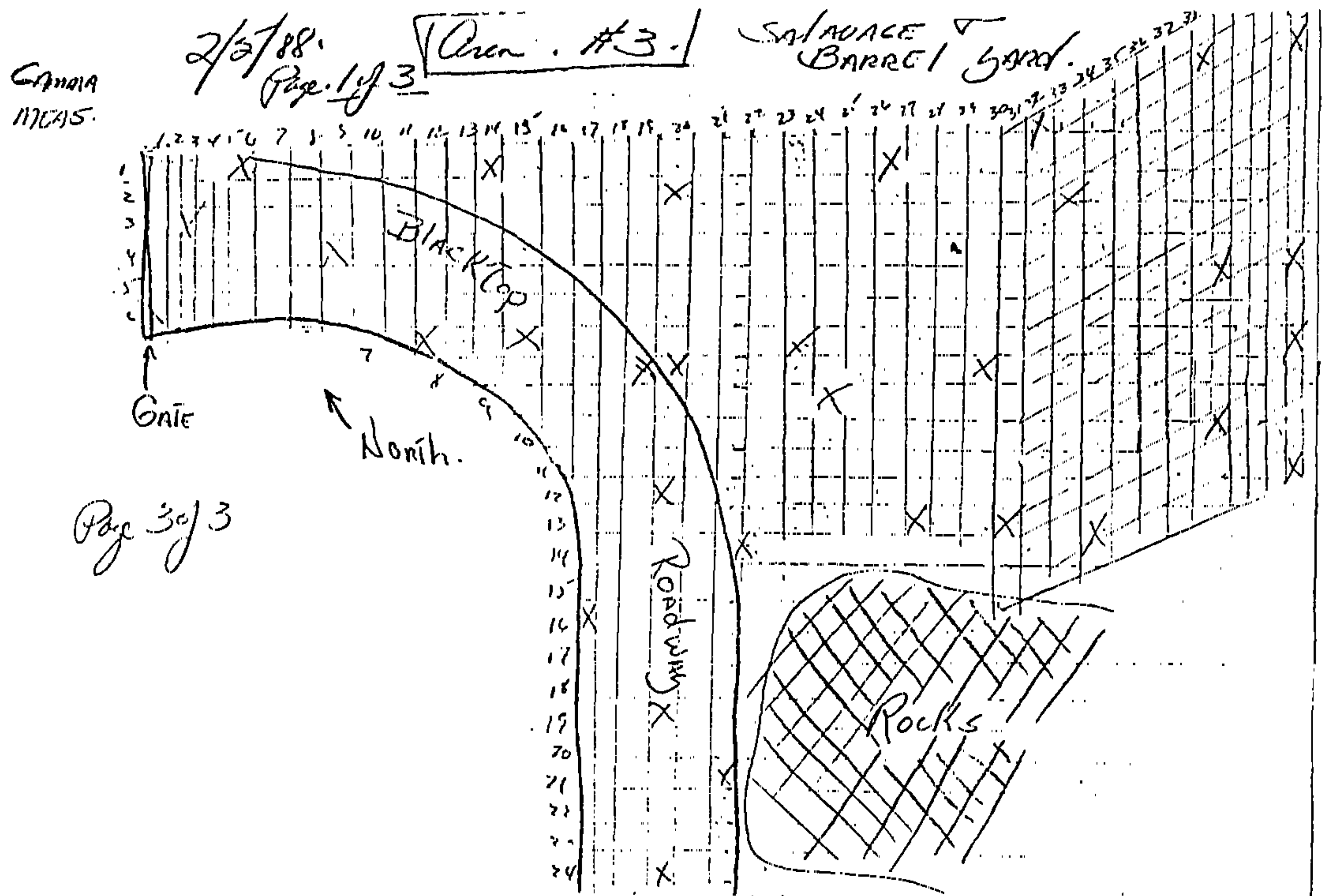


E.1 Old ESG Salvage Yard (Zone 1)

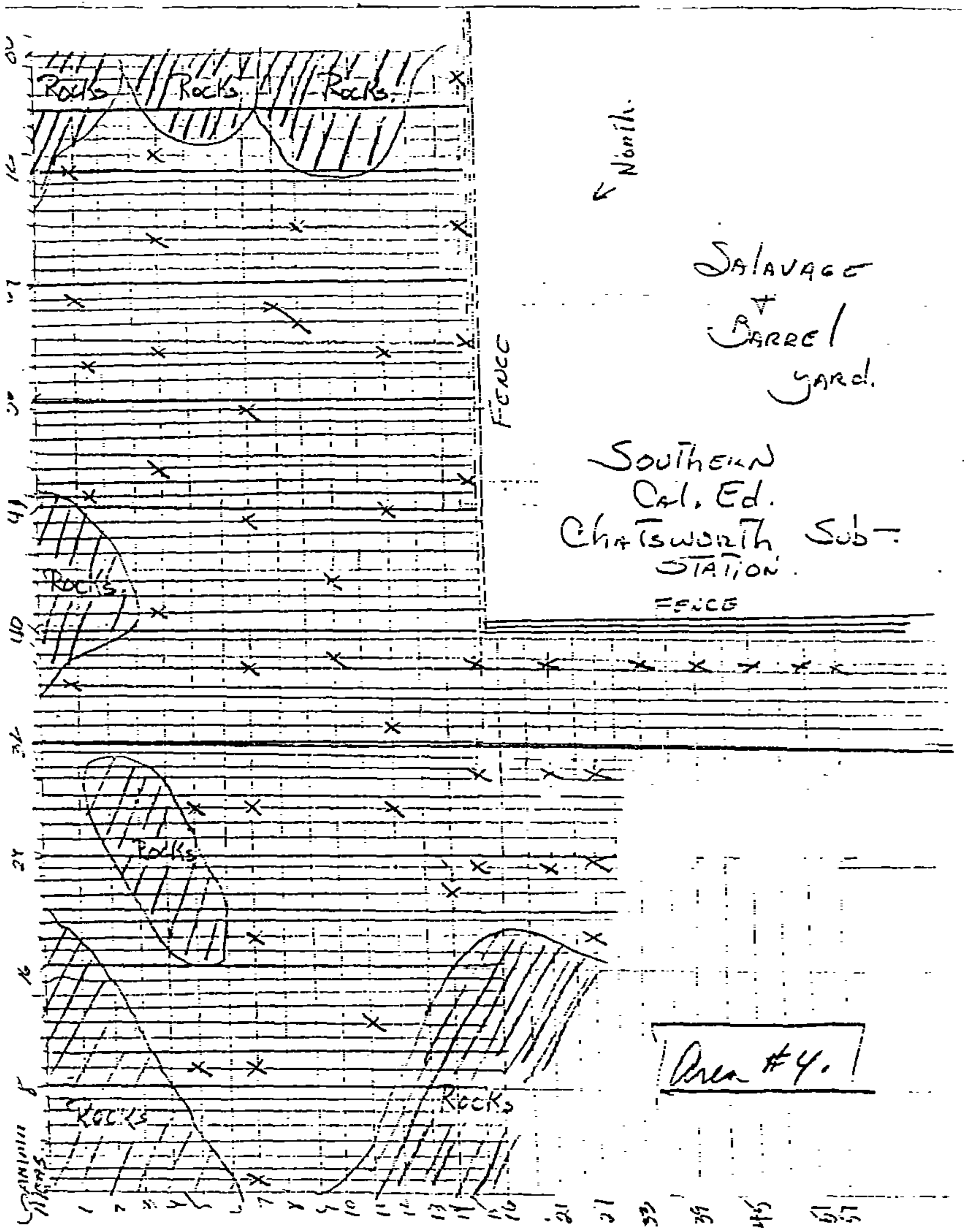
North.



L.2 Old LSG Salvage Yard (Zone 2)



1.3 Old ESG Salvage Yard (Zone 3)



Old_LSG_Salvage_Yard_(Zone 4)

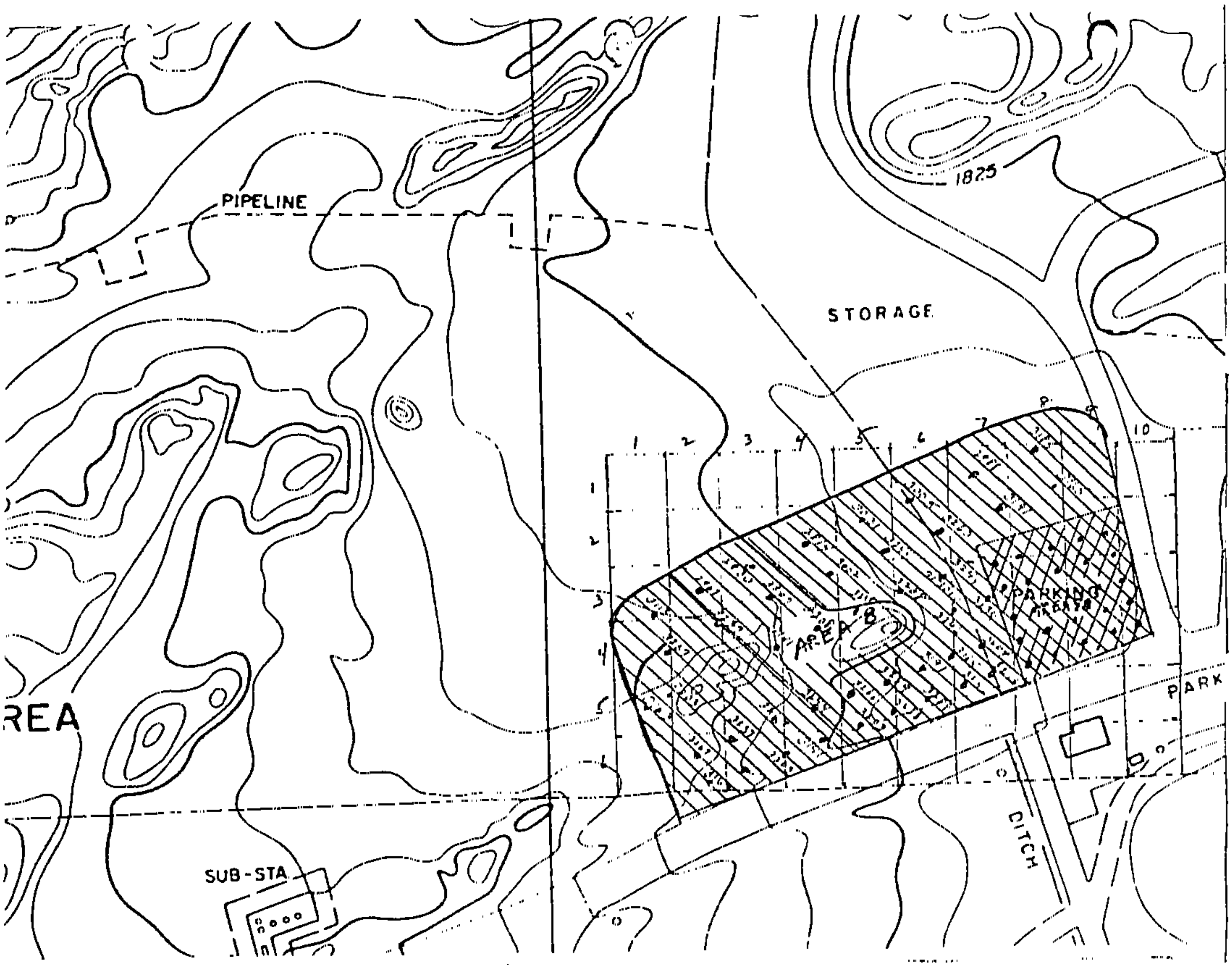
L.4

Area No. 5

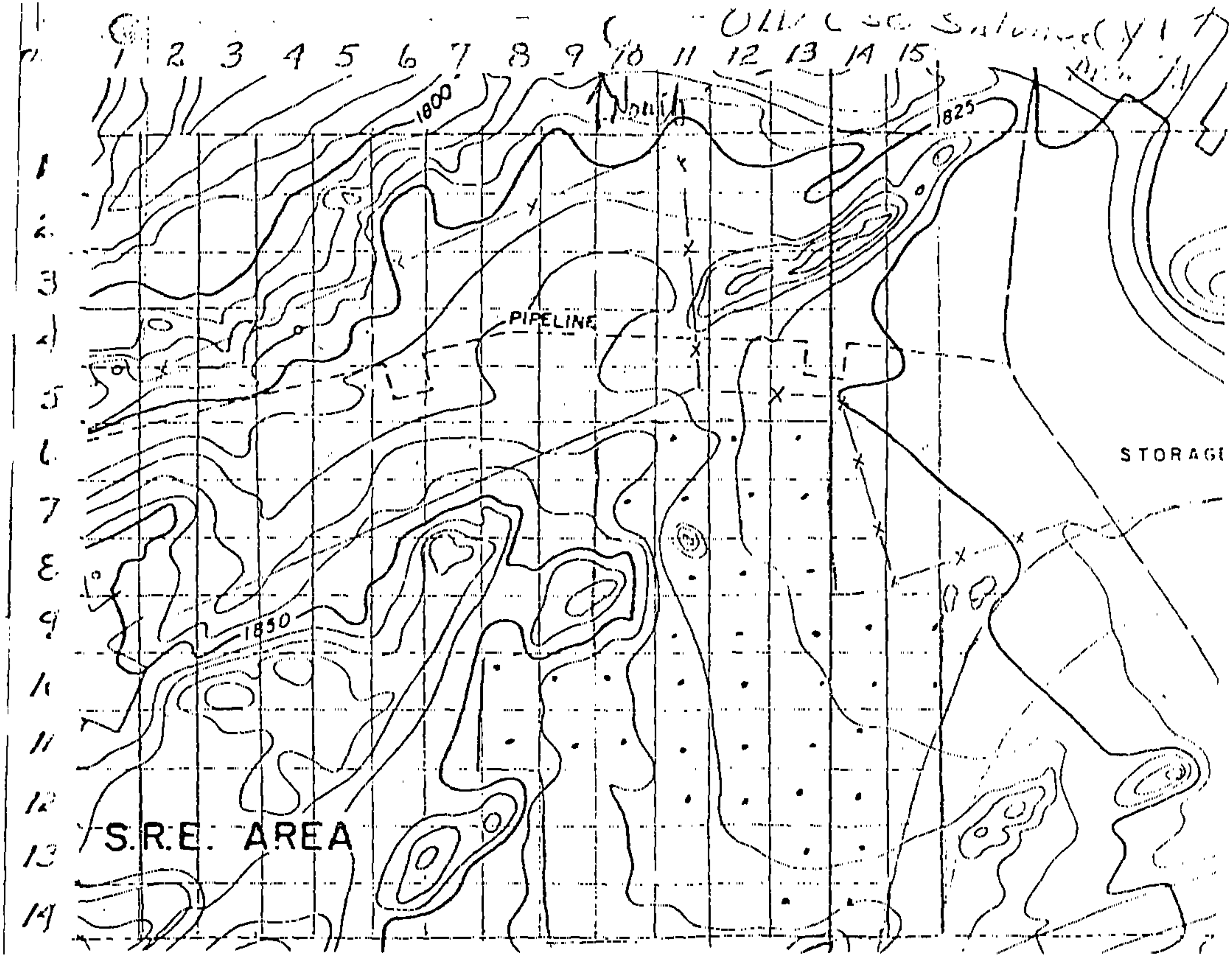
	1	2	3	4	5	6	7	8	9
-3								3395(R)	3299
-2									3392(R)
-1					3098				
1	2766	2911	3121	3146	3136	3057	3306	3308	
2	2542	2492	2923	2966	3034	3274	3288		
3	3082 (R)	3137	2931	3119	2991	3110	3280 (R)		
4	3342 (R)	3217	3160	2816	2973	3049	3270 (R)		
5	3197 (R)	3257 (R)	3081	2762	2874	3062	3176		
6			3111	2832	2963	3106	3292 (R)		

(4-18) (7-15)

E.5 Old ESG Salvage Yard (Zone 5)

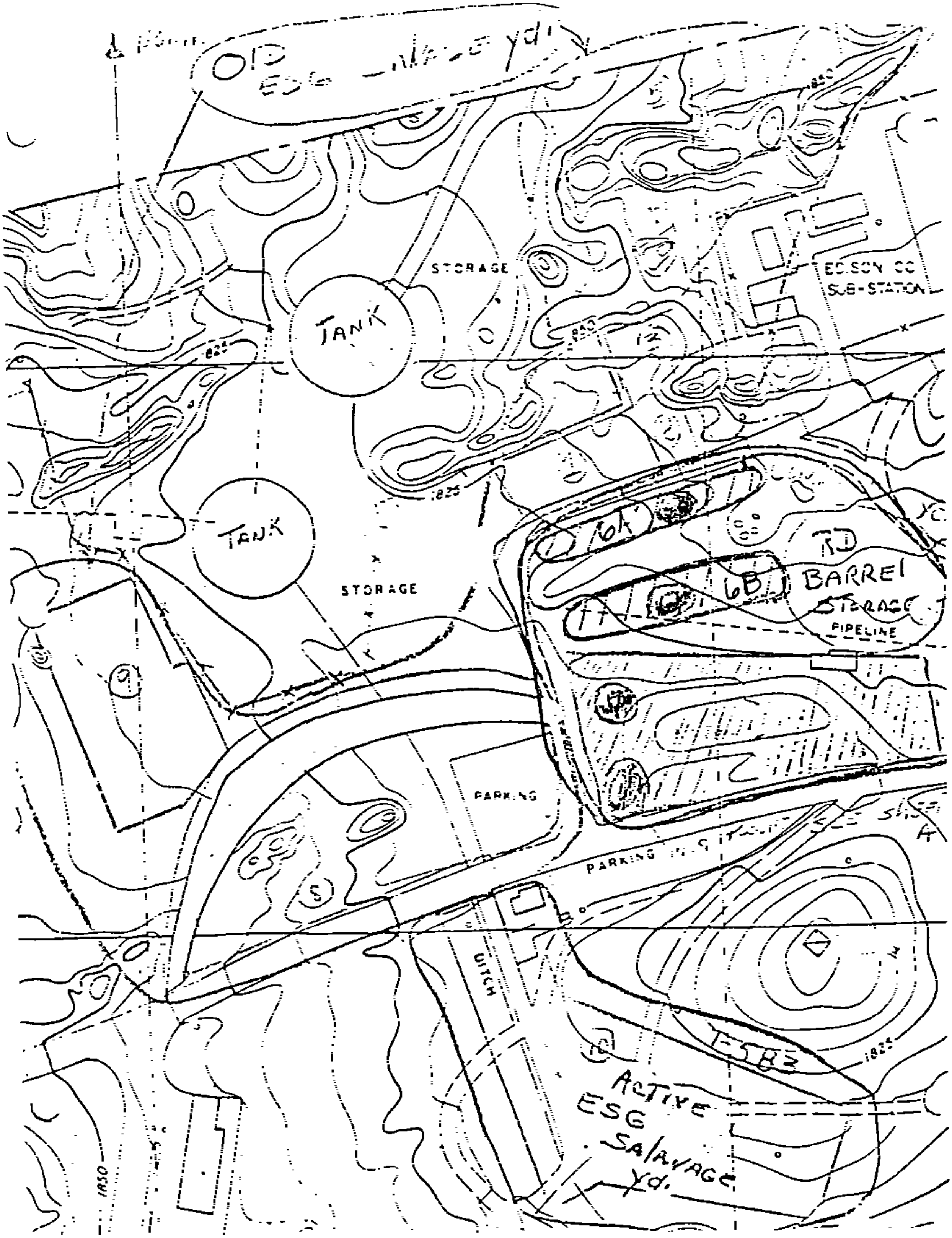


F.6 Old ESG Salvage Yard (Zone 8)



E.7 Old ESG Salvage Yard (Zone 9)

E.8 Rocketdyne Barrel Storage Yard (Zones 6A and 6B)



AREA No. 7

OLD ROCKETDYNE CONSERVATION YARD

N

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	3116	2902	2997	2813(m)	2844 (M)	2745	3046	3021	3116	3181	3208	3029	2953	2553 (M)
2	3121	2982	2915	2878	2775	2805	2710 (M)	2583 (M)	2530 (M)	2673 (M)	2804	2716	2821	2346 (M)
3	3067	2990	2776	2918	2729	2638	2639	2614 (m)	2607 (m)	2685	2665	2773	2914	2755
4	3172	3128	WET	2833	2891	2715	2763	2718	2706	2825	2747	2717	2884	2767
5	3035	3212	6023 5030	3050	2770	2745	2715	2733	2716	2702	2804	2735	2800	2768
6	3294	3263	3169	[illegible]	2904	2869	2962	2918	2775	2912	2840	2821	2718	2734

FUEL OIL TRUCK ENTRANCE

"G" STREET

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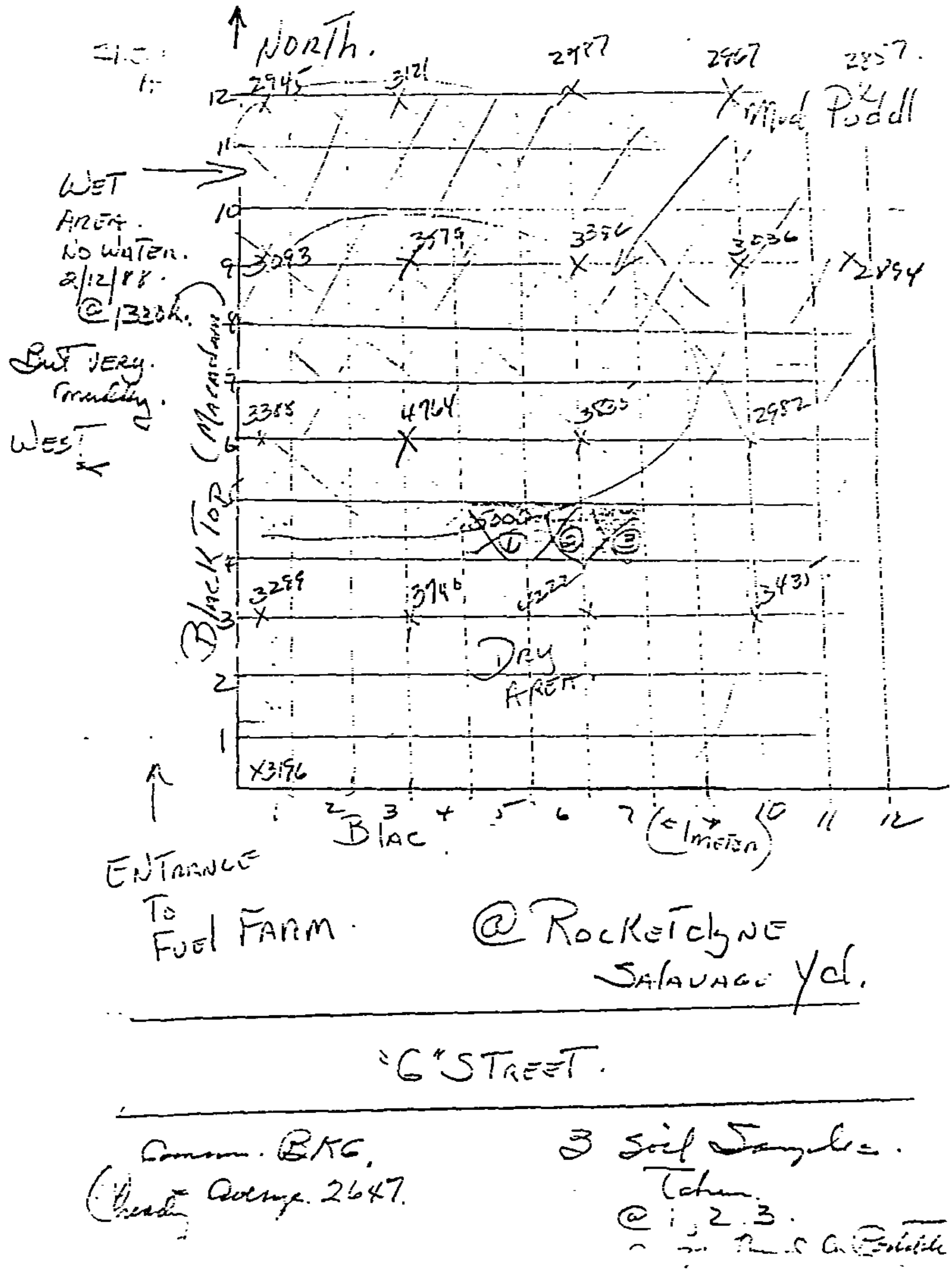
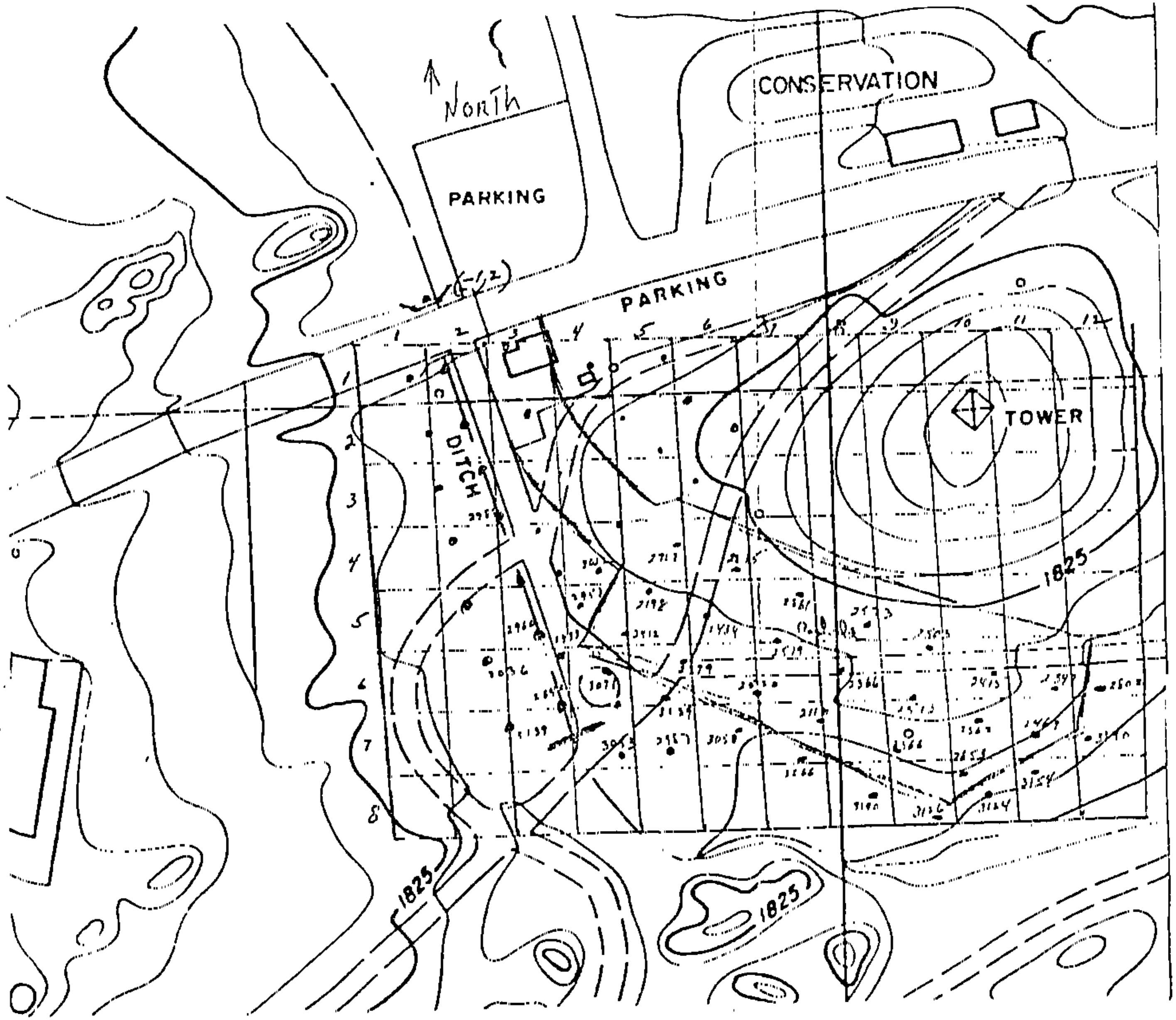
E.9 Rocketdyne Barrel Storage Yard (Zone 7)

E.10 Rocketdyne Barrel Storage Yard (Contaminated Area in Zone 7)





L.11 New Salvage Yard (T583) (Zone 10)