APPENDIX D

Final Radiological Status Report for The Reference Uranium Fuel Fabrication Plant

D-ii

(Intentionally Blank)

Preface

An example of a final status survey report for a reference uranium fuel fabrication plant is provided in this Appendix. This sample report duplicates some of the background, site description, and other general information presented in the survey plan for this same reference facility (see Appendix C); it is repeated here for thoroughness and to provide the Manual user with a more complete pattern to follow during report preparation.

The major features used in the site description, such as plant design, radionuclides used, operations conducted, waste-disposal practices, levels of radionuclides remaining, etc., were taken from reports prepared for the NRC for the purpose of evaluating the technology, safety, and costs of decommissioning. The specific source documents were: *NUREG/CR-1266, Technology, Safety, and Costs of Decommissioning a Reference Uranium Fuel Fabrication Plant*, and *NUREG/CR-2241, Technology and Cost of Termination Surveys Associated with Decommissioning of Nuclear Facilities.*

Some alterations of and/or additions to information from these documents have been made, however, to demonstrate principles and procedures given in this manual. Care has been taken to ensure that these additions represent typical conditions that could be expected at the reference facility. To enhance readability, the term "reference" has been used as though it were the name of the facility; e.g., Reference Uranium Fuel Fabrication (RFF) Plant. Also, a fictitious company, e.g., General Nuclear Corporation, has been named as the owner and operator of the plant.

1.0 Background Information

The *Reference Uranium Fuel Fabrication Plant (RFF)* in Yorktown, Pennsylvania was built between 1960 and 1964 and was operated from 1964 until mid 1985 by the *General Nuclear Corporation*. Operating under NRC License XXX-100, Docket No. 00-000, the plant converted natural and enriched uranium hexafluoride (UF_6) to uranium oxide (UO_2), formed the UO_2 into pellets, and incorporated pellets into fuel rods and bundles. Auxiliary facilities were used to recover uranium from scrap and waste materials. Two processes were used for the UF_6 to UO_2 conversion. The primary method involved the hydrolysis of UF_6 to ammonium diuranate (ADU), which was then reduced and calcined to produce dry UO_2 powder; the secondary process was the conversion of UF_6 to U_3O_8 in a flame conversion reactor, followed by reduction to UO_2 powder in a reduction-calciner.

In 1985 the plant was shut down and nuclear materials were removed and shipped to Department of Energy facilities in Idaho Falls, Idaho. The plant remained in the shut-down state until 1986, when decommissioning efforts were initiated. Process equipment, fixtures, piping, etc., were removed and disposed of as radioactive waste. Buildings and adjacent grounds were characterized and those areas exceeding NRC guidelines for license termination were decontaminated; these efforts were completed in late 1990. This document describes the plan for conducting the final status survey of the site. Supporting information is presented in the Site Decommissioning Plan, prepared and submitted to the NRC in May 1986, and in the Characterization Survey Report, submitted in February 1988.

Beginning in April 1991, a survey to determine the final radiological status was performed. The survey was performed in accordance with a survey plan, reviewed and approved by the NRC. This report describes the results of that survey and demonstrates that the facility now satisfies the NRC guidelines, established for release of formerly licensed sites to unrestricted use. Supporting information is presented in the Site Decommissioning Plan, prepared and submitted to the NRC in May 1986, the Characterization Survey Report, submitted in February and the Final Site Decommissioning Report, submitted in January 1992.

2.0 Site Information

2.1 Site Description

The *Reference Uranium Fuel Fabrication Plant* is located on a total land area of approximately 470 hectares (1160 acres); there is a moderate size stream (Wandering River) running through one corner of the site (Figure 1). Actual plant processing facilities were on a much smaller, restricted, fenced-in area of

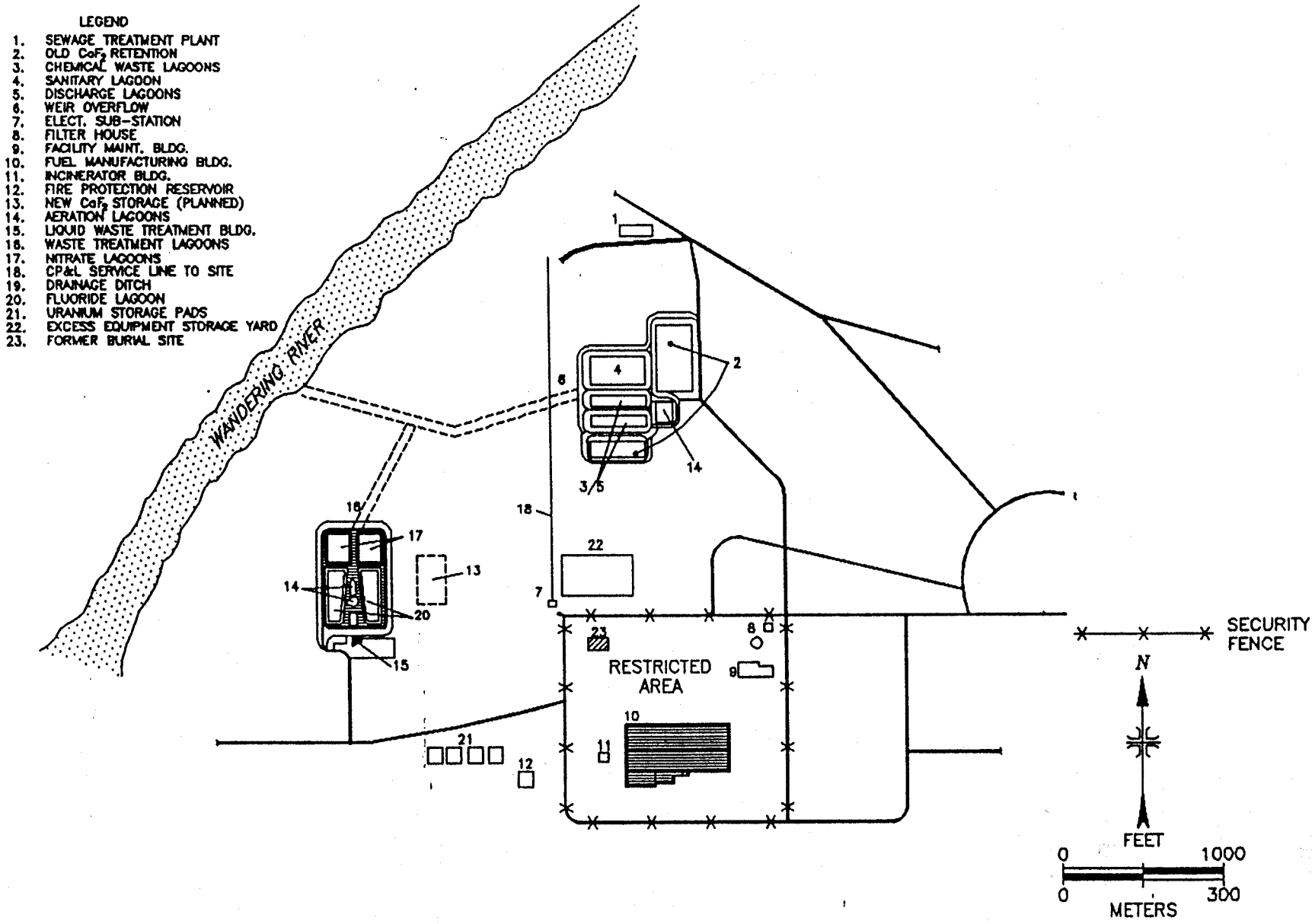

FIGURE 1: Map of the Reference Uranium Fuel Fabrication Plant Site

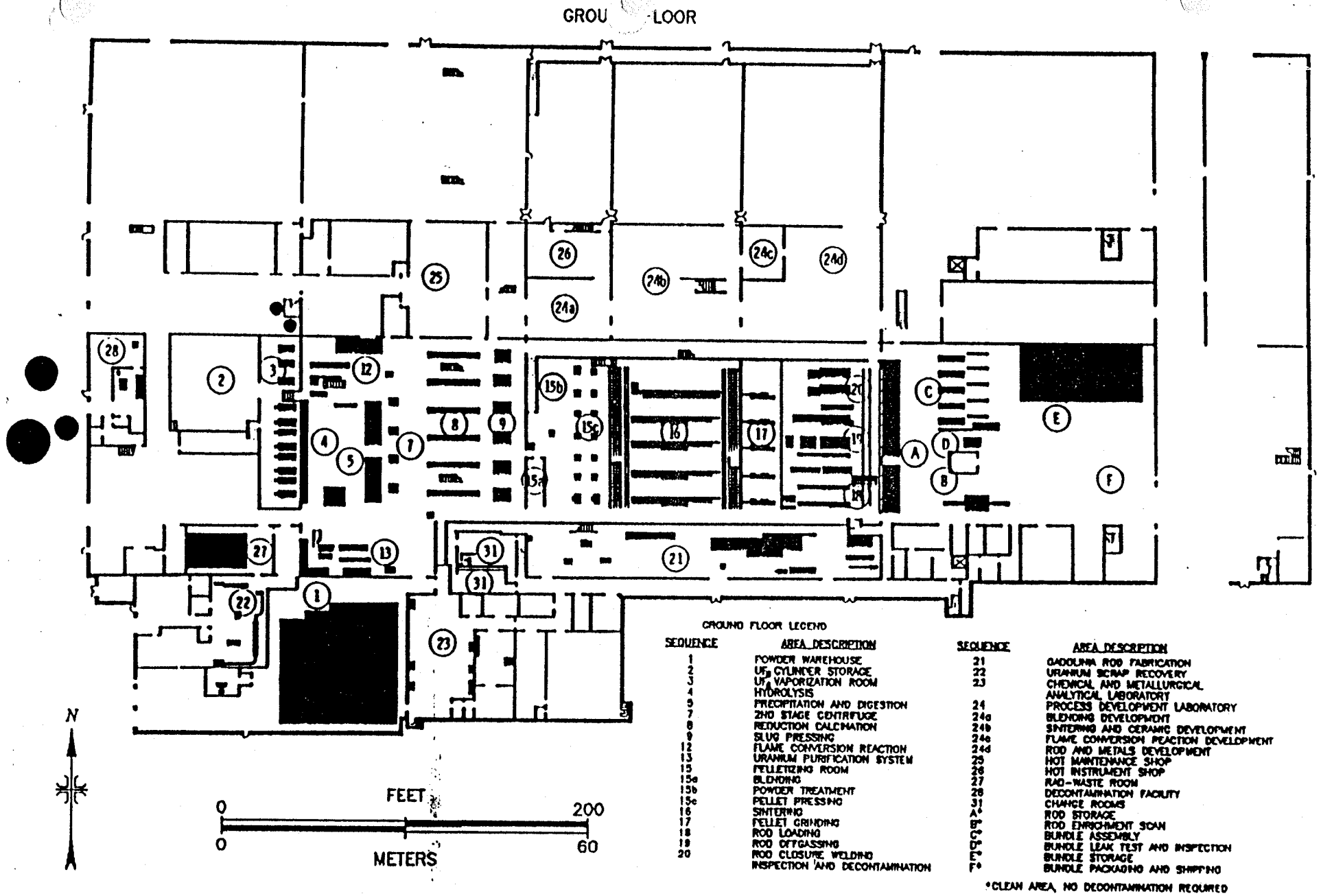

FIGURE 2A: Process Building Layout, Indicating Those Areas Used for Licensed Activities

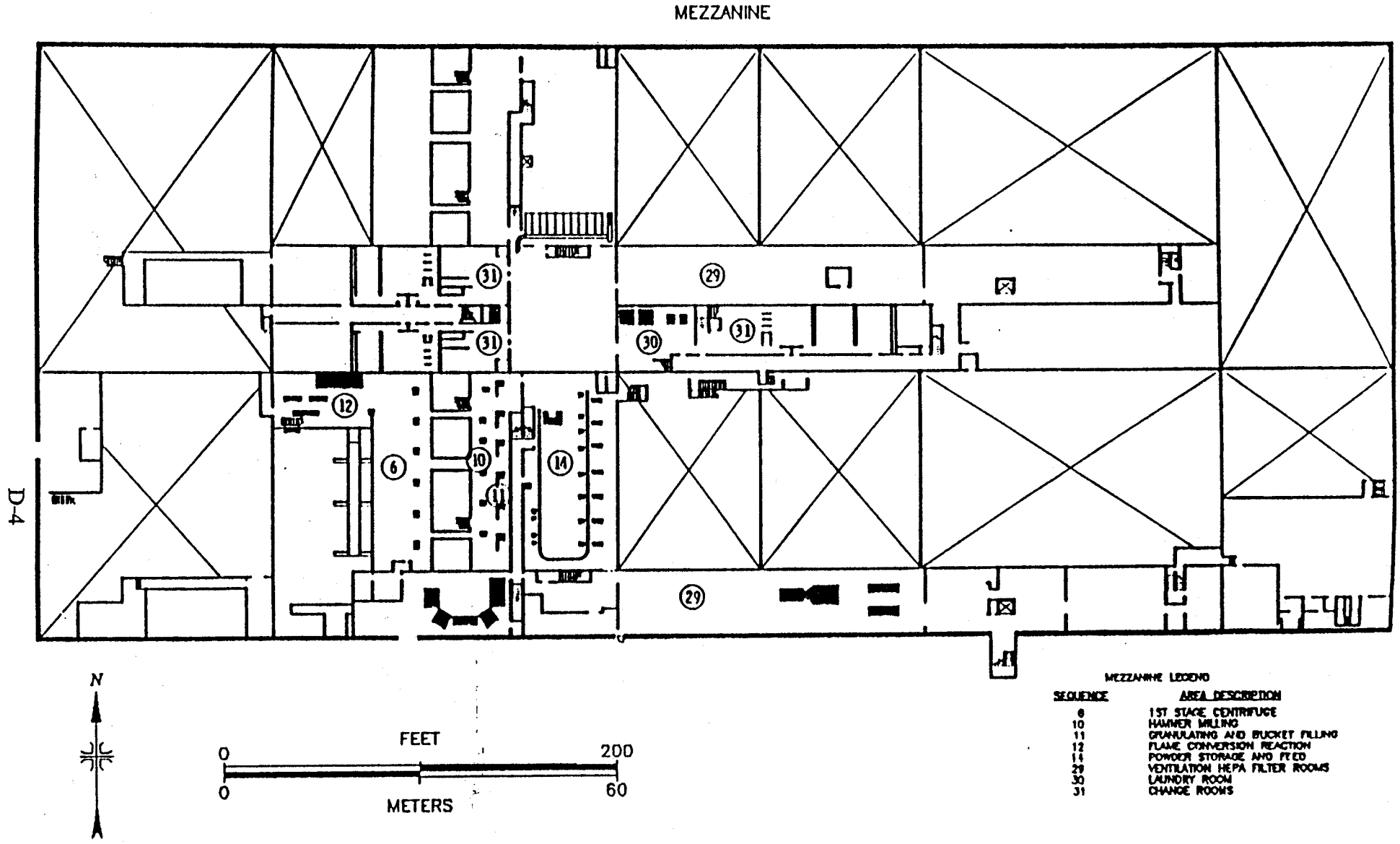

FIGURE 2B: Process Building Layout, Indicating Those Areas Used for Licensed Activities

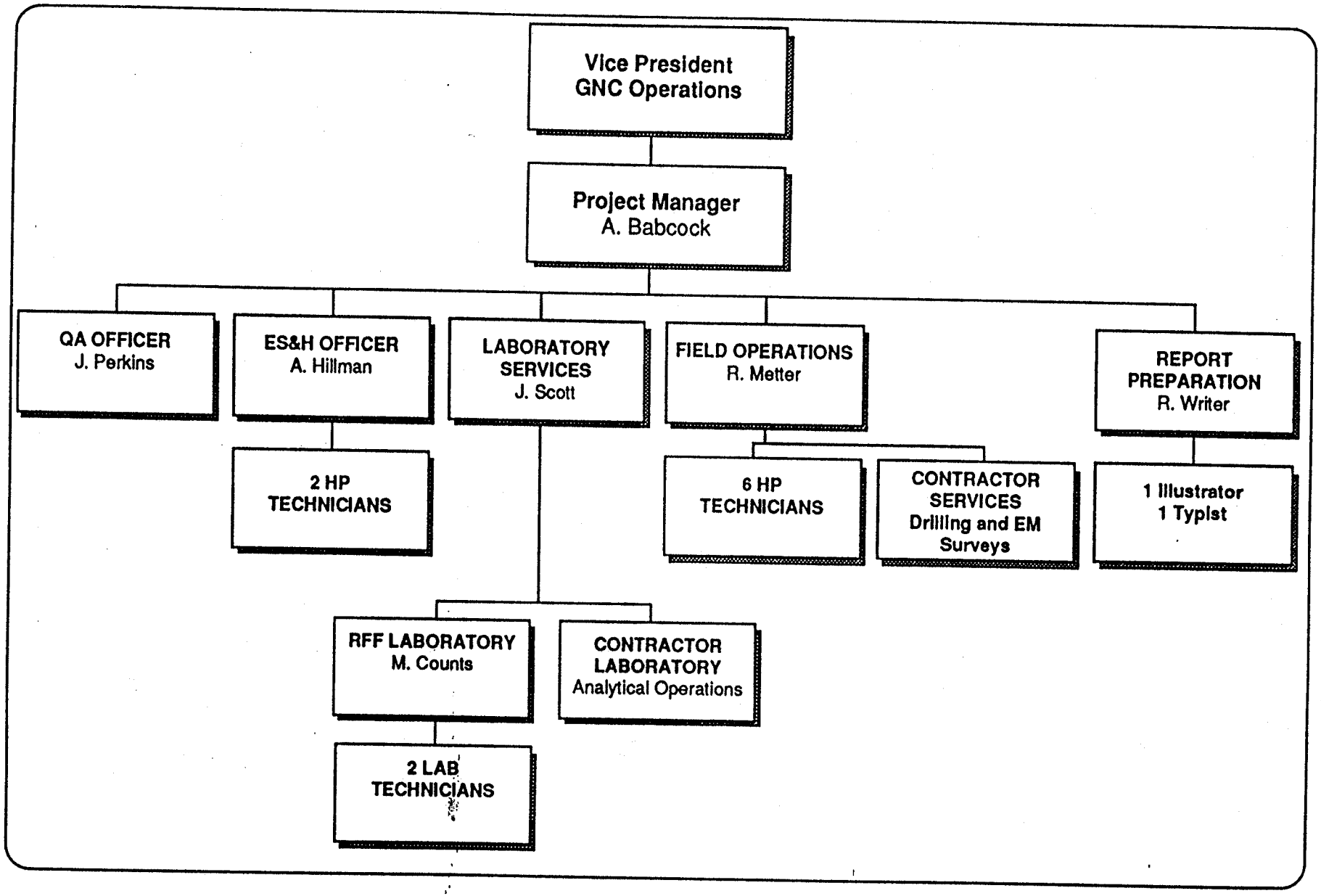

FIGURE 3: Organization Chart for Final Status Survey Activities

approximately 30,000 m^2 (3 hectares). The plant area occupies a low bluff that forms a bank of the river, and several flat alluvial terraces comprise the main topographical features of the property. These terraces lie at average elevations of 280 to 284 m above sea level and slope away from the river at grades of 2 to 3 percent. The river was used for disposal of acceptable liquid effluents from the on-site liquid waste systems.

The major structures in the formerly restricted processing area include the main building (with inter-connected chemical/metal laboratory and uranium scrap recovery and powder warehouse rooms), an incinerator building, a maintenance building, and a filter house (Figures 2A & 2B).

Auxiliary facilities are located outside the fenced area. These include a boiler house, a fluoride and nitrate waste treatment plant and associated lagoons, liquid chemical waste treatment lagoons, a sewage treatment plant and sanitary lagoon, and concrete uranium storage pads. The auxiliary facilities were used to recover uranium from scrap and waste materials and to recover valuable chemicals from gaseous and liquid wastes.

During the plant's 21 years of operation, an estimated total of 0.2 Ci of radioactivity was released into the atmosphere and subsequently deposited on the site. The property also contained one small, shallow land burial area for low-level radioactive waste. This area was operated in accordance with 10 CFR 20.304 between 1966 and 1970, receiving an estimated total activity of 0.3 Ci of uranium. This waste was excavated and disposed of at an authorized burial site as part of the decommissioning process.

2.2 Site Conditions at Time of Final Survey

As part of the decommissioning activities, process equipment and supporting fixtures were removed from radioactive materials areas and cleaned and released or disposed of as radioactive waste. Potentially contaminated structural surfaces were stripped of coatings by grit blasting or use of chemical agents. Contaminated surfaces identified by the characterization survey were cleaned or removed.

The on-site shallow land burial was excavated. Facilities used for processing of potentially contaminated effluents such as the lagoons and sewage treatment plant were characterized, and, where necessary, decontamination was performed. Soil contamination in the vicinity of process building was identified and removed to depths ranging from 5 cm to 1.5 m.

Details regarding the decontamination actions are presented in the Final Site Decommissioning Report.

2.3 Identity of Potential Contaminants and Release Guidelines

Based on the knowledge of site operations and the results of the preliminary assessment and characterization survey the significant radiological contaminants were determined to be isotopes of uranium. The uranium is enriched in U-234 and U-235 above naturally occurring levels; the average activity ratios of the uranium isotopes is:

U-234	81.4%
U-238	15.5%
U-235	3.1%

On the basis of this combination of contaminants the surface contamination guideline values for the site are:

5000 dpm/100 cm^2, average over 1 m^2*
150000 dpm/100 cm^2, maximum over 100 cm^2 *
1000 dpm/200 cm^2, removable*

*Hypothetical values, chosen for the purpose of demonstrating survey design and data evaluation.

The soil contamination guideline value is 30 pCi/g, total uranium.

3.0 Final Status Survey Overview

3.1 Survey Objectives

The purpose of the final status survey was to demonstrate that the radiological conditions at the *Reference Uranium Fuel Fabrication Plant* satisfy the NRC guidelines and that the plant site can, therefore, be released from licensing restrictions for future use without radiological controls. The specific objectives of the survey were to show that:

A. Surface Activity of Buildings and Structures

- Average surface activity levels (total of fixed and removable activity) are at or below guideline values established as acceptable by NRC.

- Reasonable efforts have been made to identify, evaluate, and remove, if necessary, areas of residual activity exceeding the

guideline value, known as elevated areas, may be acceptable, provided the activity levels are less than three times the guideline values, when averaged over a surface region of 100 cm^2, and provided the average level within a 1 m^2 area containing the elevated area is within the guideline value.

- Reasonable efforts have been made to clean up removable activity and removable activity in any 100 cm^2 area does not exceed 20% of the average surface activity values.

B. Volume Activity of Soil and Building Materials

- Average radionuclide concentrations are at or below guideline values, established as acceptable by the NRC. For your land areas, averaging is based on a 100 m^2 (10 m x 10 m) grid area.

- Reasonable efforts have been made to identify, evaluate, and remove, if necessary, areas of residual activity exceeding the guideline values. Areas of residual activity exceeding the guideline value, known as elevated areas, may be acceptable, provided they do not exceed the guideline value by greater than a factor of $(100/A)^{½}$, where A is the area of residual activity in m^2, and provided the activity level at any location does not exceed three times the guideline value.

C. Exposure Rate

- Exposure rates do not exceed 5 μR/h above background at 1 m above the surface. Exposure rates may be averaged over a 100 m^2 grid area. Maximum exposure rates over any discrete area may not exceed 10 μR/h above background.

The objective of the survey was to demonstrate at a 95% minimum level of confidence, that the above conditions have been met. For the purpose of this demonstration, each survey unit independently evaluated.

3.2 Organization and Responsibilities

The survey was performed by a team composed of qualified personnel of the *RFF Plant* and *General Nuclear Corporation.* This is the same organizational structure which conducted the characterization survey activities; the Survey Plan contains further details on this organization.

Analytical services for gross alpha/beta levels on smears, air, and water samples were performed by the Plant Analytical Services Laboratory in accordance with standard Plant procedures, "Laboratory Analyses of Environmental Samples" procedures GNC/RFF-HP 3.1, 3.2, 3.4, and 3.7 (1988). Samples of soil and other special samples, requiring gamma spectrometry or wet chemistry analyses were conducted by a contract laboratory, *Analytical Operations, Inc.* QA/QC programs for both in-house and contractor laboratory services were monitored by the QA coordinator of the final status survey team.

3.3 Instrumentation

Table 1 lists the instrumentation used for the survey activities, along with parameters and detection sensitivities for the instrumentation and survey technique. The combination of instrumentation and technique were chosen to provide a detection sensitivity of 25% or less of the guideline levels. All instruments were calibrated a minimum of once every 3 months, using NIST-traceable standards. Calibration was for the specific uranium radiation energies expected to be present at the site. Operational and background checks were performed at least once each 4 hours of instrument use.

3.4 Survey Procedures

Survey planning and procedures were in accordance with the *Manual for Conducting Radiological Surveys in Support of License Termination, NUREG/CR-5849.* Procedures are briefly described in this section; further detail on procedures is presented in Appendix A.

3.4.1 Area Classification

For purposes of establishing the sampling and measurement frequency and pattern, the site was divided into affected and unaffected areas. The bases for these classifications are:

- **affected areas:** Areas that have potential radioactive contamination (based on plant operating history) or known radioactive contamination (based on past or preliminary radiological surveillance). This includes areas where radioactive materials were used and stored, where records indicate spills or other unusual occurrences that could have resulted in spread of contamination, and where radioactive materials were buried. Areas immediately surrounding or adjacent to locations where radioactive materials were used or stored, spilled, or buried were included in this classification because of the potential for inadvertent spread of contamination.

- **unaffected areas:** All areas not classified as affected. These areas are not expected to contain residual radioactivity, based on a knowledge of site history and previous survey information.

Table 2 lists the various site areas in each classification category.

TABLE 1
INSTRUMENTATION FOR RADIOLOGICAL SURVEYS

Type of Measurement	ID	Instrumentation Detector	Instrumentation Meter	Bkgd.[1]	4 π[1] Eff. (%)	Detection Sensitivity
Surface scans - alpha	1	large area gas prop., AB Co., Model 100	Countrate meter[2], AB Co., Model 1000	20 cpm	25	70 dpm/100 cm^2
Surface scans - alpha	2	scintillation, XYZ Inc. Model 10	Countrate meter[2], AB Co., Model 1000	2 cpm	18	100 dpm/100 cm^2
Surface scans - beta	3	large area gas prop., AB Co.,Model 100	Countrate meter[2], AB Co., Model 1000	1500 cpm	30	1500 dpm/100 cm^2
Surface scans - beta-gamma	4	pancake GM, XYZ Inc., Model 20	Countrate meter[2], XYZ Inc., Model 120	40 cpm	20	3500 dpm/100 cm^2
Surface scans - gamma	5	NaI scintillation, N Products, Model X	Countrate meter[2], XYZ Inc., Model 120	3500 cpm	N/A	2 μR/h
Surface activity - alpha	6	gas prop., AB Co.,Model 200	Digital scaler[3], N Prod., Model Y-1	5 cpm	25	60 dpm/100 cm^2
Surface activity - alpha	7	scintillation, XYZ Inc., Model 10	Digital scaler[3], N. Prod., Model Y-1	2 cpm	18	100 dpm/100 cm^2
Surface activity - beta	8	gas prop., AB Co.,Model 200	Digital scaler[3], N. Prod., Model Y-1	350 cpm	30	300 dpm/100 cm^2
Surface activity - beta-gamma	9	pancake GM, XYZ Inc., Model 20	Digital scaler[3], N. Prod., Model Y-1	40 cpm	20	1100 dpm/100 cm^2
Exposure rates	10	pressurized ionization, R. Co., Model 1111	(same as detector)			$<$1 μR/h
Gross α/β on smears	11	gas prop., T&C Co., Model 5000	(same as detector)	0.2 cpm α 1.5 cpm β	35 40	10 dpm 20 dpm

[1]Nominal Values.
[2]Monitoring audible signal.
[3]1 minute integrated count.

3.4.2 Reference Grids

Grids were established for the purpose of referencing locations of samples and measurements, relative to buildings and other site features. The gridding intervals were based on the potential for residual contamination in the various plant areas. (See Table 2). All affected building area floor and lower wall (up to 2 m_2) surfaces were gridded at 1 m intervals; upper walls and ceilings of affected areas were also gridded at 1 m intervals, if residual activity above 25% of the guideline was known or suspected. Building surfaces in unaffected areas or those upper surfaces in affected areas that were not contaminated as a result of prior activities were not gridded; measurements were referenced to other grid systems or to prominent building features. Affected outside areas were gridded at 10 m intervals; unaffected areas were not gridded. This grid system is identical to the one used during the characterization survey and the remedial action activities; where necessary the earlier grid was reestablished, expanded, or subdivided.

The facility was divided into "survey units" having common history, contamination potential, or that are naturally distinguishable from other sites areas. These survey units were sized to assure a minimum of 30 measurement locations each for floor and lower walls, other vertical surfaces, and other horizontal surfaces. Areas of building surface survey units, classified as affected, were limited to a maximum of 100 m^2. A total of 48 affected area survey units and 5 unaffected areas survey units were established.

During the survey, two small soil areas on the unrestricted plant site and one office area, adjacent to the processing facility, were found to contain residual activity exceeding 75% of the guideline levels. These areas were reclassified from unaffected to affected areas and surveyed by a more intensive procedure than initially planned.

3.4.3 Surface Scans

Scanning of surfaces to identify locations of residual surface and near-surface activity was performed according to the following schedule:

Affected Area Surfaces - 100% of surface

Non-contaminated upper surfaces in affected areas - in immediate vicinity of measurement

Unaffected Area Surfaces - 10% of lower surface

TABLE 2

CLASSIFICATION OF RFF PLANT SURFACES
AND AREAS ACCORDING TO CONTAMINATION POTENTIAL

Plant Area	Bldg. or Facility	Room or Area	Classification of Contamination Potential	Remarks
Restricted	Process Bldg.	Powder Warehouse	Affected	
		UF_6 Cyl. Storage	Affected	
		UF_6 Vapor. Rm.	Affected	
		Hydrolysis	Affected	
		Precip. & Digestion	Affected	
		2nd Stage Centrifuge	Affected	
		Reduction Calcination	Affected	
		Slug Pressing	Affected	
		Flame Conv. Reaction	Affected	
		Uranium Purif. System	Affected	
		Pelletizing Room	Affected	
		Blending	Affected	
		Powder Treatment	Affected	
		Pellet Pressing	Affected	
		Sintering	Affected	
		Pellet Grinding	Affected	
		Rod Loading	Affected	
		Rod Offgassing	Affected	

TABLE 2 (Cont'd)

CLASSIFICATION OF RFF PLANT SURFACES
AND AREAS ACCORDING TO CONTAMINATION POTENTIAL

Plant Area	Bldg. or Facility	Room or Area	Classification of Contamination Potential	Remarks
Restricted	Process Bldg.	Rod Closure Welding Inspection & Decon.	Affected	
		Gadolinia Rod Fab.	Affected	
		Uran. Scrap Recovery	Affected	
		Chem & Metallurgical Anal. Laboratory	Affected	
		Process Devel. Lab.	Affected	
		Blending Development	Affected	
		Sint. & Cer. Develop.	Affected	
		Flame Con. Reac. Dev.	Affected	
		Rod & Metal Develop.	Affected	
		Hot Maint. Shop	Affected	
		Hot Inst. Shop	Affected	
		Rad-Waste Rm.	Affected	
		Decon. Facility	Affected	
		Change Rooms	Affected	
		1st Stage Centri.	Affected	
		Hammer Milling	Affected	

TABLE 2 (Cont'd)

CLASSIFICATION OF RFF PLANT SURFACES
AND AREAS ACCORDING TO CONTAMINATION POTENTIAL

Plant Area	Bldg. or Facility	Room or Area	Classification of Contamination Potential	Remarks
Restricted	Process Bldg.	Gran. & Bucket Fill	Affected	
		Flame Conv. Reaction	Affected	
		Powd. Storage & Feed	Affected	
		Vent. Hepa Filt. Rm.	Affected	
		Laundry Room	Affected	
		Rod Storage	Affected	Upper surfaces not affected.
		Rod Enrichment Scan	Affected	Upper surfaces not affected.
		Bundle Assembly	Affected	Upper surfaces not affected.
		Bundle Leak Test & Inspection	Affected	Upper surfaces not affected.
		Bundle Storage	Affected	Upper surfaces not affected.
		Bundle Packaging & Shipping	Affected	Upper surfaces not affected.
		Office and Admin. Areas	Unaffected	Upper surfaces not affected.

TABLE 2 (Cont'd)

CLASSIFICATION OF RFF PLANT SURFACES
AND AREAS ACCORDING TO CONTAMINATION POTENTIAL

Plant Area	Bldg. or Facility	Room or Area	Classification of Contamination Potential	Remarks
Restricted	Filter House	Entire Interior	Affected	
		Roof	Affected	
	Former Waste Burial Site	-----	Affected	
	Grounds Adj. to Proc. Areas	-----	Affected	
	Liquid Waste Transfer Line	-----	Affected	
		Soil	Affected	
		Paved Areas	Affected	
Unrestricted	Other Buildings	Entire Interior	Unaffected	Upper surfaces not affected.
	Roofs		Unaffected	
	Sewage Trmt. Plant	Entire Interior	Affected	Upper surfaces not affected.
		Roof	Unaffected	
	Grounds	Entire Unrestricted Plant Area	Unaffected	

Building interior surface scans were conducted for alpha, beta, and gamma radiations. Scans of exterior building and paved surfaces were for beta and gamma radiations. Soil surfaces were scanned for gamma radiations only.

Instrumentation for scanning is listed in Table 1. The instruments having the lowest detection sensitivity were used for the scans, wherever physical surface conditions and measurement locations permitted.

Scanning speeds were 1 detector width per second for alpha and beta detection instruments and 0.5 m per second for gamma instruments. Audible indicators (headphones) were used to identify locations, having elevated (>1.5 to 3 times ambient) levels of direct radiation. These locations were noted for further investigation.

3.4.4 Surface Activity Measurements

Direct Measurements

Direct measurements of alpha, beta, and/or beta-gamma surface activity were performed at selected locations using instrumentation described in Table 1. Unless precluded by surface conditions or physical parameters, the most sensitive of the instruments listed for surface measurements (Table 1) were used. Measurements were conducted by integrating counts over a 1 minute period. Appendix B contains facility drawings showing the locations of measurements.

Measurement spacings/frequencies were as follows:

Floors and lower walls

Affected Areas - 2 m intervals
Unaffected Areas - 1 per 50 m^2 of surface

Other Surfaces

Affected Areas -
2 m intervals if residual activity expected to exceed 25% of guideline; otherwise 1 per 20 m^2 of surface.
Unaffected Areas - 1 per 50 m^2 of surface

Removable Contamination Measurements

A smear for removable contamination was performed at each direct measurement location.

3.4.5 Exposure Rate Measurements

Gamma exposure rates were measured at 1 m above ground or floor surfaces, using a pressurized ionization chamber or a gamma scintillation instrument, calibrated for low enrichment uranium energies. Measurements were uniformly spaced according to the following pattern:

Building Interiors

Affected Areas: 1 measurement per 4 m^2.
Unaffected Areas: 1 measurement per 200 m^2.

Grounds

Affected Areas: 5 measurements per 100 m^2 grid block.
Unaffected Areas: 50 measurements at randomly selected locations.

3.4.6 Soil/Sediment Sampling

Surface

Samples (about 500 grams each) of surface soil (0-15 cm) were systematically collected from the center and 4 points midway between the center and the block corners for each 10 m x 10 m grid in affected areas. Sixty samples were obtained from random locations in unaffected areas, outside the restricted plant site. Samples were collected at 10 m intervals along the drainage ditches from the former waste processing facilities to the *Wandering River* and from other natural surface drainage pathways to the River. At each surface sampling location, contact gamma levels before and after sampling were monitored to determine whether subsurface contamination may be present.

Sediment (about 500 grams) samples were obtained at the outfall of drainage ditches to the *Wandering River* and from 25 to 50 m upstream and downstream of the outfall. Sampling was from the River center and near both banks. Locations of surface soil sampling are indicated on facility drawings in Appendix B.

Subsurface

Subsurface investigations were performed at the locations of the former burial site, liquid waste lagoons, and previously excavated underground piping between the processing areas and the waste ponds. These locations were scanned by a commercial contractor using electromagnetic sensors (ground penetrating radar) to verify that no buried objects remain and to guide placement of subsurface sampling locations. Results of that survey

are included as Appendix C of this report. Subsurface samples were obtained by a commercial contractor, using the split-barrel method. Sampling was at the surface (0-15 cm) and at 1 m intervals to a depth of 10 m at the former burial site and liquid waste lagoon areas; along the path of the previously excavated liquid waste transfer piping, sampling was at 1 m intervals to a depth of 3 m. Fifteen, uniformly spaced sampling locations were selected in the former burial site and twenty-five uniformly spaced locations were selected in the area of the lagoons. In addition, two sampling locations were selected on each side around the perimeter of these facilities, to confirm absence of subsurface migration. Subsurface samples were obtained at approximately 5 locations along the former waste transfer piping system.

Following sampling, a gamma scintillation probe was inserted into the borehole and relative count rates determined at approximately 50 cm intervals between the surface and the hole bottom. If results were positive, additional subsurface sampling was conducted to define the area of residual contamination.

Locations of subsurface soil sampling are indicated on drawings in Appendix B.

3.4.7 Special Measurements and Samples

Building Interiors

Samples of paint were obtained from 100 cm^2 areas on lower walls in former liquid and powder processing rooms. One paint sample per 10 m^2 was obtained from these surfaces. Paint samples were also collected from surfaces where direct and removable activity measurements suggested contamination may have been painted over.

Trenches where contaminated drain piping was excavated in the Analytical Laboratory, Rad Waste Decontamination, and Change Room facilities were sampled at locations of elevated direct radiation and at approximately 3 m intervals along the excavations. Other remaining drains and piping in affected areas were accessed, direct alpha and beta-gamma scans and measurements performed at all access points, and a large-area swab obtained from the piping, using a plumbers "snake" and piece of cloth.

Remaining ducts, electrical boxes, conduit, or other interior surfaces in affected areas, which may contained residual contamination, were accessed at random and measurements of direct and removable activity performed. Swabs were obtained from insides of wall and floor penetrations, anchor bolt holes, and floor cracks or expansion joints.

Floor cores were removed from 17 locations in the areas where conversion was performed; gamma scans of subfloor soil were performed and soil samples from the floor/soil interface and 0.5 m below the interface were collected at each coring location.

Building Exteriors

Measurements of direct and removable activity were performed on exterior and interior surfaces of air exhaust equipment and at representative locations on roof drains. Samples of roofing material were obtained where direct measurements suggested possible entrained contamination.

Grounds

Cores were removed at 5 locations on the uranium storage pads and samples of subpad soil collected. Coring and soil sampling was also performed on three other paved outside surfaces, where scans or direct measurements suggest possible contamination beneath the paving.

Locations of special samples are shown on Figures in Appendix B.

3.5 Background Level Determinations

Background exposure rates were determined for the building interior by taking of 8 pressurized ionization chamber measurements at locations of similar construction but without a history of radioactive materials use. Also, 8 locations for area background measurement and sampling will be selected within a 0.5 to 10 km radius of the site. Exposure rate measurements were performed using a pressurized ionization chamber. A background soil sample was collected from each location of external background measurement. Results of background exposure rate and uranium soil concentrations were evaluated to assure that the averages determined were representative of the true averages, using procedures described in NUREG/CR-5849. Based on this evaluation, an additional 6 samples were obtained for determining the uranium average background concentrations in soil. Figures B-97 and B-98 in Appendix B indicate the locations of background measurements and samples.

3.6 Sample Analysis

Smears and swabs for removable contamination were analyzed for gross alpha, gross beta activity. Soil, sediment, gravel, roofing material, and other large volume samples were analyzed for U-235 and U-238 by gamma spectrometry; total uranium was calculated on the basis of previously determined isotopic activity ratios for this site. Samples of paint, residue, and other samples of

small volume were analyzed for uranium by wet chemical separation and alpha spectroscopy.

3.7 Data Interpretation

Data conversions and evaluations were performed, following the guidance in NUREG/CR-5849. Calibrational methods and sample calculations are provided in Appendix D. Measurement data were converted to units of dpm/100 cm^2 (surface activity), μR/h (exposure rates) and pCi/g (soil concentrations) for comparison with guidelines. Values were adjusted for contributions from natural background. Individual measurements and soil radionuclide concentration levels were compared with "hot-spot" criteria. Average values for survey units were determined and compared with guideline levels. Data for each survey unit were tested against the confidence level objective.

Additional remediation and/or further sampling and measurements were performed where guidelines were not met or could not be demonstrated to the specified level of confidence. Computations and comparisons were repeated, as necessary.

The average activity levels were used to estimate the total residual inventory of uranium at the site.

3.8 Records

All samples and original survey data have been archived at the General Nuclear Corporation main offices and will be held until such time as authorized by the NRC for disposal.

4.0 Survey Findings and Results

Appendix E contains tables of data, affected during the survey. Data are summarized in tables of Appendix F; Appendix F also contains results of data interpretations and comparisons with guidelines and conditions established as survey objectives.

4.1 Background Levels (Table E-1)

Background exposure rates for interior and exterior areas averaged 9.3 and 10.1 μR/h respectively. Concentrations of uranium in area soil averaged 1.1 $\pm$ 0.3 pCi/g, U-234; 0.1 $\pm$ 0.1 pCi/g, U-235; and 1.2 $\pm$ 0.3 pCi/g, U-238.

4.2 Building Surveys

Scans

Scans of surfaces (Table E-2) identified approximately 50 small isolated areas of residual contamination and 1 larger area, adjacent to the lower conversion operation. The area adjacent to the conversion operation was reclassified from "unaffected" to "affected" for purposes of surface activity surveys. All other locations identified by scans were evaluated to determine status relative to guidelines and, if necessary, remediated and resurveyed (refer to Tables E-4 and E-5).

Surface Activity Measurement

Table E-3 present the results of surface activity measurements. All individual measurements were within guideline levels, with many of the measurement being below the sensitivity levels of the procedures.

Sampling

Table E-6 and E-7 contain results of paint samples from building interior surfaces and soil samples from below floors of several former process areas. No evidence of sample activity exceeding guidelines was noted. Gamma scans at subfloor sampling locations did not indicate potential residual activity.

Exposure Rates

Exposure rates inside structures ranged from 8 to 12 μR/h (Table E-8). These rates were within the guideline levels of 5 μR/h above background.

4.3 Grounds Surveys

Scans

Scans identified 11 locations of elevated contact gamma radiation, suggesting residual soil activity (See Table E-9). Two of these locations were reclassified as affected areas for further survey; the remainder of the locations were remediated by removal of small areas of surface soil.

Exposure Rates

Exposure rate measurements are presented in Table E-10. Rates ranged between 9 and 13 μR/h; all locations satisfied the guidelines.

Uranium Concentrations in Soil

Tables E-10 and E-11 summarize the results of surface and subsurface soil sampling. Fifteen individual surface soil samples exceeded the guideline level; the maximum was approximately 5 times the guideline. Further sampling at the locations of the hot-spots indicated that in each case the area of residual activity was 1 m^2 or less in area and averaging conditions for the grid containing these sampling locations were satisfied. No subsurface samples contained in excess of the uranium guideline. Borehole gamma logging did not identify any locations of elevated subsurface gamma radiation.

4.4 Data Evaluation

Tables F-1, F-2, and F-3 summarize the average levels in the different survey units for building and grounds surveys. Comparisons of averages with guidelines indicated the guidelines were satisfied for all survey units, at the 95% confidence level conditions.

4.5 Residual Activity Inventory

Calculations indicate that residual activity above the average background on building surfaces and in soil is approximately 4.3×10^8 and pCi and 2.7×10^6, respectively.

5.0 Summary

Between April and September 1991, surveys of the Reference Uranium Fuel Fabrication Plant were conducted. Results of the survey demonstrate that the decontamination actions were effective in reducing residual activity at the site meet the NRC limits for release for unrestricted use.

SAMPLE

TABLE E-1

BACKGROUND EXPOSURE RATES AND
SOIL CONCENTRATIONS
REFERENCE URANIUM FUEL FABRICATION PLANT

Location[a]	Exposure Rate	Uranium Concentrations (pCi/g)								
		U-234			U-235			U-238		
	μR/h	Conc.	Uncert[b]	MDA	Conc.	Uncert.	MDA	Conc.	Uncert.	MDA
Bldg. Interior										
1	8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2	9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
-	-	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
-	-	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Exterior										
1	10	1.3	0.2	0.2	0.1	0.1	0.1	1.5	0.3	0.2
2	9	0.9	0.2	0.1	0.1	0.1	0.1	1.1	0.2	0.2
-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-

[a]Refer to Figures 97 and 98.
[b]Uncertainties represent the 95% confidence level, based on counting statistics.

SAMPLE

TABLE E-2

RESULTS OF SURFACE SCANS
REFERENCE URANIUM FUEL FABRICATION PLANT

Building/ Area and Surface	Figure	Scan Results						Areas of Residual Activity Identified
		Alpha		Beta-Gamma		Gamma		
		Instrument*	c/m	Instrument	c/m	Instrument	c/m	
Conversion								
floor	7	#1	40-460	#3	320-5000	#5	3.0 K - 3.5 K	2 (See Figure 7)
lower wall	7	#1	30-300	#3	280-450	#5	2.8 K - 3.2 K	0

*Refer to Table 1 for instrument type.

SAMPLE

TABLE E-3

SURFACE ACTIVITY MEASUREMENTS
BUILDING INTERIORS
REFERENCE URANIUM FUEL FABRICATION PLANT

Building/ Area and Surface	Measurement Location	Figure	Activity (dpm/100 cm²)											
			Total						Removable					
			Alpha			Beta-Gamma			Alpha			Beta		
			Act.	Uncert.[a]	MDA	Act.	Uncert.	MDA	Act.	Uncert.	MDA	Act.	Conf. Lev.	MDA
Conversion														
floor	C,0	7	850	220	150	2200	460	460	4	4	7	15	5	9
	C,2	7	2100	430	150	4500	510	470	-2	5	7	10	4	9
	C,4	7	-50	120	150	200	500	470	0	3	7	-2	5	9
	D,0	7	-	-	-	-	-	-	-	-	-	-	-	-
upper walls	1	9	-	-	-	-	-	-	-	-	-	-	-	-
	2	9	-	-	-	-	-	-	-	-	-	-	-	-
	3	9	-	-	-	-	-	-	-	-	-	-	-	-
	4	9	-	-	-	-	-	-	-	-	-	-	-	-

[a]Uncertainties represent the 95% confidence level, based on counting statistics.

SAMPLE

TABLE E-4

LOCATION OF ELEVATED DIRECT RADIATION IDENTIFIED BY SCANS
REFERENCE URANIUM FUEL FABRICATION PLANT

Building/Area and Surface	Location	Figure	Area Involved (cm^2)	Total Activity (dpm/100 cm^2)		Exceed Guidelines		Resolution
				Alpha	Beta	Hot Spot	Average	
Conversion								
floor	1H	7	20	27000	39000	yes	no	remediated
	2H	7	300	3800	4200	no	no	more required

SAMPLE

TABLE E-5

LOCATIONS OF RESIDUAL CONTAMINATION IDENTIFIED BY SCANS AND ACTIVITY MEASUREMENTS FOLLOWING REMEDIATION REFERENCE URANIUM FUEL FABRICATION PLANT

Building/ Area and Surface	Measurement Location	Figure	Activity (dpm/100 cm²)											
			Total						Removable					
			Alpha			Beta-Gamma			Alpha			Beta		
			Act.	Uncert.[a]	MDA	Act.	Uncert.	MDA	Act.	Uncert.	MDA	Act.	Conf. Lev.	MDA
Conversion floor	D + .5, 3.7 (1H)	7	700	150	150	1900	600	470	1	4	7	10	5	9

[a]Uncertainties represent the 95% confidence level, based on counting statistics.

SAMPLE

TABLE E-6

ACTIVITY IN PLANT AND RESIDUE SAMPLES
REFERENCE URANIUM FUEL FABRICATION PLANT

Building/Area and Surface	Sample Location	Sample Type	Figure	Uranium Activity Content (pCi/100 cm²)		
				Activity	Uncertainty	MDA
Conversion Lower Wall	4P	Paint	10	100	40	10

SAMPLE

TABLE E-7

URANIUM CONCENTRATIONS IN SUBFLOOR SOIL
REFERENCE URANIUM FUEL FABRICATION PLANT

Building/ Area and Surface	Sample Location	Depth (cm)	Figure	Uranium Concentration (pCi/g)					
				U-238			U-235		
				Act.	Uncert.	MDA	Act.	Uncert.	MDA
Process 1 Floor	3B	30	11	1.8	0.7	1.0	0.1	0.1	0.1

SAMPLE

TABLE E-8

EXPOSURE RATES INSIDE BUILDINGS
REFERENCE URANIUM FUEL FABRICATION PLANT

Building/Area	Location	Figure	Exposure Rate at 1 m Above Surface (μR/h)
Conversion	1E 2E	12 12	9.0 10.2

SAMPLE

TABLE E-9

AREAS OF ELEVATED GAMMA RADIATION IDENTIFIED BY SCANS REFERENCE URANIUM FUEL FABRICATION PLANT

Location	Figure	Maximum Contact Gamma Level (c/m)	Resolution
1G	99	55,000	remediated
2G	30	70,000	remediated
3G	10	10,000	area reclassified

SAMPLE

TABLE E-10

EXPOSURE RATES AND
SURFACE SOIL CONCENTRATIONS
REFERENCE URANIUM FUEL FABRICATION PLANT

Location[a]	Exposure Rate μR/h	Uranium Concentrations (pCi/g)					
		U-235			U-238		
		Conc.	Uncert.[b]	MDA	Conc.	Uncert.	MDA
Cylinder Storage							
13 N, 27 E	10	0.2	0.2	0.1	2.3	0.7	0.8
18 N, 32 E	12	0.1	0.2	0.2	1.2	0.6	0.7

[a]Refer to Figures _____.
[b]Uncertainties represent the 95% confidence level, based on counting statistics.

SAMPLE

TABLE E-11

SUBSURFACE SOIL CONCENTRATIONS
REFERENCE URANIUM FUEL FABRICATION PLANT

Location[a]	Small Depth (m)	Uranium Concentrations (pCi/g)					
		U-235			U-238		
		Conc.	Uncert.[b]	MDA	Conc.	Uncert.	MDA
Cylinder Storage							
1 BH	Surface	0.1	0.2	0.2	1.3	0.6	0.7
	0.5	0.3	0.2	0.2	1.8	0.7	0.8
	1.0	0.2	0.2	0.2	0.9	0.5	0.7

[a]Refer to Figures _____.
[b]Uncertainties represent the 95% confidence level, based on counting statistics.

SAMPLE

TABLE F-1

SUMMARY OF BUILDING SURFACE ACTIVITY RESULTS
REFERENCE URANIUM FUEL FABRICATION PLANT

Building/ Area and Surface	Surface Area (m^2)	Average Total Activity (dpm/100 cm^2)						$\mu_{\alpha(5)}$	$n_{1(4),(5)}$	Guidelines/ Conditions Satisfied
		Alpha			Beta-Gamma					
		$n^{(1)}$	$\bar{x}$ (2)	$s^{(3)}$	n	$\bar{x}$	s			
Conversion floor and lower walls	440	445	1280	620	445	2940	820	4120*	280*	yes/yes
ceiling	270	30	130	100	30	480	200	590*	24*	yes/yes
upper walls	220	35	190	95	35	480	230	630*	19*	yes/yes

$^{(1)}$n = number of measurements

(2) $\bar{x}$ = average

$^{(3)}$s = standard deviation

$^{(4)}$n = number of data points to demonstrate 95% confidence level

(5) = based on beta-gamma level

* = numbers are hypothetical (not actual calculations)

SAMPLE

TABLE F-2

SUMMARY OF SOIL SAMPLING RESULTS
REFERENCE URANIUM FUEL FABRICATION PLANT

Survey Unit	# of Samples (n)	Total Uranium Activity (pCi/g) (Includes Background)		$\mu_{\alpha(c)}$	n_1[(d)]	Guidelines/Conditions Satisfied
		$\bar{x}$ [(a)]	s[(b)]			
Former Burial Site	95	6.2	3.1	13.4	55	yes/yes

(a) $\bar{x}$ = average

(b) s = standard deviation

(c) μ_d = comparison value (hypothetical)

(d) n_1 = total # of samples for 95% confidence level (hypothetical)

SAMPLE

TABLE F-3
SUMMARY OF EXPOSURE RATE MEASUREMENTS
REFERENCE URANIUM FUEL FABRICATION PLANT

Survey Unit	# of Measurements (n)	Exposure Rate (μR/h)		$\mu_{a(c)}$	n_1[(d)]	Guidelines/Conditions Satisfied
		$\bar{x}$ [(a)]	s[(b)]			
Building Group #7	26	11.3	1.5	13.2	21	yes/yes
Former Burial Site	39	12.0	1.7	14.0	35	yes/yes

(a) $\bar{x}$ = average

(b) s = standard deviation

(c) μ_d = comparison value (hypothetical)

(d) n_1 = total # of samples for 95% confidence level (hypothetical)