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FINAL REPORT

on

A COMPREHENSIVE CHARACTERIZATION AND HAZARD ASSESSMENT OF THE DOE-NIAGARA FALLS STORAGE SITE

prepared for

U.S. DEPARTMENT OF ENERGY
REMEDIAL ACTION PROGRAM

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NOTICE

EXECUTIVE SUMMARY

A comprehensive radiological and nonradiological characterization and hazards assessment was conducted on the DOE-Niagara Falls Storage Site. Results of the study will permit the U.S. DOE to form an appropriate remedial action plan for the Site.

SITE DESCRIPTION

The DOE-Niagara Falls Storage Site, located near Niagara Falls, New York, is a portion of the original Lake Ontario Ordinance Works established by the U.S. Department of the Army early in World War II. Pitchblende residues and other low-level nuclear waste have been stored on the Site since 1944. The most highly radioactive residues were stored in four abandoned buildings, while other wastes were deposited in pits or piled on surface soils on the Site. Several ditches were constructed on the Site to facilitate drainage of excess precipitation. Saturation zones on the Site are within 1.5-6 m (5-20 ft) of the soil surface.

During the time radioactive waste was actively being deposited on the Site, management practices did not provide accurate records on waste characterization, inventories, or detailed location of stored wastes. This difficulty was also compounded by the fact that the Site was used for several different purposes since its construction. Thus, without prior knowledge of where or how much contamination would be found, an intense grid survey and characterization was required to adequately characterize the Site. Intense characterization insured that the volumes of waste above action limits were completely defined and that all contaminated areas were identified.

OBJECTIVES

The primary goals of the characterization and hazard assessment of the DOE-Niagara Falls Storage Site were to (1) locate and determine amounts of radioactive and chemical wastes which exceed established exposure guidelines, and (2) estimate the potential effects on human health and the environment arising from existing conditions. This study identifies the chemical characteristics and volumes of waste on the Site which, on the basis of current standards and guidelines, may be subject to remedial action by the U.S. DOE.

Specific objectives of the study were to:

- Characterize the radio- and stable chemical composition and prepare inventory of the stored pitchblende residues on the Site;
- Survey all buildings, structures, and foundations on the Site for radioactive contamination;
- Geographically locate soils, vegetation, surface and groundwater on the Site which have been contaminated by radiological or nonradiological wastes;
- Estimate potential hazards to human health and the environment associated with contaminated section of the Site.

SIGNIFICANT FINDINGS

The Site characterization and hazards assessment study resulted in the identification of contaminated buildings, soils, vegetation, and groundwater. Additionally, stored and buried residues were found to emanate radon in excess of current guidelines. The following list is a summary of the most significant contamination and associated hazards on the Site.

(1) Five pitchblende-residue storage buildings were located on the Site representing a total estimated volume of 11,099 m^3 (391,350 ft^3). In addition, three associated buildings were significantly contaminated with pitchblende residues.

(2) Fifteen non-residue storage buildings were surface grid-surveyed for residual radioactivity. Three of these buildings were found to have significant surface contamination.

(3) Extensive on-site environmental surveys for radioactive contamination revealed:

- A total approximate area of 4.2 ha (10.4 acre) of the 77 ha (190 acre)-site contained 61,000 m^3 (2.2 x 10^6 ft^3) of contaminated soil having concentrations of ^{226}Ra in excess of the 5 pCi/g guideline level.
- The majority of the contaminated volume was found in one of the nine distinct contaminated areas on the Site.
- A total length of 5,993 m (19,650 ft) of the primary on-site and adjacent off-site drainage ditches were found to contain 21,662 m^3 (772,400 ft^3) of sediments in excess of the 5 pCi/g ^{226}Ra action limit.
- Groundwater underlying the R-10 residues was found to have maximum concentrations of ^{226}Ra of 34 pCi/l which is below the recommended guideline of 40 pCi/l for uncontrolled-access sites. ^{226}Ra concentrations in off-site groundwater were also within guidelines.

(4) Atmospheric ^{222}Rn levels of 1-440 pCi/l found in the southwest storage area exceeded the 30 pCi/l New York State standard for controlled areas. Atmospheric ^{222}Rn concentrations at the Site perimeter of 4.3-5.7 pCi/l also exceeded the standard of 3 pCi/l for uncontrolled sites. The source term responsible for elevated atmospheric ^{222}Rn is the southwest storage area on the Site, which includes the R-10 residues and three residue storage buildings.

Although several contaminated areas were identified and characterized on the Site, they pose no immediate danger to the public. Assuming adequate health physics practices, the workers on the Site have no significant occupational hazards. The primary hazard to human health is exposure to atmospheric ^{222}Rn on the Site and at the Site boundary. However, natural atmospheric dispersion processess are sufficient to prevent accumulation of ^{222}Rn in dwellings and public buildings located in close proximity to the Site. Ditch sediment contamination by ^{226}Ra above action limits is also of concern both on-site and immediately off-site. Since sediments are potentially mobile, failure to clean the ditches and eliminate source terms will likely result in increased contamination levels in on-site and off-site drainages.

Results of this intensive characterization and hazards assessment study of the DOE-Niagara Falls Storage Site should provide the U.S. DOE with accurate information on which to base a cost-effective remedial action plan.

TABLE OF CONTENTS

TABLE OF CONTENTS
(Continued)

TABLE OF CONTENTS
(Continued)

TABLE OF CONTENTS
(Continued)

TABLE OF CONTENTS
(Continued)

LIST OF FIGURES

LIST OF FIGURES
(Continued)

LIST OF TABLES

LIST OF TABLES
(Continued)

CHAPTER 1: INTRODUCTION

1.1. SITE DESCRIPTION

The Niagara Falls Storage Site is owned by the U.S. Department of Energy (DOE) and operated by National Lead of Ohio (NLO), Inc. This Site is a 77-hectare (190-acre) tract of land used for storage of pitchblende residues owned by the United States and by African Metals Corporation. The Site is located in western New York (43°12'41"N and 79°2'3"W), lying within the Town of Lewiston, Niagara County, and is approximately 6.4 km (4 mi) south of Lake Ontario, 16 km (10 mi) north of the City of Niagara Falls, and 24 km (15 mi) west of the City of Lockport (Figure 1-1). It is a portion of the original Lake Ontario Ordnance Works established by the U.S. Department of the Army in the early 1940's.

The Niagara Falls Storage Site is diagrammed in Figure 1-2. The Site is level, tilting slightly to the northwest and lies between 96 and 99 m (315 and 325 ft) above sea level. The features on the Site include the storage buildings, including a 50 m (164 ft) tower, service structures, and a mound of 11,475 cu m (15,000 cu yds) of contaminated soil, paved and gravelled roadways, and drainage ditches (Figures 1-2 and 1-3).

The climate of the Site is classified as humid continental with some influence from the lake. The long-term temperature range is -4° to 24°C (25-76°F) with a mean annual temperature of 9°C (48°F). Mean annual precipitation is 81 cm (32 in.) with approximately 14 cm (5.5 in.) recorded as snowfall. Wind speed averages 8-16 kph (5-10 mph) from the southwest about 50 percent of the time (see Appendix A.3).

The Site is underlain by Ordovician Queenstone shale (Kindle and Taylor, 1914). The shale lies between 9-15 m (30-50 ft) below the surface and is 366 m (1,200 ft) deep at its maximum. The overlying materials are primarily derived from lake bed sediments. Sand-gravel inclusions are frequent (Higgins et al., 1972). Two soil types dominate the Site; both are poorly drained silt loams with low organic matter (see Appendix A.2

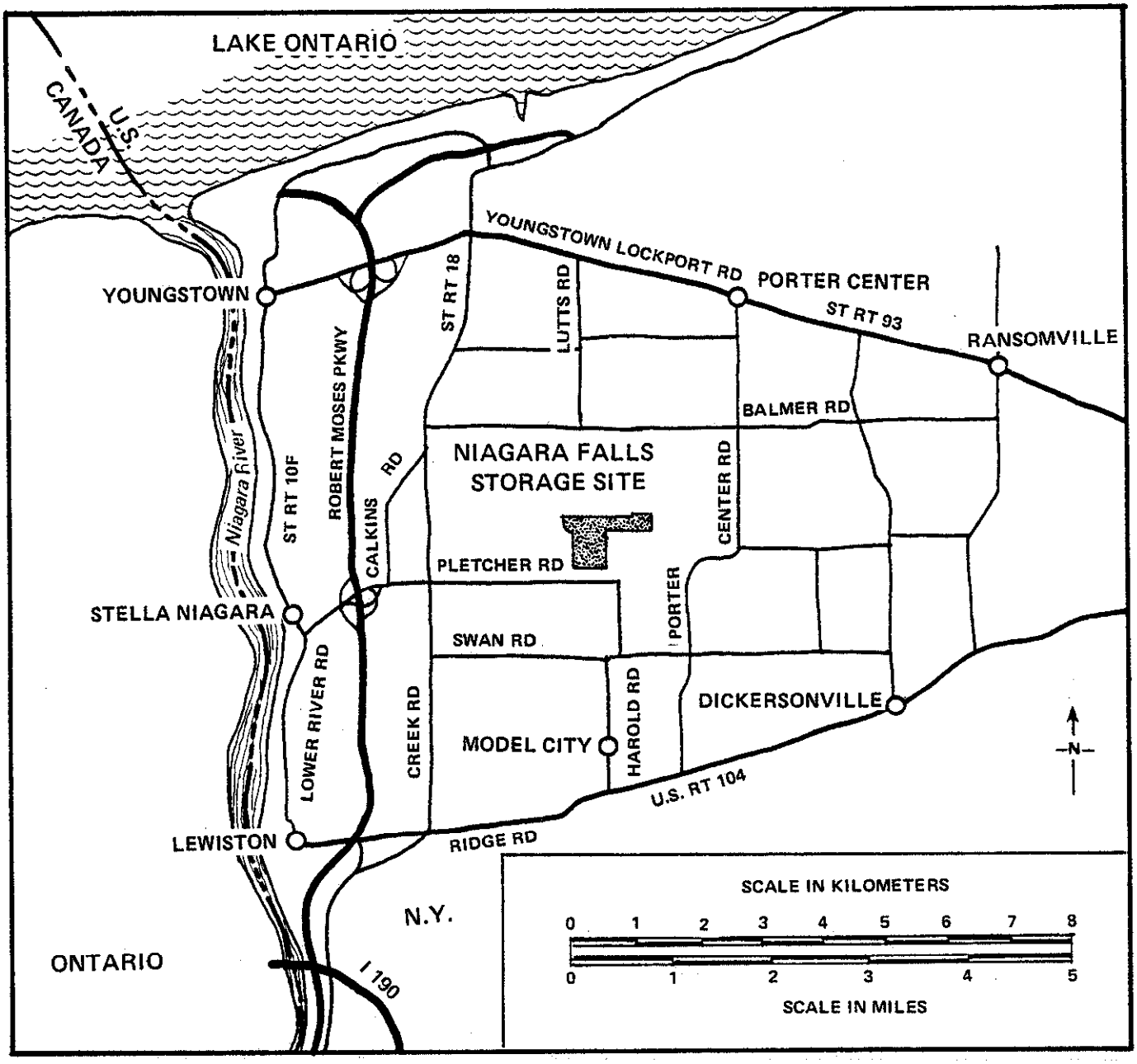

FIGURE 1-1. THE DOE-NIAGARA FALLS STORAGE SITE

(Located within the Town of Lewiston,
Niagara County, New York.)

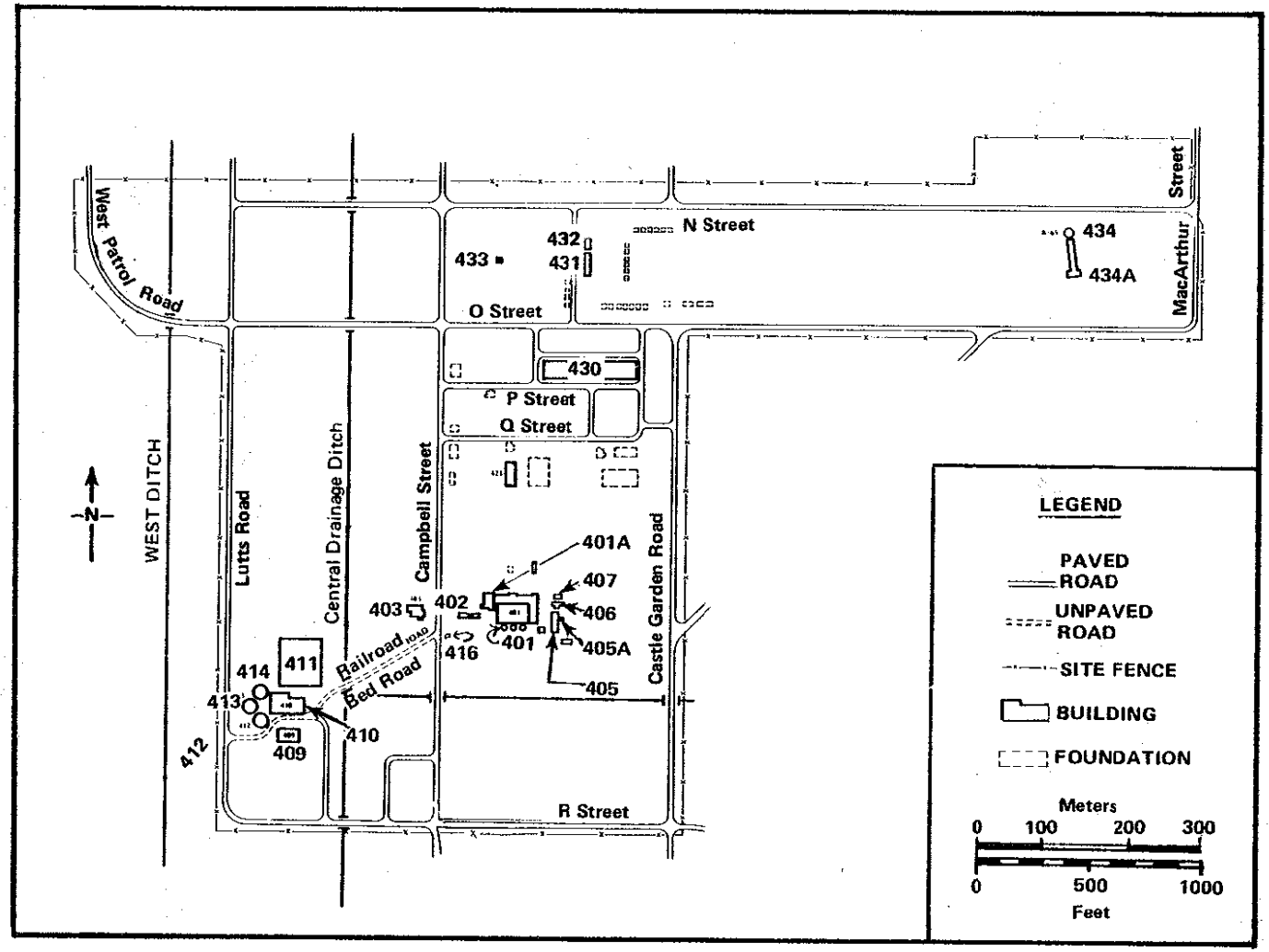

FIGURE 1-2. DIAGRAM OF THE DOE-NIAGARA FALLS STORAGE SITE SHOWING STRUCTURES AND FEATURES OF THE SITE

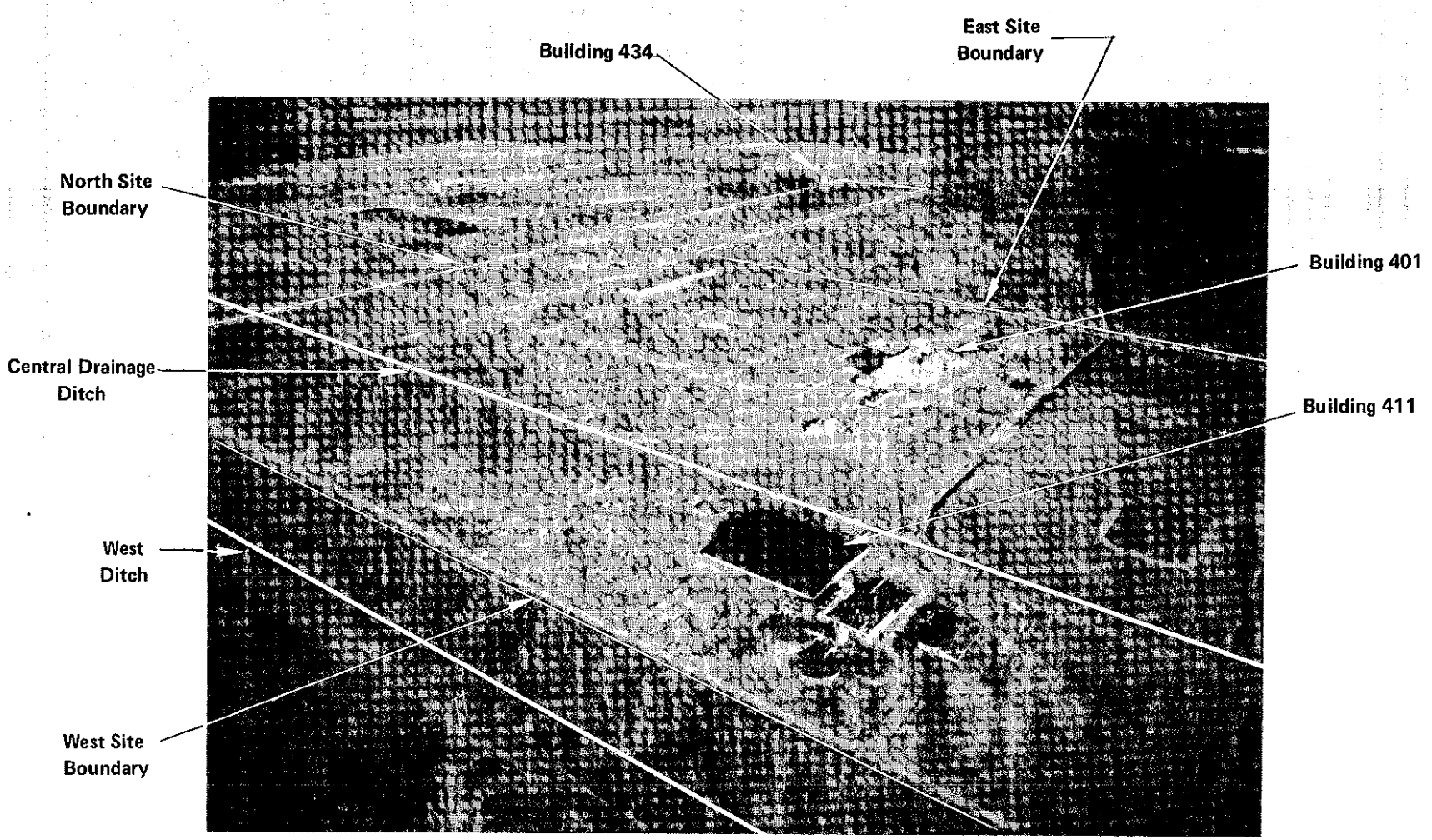

FIGURE 1-3. AERIAL PHOTOGRAPH OF THE DOE-NIAGARA FALLS STORAGE SITE TAKEN IN DECEMBER 1979

(The view is from the southwest.)

for soil characterization). Significant volumes of fill material are also located on the Site including (1) slag, gravel, building rubble and old railroad bed materials throughout the Site, (2) 11,475 cu m (15,000 cu yds) of low-level contaminated soil and railroad ties placed on the R-10 residue storage area following the 1972 off-site decontamination, and (3) soil placed in the pond (south of Building 401) used during the Boron-10 operations.

Water is present in an aquifier at the bedrock surface, in several sand-gravel lenses, and in saturated clay zones 1.5-6 m (5-20 ft) in depth. Hydrologic contours suggest a slope of the primary aquifer to the north-northwest of approximately 1.9 m/km (10 ft/mi). The flow would empty into the northern reaches of the Niagara River close to Lake Ontario. (Personal communication, 1981, Robert Bazarnick, N.Y. State Water Resources Bureau). Surface drainage from the Site was originally facilitated by: Fourmile, Sixmile and Twelvemile creeks. However, during construction of the Lake Ontario Ordnance Works, extensive drainage ditches were installed. Surface drainage currently occurs through the Central Drainage Ditch and its adjoining ditches which empty into the Fourmile Creek. No drainage presently occurs into Sixmile or Twelvemile creeks.

During the early operations of the Site, a 107 cm (42 in.) emergency water supply was provided by an underground conduit from the Niagara River. A water tower (Building 434), three accelators (Buildings 412-414), a process building (Building 410), and two water storage reservoirs (Buildings 409, 411) were built as emergency water treatment and storage facilities. These extensive facilities were never used for the Site operations. The water line, along with the sewage treatment plant, was turned over to the Town of Lewiston in 1972. This water line has been severed near Pletcher Road and a 5 m section backfilled.

Vegetation present at the Site is mixed second growth forest, northern shrub, grass, and aquatic emergents in the ditches. Secondary growth has been allowed since the early 1950's in most portions of the Site and the area is currently densely vegetated, furnishing an excellent wildlife habitat. (See Appendix A.2 for a more detailed description of aquatic and terrestrial ecosystems.)

1.2. SITE HISTORY

The Army established the Lake Ontario Ordnance Works (LOOW) on 2,025 hectares (5,000 acres), using approximately 612 hectares (1,511 acres) for TNT production and support activities during the early 1940's. As other production processes replaced those used at LOOW, the Army turned over the LOOW to the General Services Administration which transferred the land in 1944 to the Manhattan Engineering District (MED), which in 1947 became the Atomic Energy Commission. During subsequent years (1944 to mid-1950's), portions of the LOOW site were used for storage and transshipment of pitchblende residues from Linde and Mallinckrodt uranium extraction operations and disposal of waste from University of Rochester, Knolls Atomic Power Laboratory, Union Carbide's Electrometallurgical Operations, Middlesex Sampling Plant and Oak Ridge Operations' materials. Many of the pitchblende residues had sufficient value to warrant storage (the L-30, L-50 and K-65 residues) and were placed in Buildings 411, 413, 414, and 434 during the mid-1940's to the early 1950's and remain the property of African Metals Corporation (Afrimet). Other materials were removed from the LOOW site before portions were sold. In 1972, some of the off-site areas as well as portions of the Central Drainage Ditch received additional clean-up and materials removed (approximately 15,000 cu yds) were placed on top of a portion of the R-10 residue storage area immediately north of Building 411.

The original steam plant (Building 401) was modified and used for production of Boron-10 during two periods (1953-1959 and 1965-1971). After 1971, the facility was gutted and the instrumentation and hardware were disposed of as surplus materials. (See Appendix A.1 for further details of the Site history.)

Since the Boron-10 operations ceased, the Site has been maintained as a storage area. NLO, Inc., assumed responsibility for maintenance and surveillance of the Site in 1972. Recently, DOE has undertaken projects for radon abatement and upgrading of Site facilities. The Site is now identified as a surplus facility and is the responsibility of the

DOE Remedial Action Program Office. The characterization summarized herein is the initial portion of the planning for improved management and ultimate disposition of the Site.

CHAPTER 2: OBJECTIVES AND APPROACH

2.1. INTRODUCTION

DOE has recently undertaken projects for radon suppression and facility upgrading of abandoned sites such as the Niagara Falls Storage Site. Current plans call for upgrading the facilities and residue storage conditions and for the development of plans for final disposition of the Site. The project conducted by BCL was designed to be a comprehensive radiological and nonradiological characterization of the DOE-Niagara Falls Storage Site. This information will provide baseline information for timely and cost-effective assessment, planning, and implementation of remedial action. The characterization of the Site had to be as complete as possible to provide sufficient information for future assessments of disposition options. Site surveys were conducted using instrumentation and procedures designed to: (1) establish contaminated areas in buildings above American National Standards Institute (ANSI) or Nuclear Regulatory Commission (NRC) standards for unrestricted use, (2) discriminate background radiation levels from those present due to contamination, (3) determine presence and levels of metals and rare earths which could present occupational hazards, (4) estimate volumes of contaminated materials requiring remedial action under U.S. Environmental Protection Agency (EPA) proposed guidelines (e.g., ^{226}Ra concentrations in soil of 5 pCi/g and ^{222}Rn emanation rates from surfaces of 2 $pCi/m^2/sec$), and (5) allow hazard identification and assessment of current Site conditions.

2.2. OBJECTIVES

Several objectives were defined for the characterization and hazard assessment of the DOE-Niagara Falls Storage Site. These objectives had as their collective goal determining radionuclide composition and concentrations in residues and contaminated soils/sediments on

the Site. In addition, an initial hazard assessment of current Site conditions was performed to provide baseline information to permit DOE to establish priorities and restrictions to remedial actions planned for the Site. Specific objectives of the project were:

- quantify radionuclide composition, chemical form, and inventories of pitchblende residues in storage;
- identify and quantify radioactive contamination of Site buildings, structures, and foundations;
- identify and characterize contaminated areas, including radionuclide and nonradiological contaminants, radon levels, and biological uptake;
- determine the extent of contamination of surface waters and groundwater on the Site; and
- identify and assess hazards associated with current conditions of the Site.

This report was designed to summarize findings of the characterization and hazard assessment. In addition, complete data base, procedures and quality assurance methods, instrumentation, and health physics surveillance are reported in the appendices to the report.

2.3. APPROACH TO CHARACTERIZATION

To meet the objectives of the project, characterization of the Site centered on the identification and quantification of radiological and nonradiological contamination. The primary components of the characterization were: (1) residues, (2) buildings and other structures, (3) undeveloped land, (4) drainages, and (5) saturated zones.

The residues stored within buildings at the Site were physically and chemically characterized to provide data necessary for evaluations of alternative extraction, storage, and disposal options. Volumes of the residues were estimated from inventory records and observations made during the project. Radon concentrations were measured for residues stored in Buildings 413 and 414 and estimated for those in Buildings 411 and 434 using air concentration and minimal emanation measurements.

Buildings and other structures on the Site were radiologically characterized using a 2 m x 2 m grid for instrumental and smear analyses of all interior surfaces of buildings not used for residue storage. A minimum of 30 percent of surfaces were surveyed in buildings having significant inaccessible areas. Foundations and concreted pads were surveyed by using radon instrumental and smear measurements on accessible areas. Residue storage and associated buildings were characterized to determine chemical and radiochemical properties, radon concentrations, and radiological exposures associated with the stored residues.

Undeveloped land was radiologically characterized using instrumental surveys, total activity screening of surface soil samples, and quantitative analyses of selected samples from a 15 x 15 m (50 x 50 ft) grid established throughout the Site. Depth profiles were established using continuous coring split-spoon sampling techniques. Thermoluminescent dosimeters (TLD's) were used to establish gamma/X-ray exposures in both background and significantly contaminated areas. Techniques applied allowed sample archival while screening methods established sample priorities. Selected radiochemistry and spark source mass spectroscopy allowed radiological and nonradiological characterization of surface and subsurface samples. Permanent monitoring wells were established in saturated zones of coring locations at the Site periphery and in several contaminated areas. Radon levels in air and contaminant concentrations in vegetation and animal tissue were established in both background and contaminated areas.

Ditches and creeks draining the Site were investigated to determine contamination in sediments in excess of the EPA guideline of 5 pCi/g ^{226}Ra. Off-site migration was quantified by investigating all potential drainage into Lake Ontario from the Site. Subsurface migration of contaminants was evaluated by characterization of saturated zones in the primary contaminated areas and at the west and north boundaries of the Site.

Radionuclides of particular interest were: total uranium, ^{226}Ra, ^{222}Rn and its particulate alph-emitting daughters, and ^{210}Pb.

Metals emphasized included: lead, copper, cobalt, chromium, arsenic, nickel, titanium, zinc, and zirconium.

2.4. APPROACH TO HAZARD ASSESSMENT

The purpose of hazard identification and assessment was to determine current problems at the Site which might present on-site or off-site hazards. The approach used was three-fold. First, concentrations of nuclides and metals present at the Site were compared to (1) regulatory guidelines for restricted and unrestricted access areas and (2) concentrations causing known biological or health effects. Second, off-site exposure to radon and radon daughters was estimated by using collected data and a mathematical dispersion model. Finally, a dose assessment model for ^{226}Ra and ^{222}Rn was used to simulate a worst-case dose to an individual living on the Site for periods up to 70 years (see Chapter 7).

CHAPTER 3: CHARACTERIZATION OF RESIDUES

3.1. INTRODUCTION

The DOE-Niagara Falls Storage Site is the depository for six pitchblende residues of uranium extraction from African and U.S. ores during and following World War II. The residues currently identifiable in storage are: K-65, L-30, L-50, F-32, R-10, and Middlesex Sands (Table 3-1). The 1965 residue inventory is shown in Appendix F, Table F-1. The R-10 residues were intermixed with soils and were characterized as contaminated soils (see Chapter 5). The purpose of the residue characterization was to establish radiological and chemical composition and form.

3.2. APPROACH

Characteristics of the pitchblende residues dictate the migration potential and applicable remedial actions. Inventory records, radiological and chemical analyses, and extraction processing were examined. In addition, several analytical techniques were used to characterize the stored pitchblende residues. Trace element analysis by spark source mass spectroscopy, lead isotope analysis, and optical (microscopy) and crystallographic analyses were performed on L-30, L-50, and K-65 residues. In addition, selected gamma spectroscopy, energy dispersive X-ray fluorescence analysis, and electron microscopy were used (see Appendix B, QA Documents MN-PP-113, NS-NS-116, NS-NS-118, NS-NS-121, NS-NS-122, and NS-NS-123 for detailed characterization procedures).

TABLE 3-1. SUMMARY OF MAJOR PITCHBLENDE RESIDUES STORED AT THE DOE-NIAGARA FALLS STORAGE SITE[a]

Residue I.D.	Ownership	Storage Location	Weight, 10^6 kg (ton)	Volume, m^3 (ft^3)
K-65	Afrimet[b]	Building 434	3.53 (3,891)	3,080 (110,000)
L-30	Afrimet	Building 411	7.46 (8,227)	6,020 (215,000)[c]
L-50	Afrimet	Buildings 413-414	1.70 (1,878)	1,624 (58,000)
F-32	Afrimet	Recarboration Pit	0.13 (138)	110-336 (3,950-12,000)
Middlesex Sands	U.S.	Building 410	0.002 (2)	175 (6,180)
R-10	U.S.	North of Building 411	7.47 (8,235)	7,084 (253,800)[d]

(a) Primary source: Cavendish et al., 1978.

(b) Afrimet—African Metals Corporation.

(c) This residue is also covered by approximately 2,940 m^3 (105,000 ft^3) of water.

(d) Approximate volume at time of disposal; total volume and weight of R-10 contaminated material found to be greatly in excess of this number; i.e., 11,340 m^3 (405,000 ft^3) of overburden and ≈35,000 m^3 (1,235,990 ft^3) of R-10 contaminated underlying soil. More detailed discussion in Chapter 5.

3.3. RESIDUE CHARACTERIZATION

3.3.1. K-65 Residue (Building 434)

The K-65 residue resulted from the processing of high-grade Katangan pitchblende from Africa (35-60 percent U_3O_8) by Mallinckrodt Chemical Works, St. Louis, MO. Prior to April 1, 1949, all residues were shipped to Belgium (African Metals Corporation); from April 1949 until 1953, the residues were drummed and shipped to the Lake Ontario Ordnance Works now known as the DOE-Niagara Falls Storage Site. After temporary on-site storage (in igloos north of Balmer Road, in Building 410, and in the open), residues were placed in Building 434 which had been modified for this purpose.

The process used to extract uranium from the Katangan pitchblende ore consisted of a 3-hr, 90°C oxidizing H_2SO_4 leach radium precipitated as $RaSO_4$ (MnO_2 oxidant to dissolve the uranium). $BaSO_4$ was added to ensure coprecipitation. Continued digestion of the leach slurry at 60°C with Na_2CO_3 converted uranium to a soluble uranyl carbonate, causing precipitation of impurities including ferric, aluminum, and manganese hydroxides.

The pitchblende ore contained a variety of uraniferous minerals including largely hydrated uranium oxides and secondary minerals such as soddyite ($12UO_3 \cdot 5SiO_3 \cdot 14H_2O$). The ores were rich in precious metals including gold, platinum, palladium, and silver. Extractions of these precious metals were performed on at least some shipments of pitchblende ore prior to processing at Mallinckrodt Chemical Works.

The residues are composed of two fractions: (1) a "slimes" fraction (<400 mesh) containing solubilized recrystallized fractions including radium-contaminated barium sulfate and (2) a "sand" fraction (>400 mesh) containing undissolved ore particles and primarily less soluble silicate secondary minerals. According to Litz (1974), only about 5.6 percent of the radium content of the residue is found in the 26.9 percent sand fraction (24 ppb in 65 x 100 mesh, 105 ppb in >65 mesh). The average residue radium concentration was reported by Litz (1974) to be approximately 300 ppb.

The samples analyzed by Litz (1974) were taken from the FMPC (Feed Materials Production Center, NLO, Inc., Fernald, OH). The residue stored on the Niagara Falls Storage Site is similar (Table 3-2) but may be depleted in many of the metals (see Appendix F, Table F-2). However, samples of the K-65 residue stored at the Niagara Falls Site were taken from near the base of the tower and may not be totally representative of the stored residues. Based on the best available data, the K-65 residues at the Site have a uranium concentration of 1410-1965 ppm and radium concentration of approximately 220 ppb. The ^{222}Rn concentration in air at the top of the tower prior to the tower being sealed ranged from 4-117 nCi/l in late summer. The isotopic analyses conducted by gamma spectroscopy (see Appendix F, Table F-3) suggest the residues resulted from ores 40-50 percent U_3O_8. ^{214}Pb, ^{214}Bi, and ^{210}Pb are in secular equilibrium with their parent, ^{226}Ra. The other nuclides detected (^{231}Pa, ^{227}Th, ^{223}Ra, and ^{219}Rn) result from the decay of the small amount of ^{235}U found in the ore. No ^{234}Th was detected, supporting the conclusion that ^{238}U concentrations of the residues are <2000 ppm. The detection of ^{231}Pa results from its long half-life compared to ^{234}Th.

The physical form of the residue is a wet clay [~30 percent water (Vitro Corp., 1952)] with an appreciable alpha quartz ($-SiO_2$) fraction. The clay is a sheet-like muscovite (mica) present as $KAl_2Si_3AlO_{10}(OH)_2$. The muscovite constitutes approximately 60 volume percent; the alpha quartz, approximately 25 volume percent. This conclusion is consistent with the analysis of the K-65 residues stored at FMPC and their particle sizes (Litz, 1974). Barite was present as a discrete phase. Wulfenite ($PbMoO_4$) was present as <10 volume percent. Chemically, the K-65 residues are mixtures of oxides, carbonates, and sulfates. Oxides are approximately 40 percent of the residues; carbonates and sulfates, 20 percent (Vitro Corp., 1952). The primary form of the uranium is sodium uranyl carbonate.

TABLE 3-2. CHARACTERISTICS OF THE K-65 RESIDUES STORED IN BUILDING 434 OF THE DOE-NIAGARA FALLS STORAGE SITE AND AT THE FMPC, FERNALD, OH

Characteristic	FMPC Stored K-65			Niagara Falls Stored K-65	
	Litz(a)	NLO(b)	Vitro(c)	BCD(d)	NLO(b)
Dry wt, kg (tons)	-	8.79×10^6 (9,690)	1.59×10^6 (1,753)	-	1.6×10^6 (1,757)
Estimated volume, m^3 (ft^3)	-	5,522 (195,000)	3,115 (110,003)	-	3,080 (110,000)
Density, kg/m^3 (lb/ft^3)	-	-	1,179 (73)	-	1,179 (73)
Uranium, ppm	1,800-3,200	600	2,110	500(e) 18,240(f) 30,000(g) 1,410-1,961(h)	500
Lead, ppm	60,000-70,000	48,000-52,000	94,900	35,000	95,000
Radium, ppb	280-360	200	300	217	180
Barium, ppm	50,000	-	45,300	30,000	-
Iron, ppm	13,000-18,000	-	-	5,000	-
Gold, ppm	65-78	<40-60	-	<0.2	-
Platinum, ppm	0.9-1.4	-	-	<0.5	-
Palladium, ppm	13-18	-	-	20	-
Silver, ppm	18	<20	-	< 3	-
Copper, ppm	500-800	400-600	-	600	-
Cobalt, ppm	1,600-2,000	1,500-2,000	-	2,000	-
Nickel, ppm	3,500-3,700	2,000-3,000	-	3,000	-

(a) Litz, 1974.

(b) NLO, Inc., and Battelle Columbus Laboratories, 1980.

(c) Vitro Corp., 1952.

(d) Same as (b) above.

(e) Direct gamma spectorscopy of the residue.

(f) X-ray diffraction of the residue.

(g) Spark source mass spectroscopy.

(h) Calculated U from Ra measurements.

3.3.2. L-30 Residues (Building 411)

The L-30 residue resulted from extraction of a low-grade pitchblende (approximately 10 percent U_3O_8) by the Linde Ceramics Plant, Tonawanda, NY (December 1943 - October 1944). The Linde process was a H_2SO_4 leach followed by Na_2CO_3 neutralization of the slurry and filtration of the uranyl carbonate slurry. The filter cake was stored in Building 411 of the Lake Ontario Ordnance Works (now the Niagara Falls Storage Site).

Spectral analysis of grab samples of L-30 taken from the west bay of Building 411 are summarized in Appendix F (see Table F-4). The abnormally high value of ^{208}Pb suggests that a small amount of ^{232}Th (thorium) residues were stored in the building. The data available suggest uranium concentrations varying from 830-5000 ppm and radium concentrations from 2-12 ppb. Elemental analysis of the residues are listed in Appendix F, Table F-2.

The wide range of values is indicative of the heterogeneity of these residues. The L-30 residues are stored in both the east and west bays of Building 411. The west bay is covered with water, and standing water covers residues in the south part of the east bay. In addition, several barrels of residue marked L-50 and other residues, unmarked, were placed on the residues in the north portion of the east bay. Approximately 2970 m^3 (105,000 ft^3) of water cover portions of the residues.

The concentrations of precious metals in these residues are quite low (Table 3-3). The density of the residues is significantly lower than that of the K-65 residues. The L-30 residue contains the highest concentration of chamosite clay of the residues stored at the Site (70 volume percent). This clay appears to have nickel substituted for much of its iron. Sodium uranyl carbonate [$Na_2UO_2(CO_3)_3$] is present in the residues. Alpha quartz represents approximately 20 volume percent and barite ($BaSO_4$) is present as a few volume percent.

7.46 12 74.6 90 25,150

TABLE 3-3. CHARACTERISTICS OF THE L-30 RESIDUES STORED IN BUILDING 411 OF THE DOE-NIAGARA FALLS STORAGE SITE

Characteristic	BCL[a]	NLO[a]	Vitro[b]	Litz[e]
Dry wt, kg (tons)	-	7.5×10^6 (8,227)	7.9×10^6 (8,740)	-
Estimated volume, m^3 (ft^3)	-	6,020 (215,000)	-	-
Density, kg/m^3 (lb/ft^3)	-	842.6 (52.6)	-	-
Uranium, ppm	5,000	1,800	1,950	830
Lead, ppm	7,500-23,500	-	-	7,600
Radium, ppb	12[c]	8	-	2
Barium, ppm	10,000-20,000	-	-	1,900
Iron, ppm	10,000-20,000	-	-	66,000
Gold, ppm	<0.2	-	-	0.7
Platinum, ppm	<0.5	-	-	0.2
Palladium, ppm	2	-	-	6.2
Silver, ppm	<2	-	-	6-2
Copper, ppm	1,500-5,000	2,000	-	1,100
Cobalt, ppm	5,000-10,000	6,200	-	2,600
Nickel, ppm	30,000-50,000	20,000	-	6,200

(a) Source: NLO, Inc., and Battelle Columbus Laboratories, 1980.

(b) Source: Vitro Corp., 1952.

(c) Source: Litz, 1974.

(d) Sample of west bay-stored residues only.

R-10 780 gm
L-30 90 gm
L-50 17 gm

3.3.3. L-50 Residues (Buildings 413-414)

The L-50 residues resulted from uranium extraction of African pitchblende ores of approximately 7 percent U_3O_8. Extraction by the Linde Ceramics Plant was similar to that described for the L-30 residues. The characteristics of the L-50 residues are summarized in Table 3-4 (see Appendix F, Table F-2). Uranium concentrations range from 1000-2100 ppm; radium concentrations, 7-12 ppb.

The L-50 residues were comprised of three components. The major component, a clay, was identified as antigorite. Its cationic composition is 17 percent Mg, 27 percent Al, 48 percent Si, and 8 percent distributed among Mn, Fe, and Ni. The clay is 60 volume percent of the residue. The second component is alpha quartz (33 percent). No sodium uranyl carbonate was detected. The residues are, however, rich in both oxides and carbonates.

3.3.4. F-32 Residues (Recarbonation Pit)

This residue resulted from Linde Ceramics' extraction of Q-20 pitchblende ore from the Belgium Congo area. The F-32 residues originally consisted of 0.12-0.23 x 10^6 kg (138-250 tons) (NLO, Inc., and Battelle Columbus Laboratories, 1980; Vitro Corp., 1952). The inventory data suggest that the uranium concentration was 0.4-0.65 percent (4000-6500 ppm). These residues were stored in the recarbonation pit west of Building 411. The pit has filled with water and the residues may have been leached by the water to some degree. During the autumn of 1980, the pit was covered to prevent additional precipitation intrusion.

3.3.5. Middlesex Sands (Building 410)

Inventory records show approximately 1814 kg (2 tons) of the sands resulting from processing at the Middlesex sampling plant were stored in a bin in Building 410. The original concentration of uranium

TABLE 3-4. CHARACTERISTICS OF THE L-50 RESIDUES STORED AT THE DOE-NIAGARA FALLS STORAGE SITE

Characteristic	BCL[a]	NLO[a]
Dry wt, kg (tons)	-	1.7×10^6 (1,878)
Volume, m^3 (ft^3)	-	1,624 (58,000)
Density, kg/m^3 (lb/ft^3)	-	1,265 (79)
Uranium, ppm	1,000-2,100	1,200-1,300
Lead, ppm	7,000	7,600
Radium, ppb	8-12	7.8-9.3
Barium, ppm	20,000	-
Iron, ppm	20,000	-
Gold, ppm	<0.2	-
Platinum, ppm	<0.5	-
Palladium, ppm	2-3	-
Silver, ppm	<0.5	-
Copper, ppm	2,000-3,000	2,400
Cobalt, ppm	10,000	5,900
Nickel, ppm	20,000-30,000	19,100

(a) Source: NLO, Inc., and Battelle Columbus Laboratories, 1980.

1.7
17.

was reported to be 3 percent. Measurements made during this project indicate current levels of uranium <100 ppm and ^{226}Ra <0.01 ppb. The sands have been eroded from the bin by precipitation entering through holes in the roof and are spread through a significant portion of the lower floor of Building 410. Due to low ^{226}Ra concentrations, these materials cause only slightly elevated ^{222}Rn levels in this area.

3.3.6. R-10 Residues (Soil, North of Building 411)

The R-10 residues are U.S.-owned and resulted from extraction of pitchblende ore of 3.5 percent U_3O_8. The process of extraction was similar to that used by Linde Ceramics resulting in the L-30 and L-50 residues. The carbonate filter cake was stored on the surface of the soil north of Building 411. Iron cake residue, from the initial extraction, was placed in the same area but in a discrete pile near Lutts Road [0.14×10^6 kg (150 tons)]. Originally, the inventory suggested approximately 8.72×10^6 kg (9610 tons) dry solids with approximately 2300 ppm uranium.

The residues were stored in the open and have migrated significantly by erosion and soil transport processes. These residues were therefore characterized as a contaminated soil. The results are reported in Chapter 5.

CHAPTER 4: CHARACTERIZATION OF BUILDINGS, STRUCTURES, AND FOUNDATIONS

4.1. INTRODUCTION

4.1.1. Approach to Characterization

Three types of structures are found at the DOE-Niagara Falls Storage Site--those used for residue storage (see Chapter 3), those used for Site operations, and those no longer used. These types of structures are characterized separately. Buildings and other structures are detailed in Figure 4-1. Residue storage buildings were characterized by: (1) exposures external and internal to the buildings, (2) surface contamination, (3) radon concentrations in buildings, and (4) identification and location of connections and pipes among and leading from buildings. Nonresidue storage buildings and structures were surveyed at a level of detail commersurate to their suspected contamination level. Three survey categories were developed to address these buildings: (1) detailed, (2) intermediate, and (3) general. Nonresidue storage buildings with accessible interior surfaces were given a detailed survey which assessed all surfaces. Those buildings having inaccessible areas were given intermediate surveys which assessed a minimum of 30 percent of all surfaces. General surveys were given to old foundations and pads and usually consisted of random meter and smear surveys. The measurement techniques generally utilized included instrumental surveys of beta-gamma and alpha radiation, smears to determine transferable beta-gamma and alpha contamination, radon concentrations in air, and high volume sampling of airborne particulate radioactivity.

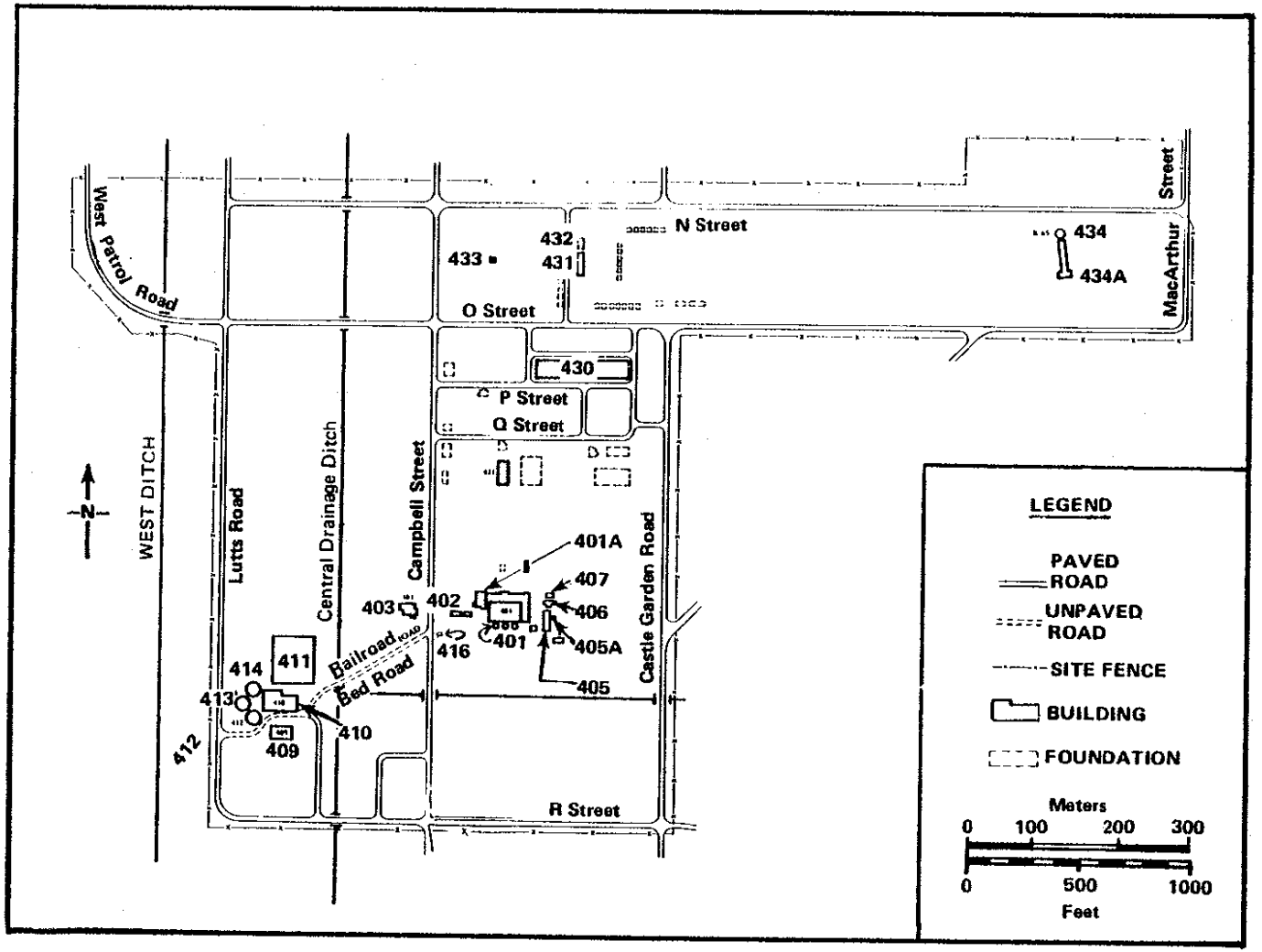

FIGURE 4-1. DIAGRAM OF THE DOE-NIAGARA FALLS STORAGE SITE SHOWING STRUCTURES AND FEATURES OF THE SITE

4.1.2. Materials and Methods

Residue Storage Buildings

Surveys of residue storage buildings were designed to furnish specific information needed for engineering assessments of alternative extraction, storage, or disposal options for the residues. Detailed procedures are given in QA Document EE-SP-10 (see Appendix B). Exposures external and internal to these buildings were established using thermoluminescent dosimeters (TLD's) as described in QA Document EE-SP-17 (see Appendix B). Surface contamination of these buildings was established using procedures similar to those applied to other buildings on-site as described in QA Document EE-SP-10 (see Appendix B). Radon concentrations were established on several dates using grab sampling and alpha scintillation techniques decribed in QA Documents EE-SP-18, EE-SP-19, EE-SP-20, EE-SP-21, and NS-NS-115 (see Appendix B). In the case of Building 434, radon concentrations were determined under the disc covering the port on top of the tower on two dates. These measurements were made prior to the capping and sealing of the tower. Connections and pipes as well as building dimensions were established from observations and from engineering drawings within Site records. Grab samples of water, sediments, and/or residues were obtained for radiochemistry and physical/chemical characterization (see Chapter 3 for results of residue characterization).

Nonresidue Storage Buildings and Structures

Buildings were surveyed in a preliminary manner to determine worker hazards in each structure (see Appendix B, QA Document EE-SP-12). Preliminary surveys included instrumental measurements, high-volume air particulate samplings, and radon measurements. Buildings were gridded into 2 m x 2 m areas (see Appendix B, QA Document EE-SP-2). Instrumental and smear surveys were conducted on contiguous 1 m areas

(see Appendix B, QA Documents EE-SP-12.1 and EE-SP-12.2). If warranted, additional high-volume and radon samplings were made. In designated areas, assigned staff were equipped with lapel filters for additional personnel dose evaluation (see Appendix B, QA Document EE-QAP-2).

Foundations, tank supports, and concrete pads were surveyed in accordance with QA Document EE-SP-9 (see Appendix B). Random portions of the surfaces of the foundations were smear surveyed. All accessible areas were surveyed instrumentally (beta-gamma and alpha). Grab samples of air for radon measurement were taken only in those structures having some enclosed areas.

4.2. RESULTS OF CHARACTERIZATION

4.2.1. Residue Storage Buildings

Two portions or the Site contain structures which have been contaminated by or have/are used to store pitchblende residues belonging to African Metals Corporation (under lease with the U.S. until June 1983) or to the United States. The southwest complex consists of the Department of Army's water treatment and distribution system, Buildings 409-415 (Figure 4-2). The other storage building is Building 434, the water tower, located in the northeast portion of the Site (Figure 4-3). This building is isolated from the rest of the water treatment facility. Residues stored in these buildings are summarized in Table 4-1. Detailed diagrams of individual structures and analyses are reported in Appendix G.

Exposures In/Around Residue Storage Complexes

Table 4-2 summarizes gamma and X-ray exposures measured in and around residue storage buildings. Inside the buildings in the southwest complex (see Figure 4-2), exposure readings ranged from 0.03 to 8.1 mR/hr.

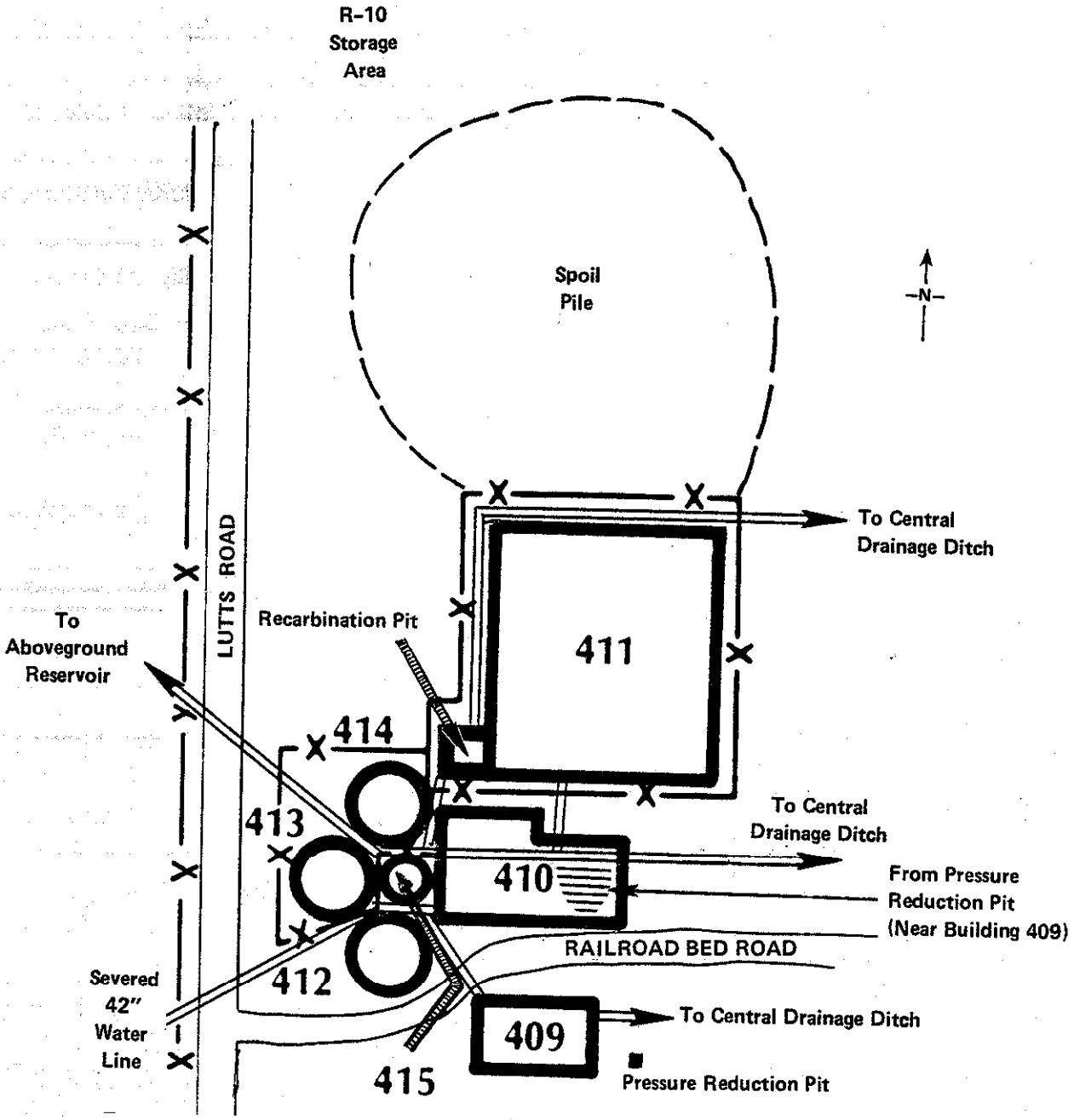

FIGURE 4-2. ENLARGED DIAGRAM OF RESIDUE STORAGE BUILDINGS IN THE SOUTHWEST PORTION OF THE SITE

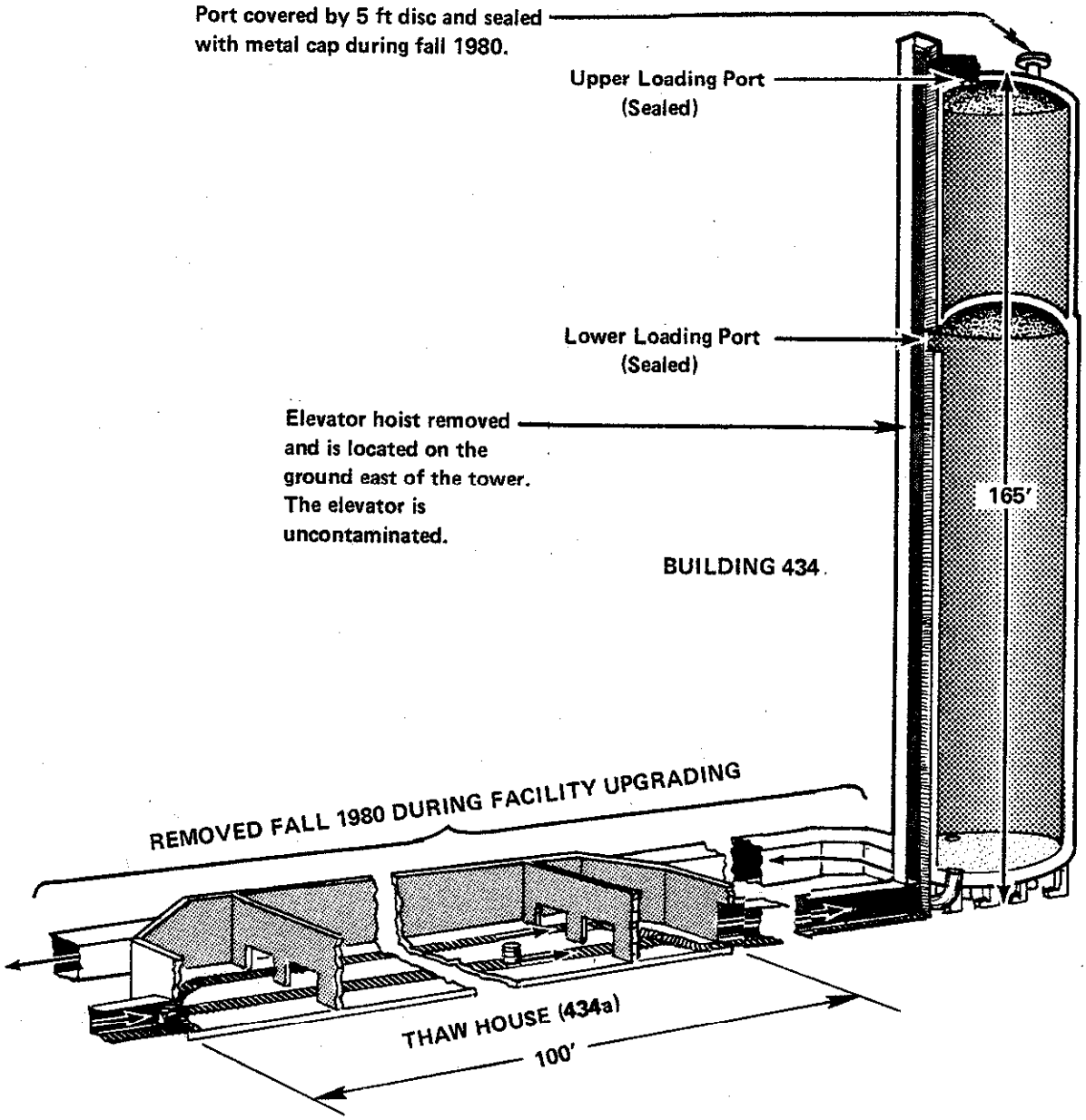

FIGURE 4-3. DIAGRAM OF BUILDING 434, THE WATER TOWER, NOW USED FOR STORAGE OF SELECTED AFRICAN METALS CORPORATION PITCH-BLENDE RESIDUES, THE K-65's, AND THE THAW HOUSE, 434A

TABLE 4-1. LOCATION OF PITCHBLENDE RESIDUES STORED IN BUILDINGS

Residue Identification	Ownership	Volume (cu m)	Storage Location
K-65	African Metals	3,080	434
L-30	African Metals	6,020	411
L-50	African Metals	1,624	413, 414
F-32	African Metals	200	Recarbonation Pit
Middlesex Sands	United States	175	410

TABLE 4-2. GAMMA AND X-RAY EXPOSURES WITHIN AND AROUND RESIDUE STORAGE BUILDINGS AS MEASURED USING THERMOLUMINESCENT DOSIMETERS (TLD's) DURING WINTER 1980

Building Number	Exposures mR/hr[a,b]	
	Inside Building	Outside Building
409	None made	0.08-0.11
410	0.03-0.08	0.06-0.17
411	0.33-4.32	0.11-0.77
412	1.11	NE:[c] 0.05-0.30 NW:[c] 0.14-3.76
413	3.12-8.10	
414	2.94-8.06	
434	No access	0.09-0.53

(a) Raw data given in Appendix G, Tables G1-1 and G1-2.

(b) Background values were 0.02 mR/hr (see Appendix H, Table H1-1).

(c) Measurements were made in the area of the accelators to the northeast and northwest.

These values were measured after asphaltic emulsions were placed on the surfaces of residues in Buildings 413 and 414 (see Radon Emanation Section below and Appendix G.2). Exposures outside the buildings were less than 1 mR/hr around Building 434 and around the southwest complex except one area on the fence around the accelators due north of Building 414 where exposures averaged slightly less than 4 mR/hr (see Table 4-2).

Contamination of Residue Storage Buildings

Three buildings in the southwest residue storage complex have minimum contamination and could probably be used for Site operations or be decontaminated and demolished with minimal decontamination. These are Buildings 409, 412, and 415 (see Appendix G, Figures G1-1, G1-5, and G1-6). The fire water reservoir, Building 409, contains detectable gamma, beta-gamma, and alpha radiation on the south wall, especially below 1 m, and on the south section of the floor (see Appendix G, Tables G1-3 and G1-4). Contamination is associated with water seepage through the south wall from the earthen berm surrounding the reservoir. Low-level contamination of soil south of Building 409 is the probable source of building contamination. No detectable radiation was found in Building 412 except three drums of residues which have now been removed to Building 411. The surge tank, Building 415, was found not to be contaminated. Sediments taken from beneath the surge tank did not contain significant concentrations of radionuclides. The concrete walls and wooden beams surrounding the surge tank were partially collapsed and were demolished during the fall of 1980.

Building 410 was found to be contaminated significantly in most rooms and areas. The presence of the Middlesex Sands on the second floor and their leachate on the floor below are the major causes of this contamination (see Appendix G, Figures G1-2 and G1-3). Contamination has also resulted from (1) prior storage and removal of drummed residues, (2) residue drums spilled and rusted in the canals of the east portion of the building, (3) leaching from a sealed pipe connection from Building

411, (4) contaminated sediments in canals and pipes, and (5) inadvertent tracking of contamination by humans and mammals.

Instrumental and smear measurements in Building 410 are given in Appendix G, Tables G1-5, G1-6. The most contaminated area not used for storage currently is Room 04 (see Appendix G, Figure G1-2), an area in which some K-65 residue drums were stored prior to storage in Building 434. Most contamination is present as dust and debris throughout the facility. Radiochemistry of selected water and sediment samples suggests that sediments should be treated as contaminated during remedial action activities since ^{226}Ra concentrations range from 30-110 pCi/g (see Appendix G, Table G1-7).

Buildings 411, 413, and 414 are highly contaminated due to presence of stored residues (see Appendix G, Table G1-8). The asphaltic emulsion treatment applied to the surfaces of the L-50 residues in Buildings 413 and 414 proved ineffective in reducing radon flux (see Appendix G.2). Wooden beams and roof materials should be regarded as contaminated waste during remedial action activities.

Instrument and smear surveys of Building 434 show a maximum reading at 30-34 m above the ground at a crack in the seal of the old catwalk door and lower loading port (see Appendix G, Table G1-9). Beta-gamma readings at the tower surface ranged from 0.2-30 mR/hr. Dose rates at the top of the tower ranged from 20-42 mR/hr (see Appendix G, Table G1-10). Random smears taken at the top of the tower showed levels 20-5,000 dpm/100 cm^2 of dominantly (70 percent) short-lived (<24 hrs half-life) alpha radiation from deposition of radon daughters from radon escaping from the port in the center of the top of the tower. The tower has been capped and sealed since these measurements were made. The thaw shed south of Building 434 was empty and only minimum contamination was found. Surface beta-gamma instrument readings did not exceed 0.5 mR/hr. No transferable beta-gamma or alpha radiation was found (see Appendix G, Table G1-9). The only contaminated area of the building was at the north end and where the conveyor belt delivered K-65 residue drums to the

the skip hoist. Non-transferable beta-gamma instrument readings were 5 mR/hr in this 3 x 3 m (10 x 10 ft) area. Alpha radiation was not significantly above background in any area of the structure. This building was demolished during the fall of 1980.

Radon and Particulate Daughters

Radon was measured using alpha scintillation methods (see Appendix B, QA Documents EE-SP-18, EE-SP-19, EE-SP-20, EE-SP-21, and NS-NS-115). Grab samples of radon concentrations in these buildings are summarized in Table 4-3.

TABLE 4-3. ^{222}RADON CONCENTRATIONS IN AIR IN BUILDING USED FOR PITCHBLENDE RESIDUE STORAGE

Building	Month	^{222}Rn (pCi/l) air[a]	Working Level[b]
410	Aug.-Oct. 1979	3-26	0.03-0.26
411	Aug.-Dec. 1979	900-2,400	9-24
412	Aug.-Nov. 1979	30-35	0.30-0.35
413	Aug.-Nov. 1979	1,800-8,075	18-80.6
414	Aug.-Nov. 1979	2,130-7,893	21.3-78.9
434	Sept.-Oct. 1979	4,000-117,000[c]	40.0-1170

(a) Raw data are given in Appendix G, Tables G1-11, G1-12, and G1-13.

(b) Working levels assuming short-lived radon daughters are in secular equilibrium (a working level is the amount of short-lived radon daughters necessary to emit 130,000 MeV/liter of air). This is the same quantity of energy as that delivered by the alpha particles from the complete decay of the radon progeny in secular equilibrium with 100 pCi of radon-222 in one liter of air.

(c) Taken under disc at top of tower (see Figure 4-3).

These data were taken prior to asphalt emulsion treatment of Buildings 413 and 414 residues. Following treatment, radon concentrations in air in these two accelators ranged from 286-588 pCi/l in December 1979 to 36,507 - 85,962 pCi/l in June 1980 (see Appendix G.2). The increased radon emanation in the summer of 1980 is possibly attributed to (1) emulsion rupture, (2) summer temperatures, and (3) increased temperatures in buildings doe to roof repairs.

Particulates in buildings provide significant airborne radiation. High volume samples of airborne particulate radiation showed alpha radiation levels 10^{-7} to 10^{-14} pCi/ml and beta-gamma levels of 10^{-6} to 10^{-13} pCi/ml in Buildings 409-414 (see Appendix G, Table G1-14 and Section G.2).

Connecting Pipes and Drains

Figure 4-2 shows connecting pipes in the southwest residue storage complex. Connecting pipes from all residue storage buildings are summarized in Table 4-4. Building 409 has connections both to the canal surrounding the surge tank, Building 415, and to the Central Drainage Ditch. However, no contamination was found in the drains of Building 409. Building 410 has an input pipe from the pressure reduction pit, the source of potable water from the Town of Lewiston. The valve was closed but water continually dripped at a slow rate from the pipe into a canal in the southeast corner of Building 410. It was resealed in the fall of 1980. A pipe connecting the west bay of Building 411 into the canal in the northeast room of Building 410 was steel plate sealed but leaked slowly into the canal until it was resealed during the fall of 1980. Contaminated sediments are apparent below the pipe in the canal (see Appendix G, Table G1-7) and a deposition pattern below the pipe is apparent. Finally, four pipes 0.8 m (30 in.) in diameter connect the Venturi vault at the extreme northeast wall of Building 410 with the Central Drainage Ditch. While these pipes are valved closed at the Central Drainage Ditch, some leakage into the ditch was occurring and pipes were sealed during the autumn of 1980.

TABLE 4-4. SUMMARY OF PIPES AND CONNECTIONS OF THE RESIDUE STORAGE BUILDINGS[a]

Building	Pipe/Connection	Condition
409	Drain to Central Drainage Ditch[b]	Functional
	Pipe from 410 canals at surge tanks[b]	Sealed at 409
410	Pipe from pressure reduction pit[b]	Sealed 1980
	4 drain pipes to Central Drainage Ditch[b]	Sealed 1980
	Connecting pipe from West Bay Building 411[b]	Sealed 1980
411	To Central Drainage Ditch[b]	Sealed 1980
412	Pipe to Building 410 canals[b]	Plate sealed, not contaminated
413	Pipe to Building 410 canals[b]	Plate sealed, not contaminated
414	Pipe to Building 410 canals[b]	Plate sealed, not contaminated
415 Canals	From 42-in. water line[c]	Severed near Pletcher Road by Lewiston
	To recarbonation pit[b]	Gated closed but leaking
	To aboveground reservoir[c]	Functional but no transport occurring
Recarbonation Pit	To Central Drainage Ditch[b]	Sealed 1980
434	Pipes to water distribution system[b]	Severed

(a) See Figure 4-2.

(b) On-site.

(c) Off-site.

The original pipes from the three accelators (Buildings 412-414) have been sealed by attachment of steel plates at the bottom of the accelators and have no contamination on the exterior of the plates. The canals originally joining the accelators have three other potential drainages or connections: first, a 42-in. water line originally designed to bring water from the Niagara River joins the canal system south of Building 412. This water line is not functional and was severed by the Town of Lewiston near Pletcher Road (personal communication, Calvin Shultz, City Engineer, summer 1979); second, a pipe connecting the canals to the recarbonation pit west of Building 410; third, a pipe originally connecting the canal area west to the aboveground reservoir, not on the current Site and not in use. This pipe is not gravity fed, would require pumping to reach the reservoir, and is not contaminated to levels requiring remedial action (see report of the drainage from the Site, Chapter 6).

Water to Building 434 was originally supplied through a pumphouse and underground pipes which have been severed. Currently the tower is not connected to any pipes or ditches. The pumphouse pipe stubs and belowground piping as determined by manhole sediment samples, were not significantly contaminated.

Discussion

Among the residue storage buildings, external exposures are greatest (slightly less than 4 mR/hr) due north of Building 414 within the exclusion fence. At ground level around Building 434, the tower used for storage of the K-65 residues, gamma/X-ray exposures were less than 1 mR/hr as measured using TLD's during winter and using beta-gamma and gamma survey meters during summer and fall (see Chapter 5 and Appendix H).

Several buildings have minimal contamination and could be reused with minor remedial actions or demolished. These include the fire water reservoir (Building 409), the surge tank (Building 415), and the most southerly accelator (Building 412). The thaw shed (Building 434a)

attached to Building 434 was only slightly contaminated but was demolished during the fall of 1980.

Radon concentrations in the storage buildings decreases in order: Building 434 > Buildings 413-414 > Building 411 > Building 410. Release from Building 434 occurs at 49 m in the air and from Buildings 410-414 at ground level. Since the Site characterization was completed, the tower has been sealed with a metal cap and should not significantly contribute to radon released from the Site. The buildings in the southwest portion of the Site lie within 30 m of the west boundary of the Site and contribute to the radon measured at the fence line (see Appendix A.4 for a brief summary of radon monitoring data and Chapter 7 for hazard assessment of radon and airborne particulate radiation associated with residue storage).

There are no connections between Building 434 and any other pipes or structures. The southwest complex has three discharge points to the Central Drainage Ditch which were not totally sealed during the characterization. These were sealed during the autumn of 1980. There are no current discharges from this complex off-site through the original 42 in. intake water line or to the aboveground storage reservoir just to the west of the current Site boundary.

The southwest building complex contains and continually receives water by surface drainage and by precipitation leaking into the buildings. Approximately 2,940 cu m (105,000 cu ft) of water cover portions of the residues stored in Building 411. The water has accumulated in the building from precipitation prior to roof repairs and from seepage from the recarbonation pit. Building 410 is also the recipient of water from runoff and precipitation. The canals within the building contain water and flow to the east slowly until the pipes to the Central Drainage Ditch were sealed during the autumn of 1980. While seepage from the recarbonation pit is occurring, this source cannot account for the volume of water in the canals. Following rainfall, volumes of water in canals and water flow are increased. It is hypothesized that ingress of surface runoff is occurring. Work performed severing and sealing the several pipes around Building 410 has decreased the amount of water in these

canals significantly. As detailed in Chapter 6, this area of the Site has large shallow saturated zones. Whether ingress from one or more of these zones is occurring could not be positively established.

Presence of large water volumes in Buildings 410 and 411 and the recarbonation pit will affect remedial actions selected for these buildings and stored residues. These waters are contaminated and turbulence caused by mixing sediments and/or residues with overlying water will require treatment provisions. Removal of water from the canals in Building 410 may be complicated if shallow saturated zones contribute significantly to water sources. Finally, covering the recarbonation pit in the fall of 1980 may decrease somewhat the volume of water to be managed within Buildings 410 and 411.

A problem identified during characterization of these buildings was access to contaminated areas and stored residues, especially in Buildings 410 and 411. As shown in Appendix G (Figures G1-2 through G1-4) only a 7.6 x 7.6 m (25 x 25 ft) clearance is available between horizontal cross beams in Building 411. Vertical access without removing sections of the roof is difficult. Access to canals in Building 410 is extremely limited (see Appendix G, Figure G1-3); a good portion of the west to east canal distance is under a concrete floor.

Finally, the interior configuration of Building 434 remains unverified. Design drawings show the tower in two sections with a catwalk around the lease of the upper portion. A U.S. government memo (to Files from Dexter Neil, July 28, 1959) reports that the bottom section of the tower received 2,725 tons of residue, the upper sections 1,166 tons. While Neil reports the tower was filled in two stages, workers interviewed during the characterization project maintain the tower was only in one section, was filled only from the loading port at the top, and the catwalk door was sealed after filling. Based on external radiation readings, it seems that both sections contain residues and that the government's documentation of the storage is accurate. Without horizontal coring of the tower at several heights, it is not possible to determine whether any

heterogeneity in the residue will impact remedial actions. For the purpose of residue characterization, inventory records and samples taken near the bottom of the tower by the Site Manager, Mr. J. P. Kirchue, were used.

4.2.2. Nonresidue Storage Buildings, Structures, and Foundations

Buildings

Evaluation of the survey results was based on acceptable surface contamination levels of 5,000 dpm/100 cm^2 alpha for average detectable and 1,000 dpm/100 cm^2 for removable alpha and beta-gamma radiation. These levels are those suggested by the U.S. NRC in Regulatory Guide 1.86, June 1974, "Termination of Operating Licenses for Nuclear Reactors", accepted by NRC, and correspond to those levels listed in the specifications for this program. Specifications also established 0.2 mR/hr at 1 cm beta-gamma as the maximum acceptable instrumentally measured limit for unrestricted use of the building. There are no definitive regulatory criteria applicable to building surfaces for the individual primary isotopes of interest (uranium, ^{226}Ra, and ^{210}Pb) on this Site. While none of the buildings, structures, or foundations listed in Table 4-5 exceed the guidelines listed above, several contain appreciable areas contaminated below these values but above background. These areas are specified in Appendix G (see Tables G3-1 through G3-25). Levels of alpha <95 dpm/100 cm^2 and of <0.2 mR/hr beta-gamma were used to define buildings and structures minimally contaminated for remedial action purposes.

Table 4-5 lists buildings as uncontaminated or contaminated based on the criteria stated above. In no building or structure was there a level of removable (smear removed) contamination above specified limits. The boron building annex (401A), dispensary (402), guardhouse (416), process cell and annex (405 and 405A), carpenter shop (406), ether building (404), and maintenance shop (407) contained no surfaces in excess of

TABLE 4-5. LISTING OF NONRESIDUE STORAGE BUILDINGS WITHIN UNCONTAMINATED AND CONTAMINATED CLASSES ON THE DOE-NIAGARA FALLS STORAGE SITE

Uncontamined/Minimally Contaminated	Contaminated[a]
401[b]	403
401A[c]	423
402[c]	430
404[d]	
405[d]	
405A[d]	
406[d]	
407[d]	
416[c]	
431	
433	
434[d]	

(a) Criteria used for classification as contaminated were: >0.2 mR/hr beta-gamma at 1 cm; surface contamination levels 5,000 dpm/100 cm^2 alpha, 1,000 dpm/100 cm^2 removable alpha and beta-gamma contamination.

(b) Only one area of contamination exists.

(c) No contamination above background levels.

(d) Building has been removed during Site renovation activities during autumn 1980.

standards although dust on windowsills and doorways contained detectable contamination, however, not above limits. The ancillary buildings to Building 401 (including Buildings 404, 405, 405A, 406, and 407) were demolished during the autumn of 1980.

The firehouse building (403) small warehouse building (423), and large warehouse building (430) had beta-gamma levels in excess of 0.2 mR/hr for instrumental detection. Areas of contamination for each building were: (1) firehouse (403), the top of the sink in Room 01 (0.40 mR/hr), and one area in the attic (1.0 mR/hr); (2) small warehouse (423), east wall 44 percent of 1 meter square areas greater than 0.2 mR/hr (ranged from 0.2-0.6 mR/hr), ceiling 12 percent of 1 meter square areas (0.2 mR/hr), and the large office roof 25 percent of 1 meter square areas averaging 1.5 mR/hr; (3) large warehouse (430), 3 percent of floor grids exceeded 0.2 mR/hr level (ranged from 0.3-8.00 mR/hr) (see Appendix G.3).

With one exception, no areas of alpha or beta-gamma contamination were found to exist in the boron isotope building (Building 401) above the permissible levels of 5,000 dpm/100 cm^2 detectable and 1,000 dpm/100 cm^2 removable alpha and 0.2 mR/hr detectable and 1,000 dpm/100 cm^2 removable beta-gamma radiation. The one exception, a ceiling beam in the northeast room of the boron isotope building (401), had a beta-gamma contamination average between 1.0 and 5.0 mR/hr. The contamination was not removable using smears. No other surfaces were found to be above standards and very few above background levels (see Appendix G.3).

A detailed listing of all data, both instrumental and smear, obtained for the buildings discussed is found in Appendix G, Tables G3-1 through G3-25. Figures of each building identifying room numbers precede the data summaries for each building, room, surface, and grid coordinates as detailed in the procedure in Appendix B, QA Document EE-SP-2.

Structures and Foundations

The northwest section of the Site contained only two concrete pad type foundations (1.25 x 1.25 m or 5 x 5 ft). Other structures in

this quadrant were wooden. These concrete pads were surveyed extensively because of the ^{137}Cs contamination in soils in the immediate area. Based on the beta-gamma instrument survey, these pads are surrounded by contaminated soil (see Chapter 5). The pads were meter surveyed and smears were taken at random. Beta-gamma readings ranged from 3-20 mR/hr. The surface radiation levels were appreciable but not transferable since smears showed only minimal contamination (see Appendix G, Table G3-25). Probably some "shine" from the soil deposits south and east of the south pad was experienced in surveying the sides of the pads. Based on the soil data, the dominant isotope is ^{137}Cs. In this area, there are large numbers of broken drain tiles and gravel. These materials are uncontaminated to slightly contaminated.

The northeast portion of the Site contains numerous foundations and supports. The large number of tank supports located near O Street and between N and O streets are uncontaminated (no meter or smear readings above background). The concrete pad north of the north vault (Building 431) has 1 to 2 mR/hr beta-gamma levels, none of it transferable. The north vault is uncontaminated, but the south vault floor has 0.5-0.75 mR/hr beta-gamma. This contamination is primarily on dust since beta-gamma smear measurements ranged from 200-250 dpm/100 cm^2. The small building near the New Naval work area which is called the radium storage vault (Building 433) is also uncontaminated (see Chapter 1, Figure 1-2).

The southwest portion of the Site contains only the concrete pads at the south-central Site border which supported the change house during Department of Army operations. These are uncontaminated.

The southeast portion of the Site contains several concrete pads. The remains of the cooling tower north of Building 401 were uncontaminated. The pads south of Building 430 are uncontaminated. The pads located near Castle Garden Road were surveyed at 1-1.5 mR/hr beta-gamma over the surface. No significant transferable contamination was found on the random smears taken. The pad east of the maintenance shop (Building 407) was surveyed at 0.75-1 mR/hr beta-gamma over the surface. No significant transferable contamination was found. The pad south of the process cell (Building 405)

was surveyed at approximately 1 mR/hr beta-gamma over the surface. Again, no transferable contamination was found.

Manholes near the firehouse and in the southwest, northwest, and northeast quadrants showed no contamination in the interiors or on valves by smear or meter survey techniques. Sediments taken from these manholes showed no significant radionuclide contamination.

CHAPTER 5: CHARACTERIZATION OF CONTAMINATED AREAS

5.1. INTRODUCTION

The DOE-Niagara Falls Storage Site was extensively investigated in order to identify and quantify contaminated areas. The purpose of this portion of the characterization was to acquire data in order to allow accurate estimation of volumes of soils and residues in excess of suggested guideline limits and to allow radiological and chemical hazards assessment.

5.1.1. Approach

The approach taken in the characterization of contaminated areas was to identify areas based on aerial surveys (EG&G, 1972, 1979), examine historical documents within Site and Oak Ridge Operations (ORO) files, and perform a thorough survey of the Site. A surface grid of 15 x 15 m (50 x 50 ft) was established throughout the Site for the 1 m gamma instrumental survey and the 1 cm beta-gamma survey above ground surface.

Areas identified as contaminated were then characterized as necessary to determine the nature and extent of contamination. Background values were established for measured parameters (see Appendix H, Table H1-1). Evaluations included: (1) screening analysis and alpha/gamma spectroscopy of surface soils and soil cores taken by continuous coring/split-spoon sampling, (2) vegetation sampling and analysis, (3) selected animal sampling and analysis, (4) selected soil analysis for metals and rare earths, and (5) determination of radon emanation rates and air concentrations of radon and suspended particulates.

Data available from the characterization were used for estimation of the volumes of contaminated material by area exceeding permissible levels. Data also allow prioritization for remedial actions among the

several contaminated areas. Finally, quantifying both radiological and nonradiological contaminants provided a basis for evaluation of hazards associated with both the current conditions and remedial action alternatives.

5.1.2. Materials and Methods

All environmental radiological surveys were based on the 15 m x 15 m (50 ft x 50 ft) grid pattern covering the 77-hectare (190-acre) DOE-Niagara Falls Storage Site. The grid was established with its origin at the intersection of Campbell and O streets with its "X" axis on O Street and its "Y" axis on Campbell Street (Figure 5-1). Each location on the grid can, therefore, be defined by its "X,Y" coordinates which are based on an alpha-numeric system of direction and distance. For example, N10E20 corresponds to a location 10 grid points north or 150 m (500 ft) and 20 grid points or 300 m (1,000 ft) east of the origin at the intersection of Campbell and O streets. With this system, any point on the Site can be located for the surveys and, through permanent markers, located at any point in the future.

A cursory survey was performed prior to the establishment of the grid to identify and delineate areas where elevated radiation levels had been previously detected by aerial radiological surveys. This allowed delineation of areas for intensive surveying and boundaries for specified health physics procedures. Transects were sighted and marked for the grid pattern using standard surveying techniques. When vegetation was impenetrable on foot or prevented sighting, land was cleared by using bulldozers, chain saws, axes, and similar appropriate means. Complete protocols controlling the creation of the grid pattern are described in Appendix B, QA Document EE-SP-3.

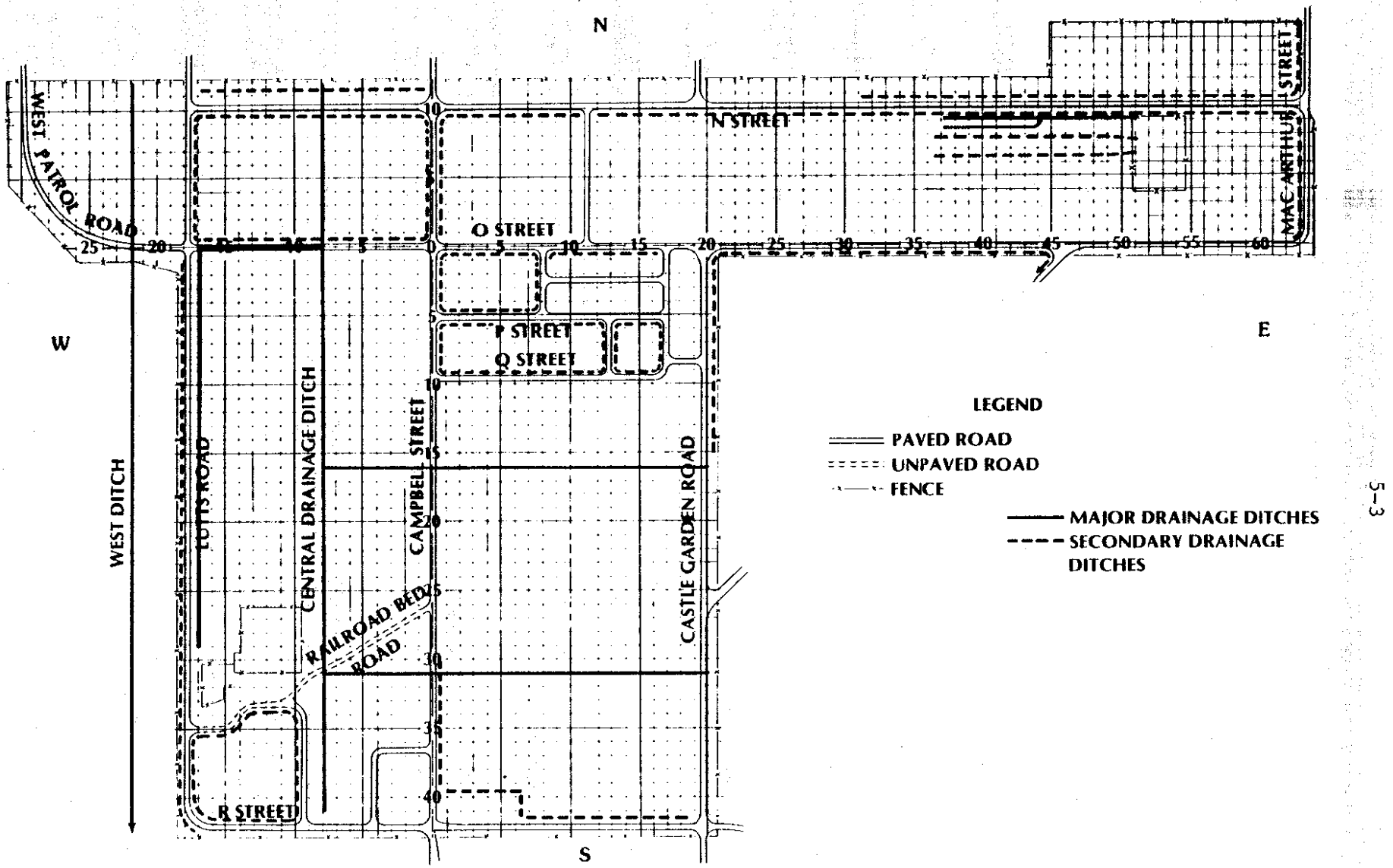

FIGURE 5-1. DOE-NIAGARA FALLS STORAGE SITE MAP SHOWING 15 x 15 METER (50 x 50 FT) GRID AND MAJOR FEATURES

Instrumental Survey

Two radiological readings were taken at each grid point. Gamma radiation at 1 m from the surface and beta-gamma at 1 cm from the surface were taken using a low-level gamma microR meter and a beta-gamma Geiger counter. Data were recorded on approved data collection forms. Grid point stakes where readings were found in excess of 0.2 mR/hr were flagged with yellow tape. Complete, detailed procedures describing the methods employed in performing the radiological surveys are presented in Appendix B, QA Document EE-SP-4.

Thermoluminescent Dosimeters (TLD's)

TLD's were placed on grid markers, stakes, or other materials at an average height of 1 m as an additional method of exposure characterization. Detailed procedures and explanation of controls are given in Appendix B, QA Documents EE-SP-17. TLD's were read after an approximate 30-day exposure; calculations were made to the nearest 4-hr period. The TLD's were read on an automated TLD reader. Averages of two chips/badges were used to calculate μR/hr exposure. On-site badges were located in all four quadrants, in and around residue storage buildings in the southwest quadrant. Off-site badges were located at the mouths of Fourmile and Six-mile creeks, at Ft. Niagara, and along streets north, south, east, and west of the Site. Additional TLD's were placed on the Niagara Mohawk power line to the west and additional transects to the west, due east, and south of the Site (see Appendix H, Figures H3-17 and H3-18).

Soil Sampling

After the radiological survey was completed in an area, surface soil samples were taken at each grid point location. In areas where levels were found by the instrumental surveys to be significantly greater than

background, samples were taken at intersections of a 7.5 m (25 ft) grid. Surface soil sample size was approximately 500 g (1 lb) of the top 5 cm (2 in.) soil.

Additional soil sampling was conducted in areas of known contamination using a 5 cm (2 in.) diameter hand auger. These cores were taken to 0.3-0.6 m (1- to 2-ft) in depth to indicate the extent of contamination. All soil samples were placed in polyethylene bags prenumbered with the grid point location and sealed. Samples, taken at locations where surface radiological readings were higher than background, were tied with yellow tape. Decontamination of sampling equipment was performed between each sample collection. Bagged samples were stored in 3.79 liter (1-gal) metal cans marked with the sample number and archived. Complete, detailed methods controlling soil sampling appear in Appendix B, QA Document EE-SP-16.

Selected soil samples were screened for gross radioactivity using a Beckman Wide-Beta II. Methods employed in these analyses appear in Appendix B, QA Document NS-NS-118.

Selected soil samples were also characterized for radionuclides using gamma-alpha spectroscopy at BCL. Complete sample handling and preparation techniques and instrumentation employed in these analyses are described in Appendix B, QA Documents NS-NS-115 and NS-NS-116, respectively.

Soil Core Sampling and Analysis

All test cores were located on or near the established grid and labelled according to location. The establishment of 24 perimeter test cores (see Appendix H, Figure H2-1) provided data for an initial evaluation of off-site subsurface migration of contamination. Perimeter areas adjacent to the major disposal sites--the spoil pile, New Naval Waste Area, and northwest area--were felt to be the most probable areas of migration and therefore were more intensely studied than the remainder of the Site perimeter. In on-site contaminated areas, test cores provided sufficient samples for characterization of the depth and composition to which contamination has migrated.

Core sampling was conducted in test areas by continuous split-spoon sampling with truck- and trailer-mounted drill rigs. In areas shown by the surface instrumental survey to be significantly above background, the test coring activities began within the area at the edge of the contamination and moved into areas of higher activity. This approach in the major contaminated areas supplied sufficient samples for the three-dimensional characterization of contamination.

Depth of coring was based primarily on (1) the occurrence of field detectable levels of contamination above background and (2) the presence of sand and gravel layers, potential sites for rapid lateral migration and groundwater influx of nuclides. Coring proceeded through these areas and 1.2-2m (4-6 ft) into clay layers below. Coring ceased at the depth that screening analyses did not discriminate radioactivity levels from background levels.

For coring activities, procedures called for field assessment of contamination by both meter and smear techniques (see Appendix B, QA Document EE-SP-11). Accurate meter detection of the presence of contamination was problematic because (1) in contaminated areas background levels were elevated sufficiently to prevent the detection of uncontaminated test core samples and (2) the samples were often wet and the additional water introduced during coring activities created some shielding, preventing accurate measurements. Analysis of activity using core smears was somewhat more refined than meter analysis. However, when compared to activity levels determined by radiochemical analysis, smear data were determined to be a poor assessment of contamination. This was probably caused by the arbitrary nature of smearing and the heterogeneity of radionuclides within a sample. Therefore, good correlation between activity levels and depth within the soil profile relies on full radiochemical analysis by gamma and alpha spectroscopy. However, field techniques had to be relied upon during test coring activities, and with few exceptions, were sufficient to ensure that test cores were extended below contaminated zones.

Perimeter cores were sampled to either bedrock or 1.2-2 m (4-6 ft) into hard dry clay below the last occurrence of sand and gravel. Cores in these locations ranged from 7.5-14 m (25 to 45 ft) in depth. A detailed discussion of sample acquisition, contamination control procedures, and field determination of contamination levels is found in Appendix B, QA Document EE-SP-11.

Biota

Vegetation samples were taken simultaneously with surface soil samples. Baseline samples were collected at every 15th location in areas of background surface radioactivity levels determined by the instrumental surveys. The remainder of the samples were taken at every grid coordinate determined to be at greater than background levels. Living, soft-stemmed plant material was clipped at surface excluding soil and roots from the sample. Samples were placed in pre-numbered brown paper bags to assure air-drying of the samples and to prevent decay. Decontamination of sampling equipment was employed between the collection of samples from contamination areas. Complete, detailed sampled procedures are described in Appendix B, QA Document EE-SP-5. Radiochemistry methods are detailed in Appendix B, QA Documents NS-NS-115 and NS-NS-117.

Resident mammals, reptiles, and amphibians were collected on the Site in order to determine the distribution and concentration in terrestrial food chains, if any, of radiological and nonradiological contaminants. Collection techniques were designed to obtain animals at various trophic levels and to collect specimens in Site areas considered to have the greatest and least (control) potential for animal uptake of radionuclides.

Three areas on the Site were selected for trapping and collection of animals. Two of the areas were selected based on the surface radiological surveys which indicated levels having a potential for animal uptake of radioactive material; the third area was considered a control due to the background levels of radioactivity observed during surface surveys.

One animal collection area included the spoil pile and R-10 residue storage area, Buildings 410 through 414, and the area immediately surrounding these five buildings. A second was the New Naval Waste Area. The background collection area was the extreme southeast portion of the Site. While the northwest area of the Site was considered, the area was too small to allow meaningful sampling of vertebrates since their home ranges are very large compared to the size of the contaminated area.

Radon and Radon Daughters

Since August 30, 1978, radon concentrations in air have been monitored on- and off-site using both charcoal canisters and TLD's under a separate program sponsored by DOE's Assistant Secretary for Environment. Monitoring locations currently include 11 locations on-site, 9 along the perimeter fence, 1 on O Street, and 1 near Building 401. Off-site, several monitoring locations are also maintained. The only locations exceeding the 3 pCi/l level established as a limit by the State of New York are on the perimeter at the southwest portion of the Site. Monitors in this area have recorded radon concentrations ranging from 0.05-23 pCi/l (charcoal system) and 3-10 pCi/l (TLD system). No off-site stations have exceeded 3 pCi/l during any collection period to date (see Appendix A.4).

Radon measurements are usually expressed in an activity level (e.g., pCi/l), flux (e.g., $pCi/m^2/sec$), or as working levels (e.g., 0.003). A working level is any combination of short-lived radon daughters in 1 liter of air that will result in the ultimate emission of 1.3×10^5 MeV of particulate alpha energy. This unit, the working level, is generally used as an index of radon within confined spaces such as buildings or uranium mines. This unit is less appropriate in unconfined areas (e.g., residues stored on the surface of the ground). Therefore environmental measurements will be reported as concentrations (pCi/l) or fluxes ($pCi/m^2/sec$).

Potential hazards from pitchblende residues are primarily associated with exposure to radon gas and particulate radon daughters. The half-life of radon is 3.82 days, while the half lives of primary radon

daughters are in terms of seconds to days. During the characterization of the Site, an attempt was made to characterize gaseous and airborne particulate radiation. Both gaseous and airborne particulate radiation varied over the survey period with changing temperature and moisture conditions. Based on the annual monitoring data collected at the Site, it is possible that the concentrations of radon and its daughters measured in the late summer during the initial Site characterization were the maximum levels for the year.

Using a variety of techniques, radon and airborne particulate radiation was measured in several portions of the Site. Areas evaluated include: (1) the vicinity of Building 434, (2) the southeast corner of the Site near the intersection of R Street and Castle Garden Road, (3) the New Naval Waste Area in the north-central portion of the Site between N and O streets, (4) the northwest quadrant of the Site between the West Ditch and West Patrol Road, and (5) the southwest quadrant of the Site, intensively in the R-10 residue storage and spoil pile area north of Building 411.

A secondary objective of the radon evaluation was to determine the relative heterogeneity of ^{222}Rn concentrations in the air above the soil surface. The surface radiological survey showed that points 25 or 50 ft apart could differ from each other in beta-gamma levels by a factor of 100. Such heterogeneity makes determining dose isoclines almost impossible and makes quantifying radon concentrations from the R-10 residue storage area difficult. Finally, it was hoped that adequate determination of ^{222}Rn and airborne particulate radiation in the vicinity of the R-10 residue storage area and the spoil pile would allow interim radon emanation reduction methods to be designed.

Several ^{222}Rn and airborne particulate radiation measurement techniques were used, including both passive and flow-through monitors. Data were obtained using instantaneous and time-integrated methods. Finally, air at the soil surface ^{222}Rn concentrations, calculated soil ^{222}Rn flux and atmospheric concentrations of ^{222}Rn were compared.

Two types of ^{222}Rn detectors were used. These were (1) Track-Etch® films (Terradex Corporation) and (2) a gas scintillation detector (Randam Corporation). The Track-Etch® detectors were used as radon cups on the surface of the soil. The radon cups were then left in place for 30 days. Following removal, cups were shipped to Terradex Corporation for interpretation. For detailed methods, refer to Appendix B, QA Document EE-SP-21. The number of tracks etched by ^{222}Rn was then calculated as pCi/l based on the calibration of the cups performed by DOE's Environmental Measurement Laboratory (EML) in New York. The gas scintillation detector was used with grab gas samples (see Appendix B, QA Document NS-NS-113) of air at the soil surface taken with a gas scintillation vial coupled to a 15 cm sampling device (see Appendix B, QA Document EE-SP-19). Flow-through ^{222}Rn concentration techniques (see Appendix B, QA Document EE-SP-18) were also used for determining concentrations.

Specifications for all instruments utilized for surveys are found in Appendix E. A listing of all samples archived on the Niagara Falls Storage Site is found in Appendix D with an explanation of the methods used to archive project data at Battelle's Columbus Laboratories.

5.2. IDENTIFICATION OF CONTAMINATED AREAS

5.2.1. Criteria

Records of the Site indicated that all radiologically contaminated materials not stored within buildings, including R-10 pitchblende residues, were stored on the surface of the ground or committed to shallow burial. For this reason, contaminated areas were identified based on 1 cm beta-gamma instrumental surveys on the 15 m x 15 m grid. Gamma instrumental surveys at 1 m were not used for identification of contaminated areas because of the "shine" (detected gamma irradiation attributable to a source other than from the surface of the soil at sampling location) from the residue storage buildings. These tentative identifications were then verified using analytical screening methods. Following identification, contaminated areas were characterized to determine the nature and extent of the contamination. The periphery of the Site was evaluated versus off-site or background conditions (see Appendix H.2).

5.2.2. Location

Figure 5-2 locates the nine contaminated areas identified within the Site. Smaller (<1 m^2) areas above background are indicated in quadrant maps reporting beta-gamma instrumental survey results (see Appendix H.3, Figs H3-1 through H3-16). Areas which were above background in instrumental readings (both beta-gamma and gamma readings) but resulted from "shine" from storage buildings are within areas indicated in these data presented in Appendix H (see Tables H3-1 through H3-4).

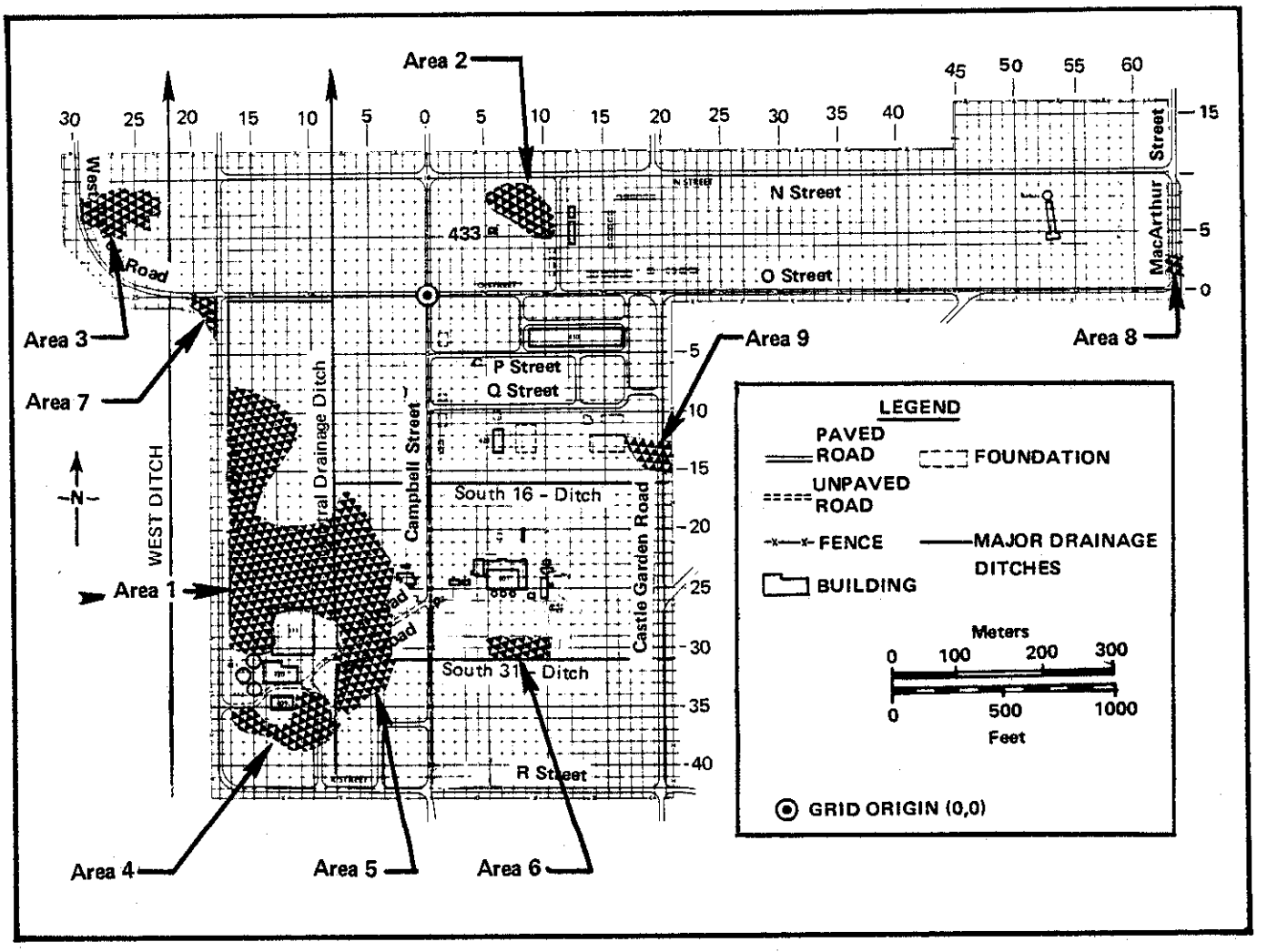

FIGURE 5-2. MAP OF CONTAMINATED AREAS OF THE DOE-NIAGARA FALLS STORAGE SITE

Area 1

Area 1 is the R-10 residue storage area, part of which is overlain by the 11,475 m^3 (15,000 yds^3) low-level spoils created from off-site decontamination activities in 1972. Surface beta-gamma readings (1 cm) in this area ranged from background (0.06 mR/hr) to 4 mR/hr (see Appendix H, Figures H3-1 and H3-2). The area containing residues, spoils, or contaminated soils covers approximately 31,350 m^2 (37,500 yds^2). The area has been fairly unstable, eroding east to the Central Drainage Ditch and eroding west onto the area west of the Site and into the West Ditch. Also, this area is underlain by one or more saturated zones, creating the potential for subsurface migration to off-site areas (see Chapter 6).

Area 2

Area 2 is the New Naval Waste Area in the north-central portion of the Site. The area derives its designation from labelled maps in the Site archives which identify this area as contaminated with naval wastes. Surface beta-gamma readings (1 cm) in this area ranged from 0.2 to 4 mR/hr (see Appendix H, Figures H3-3 and H3-4). The area contains significant volumes of construction wastes, concrete blocks, and wood debris. The area contained 20 residue drums in 1965 (see Appendix F, Table F-1) but only one drum (with beta-gamma readings >50 mR/hr) remained at the time of the characterization. The contaminated area is approximately 4950 m^2 (50,000 ft^2).

Area 3

Area 3 is a small area between West Patrol and Lutts roads slightly south of the north perimeter of the Site. Surface beta-gamma readings (1 cm) ranged up to 70 mR/hr in very small areas near two small concrete pads. On the grid points, beta-gamma readings ranged from background to 2 mR/hr in the area (see Appendix H, Figures H3-5 and H3-6).

Area 4

Area 4 is south and southeast of Building 409, east of Lutts Road. Contamination includes broken crucibles, saw blades, and other metallurgical scrap left from 1950 storage on the surface. Surface beta-gamma readings (1 cm) range from 0.1 to 0.65 mR/hr (see Appendix H, Figures H3-7 and H3-8). The area is approximately 334 m^2 (3600 ft^2).

Area 5

Area 5 is east of the Central Drainage Ditch and west of Campbell Street. Superficial contamination is spotty through this area, often located near the old railroad bed (now a gravel road). Surface beta-gamma readings (1 cm) range from 0.1 to 0.5 mR/hr (see Appendix H, Figures H3-9 and H3-10). The area is approximately 2940 m^2 (29,700 ft^2).

Area 6

Area 6 is the slurry pond fill south of Building 401. This area was used as a slurry pond during Boron-10 isotope separations and was cleaned and filled after operations ceased. Beta-gamma readings (1 cm) ranged from 0.2 to 2 mR/hr (see Appendix H, Figures H3-11 and H3-12). The area is approximately 2,090 m^2 (22,500 ft^2).

Area 7

Area 7 is a small area on the southwest corner of the Intersection of West Patrol Road and Lutts Road. Beta-gamma readings (1 cm) ranged from 1 to 2 mR/hr (see Appendix H, Figures H3-1 and H3-2). The area is approximately 743 m^2 (7500 ft^2).

Area 8

Area 8 is a 2 m^2 (2 yds^2) area east of MacArthur Street at the northeast Site boundary (see Appendix H, Table H3-2). Beta-gamma readings averaged 8 mR/hr at 1 cm.

Area 9

Area 9 is near the old railroad bed west of Castle Garden Road. Beta-gamma readings in this area ranged from background to 8 mR/hr (see Appendix H, Figures H3-13 and H3-14). The area is approximately 8 m^2 (90 ft^2).

5.2.3. Discussion

Other areas showed elevated beta-gamma readings at 1 cm above the soil surface but were found not to have significant radiological contamination. The largest of these is the area surrounding Building 434 (see Appendix H, Figures H3-15 and H3-16). While instrumental surveys suggested potential soil contamination, none was found above background (see Appendix H, Tables H3-1 through H3-8). Thermoluminescent dosimeters (TLD's) were used to verify 1 m gamma exposure levels on-site (see Appendix H, Table H3-9). Off-site TLD's (locations given in Appendix H, Figures H3-17 and H3-18) were used to establish background levels in the Niagara Frontier (see Appendix H, Table H3-10).

5.3. CHARACTERIZATION OF SITE PERIPHERY

The perimeter of the DOE-Niagara Falls Storate Site is adjacent to a hazardous waste landfill, sanitary landfill, power company right-of-way, and state-used property. The Site perimeter, therefore, is not directly adjacent to residences or other often-used public lands.

Figure 5-3 shows those portions of the periphery of the Site which exceed gamma (1 m) and/or beta-gamma (1 cm) background instrument readings. The two areas are (1) near Building 434 storing K-65 residues and (2) near the southwest storage complex (Buildings 411, 413, 414, and R-10 residue storage area) (see Appendix H.2 and H.3).

Perimeter core drillings see (Appendix H, Figure H2-1) were used to determine background concentrations of naturally-occurring isotopes (see Appendix H, Tables H2-1 and H2-2). Figure H2-2 shows the distribution of ^{226}Ra in soil profiles; Figure H2-3 shows the ^{210}Pb distribution in soil profiles. Only surface contamination was found at the Site perimeter.

Water taken from saturated zones in north and west perimeter wells showed no uranium, radium, nor metals above drinking water guidelines (see Appendix I, Tables I-17 through I-23; also see Chapter 6 for further discussion).

Contaminated areas close to the fence line include: Area 1, R-10 residue storage and spoil pile area, area 8 east of MacArthur Street and Area 9 near Castle Garden Road (see Section 5.2). Soil contamination at the perimeters and beyond was found off-site, west of Lutts Road, and near the R-10 residue storage and spoil pile area. Soil samples taken west of the fence to the West Ditch were composited for screening. ^{226}Ra ranged from background to 85 pCi/g in these composites suggesting past erosion from the R-10 area (see Appendix H, Table H2-3). The 1971 survey of the original LOOW also identified this area (designated W) as slightly contaminated (ORNL, 1971).

Radon concentrations in air near the soil surface at the west perimeter of the Site near the R-10 residue storage and spoil pile area exceeded background levels (see Appendix H, Tables H2-4 through H2-7). Routine monitoring of the Site perimeter has shown this area to be consistently above the 3 pCi/l radon limit for unrestricted access (Humphrey, 1980; see Appendix A.4).

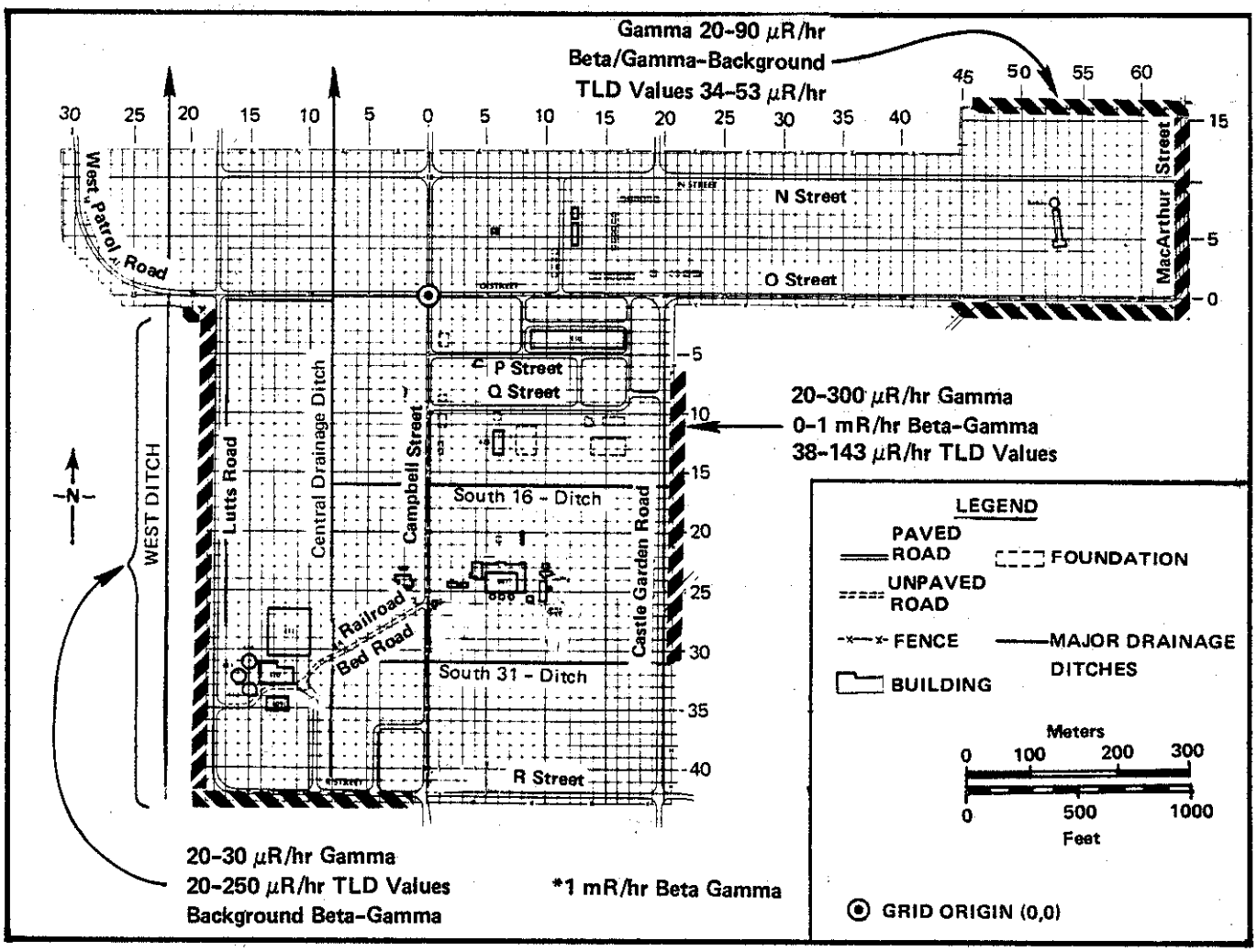

FIGURE 5-3. PERIPHERY AREAS OF THE SITE WHICH EXCEED BACKGROUND INSTRUMENTAL (1 M GAMMA, 1 CM BETA-GAMMA) READINGS

5.4. CHARACTERIZATION OF THE NINE CONTAMINATED AREAS

5.4.1. Area 1: R-10 Residue Storage and Spoil Pile

The R-10 residue storage and spoil pile area is the major contaminated area within the Site. It consists of the surface-stored (at 97.6 m or 320 ft above sea level) R-10 residues, the contaminated soil profile beneath, and an 11,475 m^3 (15,000 yds^3) spoil pile covering less than a third of the total contaminated area, increasing the topographic relief to 328-330 ft (100-100.6 m) in that area (Figure 5-4). The area is bounded on the east by the Central Drainage Ditch and on the west by Lutts Road.

Radiological and nonradiological characteristics of the R-10 residue storage and spoil pile area are summarized in Table 5-1. Both the uranium decay chains (235 and 238), including radium, radon and radon daughters, and metal contaminants, are significant and will require consideration before remedial action is undertaken because of their implications for occupational risk and ultimate waste disposal.

Radiological Characteristics

Area 1 can be characterized as (1) radiologically and chemically heterogeneous, (2) the major source of radon emanation and off-site sediment contamination, and (3) the largest volume of low specific activity waste which may have to be stabilized, immobilized, or ultimately placed in a disposal area under proposed EPA guidelines (see Appendix H.4).

Surface characteristics of the R-10 residue storage and spoil pile area were summarized for the three primary radiological species of interest: uranium, radium, and radon. Figure 5-5 diagrammatically shows the concentration of uranium in surface soils north of Building 411 (see Appendix H, Table H4-1 and H4-2). Maximum concentrations were

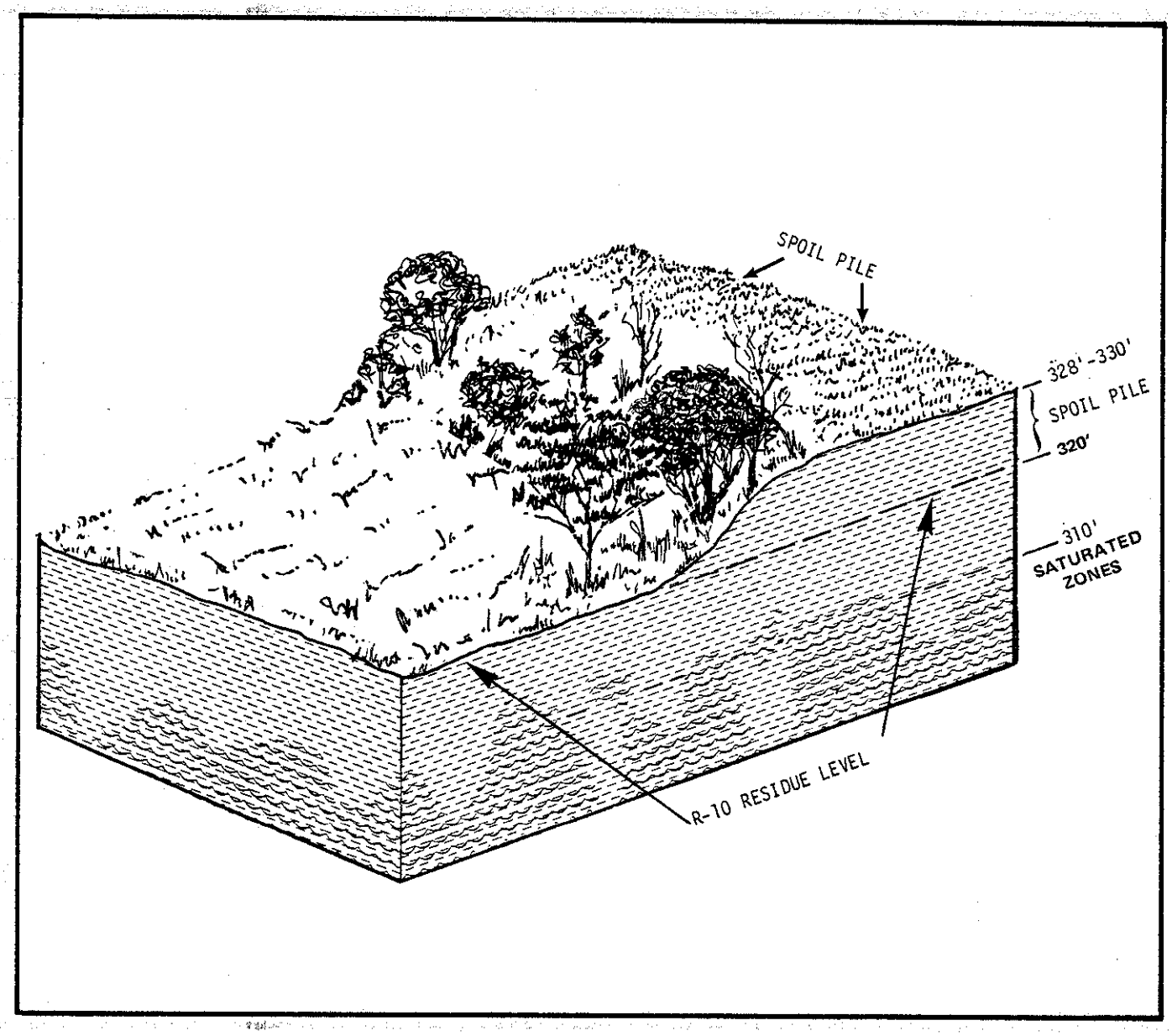

FIGURE 5-4. CUTAWAY DIAGRAM OF THE R-10 RESIDUE STORAGE AND SPOIL PILE AREA SHOWING THE LOCATION OF THE SPOILS AND THE SATURATED ZONES UNDERLYING THIS AREA

TABLE 5-1. SUMMARY OF RADIOLOGICAL AND NONRADIOLOGICAL CHARACTERISTICS OF THE R-10 RESIDUE STORAGE AND SPOIL PILE AREA

Characteristic	Range of Values
Radiological	
Gamma (1 m)	13-7000 μR/hr
Beta-Gamma (1 cm)	0.06-4 mR/hr
Surface ^{226}Ra	4-9400 pCi/g
Total Uranium	1-145 mg/g
Depth of ^{226}Ra	6 m (20 ft)
Total Volume >5pCi/g ^{226}Ra	53,340 m^3 (1.9×10^6 ft^3)(a)
Radon	
Concentration 1.5 m Above Surface	2-440 pCi/l
at Soil Surface	15-1200 pCi/l
Nonradiological	
Lead (Pb)	3-650 ppm
Arsenic (As)	0.5-5 ppm
Chromium (Cr)	20-30 ppm
Cerium (Ce)	5-100 ppm
Fluorine (F)	3-100 ppm
Strontium (Sr)	50-200 ppm
Barium (Ba)	100-500 ppm
Zirconium (Zr)	10-1000 ppm
Copper (Cu)	20-3000 ppm
Nickel (Ni)	20-5000 ppm
Cobalt (Co)	50-5000 ppm
Vanadium (V)	30-1000 ppm
Titanium (Ti)	1000-3000 ppm
Bioconcentrations	
^{226}Ra in Vegetation	5.4 pCi/g

(a) Includes contaminated subsurface soil and spoil pile.

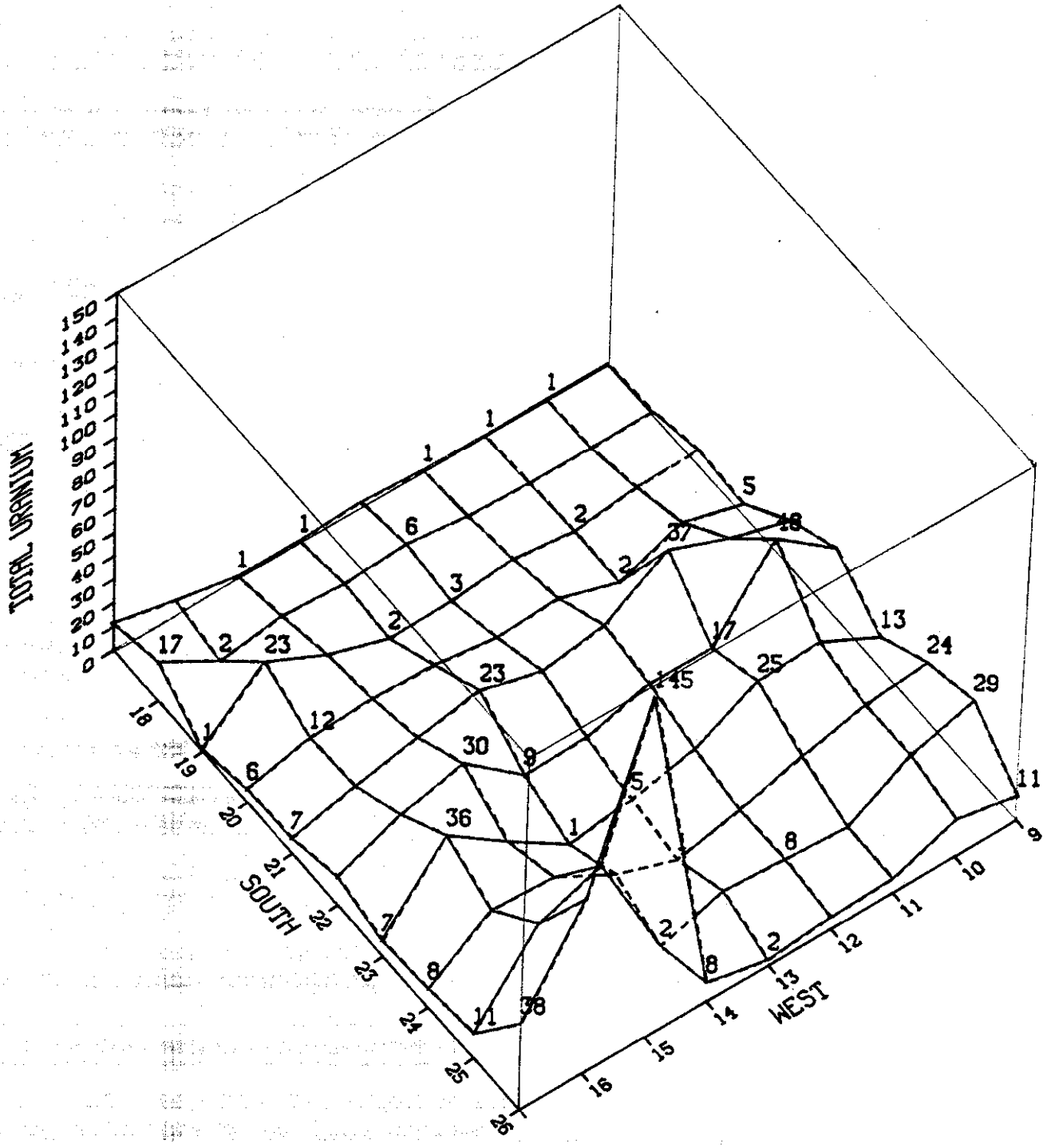

FIGURE 5-5. THREE-DIMENSIONAL REPRESENTATION OF URANIUM CONCENTRATIONS IN THE SURFACE OF THE R-10 RESIDUE STORAGE AND SPOIL PILE AREA

found on the spoil pile immediately north of Building 411. Minimal concentrations occur in the north of the R-10 residue storage area, approximately 137 m (450 ft) north of Building 411.

^{226}Ra in the 0-2 ft increment of this area is diagrammed in Figure 5-6. Maximum values were again just north of Building 411. However, there was little correlation between ^{226}Ra distribution and uranium distribution in the surface (see Appendix H, Table H4-5). ^{226}Ra concentrations (see Figure 5-5) were quite well correlated with radon concentrations in soil-surface air (see Appendix H, Tables H4-6 and H4-7).

The volume of soil in this area which is above the 5 pCi/g proposed decontamination guideline (U.S. EPA, 1980a, b) is approximately 53,340 m^3 (1,905,000 ft^3). Figure 5-7 diagrams the shape of the excavation if residues and soil/spoils greater than 5 pCi/g ^{226}Ra were removed.

Radon concentrations in air from this area ranged from 10-440 pCi/1 during late summer. Figure 5-8 shows the range and distribution of radon concentrations measured at the soil surface.

As was shown in using the Terradex radon cups, ^{222}Rn concentrations are extremely heterogeneous over the surface of the soil (see Appendix H, Table H4-6). Along the west and south perimeter, ^{222}Rn ranged from 20-340 pCi/1, 13 to 227 times background. Compared to the values obtained with the Terradex radon cups, these concentrations are somewhat higher. It should be kept in mind, however, that the radon cups represent an integrated measurement over 30 days while the gas scintillation data represent one point in time only. The greatest ^{222}Rn concentrations along the west perimeter are due west of the R-10 residue storage area. Along the south perimeter, ^{222}Rn concentrations in soil air ranged from 25-70 pCi/1.

Maximum ^{222}Rn concentrations using 15 cm diameter samplers at the ground surface were also found north of Building 411 (S26W9 through S26W17) (see Appendix H, Table H-7). However, there may have been some influence in these samples from ^{222}Rn release from the residue storage buildings since values were notably higher than those

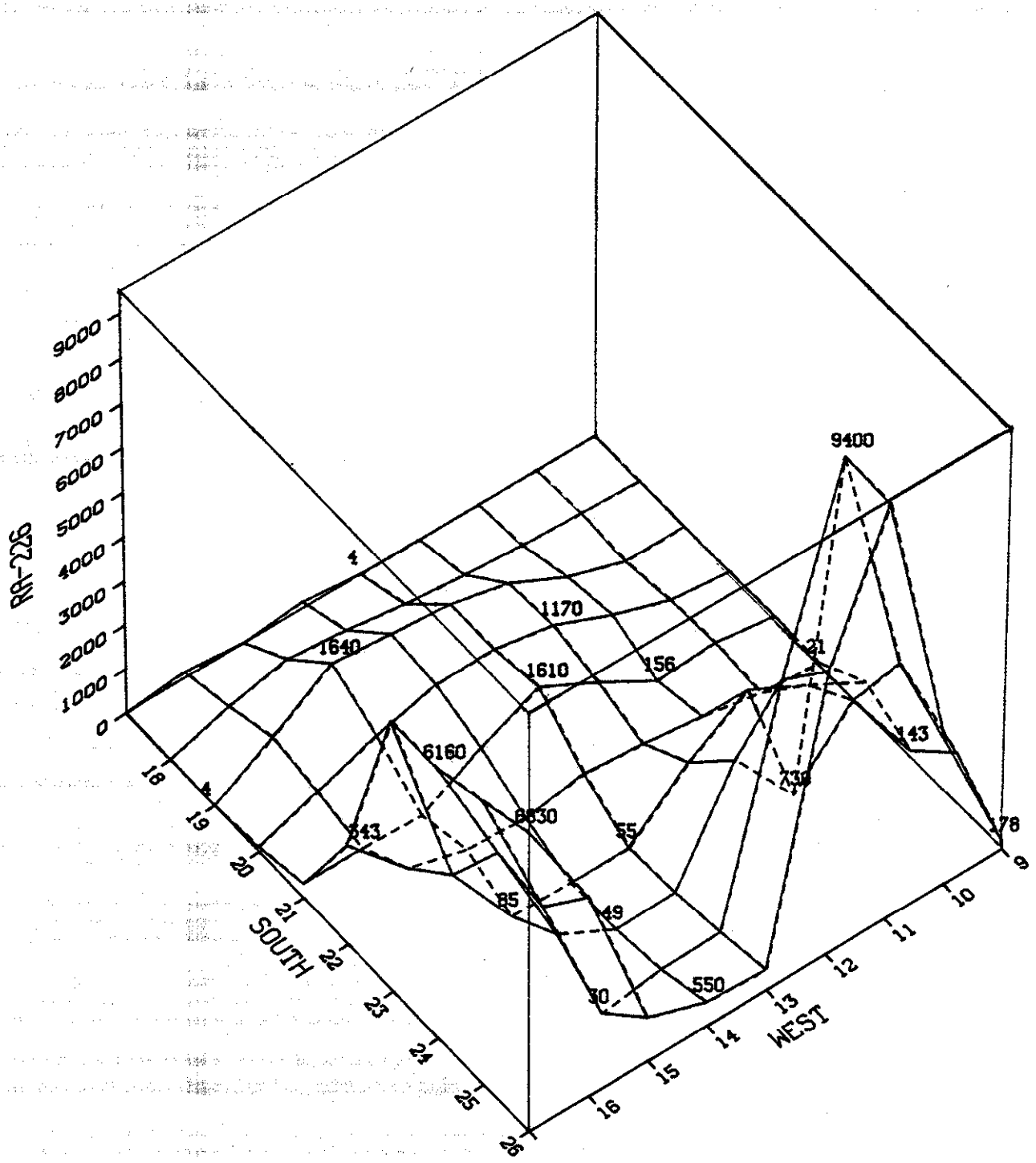

FIGURE 5-6. THREE-DIMENSIONAL REPRESENTATION OF ^{226}RA CONCENTRATIONS IN THE SURFACE (0-2 FT) OF THE R-10 RESIDUE STORAGE AND SPOIL PILE AREA

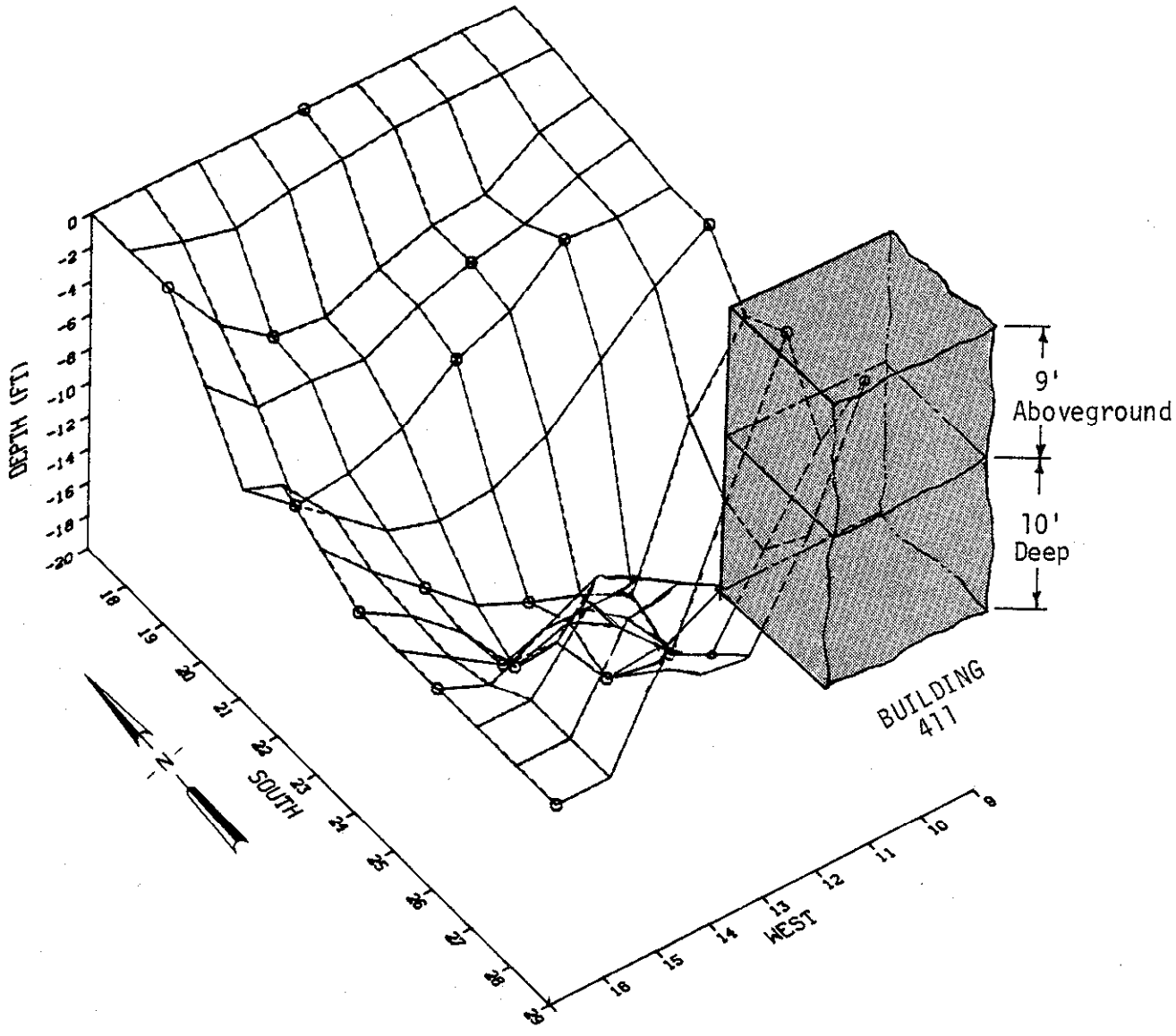

FIGURE 5-7. THREE-DIMENSIONAL REPRESENTATION OF THE DEPTH PROFILES LEFT INTACT IN THE R-10 RESIDUE AND SPOIL PILE AREA AFTER SOILS CONTAMINATED BY >5 PCI/G ^{226}RA WERE REMOVED

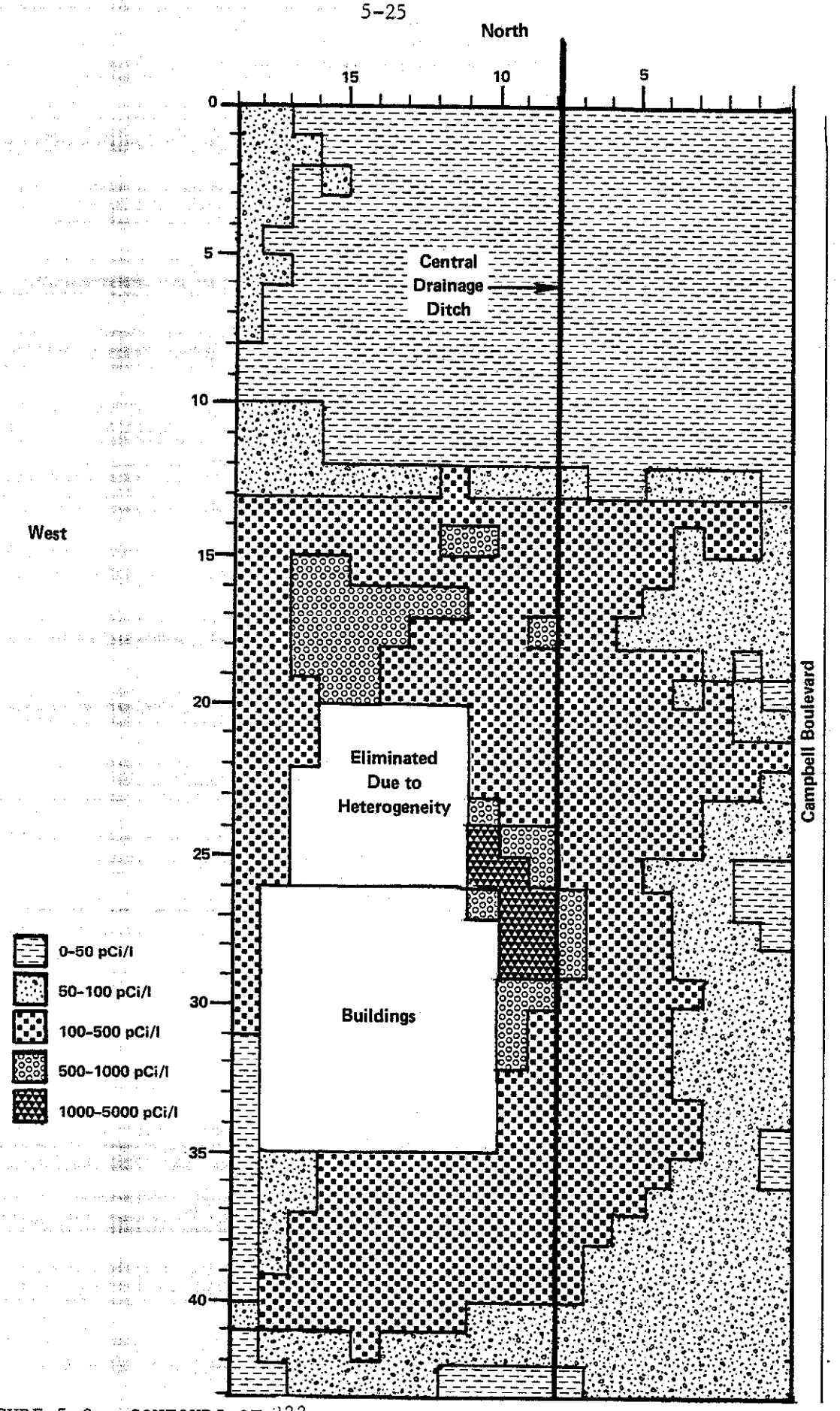

FIGURE 5-8. CONTOURS OF ^{222}RN IN SURFACE AIR IN THE SOUTHWEST QUADRANT OF THE SITE AS ESTIMATED USING A KRIEGING AVERAGING ROUTINE ON THE DATA BASE

detected using the Terradex cups. Average ^{222}Rn concentrations at the soil surface in the R-10 residue storage area ranged from 400-800 pCi/l (see Appendix H, Table H-7).

A few determinations of radon concentrations were made on an area of the R-10 residues before and after treatment with asphaltic emulsion. These values indicate some reduction in ^{222}Rn released following treatment (see Appendix H, Table H4-8). However, this reduction may be explained by the very low temperatures ($-8^{o}C$) during the post-treatment evaluation versus the pretreatment evaluation ($-18^{o}C$). Visual inspection of the treatment showed frequent cracks in the asphalt and even vegetation protruding through some of the cracks. It was not possible to place the sampling pan in areas with no holes or cracks in the emulsion.

In order to calculate potential ^{222}Rn exposure to personnel handling D&D activities, it was necessary to determine ^{222}Rn concentration in air at approximately 1.5 m (breathing height). Two types of methods were used for sample acquisition: grab and flow-through ^{222}Rn sampling. The southeast corner of the Site was chosen to establish background levels since this area was found to be uncontaminated.

^{222}Rn concentrations were determined at 1.5 m in the southwest quadrant of the Site and the control area. The same locations were sampled monthly; a 15-20 percent difference was found among the sampling periods. North of Building 411, ^{222}Rn concentrations in air averaged 27 pCi/l, more than nine times Site background levels. South of Building 409, ^{226}Ra concentrations in air averaged 7 pCi/l, more than twice background. Maximum concentrations were found at S19W16 (310-440 pCi/l). This area was also found to have high soil-surface air ^{222}Rn concentrations (see Appendix H, Table H4-9).

The flow-through system was used to supplement grab gas scintillation vial samples. The system allowed longer sampling of air and, therefore, a more integrated sample and lowered detection limits. These data confirmed the results of the grab sampling for ^{222}Rn. Levels of ^{222}Rn in the control area were slightly lower (5 pCi/l) using this technique than the grab samples (see Appendix H, Table H4-10).

A limited survey of airborne particulate radiation was conducted during Site characterization. Two methods were used: (1) filters (0.45 μ) on the flow-through system described above and (2) high volume sampling. The R-10 residue storage area yields airborne particulates greatly elevated from the control area. The area south of Building 409 did not show significant airborne particulate radiation (see Appendix H, Table H4-11).

High volume samples (16 cfm) were used to determine airborne particulate radiation in addition to the technique used with the flow-through ^{222}Rn concentration system. Data support the values determined using the other technique (see Appendix H, Table H4-12). In the R-10 residue storage area north of Building 411, airborne particulate radiation was elevated 1,000 times background for beta-gamma and alpha radiation.

Biota evaluated for radioisotope concentrations showed vegetative uptake but no significant animal uptake (see Appendix H, Tables H3-11 and H3-12). Vegetation in the area showed ^{222}Ra concentrations up to 5.4 pCi/g and detectable concentrations of three daughter nuclides--^{214}Pb (2.9 pCi/g), ^{214}Bi (2.6 pCi/g), and ^{210}Pb (9 pCi/g).

Water taken from saturated zones in the R-10 residue storage area showed detectable levels of uranium and radium. (See Chapter 6 for detailed discussion of the saturated zone water.)

Nonradiological Characteristics

Significant concentrations of several elements are associated with both carbonate (L-30, L-50, and R-10) and sulfate (K-65) residues. Concentrations in soils in the R-10 residue storage and spoil pile area suggest (1) a potential source for migration, especially since both the Central Drainage and West ditches contain significant concentrations of the same metals (see Chapter 6) and (2) potential hazards during current and remedial action alternatives.

A summary of stable element concentrations found in soil samples from the R-10 residue storage and spoil pile area is compared

on Table 5-2 to the naturally occurring levels of these elements. Generally, levels in Site soils are at or below naturally-occuring levels with the exception of vanadium (V), cobalt (Co), nickel (Ni), copper (Cu), lithium (Li) and lead (Pb).

It is apparent that soils in the southwest quadrant of the Site are contaminated with metals present in residues stored at the Site. It is not surprising that soil samples from the R-10 residue area closely resemble these residues.

Saturated zone water contained detectable levels of several metals. These concentrations were not above drinking water standards. (See Chapter 6 for discussion).

5.4.2. Area 2: New Naval Waste

This area was designated the New Naval Waste Area on old Site maps so designating the location and 1965 inventory records. The area consists of mounded soil with spoil, building rubble, and other debris and lies north and east of the small building (433) used originally as a storage vault (see Figure 5-1).

Table 5-3 summarizes the radiological and nonradiological characteristics of this area. Near the one drum of residues located in the area, beta-gamma measurements approached 70 mR/hr. The surface soils contained up to 7,140 pCi/g ^{226}Ra (see Appendix H, Table H5-1); the maximum depth extending above 5 pCi/g ^{226}Ra was 4.9 m (16 ft) (see Appendix H, Table H5-2 and Figure H5-1). Total volume was approximately 7,224 m^3 (258,000 ft^3).

Uptake of ^{226}Ra by vegetation was detectable and was approximately 0.5 pCi/g (see Appendix H, Table H3-11). Radon concentrations in air ranged from 350-450 pCi/l (see Appendix H, Table H5-3).

Metals in this area were less than that found in the R-10 residue storage. Only lead was found to exceed naturally occurring levels (see Table 5-2 and Appendix H, Table H5-4).

TABLE 5-2. COMPARISON OF MEAN STABLE ELEMENT CONCENTRATIONS IN SOILS FROM THE R-10/ SPOIL PILE AREA TO MEAN NATURALLY-OCCURRING LEVELS

Element	ppm Naturally Occurring(a)	On-Site (SE)
Na	6,300	3,786(432)
Ti	5,000	1,484(217)
V	100	196(70)
Co	8	1,030(400)
Ni	40	1,634(538)
Cu	20	449(210)
Mn	850	636(133)
Zr	300	154(71)
Ba	500	315(48)
Li	30	196(26)
Sr	300	95(13)
F	200	26(9)
La	30	24(9)
Ce	50	35(10)
Cr	100	26(3)
As	6	2(0.4)
Pb	10	321(74)

(a) Bowen, 1966.

TABLE 5-3. SUMMARY OF RADIOLOGICAL AND NONRADIOLOGICAL CHARACTERISTICS OF THE NEW NAVAL WASTE AREA

Characteristic	Range of Values
Radiological	
Gamma (1 m)	1.7-5 mR/hr
Beta-gamma (1 cm)	Background to 4 mR (70 mR near drum)
Surface ^{226}Ra Soil	3-7140 pCi/g
Vegetation ^{226}Ra	0.5 pCi/g
Depth ^{226}Ra >5 pCi/g ^{226}Ra	4.8 m (16 ft)
Total Volume >5 pCi/g ^{226}Ra	7224 m^3 (258,000 ft^3)
Radon concentration (at soil surface)	370-462 pCi/l
Nonradiological	
Lead (Pb)	<0.4-740 ppm
Arsenic (As)	1-3 ppm
Chromium (Cr)	5-50 ppm
Cerium (Ce)	1-30 ppm
Fluorine (F)	10-50 ppm
Strontium (Sr)	30-200 ppm
Barium (Ba)	20-500 ppm
Zirconium (Zr)	3-100 ppm
Copper (Cu)	3-50 ppm
Nickel (Ni)	5-30 ppm
Cobalt (Co)	2-20 ppm
Vanadium (V)	10-50 ppm
Titanium (Ti)	300-3000 ppm

5.4.3. Area 3: Northwest Pads

This area is a small portion of the northwest portion of the Site near two small concrete pads. A summary of the radiological and nonradiological characteristics of the area is given in Table 5-4.

The primary contaminant is cesium 137 (^{137}Cs) (see Appendix H, Table H6-1 and H6-2). The contamination is superficial extending to only 1.2 m (4 ft) in depth in a small area 1 m^2 (10.8 ft^2) (see Appendix H, Figure H6-1). Other isotopes (e.g., ^{226}Ra) are only present in small amounts and may be associated with the slag used for a roadbed found in the area (see Appendix H, Table H6-1). No ^{90}Sr was detected in association with the ^{137}Cs contamination.

Several metals were detected in surface soil (see Table 5-4 and Table H6-3). Copper levels exceeded those occurring naturally by an order of magnitude; however, other elements occurred at or below those occurring naturally.

5.4.4. Area 4: South of Building 409

The area south of Building 409 was used for surface storage of crucibles, saw blades, and other materials from metallurgical operations in the Niagara region. This area has residual, superficial contamination remaining (<0.75 m), over a 334 m^2 (3600 ft^2) area (see Appendix H.7, Figure H7-1 and Table H7-1). Assuming that a 0.75 m depth would be required over the area, the volume of material exceeding 5 pCi/g ^{226}Ra would be approximately 250 m^3 (8829 ft^3). Radon levels were elevated in this area (see Appendix H, Tables H7-2 and H7-3).

5.4.5. Area 5: Railroad Bed Road

The railroad bed road area lies west of Campbell Street and east of the Central Drainage Ditch. The area consists of several scattered superficial spills of pitchblende residues near the old railroad bed used for the southwest building complex (see Appendix H.8,

TABLE 5-4. SUMMARY OF RADIOLOGICAL AND NONRADIOLOGICAL CHARACTERISTICS OF THE NORTHWEST CONTAMINATED AREA

Characteristic	Range of Values
Radiological	
Gamma (1 m)	0.3-2.2 mR/hr
Beta-gamma (1 cm)	Background to 70 mR/hr
Surface ^{226}Ra	1.7-6.9 pCi/g
^{137}Cs surface	1.17×10^{3}-5.9×10^{4} pCi/g
2-4 ft	60.3 pCi/g
Volume above 5 pCi/g ^{226}Ra	NONE
Vegetation	
^{226}Ra	1 pCi/g
^{137}Cs	8.3 pCi/g
Nonradiological	
Chromium (Cr)	50 ppm
Strontium (Sr)	100 ppm
Barium (Ba)	300 ppm
Copper (Cu)	200 ppm
Nickel (Ni)	50 ppm
Titanium (Ti)	1000 ppm

Tables H8-1 and H8-2). Gamma and beta-gamma levels in these isolated areas were slightly above background levels.

5.4.6. Area 6: Slurry Pond

Area 9 is the fill in the Boron-10 slurry pond and represents an area of approximately 2,090 m^2 (22,500 ft^2). This material was assumed to be clean fill when used but contains detectable levels of uranium decay products and coal slags. Beta-gamma levels ranged from 0.2-2 mR/hr at 1 cm above the surface (see Appendix H, Table H9-1 and H9-2).

5.4.7. Area 7: South of West Patrol Road

Area 7 is presumed to be a spill. It is 743 m^2 (7500 ft^2) and was found through coring to be only superficial. Assuming 0.6 m (2 ft) depth of ^{226}Ra exceeding 5 pCi/g, the volume of wastes would be approximately 420 m^3 (15,000 ft^3) (see Appendix H, Table H3-3).

5.4.8. Area 8: East of MacArthur Road

The area 1 m^2 (10.8 ft^2) is presumed to be a spill from the road. The contamination is superficial. The volume of material exceeding 5 pCi/g ^{226}Ra is approximately 1 m^3 (35 ft^3) (see Appendix H, Table H3-4). The area was largely removed in sampling and is held within the Site's sample archival system.

5.4.9. Area 9: West of Castle Garden Road

This area is adjacent to the railroad bed and may represent a spill (Appendix H, Figs H3-13 and H3-14). The dominant contaminant is ^{137}Cs, averaging 50 pCi/g. ^{226}Ra concentrations did not exceed 5 pCi/g. The area was largely removed in sampling and is held within the Site's sample archival system.

CHAPTER 6: CHARACTERIZATION OF DRAINAGES AND SATURATED ZONES

6.1. INTRODUCTION

The existing drainages of the Site present the greatest potential route for the migration of contamination to off-site areas. Surface erosion and subsurface movement in saturated zones of contaminants from residue storage buildings and surface disposal areas have introduced contamination to the drainage ditches and off-site areas which necessitated a detailed investigation to sufficiently characterize the extent of contamination in both drainages on-site and off-site and in on-site saturated zones to plan remedial action. On-site saturated zones were investigated to determine concentrations of nuclides and metals and evaluate their potential as off-site migration routes. These characterizations provide part of the necessary baseline data for hazard assessment and assessment of remedial action needs. The discussion below is divided into two topics: (1) the drainages (both on-site and off-site) and (2) subsurface waters.

6.2. DRAINAGES

6.2.1. Background

Investigations of the drainageways progressed from the most simplistic to the more refined as the results of each survey revealed the need for additional information. Initial procedures included gamma and beta-gamma instrumental surveys and sediment grab sample analyses for radionuclides and other contaminants (primarily metals). Subsequent sample acquisition and analysis provided data sufficient to assess on-site contamination and off-site migration and also provided a depth profile sufficient to quantify the volumes of sediment above the U.S. EPA (1980 a, b) proposed guidelines of 5 pCi/g ^{226}Ra.

Surface runoff from most of the Site flows into the Central Drainage Ditch (Figure 6-1) which subsequently flows north into Fourmile Creek and to Lake Ontario. The Central Drainage Ditch is a channelized ditch approximately 3-4 m (10-15 ft) deep, 3-6 m (10-20 ft) wide at the bottom, 12-15 m (40-50 ft) wide at the top, and 4.8 (3 mi) in length from its origin at the south end of the Site to its confluence with Fourmile Creek. The second largest ditch is the West Ditch which is similar in size to the Central Drainage Ditch only as it crosses the northwest corner of the Site, a distance of approximately 183 m (600 ft). This ditch has historically received erosion inputs from the southwest portion of the Site. West and south of the Site where the West Ditch originates, it is a small ditch only a few feet in depth and width extending south of Pletcher Road. Approximately 640 m (2,100 ft) of the ditch due west of the Site were surveyed. North of the Site, the West Ditch is generally 2-3 m (6-8 ft) in depth, 3-4 m (10-15 ft) in width, and approximately 732 m (2,400 ft) in length. The South 31 (S-31) Ditch which flows into the Central Drainage Ditch is the only other ditch similar in depth and width to the Central Drainage Ditch and is approximately 421 m (1,400 ft) in length. The remaining ditches of the Site and region were investigated at a level of effort commensurate to their size and level of contamination. All natural drainages currently carrying Site runoff or historically having had the potential of carrying runoff, including Sixmile and Twelvemile creeks, were investigated (Figure 6-2).

6.2.2. Materials and Methods

Initial instrument surveys were conducted in the on-site drainages using survey meters to measure gamma exposures at 1 m and beta-gamma exposures at 1 cm above the surface. These measurements were taken every 7.5 m (25 ft) in on-site ditches in an effort to prioritize sediment sampling point. On-site sediment sampling for radiochemical analysis and spark source mass spectroscopy (SSMS) was conducted every 15 m (50 ft) or more frequently where meter surveys

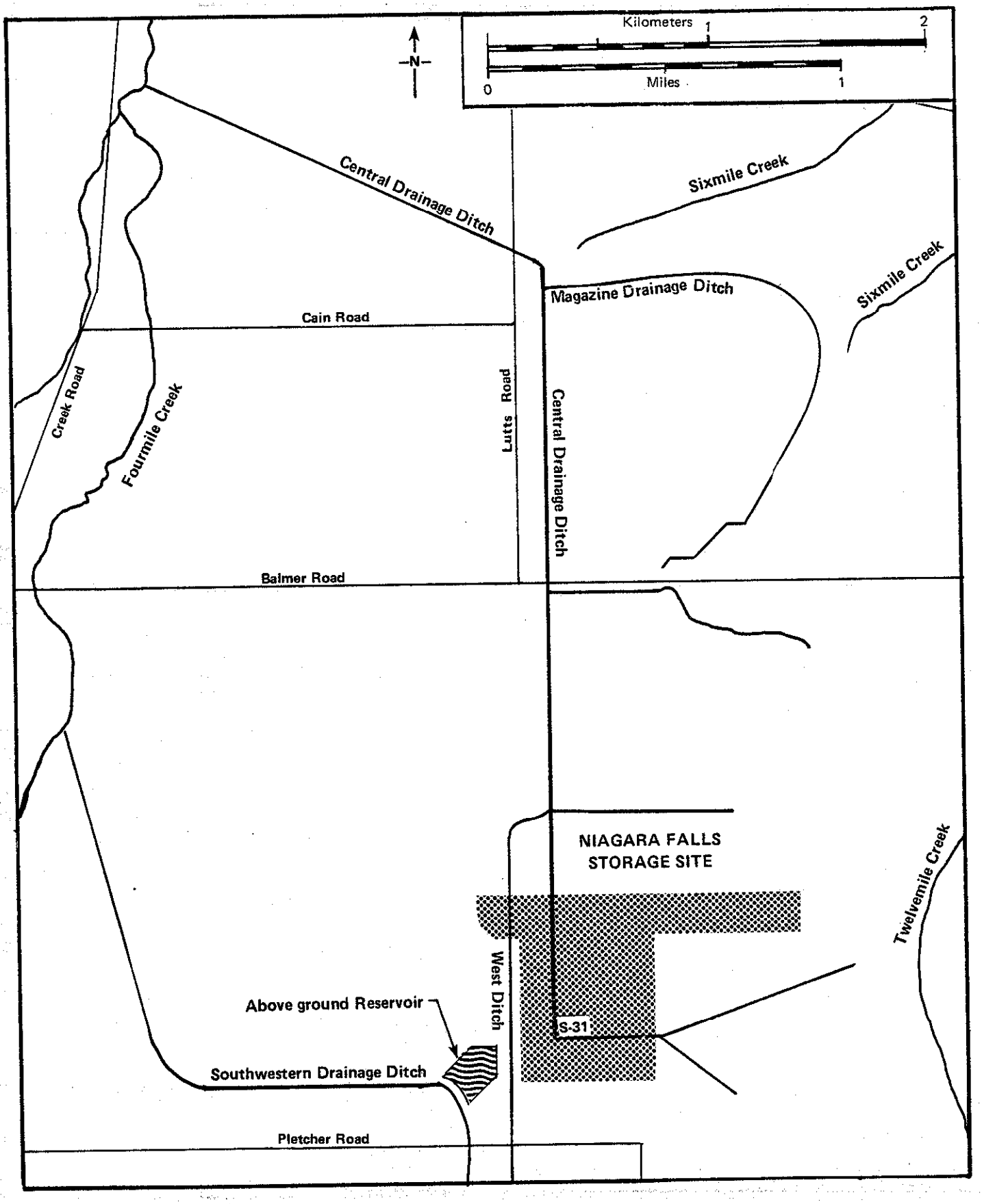

FIGURE 6-1. DRAINAGES OF THE DOE-NIAGARA FALLS STORAGE SITE

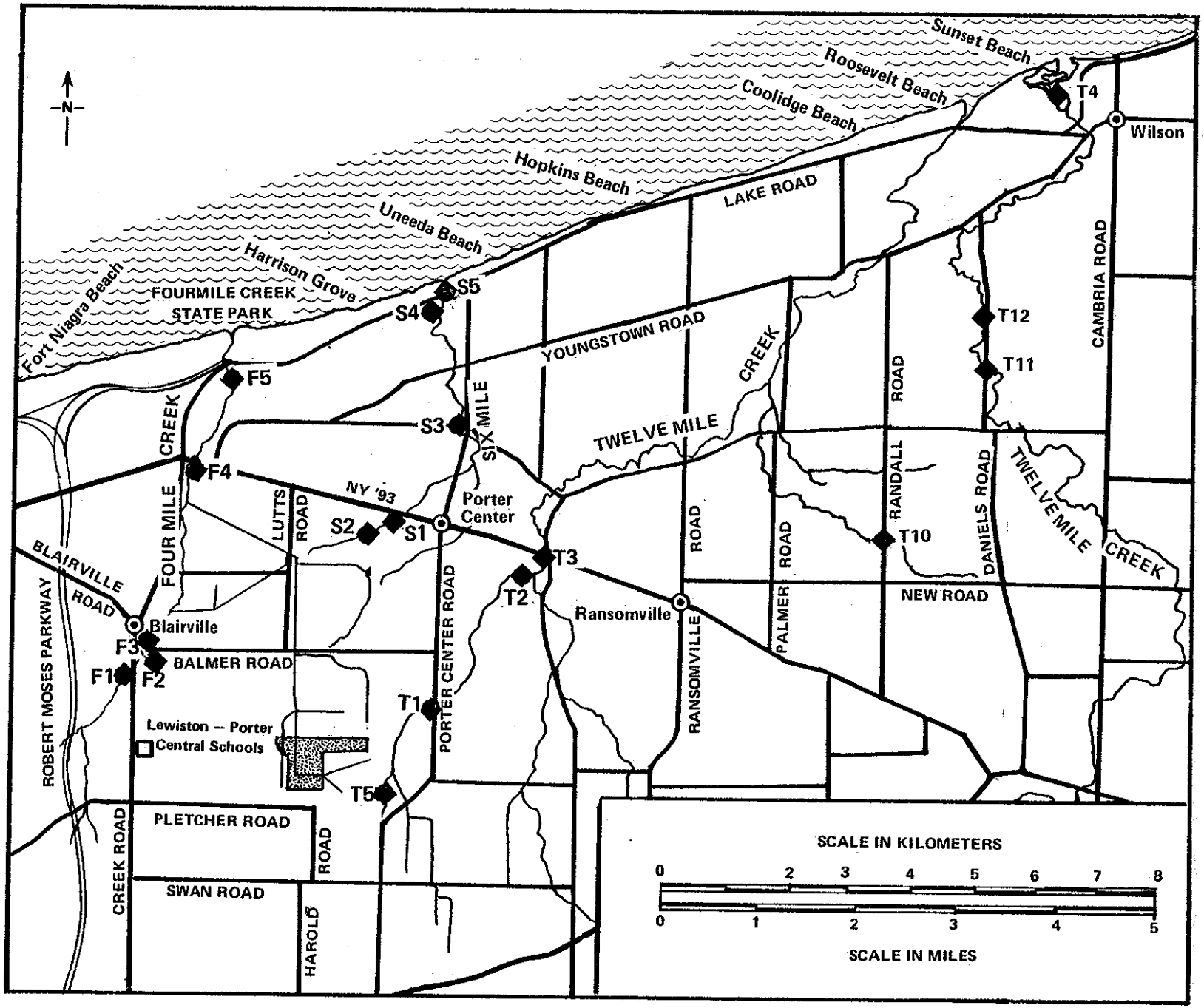

FIGURE 6-2. SEDIMENT SAMPLING LOCATIONS IN FOURMILE, SIXMILE, AND TWELVEMILE CREEKS

indicated radiation levels in excess of 0.25 mR/hr. Off-site sampling was conducted every 30 m (100 ft) and screened for ^{226}Ra or analytically characterized. A detailed discussion of these procedures is found in QA Documents EE-SP-8 and EE-SP-8.1 (see Appendix B).

Analysis of the sediment grab samples obtained revealed the presence of contamination in the surface samples of on-site ditches. These findings necessitated off-site surface sediment sampling and subsurface sampling, both on-site and off-site, to facilitate the quantification of levels.

Off-site sediment sampling was conducted every 30 m (100 ft) in the Central Drainage Ditch to its confluence with Fourmile Creek, in the West Ditch to its confluence with the Central Drainage Ditch, and for a minimum of 300 m (1,000 ft) into every current or past tributary of these ditches. Additionally, the off-site aboveground reservoir located to the west of the Site was sampled (see Figure 6-1).

The three creeks--Fourmile, Sixmile, and Twelvemile--which, based on current or historic drainage patterns, could have received runoff from the Site were also investigated (see Figure 6-2). It should be noted, however, that only Fourmile Creek currently receives Site runoff. The historic record was sufficiently vague with regard to the exact time of diversion of the headwaters of Sixmile and Twelvemile creeks away from the Site to warrant sampling these creeks. All creeks were sampled at several accessible points along their lengths and at deposition zones formed at their confluences with Lake Ontario. Background sediment samples were obtained from a branch of Twelvemile Creek free of past or present Site runoff.

Core sampling in the Central Drainage Ditch and the West Ditch provided necessary information for determination of the depth of contaminated sediments. Core sampling also permitted the detection of contaminant deposits which might be overlain by uncontaminated sediments. A detailed description of sediment coring procedures is found in QA Document EE-SP-11.1 (see Appendix B).

6.2.3. Results

The investigation of on-site and off-site drainages encompassed not only the major drainages but also all drainages potentially exposed to Site runoff based on current flow patterns or historic record. A total of 17 drainages were surveyed, 6 on-site and 11 off-site. A detailed listing and summation of all data for these drainages is found in Appendix I, Tables I-1 to I-16. The assessment evaluated the current radiation exposure levels in these drainages and the extent of contamination in sediments exceeding the proposed 5 pCi/g ^{226}Ra limit in soils.

Radiological Characterization

Exposure Levels. Exposure levels above background attributable to sediment contamination, rather than "shine" from nearby contamination, were found only in the on-site portions of the Central Drainage Ditch, the West Ditch, the South 31 Ditch, and a few isolated off-site locations within the first 1,000-2,000 ft downstream (north) of the Site in the Central Drainage and West ditches. The highest exposures within the Central Drainage Ditch occurred in the length adjacent to Building 411 and the R-10 residue storage and spoil pile area. Gamma levels (at 1 m above the sediment or water surface) were found as high as 1,000 μR/hr or 100 times background and beta-gamma levels as high as 2,200 μR/hr or 36 times background. The remainder of the Central Drainage Ditch ranged from 5-10 times background gamma radiation and 2-5 times background beta-gamma radiation on-site, decreasing with distance to background levels at the north perimeter fence and continuing at background levels in off-site areas (see Appendix I, Table I-1). Survey results of the West Ditch found exposure levels in excess of background in the on-site section of the ditch. The gamma levels on-site ranged from background to 14 times background, with beta-gamma levels from background to 6 times background,

with one point 60 times background. Gamma levels observed in the section of the West Ditch north of the Site to its confluence with the Central Drainage Ditch were generally background (see Appendix I, Tables I-1 and I-3). Exposure levels were not determined for the upstream portion of the West Ditch occurring south and west of the Site; however, sediment analysis was performed for characterization and identification of contaminants. Exposure levels in the South 31 Ditch were in excess of background from the point at which the contaminated slurry pond south of Building 401 (see Chapter 5) is eroding into the ditch to its confluence with the Central Drainage Ditch. Gamma levels and beta/gamma levels ranged from background to 15 and 8 times background, respectively (see Appendix I, Table I-5).

Sediment Radiochemistry. Sediment samples were subjected to radiochemical screening and analysis procedures to specifically identify the presence of contamination and its components. This data base coupled with data from drill cores within contaminated drainages was sufficient to permit estimation of the total volumes of contaminated material in both the on-site and off-site drainages.

Analytical procedures verified and quantified the findings of the instrumental surveys indicating significant contamination in only the Central Drainage Ditch, the West Ditch, and South 31 Ditch (see Appendix I, Tables I-1 to I-5). ^{226}Ra concentrations have been selected for summary and discussion purposes due to the proposed regulatory limit of 5 pCi/g of ^{226}Ra in soils. The drainages surveyed were detailed in Figures 6-1 and 6-2. Figure 6-3 indicates the primary drainages having contaminated sediments were found to exceed the 5 pCi/g ^{226}Ra.

The Central Drainage Ditch sediments were found to exceed the 5 pCi/g ^{226}Ra limit in all on-site areas, approximately 808 m (2,650 ft) and off-site almost to its confluence with Fourmile Creek, approximately 3569 m (11,700 ft) or a total length of 4377 m (14350 ft). The highest concentrations, 1,660-1,900 pCi/g ^{226}Ra, were found in the on-site section of the ditch adjacent to Building 411 and the R-10 residue storage and spoil pile area (see Appendix I, Table I-1 and I-2).

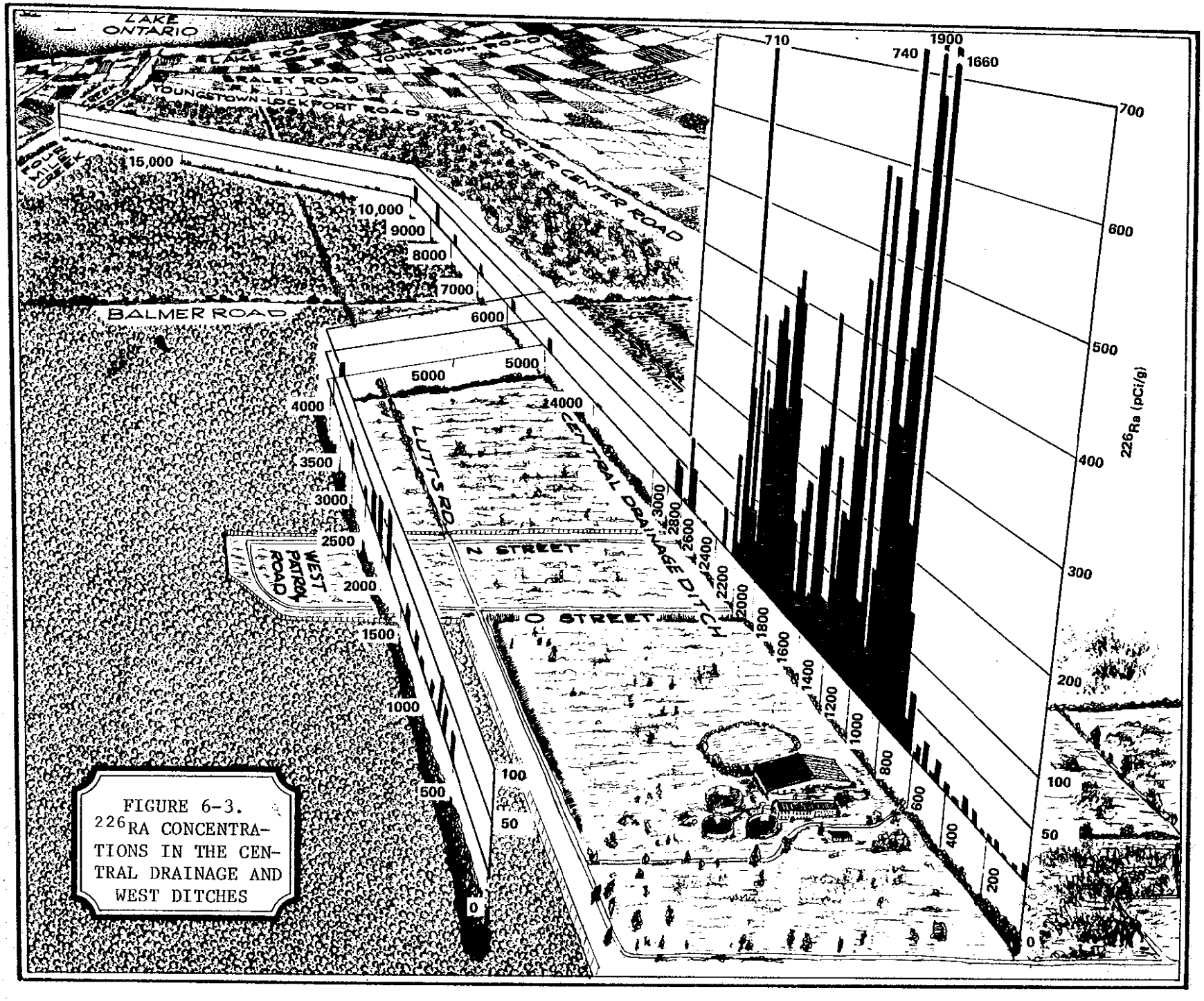

FIGURE 6-3. ^{226}RA CONCENTRATIONS IN THE CENTRAL DRAINAGE AND WEST DITCHES

In the off-site section of the Central Drainage Ditch, core analysis determined the contamination to be limited to the first 1-2 ft of sediment (see Appendix I, Tables I-6 and I-7). With only one exception, no contamination in excess of 5 pCi/g ^{226}Ra was found at or below 0.6 m (2 ft) in depth. That exception occurred at the intersection of Lutts Road and the Central Drainage Ditch on the upstream or east side of the road. The Lutts Road culvert (see Figure 6-1) has partially dammed the ditch at this point, creating a deposition zone to the east approximately 183 m (600 ft) in length. Drill coring in this area was extremely difficult due to the depth of water and siltation. The concentration of ^{226}Ra in the core (Sample 344) obtained from this area was 20 pCi/g ^{226}Ra at 1.2 m (4 ft) but less than that at 0.6 m (2 ft) and 1.8 m (6 ft) (see Appendix I, Table I-7) while analysis of the surface sediment grab sample (Sample 344) at this point found ^{226}Ra at 5.1 pCi/g at the surface (see Appendix I, Table I-1). These results reflect variability which probably occurs throughout this deposition zone but is not apparent in any other off-site section of the Central Drainage Ditch.

On-site contamination, shown to be well in excess of the proposed ^{226}Ra limits (see Figure 6-3), also appears to be limited to surface sediments. Contamination in the Central Drainage Ditch in excess of the 5 pCi/g ^{226}Ra proposed limit was found to a maximum depth of 0.6 m (2 ft), except in a short section near the R-10 residue storage and spoil pile area (see Appendix I, Table I-6). Thus, as was the case in off-site areas, contamination within most of the on-site portion of the Central Drainage Ditch is limited to the surface sediments no deeper than 0.6 m (2 ft). The exceptions to this conclusion seem to occur over a 90-m (300 ft) length of the ditch along the R-10 residue storage and spoil pile area (from S26WB to S20W8 on the Site grid). Levels in excess of 5 pCi/g were found from the surface of sediments to 1.2 m (4 ft) in depth in two cores from this area (see Appendix I, Table I-6). It should be noted, however, that subsurface contamination was not detected in the drill core taken between these two contaminated cores. This same type of heterogeneity occurred in drill cores from on-site contaminated areas

(see Chapter 5). The cause of this heterogeneity in contamination distribution is probably attributable to variability in deposition and sediment availability; however, the exact cause has not been determined. For estimation purposes, this entire 90 m (300 ft) area has been considered to be contaminated to a depth of 2 m (6 ft).

The sediments of the West Ditch are also in excess of the 5 pCi/g ^{226}Ra limit. They are not, however, contaminated to the same order of magnitude as the Central Drainage Ditch. The highest ^{226}Ra concentration detected was 75 pCi/g as compared to the 1,900 pCi/g ^{226}Ra detected in the Central Drainage Ditch (see Appendix I, Tables I-3 and I-4). Figure 6-3 provided a detailed summation of ^{226}Ra concentrations in sediments varying with distance in the West Ditch. Sampling was begun due west of the residue buildings and not at the origin of the West Ditch which is south of Pletcher Road (see Figure 6-1). Contamination in excess of 5 pCi/g ^{226}Ra was initially found at a point due west of the R-10 residue storage and spoil pile area and continued the entire length of the ditch north to its confluence with the Central Drainage Ditch. Drill cores in the section of the ditch north of the Site to the confluence did not detect contamination below the surface silt (see Appendix I, Table I-8). The on-site section of the West Ditch and the off-site section south and west of the Site, on Niagara Mohawk Property, were not accessible to drill coring equipment. It is believed, however, based on the test coring data which are available, that contamination in these areas of the West Ditch is probably limited to the first few 0.3-0.6 m (1 to 2 ft) of sediments. The most probable sources of the contamination in the West Ditch are an off-site contaminated area to the west of the R-10 residue storage and spoil pile area and the residue buildings east of the ditch and on-site contaminated area Number 7 at the corner of Lutts Road and West Patrol Road which were discussed in Chapter 5.3.

Contamination in the South 31 Ditch contributed to a very slight exposure level in this ditch which was generally only a few times

larger than background. Radiochemical analysis detected elevated ^{226}Ra concentrations in only a few sediment grabs and cores and then only slightly in excess of 5 pCi/g (see Appendix I, Tables I-5 and I-9). No contamination in excess of background was detected greater than 0.6 m (2 ft) in depth and none was detected in off-site tributaries to the South-31 Ditch (see Appendix I, Tables I-9 and I-10).

Secondary Ditches. Numerous minor on-site ditches were surveyed in an effort to adequately evaluate all possible migration pathways of contaminated materials. Of those surveyed, only the Building 434 Ditch, the South 16 Ditch, and the Lutts Road Ditch have any appreciable flow. Both the Building 434 Ditch, located just east of the tower, and the South 16 Ditch were found to have slightly elevated instrumental readings which were, however, attributable to "shine" from nearby contaminated areas. These data are tabulated in Appendix I, Tables I-11, I-12 and I-13. The Lutts Road Ditch had contamination levels sufficient to be instrumentally detectable as would be expected considering the close proximity of this ditch to the R-10 residue storage and spoil pile area. As all of these drainages have very limited flow and, if they have a discharge it is directly into the Central Drainage Ditch, detailed analysis was not necessary.

Natural Drainages and Tributaries. Analysis of sediment samples from Fourmile, Sixmile and Twelvemile creeks did not detect ^{226}Ra concentrations in excess of 5 pCi/g, with most concentrations at background concentrations of 0.5 pCi/g ^{226}Ra (see Appendix I, Table I-14). Similar results were obtained on five tributaries of either the Central Drainage Ditch or Fourmile Creek (see Appendix I, Table I-10). Sediments in these tributaries were generally slightly above background in ^{226}Ra concentrations, ranging from 0.3 to 4.5 pCi/g though still below the 5 pCi/g proposed limit for ^{226}Ra in soils. Exposure levels of gamma and beta-gamma were all at background levels in these drainages.

Volumes of Sediments Exceeding 5 pCi/g ^{226}Ra. The major drainages of the DOE-Niagara Falls Storage Site have been contaminated both on- and off-site from on-site contaminated areas. Contamination levels in excess of the 5 pCi/g ^{226}Ra concentration limit in soils were detected in approximately 4,377 m (14,350 ft) of the Central Ditch, 808 m (2,650 ft) on-site and 3,589 (11,700 ft) off-site. The 1,010 m (3,310 ft) of the Central Drainage Ditch remaining between the last detected point of contamination 686 m (2,250 ft) east of Lutts Road and the confluence with Fourmile Creek had levels ranging from 2-4.5 pCi/g which is below the 5 pCi/g ^{226}Ra suggested limit. However, based on the lack of analytical sensitivity at these low detection levels, these concentrations are probably not sufficiently low to warrant exclusion from remedial action considerations. With the exceptions already noted, the extent of contamination does not extend below 2 ft in depth. Based on these data, the total volume of contaminated material in the Central Drainage Ditch is estimated to be 18,100 m^3 (645,200 cu ft). The contamination levels in the West Ditch were not as great as those in the Central Drainage Ditch but were in excess of the proposed 5 pCi/g ^{226}Ra concentration for most of the length characterized, a total of approximately 1,616 m (5,300 ft). As was the case in the Central Drainage Ditch, the verticle distribution of contamination is limited to the surface of the sediments and was not detected below 0.6 m (2 ft). The total volume of materials in the West Ditch exceeding the proposed limit is approximately 3,562 m^3 (127,200 cu ft). Contamination of the South 31 Ditch was limited to surface sediments also, a total volume of 504 m^3 (18,000 ft^3).

Nonradiological Characterization

The sediments of both the Central Drainage Ditch and the West Ditch were analyzed for stable elements. With few exceptions, detected levels were at or below naturally-occurring levels in soils (Table 6-1)

TABLE 6-1. SUMMARY OF STABLE ELEMENTS DETECTED IN DITCH SEDIMENT SAMPLES FROM ON-SITE DITCHES USING SPARK SOURCE MASS SPECTROSCOPY[a] COMPARED TO NATURALLY-OCCURRING[b] LEVELS IN SOIL

Element	Naturally Occurring in Soil (ppm) Mean	Central Drainage Ditch (ppm) Mean (SE)	West Ditch (ppm) Mean (SE)
Na	6,300	6,550 (1,535)	7,500 (3,354)
Ti	5,000	3,400 (528)	1,666 (729)
V	100	153 (100)	36 (16)
Co	8	687 (513)	66 (58)
Ni	40	828 (511)	32 (17)
Cu	20	43 (19)	19 (8)
Mn	850	54 (194)	560 (361)
Zr	300	21 (5)	26 (9)
Ba	500	733 (515)	270 (184)
Li	30	121 (30)	150 (45)
Sr	300	106 (47)	102 (51)
F	200	311 (194)	8 (3)
La	30	59 (49)	4 (1)
Ce	50	84 (51)	9 (3)
Cr	100	43 (19)	20 (4)
As	6	2 (1)	0.9 (0.5)
Pb	10	20.2 (6.4)	0.5 (0.3)

(a) See Appendix I, Tables I-15 and I-16.

(b) Bowen, 1966.

(see Appendix I, Table I-15). The exceptions in the Central Drainage Ditch were cobalt, nickel, copper, barium, lithium, fluorine, and cerium. In the West Ditch, sodium, cobalt, and lithium were in excess of naturally-occurring levels. There is little or no indication of a gradient of concentrations with distance downstream in the on-site sampling.

6.3. SATURATED ZONES

6.3.1. Background

Test coring activities determined that the soils of the Site contain numerous shallow saturated zones in both clay and sand-gravel zones. The potential for off-site migration of nuclides or other contaminants in these zones was identified during intensive coring of the R-10 residue storage area when extensive sand-gravel lenses were located.

Saturated zones were investigated on the west and north periphery of the Site and in the R-10 residue storage and spoil pile area. Investigations included depth to free water, uranium and ^{226}Ra concentrations and concentrations of metals and rare earths.

6.3.2. Materials and Methods

Monitoring wells used for these evaluations were established during the summer of 1979 and sampled during 1980. Locations of wells at the Site periphery and in the R-10 residue storage area used for this characterization are shown in Figures 6-4 and 6-5. Wells were encased as specified. Depths to saturated zones were established during split-spoon sampling during 1979 and by measuring depth to free water in wells during 1980 (see Appendix B, QA Documents EE-SP-11, EE-SP-26 and HL-QAP-J-5594).

During May, June and August, saturated zones were sampled and ^{235}U and ^{226}Ra in solution determined. May samples were also evaluated using spark source mass spectroscopy (see Appendix B, QA Document MN-PP-113) in order to determine dissolved concentrations of metals and rare earths which are associated with stored pitchblende residues.

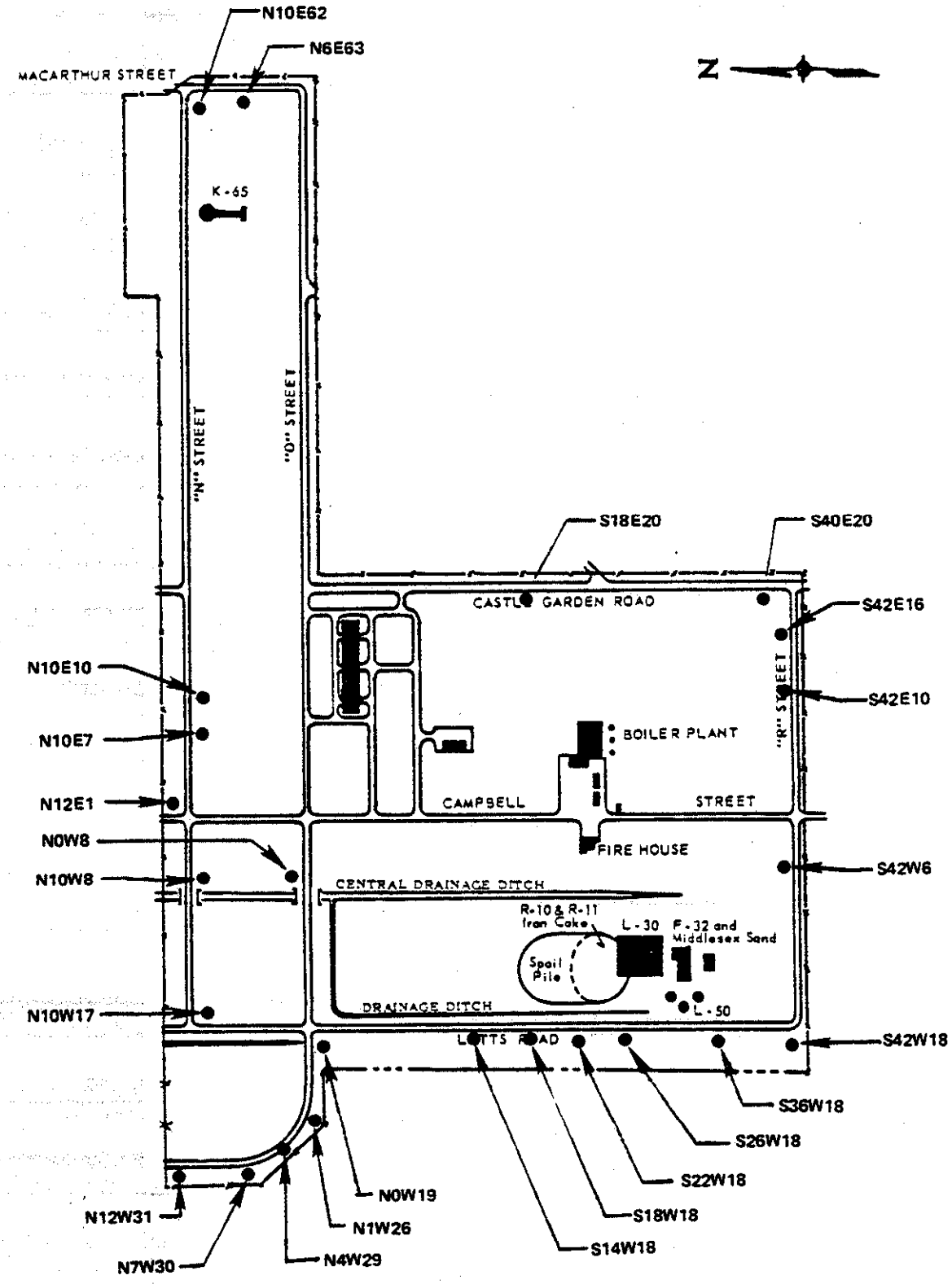

FIGURE 6-4. LOCATION OF PERIMETER WELLS

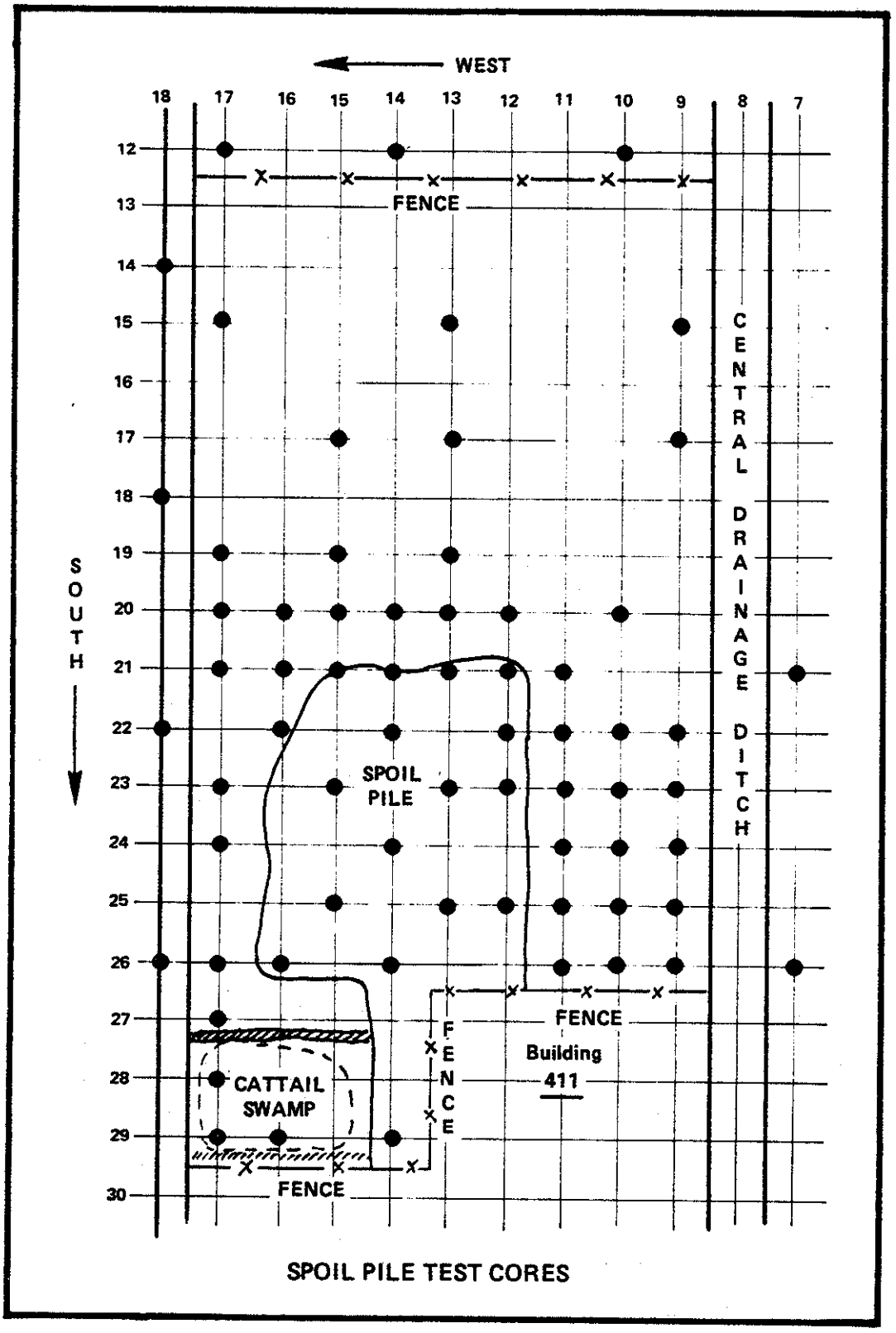

FIGURE 6-5. LOCATION OF WELLS ON THE R-10 RESIDUE STORAGE AND SPOIL PILE AREA

6.3.3. Results

Water Flow

Using all wells established for engineering and radiological assessment of the Site, soil particle size and depths to and thickness of saturated zones were established (see Appendix A, Figure A2-2). Average sand portion of soils was 20 percent and the range was 5-50 percent. While clays ranged from 5-30 percent, silt fractions were less than 20 percent. The average depth of the saturated zone below the ground surface ranged from 2.4-5.5 m (8-18 ft); and the average thickness of the zone was 0.6 m (2 ft) (see Appendix I, Table I-17 for details).

During summer and fall of 1980, the depth of free water below the soil surface ranged from 1.8-3 m (6-10 ft) and was constantly present. As shown in Table 6-2, relative depth below the surface suggests slow flow since little differential east to west or north to south was found. Since both topography and geologic relief of the area are minimal, low flow in the saturated zone is expected. Therefore, it is difficult to determine with any certainty whether the saturated zone in the R-10 residue storage area drains predominantly to the Central Drainage Ditch or whether significant drainage occurs off-site to the west.

TABLE 6-2. SUMMARY OF DEPTHS TO FREE WATER IN MONITORING WELLS FROM WEST TO EAST IN THE SOUTHWEST QUADRANT (BETWEEN LUTTS ROAD AND CAMPBELL STREET) OF THE SITE

Location	Average depth, meters (ft)
West boundary	1.8-2.4 (6-8)
East of Lutts Road	0.9-1.8 (3-6)
350 ft West CDD[a]	~.3 (~1)

TABLE 6-2. (Continued)

Location	Average depth, meters (ft)
300 ft West CDD	1.2-4.3 (4-14)
250 ft West CDD	2.4 (8)
150 ft West CDD	1.5-2.4 (5-8)
100 ft West CDD	1.2-1.8 (4-6)
50 ft West CDD	1.2-1.8 (4-6)

(a) CDD = Central Drainage Ditch.

Radiological Characterization

Soluble uranium and radium were detected in saturated zones in the R-10 residue storage area and in peripheral wells on the west side of the Site. The average uranium and ^{226}Ra concentrations in the saturated zones of the R-10 were 40.8 µg/l U and 2.14 pCi/l ^{226}Ra, and in the peripheral areas were 20.36 µg/l U and 0.26 pCi/l ^{226}Ra (see Appendix I, Tables I-18 and I-19). While levels were elevated in the R-10 area, none were above guidelines for unrestricted water use.

Nonradiological Characterization

Trace (ppb) levels of lead, barium, nickel, copper, chromium, and cobalt were found in periphery well water samples from the west of the Site and from the R-10 residue storage area (see Appendix I, Tables I-20 to I-23). Both selenium and zirconium were detected in water from the R-10 residue storage area. None of the elements were found in concentrations above published regulations.

6.3.4. Discussion

Large saturated zones are found throughout the DOE-Niagara Falls Storage Site. Saturated zones are largely correlated with high sand fractions (40-60 percent) in soil. The west portion of the Site, including the R-10 residue storage area, contains the greatest fraction of saturated zones and sand fractions in soil (see Appendix A, Figure A2-2). It is difficult to determine the dominant direction of flow in the saturated zones due to lack of relief in both the geological formation and topography. General geohydrology of the area suggests a northwest flow from the Site. It is hypothesized that flow within these saturated zones is extremely low since depth to free water is almost constant among wells throughout the year.

Concentrations of uranium and ^{226}Ra as well as trace metals and rare earths in water in the saturated zones are detectable, yet low. Neither radiological nor stable elements in the water below the R-10 residue storage area and at the Site periphery exceed specified regulations or guidelines for waters in unrestricted areas.

The water in the saturated zones at the DOE-Niagara Falls Storage Site does not present an immediate hazard on-site or off-site. Primary contamination of off-site drainages is postulated to be by erosion into the Central Drainage Ditch and into the West Ditch. However, saturated zones will significantly impact remedial actions at the Site. Specifically, removal of the R-10 residues, spoils, and contaminated soils will both impact and be impacted by these waters. Engineering alternatives being considered are incorporating these data into ongoing evaluations.

CHAPTER 7: HAZARD ASSESSMENT

7.1. INTRODUCTION

A hazard assessment is an identification and critical evaluation of potential risks posed to human health and environmental systems by chemical or radionuclide concentrations in air, water, soil/sediment, and biota. The assessment addresses occupational and public exposure via direct (e.g., inhalation) or indirect (e.g., ingestion of contaminants accumulated by the plant or animal used as a food) routes.

The purpose of conducting a hazard assessment in conjunction with the characterization of the Site is to identify current problems at the Site which may require near-term corrective action prior to disposition. This assessment will also facilitate the evaluation of occupational and public exposures which may result from alternative remedial action.

The approach to hazard assessment included four major steps: (1) Concentrations of nuclides and metals were compared to regulatory standards and guidelines where possible and to concentrations causing known health or biological effects; (2) dispersion of radon and radon daughters was estimated using collected data and mathematical modeling techniques; (3) a dose assessment model was used to determine worst case doses under current on-site conditions; and (4) potential hazards from radionuclides and metals were evaluated to determine where remedial action may be warranted.

7.2. STATEMENT OF THE PROBLEM

7.2.1. Approach

Assessment of hazards associated with the DOE-Niagara Falls Storage Site requires cognizance of the behavior of specific nuclides and chemicals in environmental media and the sensitivity of human and other biological receptors to these contaminants. Figure 7-1 is a diagram of the approach to hazard identification and assessment. A site

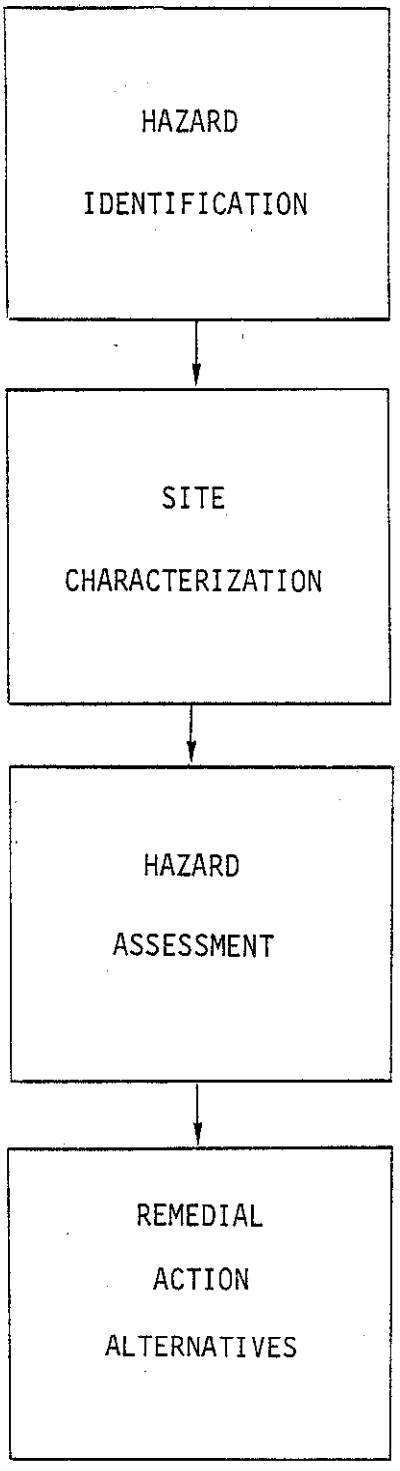

FIGURE 7-1. APPROACH TO HAZARD ASSESSMENT OF A CONTAMINATED STIE

is identified as a candidate for remedial action based upon the existence of potential hazards on the site.

Source terms identified during characterization (see chapters 3-6 of this report) were used to evaluate exposure conditions and their potential effects on humans and ecosystems. Site characterication and hazard assessment information serve as inputs to engineering evaluations of alternative remedial actions. Ultimately, selection of a remedial action alternative for implementation is based upon an attempt to minimize both effects and economic impacts.

7.2.2. Hazard Identification

Based upon the history and characterization of the DOE-Niagara Falls Storage Site, radiological and nonradiological hazards were assessed. Table 7-1 lists radionuclides and metals which are (1) components of stored residues or in contaminant materials, soils, or sediments at the Site and (2) present in concentrations sufficient to warrant their assessment. The African-derived ore was extremely rich in metals (even precious metals which were extracted before uranium processing). Processing enriched some metals in the form of carbonates (see Chapter 3 for chemical and radiological characterization of pitchblende residues stored at the Site).

TABLE 7-1. RADIONUCLIDES AND METALS WHICH MAY BE CONSIDERED HAZARDS UNDER CURRENT OR REMEDIAL ACTIONS AT THE DOE-NIAGARA FALLS STORAGE SITE

Type of Potential Hazard	Chemical
Radionuclides	Uranium decay series, ^{137}Cs
Metals	Cu, Ni, Co

Health and environmental implications of current conditions must be considered on a total Site basis. That is, posed hazards will be at least as great as the sum of the hazards of individual combinations of current conditions and the proposed actions. This is due to personnel exposure which may occur through several actions occurring concurrently or sequentially as well as continued potential for degradation of environmental quality.

Implications of contaminated areas on both human health and other bioloigcal systems were assessed. The need for health evaluations is obvious. Assessment of potential impacts on other biological systems is necessary because (1) biological processes provide an indirect exposure pathway to man and (2) stabilization of the Site is necessary to prevent off-site contamination.

One of the greatest weaknesses in current methodology used for hazard assessment is the inability to assess the effects of multiple contaminants. That is, while the hazard associated with an individual nuclide or metal may be adequately determined for a specific case, the total hazards associated with ores, residues, or other complex mixtures are difficult to establish. Consequently, a conservative approach must be taken such that a hazard is perceived and acted upon based on the individual chemical or nuclide which has the highest probability of causing problems under existing conditions. This method assures that the most stringent of applicable guidelines and dose assessments are used to define procedures to be used to minimize occupational and public exposure and assure environmental quality.

7.2.3. Applicable Guidelines and Regulations

Several agencies and the State of New York have established regulations and guidelines which can be used in evaluation of potential hazards at the Site. Specific documentation of the federal regulations and guidelines is given in Appendix J.1. A paramount consideration throughout the characterization and hazard assessment has been the proposed EPA guidelines for uranium mill tailings. The 5 pCi/g ^{226}Ra proposed action limit has been used to estimate volumes of material which may need to be

removed from contaminated areas and ditches. The action limit for the emanation of ^{222}Rn from surfaces is proposed to be 2 $pCi/m^2/sec$. Air concentrations of ^{222}Rn in uncontrolled and controlled areas, respectively, are to be a maximum of 3 pCi/l and 30 pCi/l, respectively.

Regulatory guidance is available for several aspects of hazard assessment. For restricted and unrestricted access sites, these include: (1) direct external radiation levels, (2) air concentration of selected nuclides and metals, (3) water concentrations of selected nuclides and metals, and (4) soil/sediment concentrations of specific nuclides.

7.2.4. Toxicity and Bioaccumulation Information

Data are available for some nuclides and other elements regarding their uptake (bioaccumulation) by plants and animals and effects on biological processes. These data are summarized in Appendix J.2 for those species which would be appropriate for assessment purposes on the Site.

Bioaccumulation data are particularly useful for hazard assessment because they allow estimation of indirect exposure pathways. For example, contaminants in ditch and creek sediments could be accumulated in aquatic biota, fish, and ultimately ingested by humans.

7.2.5. Dose Assessment Model

A mathematical methodology for estimating dose to a hypothetical individual or population under worst case conditions has been developed. The mathematical model used in this assessment is described in Appendix J.3. The model allows calculation of ingestion and inhalation doses of specific nuclides for which ICRP (International Commission on Radiological Protection) has developed data over specified time periods. Inputs include radionuclide concentrations in air, soil, plants, and animals. Outputs are dose commitments estimated over chosen time periods.

For this assessment, nuclides used for model inputs were ^{226}Ra, ^{222}Rn, and radon daughters because of their documented implications to human health.

7.2.6. Plume Dispersion Model

Building 434 and the storage buildings in the southwest area as well as the R-10 residue storage area have appreciable radon flux. The release from Building 434 is 49 m (165 ft) above ground level while that from other sources is at ground level. Building 434 has now been sealed. Modeled values were based on information gathered prior to the December 1980 sealing of the building. A model is available allowing calculation of dispersion of radon from each of these two sources. Details of the model are given in Appendix J.4. Calculation of dispersion of radon in the area surrounding the Site allows an estimate of exposure to radon and radon daughters to be made.

7.3. ASSESSMENT OF RADIOLOGICAL HAZARDS

The two potential radiological hazards associated with stored residues and contaminated areas in the DOE-Niagara Falls Storage Site are ^{226}Ra and ^{222}Rn. ^{226}Ra is of concern because of its long half-life (1,602 yrs), its potential for environmental transport, and its decay chain. ^{222}Rn is of concern because it is a gas which decays to alpha-emitting daughter products which can result in significant inhalation doses. Other nuclides on the Site present relatively minor hazards because of their low concentrations, isolation from the biosphere, or low bioloigcal toxicity.

7.3.1. Radium

Allowable ^{226}Ra concentrations in soils/sediments are proposed by U.S. EPA (1980a, b) to be 5 pCi/g. This value represents twice background levels in the soils of the Niagara Falls Storage Site. ^{226}Ra, like Ca, primarily accumulates in bone and secondarily in kidney tissues. The major route of ^{226}Ra exposure is via ingestion of contaminated food and water. Because of its potential for bioaccumulation, ^{226}Ra can provide appreciable doses over a period of time.

Off-site soils and sediments (1) between Lutts Road and the West Ditch and (2) in the West Ditch and Central Drainage Ditch are in excess of the 5 pCi/g guideline. The greatest concentration of ^{226}Ra in the off-site ditches was 107 pCi/g. Exposures to this level in addition to the potential consumption of foodstuffs from the ditch (e.g., fish, cattails and frogs) are the primary dose sources to man. The maximum on-site ^{226}Ra concentration in groundwater of 34 pCi/l (see Appendix I, Table I-19) was found to be below the federal limit for uncontrolled areas (40 pCi/l) (see Appendix J.1). Therefore, ^{226}Ra in groundwater presents a negligible hazard.

Hypothetical ^{226}Ra doses were calculated using known concentrations in residues and background soils and a computer model which allows calculation of total dose from all pathways under worst case (total dietary intake from R-10 residue storage area) and background (off-site conditions). The chemical toxicity of ^{226}Ra is assumed to be negligible in this analysis. ^{226}Ra concentrations for the R-10 residues and background soils were 3,000 and 3 pCi/g, respectively; which were used as source terms in the model.

The results of the dose assessment model are summarized in Table 7-2.

TABLE 7-2. SIMULATED DOSE OF ^{226}RA AND ^{222}RN RECEIVED BY A PERSON RESIDING ON THE R-10 RESIDUE SPOIL PILE AND OFF-SITE (BACKGROUND) OVER A 70-YR EXPOSURE PERIOD

Parameter	R-10 Residues (times background)		Background (rems)	
	^{226}Ra	^{222}Rn	^{226}Ra	^{222}Rn
Bone	47.3	--	3099.0	--
Whole Body	45.8	--	419.0	--
Tracheal	--	846.0	--	2.1
Pulmonary	--	84.6	--	285.0

The worst case conditions were defined as the dose to a hypothetical person living on the R-10 residue storage area for as long as 70 yrs, utilizing only air, water, and food sources derived from the Site. The background conditions were defined as the dose to a hypothetical person living off-site within the proximity. The worst case condition is quite unrealistic in terms of occupational exposure under current Site conditions (see Appendix J.3) since a worker on the Site would not obtain any dietary intake from the spoils pile. Thus, a more reasonable dose estimate would be a small fraction of the computed dose primarily based on ingestion of resuspended particulates.

7.3.2. Radon

^{222}Rn, a noble gas, has a half-life of 3.82 days and is considered for hazard assessment because of its alpha-emitting daughter products. Table 7-3 summarizes the calculated radon flux from an air concentration above residues stored in buildings and on the ground at the Site. Due to the exposed surface area, the R-10 residue area represents the greatest source term for ^{222}Rn on the Site. Moreover, the southwest residue storage area (Buildings 411, 413 and 414 and the R-10 residue storage area) contributes the most to ^{222}Rn transport off-site because of its amount of exposed surface area and because the release is at ground level which inhibits atmospheric dispersion.

Regulatory limits for ^{222}Rn in air for uncontrolled and controlled area are 3 and 30 pCi/l, respectively (see Appendix J, Table J1-1). The southwest portion of the Site exceeds the controlled area limit (see Appendix H.4) and the boundary exceeds uncontrolled area limit (see Appendix A.4). Radon abatement experiments in Buildings 413, and 414 and on test plots in the R-10 residue storage area were unsuccessful because the asphaltic emulsion applied did not retain its integrity (see Appendix G.2). The top of Building 434 has recently been sealed using a metal cap. Therefore, flux release from this source should be minimal after 1980.

TABLE 7-3. RADON EMANATION FROM AND CONCENTRATIONS ABOVE PITCHBLENDE RESIDUES STORED AT THE DOE-NIAGARA FALLS STORAGE SITE

Source (Residue)	Soil ^{226}Ra (pCi/g x 10^3)	Calculated ^{222}Rn(a) Flux (pCi/m^2/sec x 10^4)	Exposed Surface (m^2)	Total Calculated ^{222}Rn Flux (pCi/sec x 10^6)	^{222}Rn Concentration in Air (pCi/l)(b)
434(K-65)	180	6.2	117.0	1.0	4000-117,000
411(L-30)	7.	8.9	1860.5	5.6	900-2400
413(L-50)	8	0.3	281.2	1.1	1800-8075
414(L-50)	8	0.4	281.2	1.1	2130-7893
R-10(R-10)	3	0.15	37,373.0	55.6	260

(a) Wilkening, 1977. Assuming 8,750 atoms $^{222}Rn/m^2/sec/pCi$ $^{226}Ra/g$ and 1 atom of ^{222}Rn = 56.7 x 10^{-6} pCi ^{222}Rn.

(b) Measured 1.5 m above surface except Building 434 where measurements were made at loading port at top of tower.

Table 7-4 shows predicted concentrations of ^{222}Rn contributed by the several residue storage areas on the Site within the proximity. These values were calculated using a plume dispersion model (see Appendix J.4) with the release from Building 434 being elevated 50 m (prior to capping) and from the southwest storage area being at ground level. The short-term maximum and highest annual average concentrations occurred at the West Ditch, approximately 30 m west of the Site boundary. Potentially, the short-term maximum radon concentration at Creek Road would be 668 pCi/l ^{222}Rn. Based on both measured concentrations (see Table 7-3) and predicted dispersion (see Table 7-4), the off-site area to the west would benefit from radon abatement in the southwest residue storage complex.

Using the dose assessment model (see Appendix J.3), the dose to a hypothetical person living on the R-10 residue area and off-site was evaluated. ^{222}Rn concentrations in air for R-10 residues and background conditions were assumed to be 180-260 and 0.23-0.30 pCi/l, respectively, as source terms in the model. Results of the model indicate the greatest dose would be to the trachea at 846 times background. However, a worker on the site would receive only a small fraction of the calculated dose based on the amount of time spent on the site.

Direct inhalation of radon daughters is also possible on the Site. Based on health physics surveillance (see Appendix C), a 40-hr exposure to suspended particulates in the R-10 residue storage area might result in an inhaled quantity of 4.8×10^{-4} pCi alpha, 4.8×10^{-2} pCi beta-gamma. Based on the short-lived daughters of ^{222}Rn (^{218}Po: ^{214}Pb:^{214}Po have relative abundances of 1:0.6:0.5), the risk may be small because of the 164 μsec to 3 min. half-lives involved. Analysis of high volume samples taken at the Site suggests average particle sive <10 μm and that >90 percent of the suspended radioactive particles are short-lived daughters which decay to undetectable levels in less than 24 hrs. Short-lived daughters constitute a greater health problem to occupational staff than to the general public because of (1) relatively higher concentrations and (2) the diminution of radionuclides with diffusion time and distance involved in transporting airborne particles off-site.

TABLE 7-4. PREDICTED CONCENTRATIONS OF ^{222}Rn CONTRIBUTED BY SOURCES[a] AT THE DOE-NIAGARA FALLS STORAGE SITE TO SIGNIFICANT RECEPTORS

Receptor Site	Location	Predicted Concentrations From All Sources[a] on Storage Site	
		Short-term Maximum[b,c] (pCi/ℓ)	Annual Average[c,d] (pCi/ℓ)
Niagara River	4 km west of Site	3.5	0.06
Lake Ontario Shore	6.5 km north of Site	1.9	0.02
City of Niagara Falls	16 km south of Site	0.6	0.01
Creek Road	300 m west of Site	23.2	1.05
West Ditch	Western boundary of Site 30 m from Bldgs. 411, 413, 414 and R-10	668.0	3.88

(a) Flux rates of ^{222}Rn used in the calculations were 6.5×10^7 pCi/sec from Building 434 considered as a point source and 4.4×10^7 pCi/sec from Buildings 411, 413, 414, and R-10 combined as one area source.

(b) The short-term value represents the maximum 1-hr average that might be observed. Because of variations in meteorological conditions, longer term averages would be smaller.

(c) No contribution from natural radon is included.

(d) The annual average calculation was based on the wind speed and direction frequencies of 1955-1959 (Bell Aerospace).

7.3.3. External Exposure

Exclusive of the residue storage buildings, the area with significant external exposure (gamma instrumental readings at 1 m) is in the southwest quadrant of the Site, with a maximum of 4 mR/hr. Using occupational regulatory guidelines (ERDA Manual Chapter 0524 and 10 CFR 20), 5 rems is the maximum permitted exposure yearly. A maximum of 1,250 hrs, 62 percent of the 2,000-hr workyear, could be spent in this area. A maximum of 625 hrs could be spent in the southwest residue storage buildings due to external exposure alone (maximum of 8 mR/hr; see Chapter 4). There is no limitation to working on the ground external to Building 434. Prior to the capping of the tower, a maximum of 167 hrs could have been spent in the area on top due to external exposure alone (maximum of 30 mR/hr; see Appendix G). Obviously, respiratory protection would also have been required due to radon daughters (see Appendix C). Remedial actions involving removal and handling of K-65 residues will require remote operations since the surfaces of drums containing the residues varied from 200-900 mR/hr gamma radiation during 1949 off-loading operations (Heatherton, 1950). Since ^{226}Ra has a half-live of 1,602 yrs, this high exposure rate would still be expected.

7.4. NONRADIOLOGICAL HAZARD ASSESSMENT

The residues stored and the contaminated areas within the DOE-Niagara Falls Storage Site have significant quantities of metals. Because of their potential toxicities, long residence times in soil, and bioaccumulation potentials, these metals were considered within this hazard assessment. While chemical and biological behavior of some substances, such as lead, are fairly well documented, others such as zirconium have received only cursory treatment. Further, synergistic effects due to exposure to several of the metals within the ore residues have not been explored.

Using drinking water criteria (see Appendix J.1), saturated zone water samples from the R-10 residue storage area and the Site periphery were examined. No metals were present in excess of standards. Metals

tend to be minimally soluble and are associated with clay fractions of soil and sediment rather than in water.

There are no guidelines or regulations applicable to concentrations of these metals in soils or sediments. Therefore, two comparisons of concentrations in the R-10 residue storage area and in the ditch were made: (1) to the average U.S. background soil concentrations and (2) to the estimated environmental concentrations (EEC) potentially allowing threshold toxicity levels to be reached (see Appendix J, Table J4-2). These EEC values are set extremely low because of the potential toxicity to organisms if these metals are bioaccumulated. These EEC values are calculated for the most mobile chemical form of the metals. The contaminated soils and sediments in the Niagara Falls Site are alkaline (pH 7-8) and have significant clay fractions. Both these factors greatly reduce the availability of these metals for biouptake.

Two potential hazards are associated with metal contamination of soils/sediments: (1) bioaccumulation and (2) impacts on soil fertility (nutrient cycling ability). Concentrations of metals warrant evaluation of hazards based on both these potential impacts. Bioaccumulation might lead to increased exposure of animal or human populations increasing risk (Jackson and Watson, 1977; see Appendix J, Table J2-3).

Metal concentrations were determined in a few plant and animal tissues taken from the R-10 residue storage area (animals) and Central Drainage Ditch (plant). Vegetative uptake is significant (see Appendix J, Table J2-5). Terrestrial animal tissue showed no detectable uptake. However, animals from the ditches were not examined. These data must be considered minimal and not an exhaustive characterization of nonradiological contaminants in biota on the Site.

The pathways to man, (e.g., ingestion of animal tissues with significant metal concentrations) are minimal to negligible in the proximity of the Site. The metals have low solubilities and are bound within clays. Metal uptake by aquatic organisms would be primarily by root uptake of macrophytes (such as cattails) or fish which may ingest sediment while browsing along the bottom. Such uptake would be minimal and slow, requiring times longer than the lives of most aquatic organisms to reach toxic levels.

Metal concentrations may impact remedial action activities in several ways. First, vegetation from contaminated areas and ditches may have to be considered contaminated for purposes of disposal. Second, if remedial actions include processes which dry or powder contaminated soils/sediments, an industrial hazard from metals resuspended in air may be presented and require resolution.

The state-of-the-art in assessment of nonradiological hazards is far less than in assessment of radiological hazards. It is possible to identify these metal concentrations as a potential hazard but their actual risk to man or ecological systems in their present chemical forms, predominantly associated with clays, cannot be accurately quantified. Based on studies by Bruns (1979), Cohen and Lee (1979), and Crawford and Leggett (1980), it is conceivable that these stable elements may present at least as great a risk to the environment as the low-level radioactive materials in storage.

7.5. IMPLICATIONS TO HEALTH AND ENVIRONMENTAL QUALITY

In order to conduct Site operations and remedial action activities while minimizing risk, procedures are defined which apply a conservative approach. This simply means that procedures used are designed to be as conservative as necessary to minimize risk from the most severe hazard existing at the Site. This concept suggests that if procedures are developed to minimize risk of the most severe hazard, other risks will be minimized simultaneously. However, synergistic effects of multiple contaminants cannot be dealt with using this simple approach. In the case of the Niagara Falls Storage Site, however, the chemical nature of the contaminants suggests synergistic effects would also be minimal.

7.5.1. Human Exposure

The primary risk on the Site is associated with inhalation of contaminants, primarily radon gas and airborne suspended particulates. The most restrictive conditions will be imposed by high radon concentrations and gamma exposures due to high ^{226}Ra concentrations. Procedures

required will be those defining respiratory protection and length of exposures allowed to (1) satisfy regulatory limits, (2) allow repeated assignment of the same personnel, and (3) minimize exposure rate and total exposures.

Additional procedures may be required depending on remedial action options selected for implementation. Two primary problems could be encountered: (1) increased external exposure risks if the K-65 residues are removed from Building 434, potentially requiring remote handling, and (2) increased resuspension if residues or contaminated soils/sediments are dried or processed into powders. Both radiological and metal resuspension would increase if contaminated materials were dried.

Procedures used to minimize personnel exposure must be compatible with keeping public exposures within regulatory limits. For example, ventilation of residue buildings prior to or during entries should not increase off-site ^{222}Rn concentrations or resuspended airborne particulates above levels which would increase average exposures significantly and no more than a factor of 10 greater than average air concentrations in working areas for any time period.

7.5.2. Ecological Implications

The major ecological risk occurs from (1) bioaccumulation of contaminants to toxic levels or (2) disruption of nutrient cycling processes. Both these processes can pose increased hazards during remedial actions and procedures to minimize these may be needed. Small animals (with very small home ranges) living in the R-10 residue storage and spoil pile area could experience significant radon daughter lung doses. The sensitivity of these animals to such doses is not known.

Bioaccumulation of contaminants is minimal currently because of their chemical form which minimizes their availability for biouptake. However, remedial action activities could increase ecological risks. Turbulence in ditches during excavation of contaminated sediments might affect ecological receptors directly (toxic), increase biouptake or change chemical forms of contaminants, and thus increase toxicity. The most easily implementable measure to minimize such risks is to isolate processing from the environment.

The effects of metals on nutrient cycling processes may dictate procedures to be used in remedial action activities, especially if some contaminated areas are to be stabilized in situ. Metal migration from other contaminated areas may suggest implementation of procedures selecting amendments to add to soil and/or vegetative cover to minimize metal transport and sustain soil productivity.

7.6. SUMMARY

The area of the DOE-Niagara Falls Storage Site presenting the greatest potential radiological and nonradiological hazard is the R-10 residue storage and spoil pile area. The greatest potential hazard is ^{222}Rn emanation and subsequent inhalation dose to lungs. The R-10 residue storage area is at and above the regulatory value of 30 pCi/l ^{222}Rn in air for controlled sites. The off-site area to the west exceeds the annual permissible average of 3 pCi/l ^{222}Rn in air.

The R-10 residue storage and spoil pile area is the primary source of off-site contamination through (1) erosion to the Central Drainage and West ditches and (2) soluble nuclide and metal transport to drainages and saturated zone water. Saturated zone water, even in the R-10 residue storage area, is currently within drinking water guidelines for uranium, ^{226}Ra, and metals.

The hazards posed by ^{226}Ra and metals in contaminated areas are lessened because of the (1) alkaline nature of the soils, (2) clay adsorptivity, and (3) slow bioaccumulation rates. However, these hazards have significant implications during remedial actions. The many saturated zones in the R-10 residue storage area present a potential for increased migration during excavation. While these materials are somewhat stabilized in the vegetative cover and clay fractions of soil, excavation will destroy existing stability and increase the hazard of resuspension and migration. Finally, any waste processing activities would require care to minimize the industrial hazards from metal resuspension.

CHAPTER 8: REFERENCES AND SELECTED BIBLIOGRAPHY

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CHAPTER 9. GLOSSARY

AEC	U.S. Atomic Energy Commission (federal agency that preceded DOE and the U.S. Nuclear Regulatory Commission)
ANSI	American National Standards Institute
BCL	Battelle Columbus Laboratories
cm	Centimeter, a unit of length equal to approximately 0.297 inch
Cs	Cesium, an element possessing radioactive isotopes; ^{137}Cs is one of the long-lived fission products
cu yds	Cubic yards
curie	Unit for measuring radioactivity; one curie equals that quantity of any isotope undergoing 3.7×10^{10} disintegrations per second; the curie is also defined as that amount of radioactivity which has the same disintegration rate as 1 gram of ^{226}Ra
D&D	Decommissioning and decontamination—the cleanup and restoration of a facility and/or site to an acceptable, reasonable condition
DOE	U.S. Department of Energy (established in 1977)
EEC	Estimated environmental concentration.
EPA	U.S. Environmental Protection Agency
ft/mi	feet per mile
in	inch
LOOW	Lake Ontario Ordnance Works
MED	Manhattan Engineering District
mg/g	Milligram (10^{-3}) per gram; a gram is a metric unit of mass weight equalling 0.0352 ounce
mi	mile
MPC	Maximum permissable concentration

nCi/l (gm)	Nano (10^{-9}) curies per liter (or per gram) (see curie); a liter equals 1.057 quarts
Niagara Frontier	Proper name for the region surrounding the Niagara River north of the escarpment
NLO, Inc.	Formerly the National Lead Company of Ohio, Incorporated
NRC	Nuclear Regulatory Commission
ORO	Oak Ridge Operations
Pb	lead
PNL	Battelle Pacific Northwest Laboratory
pCi/l (gm)	Pico (10^{-12}) curies per liter (or per gram)
pitchblende	Brown-black mineral containing uranium and its decay products; ores are extracted for uranium and residues and wastes result
QA	quality assurance
Ra	Radium, a naturally-occurring radioactive element possessing 16 isotopes; it is present in pitchblende and residues as ^{226}Ra
Rn	Radon, a naturally-occurring radioactive element possessing 20 isotopes; ^{222}Rn is the first decay product of radium and is a noble gas; decay products of ^{222}Rn are particulates
sq ft	square foot
sq yds	square yards
TLD	Thermoluminescent dosimeter, a device for measuring environmental/personnel exposure to radioactivity
TNT	Trinitrotolulene, an explosive