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Formerly Utilized Sites Remedial Action Program (FUSRAP)
Contract No. DE-AC05-91OR21949

NIAGARA FALLS STORAGE SITE ENVIRONMENTAL SURVEILLANCE REPORT FOR CALENDAR YEAR 1993

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Lewiston, New York

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LEWISTON, NEW YORK

MAY 1994

Prepared for

United States Department of Energy
Oak Ridge Operations Office
Under Contract No. DE-AC05-91OR21949

By

Bechtel National, Inc.
Oak Ridge, Tennessee

Bechtel Job No. 14501

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INTRODUCTION

This report summarizes the results of environmental surveillance activities conducted at the Niagara Falls Storage Site (NFSS) during calendar year 1993. It includes an overview of site operations, the basis for radiological and nonradiological monitoring, a summary of the results, and the estimated dose to the offsite population. Environmental surveillance activities were conducted in accordance with the site environmental monitoring plan, which describes the rationale and design criteria for the surveillance program, the frequency of sampling and analysis, specific sampling and analysis procedures, and quality assurance requirements. NFSS is in compliance with National Emission Standards for Hazardous Air Pollutants (NESHAPs) Part H of the Clean Air Act as well as the requirements of the National Pollutant Discharge Elimination System (NPDES) under the Clean Water Act.

The U.S. Department of Energy (DOE) has conducted environmental monitoring of NFSS since 1981. The site is assigned to DOE's Formerly Utilized Sites Remedial Action Program (FUSRAP). FUSRAP was established in 1974 to identify and decontaminate or otherwise control sites where residual radioactive materials remain from the early years of the nation's atomic energy program or from commercial operations causing conditions that Congress has authorized DOE to remedy. Located in northwestern New York, the site covers 191 acres. From 1944 to the present, the primary use of NFSS has been storage of radioactive residues that were by-products of uranium production. Most onsite areas of residual radioactivity above regulatory guidelines were remediated during the early 1980s. Materials generated during remediation are stored onsite in the 10-acre waste containment structure, a clay-lined, clay-capped, and grass-covered storage structure or were disposed of at offsite facilities. Additional isolated areas of onsite contamination were remediated in 1989, and the materials were consolidated into the waste containment structure in 1991. Remediation of the site has now been completed.

Environmental remediation of NFSS was conducted in accordance with the National Environmental Protection Act (NEPA), and applicable DOE requirements authorized by the Atomic Energy Act before enactment of the Superfund Amendments and Reauthorization Act (SARA). The Comprehensive Environmental Response, Compensation, and Liability Act

(CERCLA), as amended by SARA, and the National Oil and Hazardous Substances Pollution Contingency Plan are the primary sources of federal regulatory authority for any further remedial actions that may be conducted at NFSS.

During 1993, site activities included routine grounds and equipment maintenance and environmental surveillance. A stormwater runoff permit review was also completed, and the application for a NPDES general stormwater permit was initiated. Monitoring results in 1993 for air, surface water, and sediment indicated that NFSS is not making a significant contribution of radioactivity to the environment. Groundwater monitoring results show that concentrations of radiological and chemical constituents were within DOE guidelines and below levels that would require remedial action. Appendix A contains a discussion of the nature of radiation, the way it is measured, and common sources of it.

Copies of this report are distributed to government officials, members of Congress, environmental and civic groups, the news media, and interested individuals. Results of the NFSS environmental surveillance program have been published each year since the program began in 1981. The environmental surveillance report for 1993 and all previous reports are available in the Niagara Falls reference file in the Lewiston Public Library and at the DOE office at NFSS. The address is 1397 Pletcher Road, Lewiston, New York 14092. The telephone number is (716) 754-4442. The data used to compile this environmental surveillance report are available upon request.

DOE maintains a 24-hour, toll-free telephone number, 1-800-253-9759. An answering machine records comments or questions. The machine is checked frequently, and all calls are returned.

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HISTORY OF THE NIAGARA FALLS STORAGE SITE

NFSS is located at 1397 Pletcher Road in the township of Lewiston, Niagara County, New York, approximately 8 miles northeast of Niagara Falls and 4 miles south of Lake Ontario (Figure 1). The site occupies 191 acres. NFSS originated during World War II, when the U.S. Army Corps of Engineers, Manhattan Engineer District, predecessor to the U.S. Atomic Energy Commission, used part of the Army's Lake Ontario Ordnance Works (LOOW) as a transshipment and storage site for radioactive materials. The site was also used for enriching nonradioactive boron-10 (1954 through 1958 and 1964 through 1971). However, the primary use of the site (1944 to present) has been for storage of radioactive residues that were by-products of uranium production.

The NFSS property includes a three-story building (Building 401) with three adjacent silos, an office building, a small storage shed, and a storage building. The waste containment structure is a clay-lined, clay-capped, and grass-covered storage structure encompassing approximately 10 acres. The containment cover consists of 3 ft of compacted clay covered by 1.5 ft of topsoil and grass. The grass is maintained regularly to control airborne migration, and the property is posted and fenced to restrict public access. Approximately 255,000 yd^3 of contaminated materials moved from vicinity properties and other parts of NFSS areas during remediation are stored in the waste containment structure.

DOE maintains NFSS and performs environmental surveillance to ensure that the site does not adversely affect public health or the environment and that the site complies with all environmental regulations.

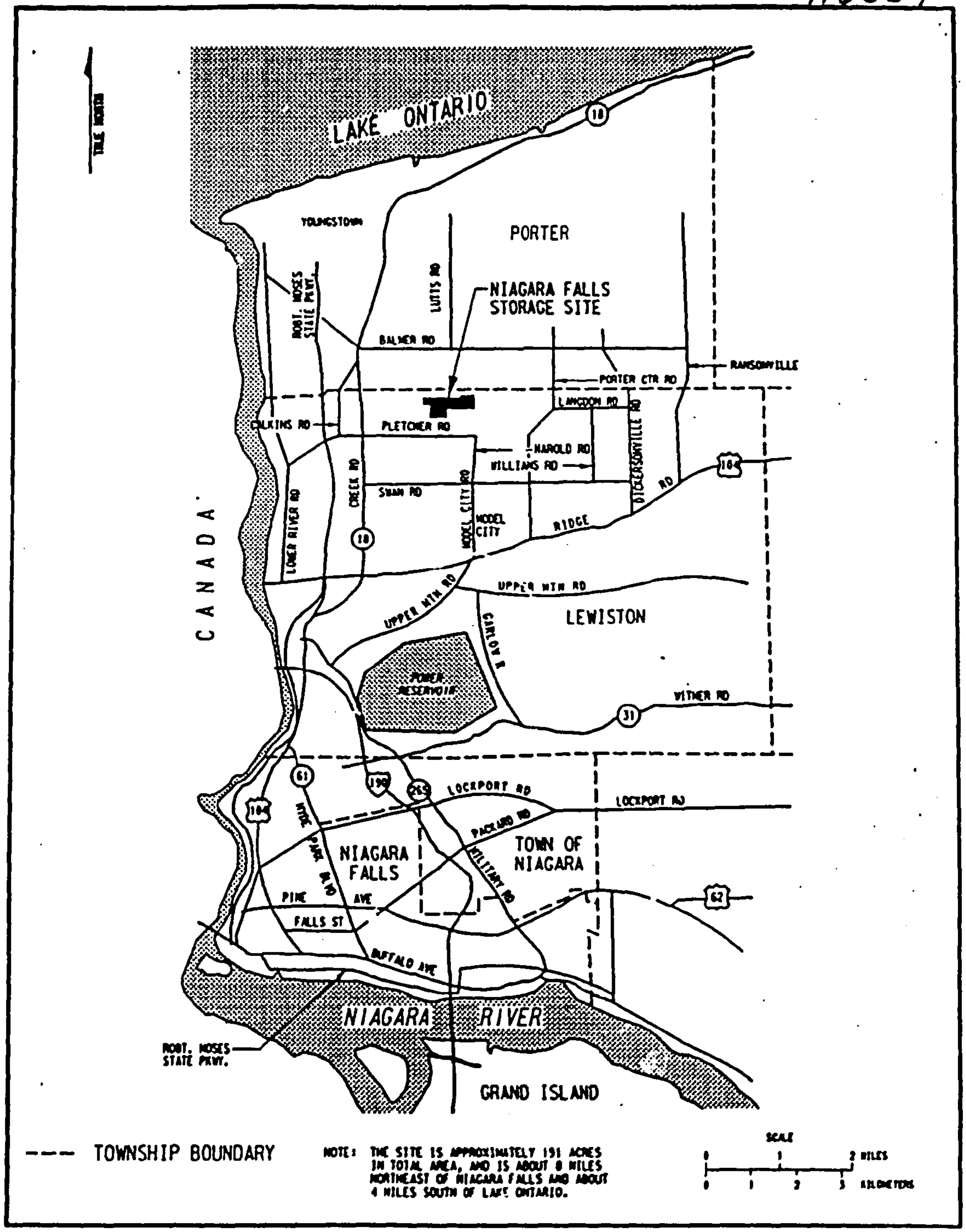

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Figure 1
Location of the Niagara Falls Storage Site

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THE ENVIRONMENTAL SURVEILLANCE PROGRAM AT NFSS

The goals of the environmental surveillance program at NFSS are to identify and quantify the effect of site activities on the environment and public health. DOE wants to be certain that site conditions do not adversely affect public health or the environment and that activities at the site comply with all environmental laws and regulations. Through the environmental surveillance program, DOE routinely collects the environmental data needed for evaluating the site.

Surveillance Program Description

The surveillance program monitors routes (or pathways) by which contaminants could migrate from the site to the offsite environment where they could potentially become sources of exposure to the public. Potential pathways include migration of dissolved contaminants in rainfall runoff or dispersion of radon gas or radioactive soil in the air. For example, if radioactive soil is present in the air, it could be deposited on a garden. A person could be exposed to this radioactivity by eating unwashed vegetables from the garden or by inhaling any radioactive soil that became airborne as the garden was cultivated.

Monitoring devices and sampling stations are located to be most effective in detecting potential contamination sources and ensuring that no contaminants are migrating from the site. In locating the sampling stations, the surveillance program considers factors such as wind directions, site terrain, and the paths through which water flows on and off the site. Other considerations include regulatory requirements, sampling frequency, and the kinds of sampling devices and laboratory analyses that are best for detecting or measuring a specific contaminant.

After an environmental surveillance program is established, it is continuously reevaluated and modified for effectiveness. Sampling and monitoring stations are relocated, new ones are added, and old ones are eliminated as information needs change.

Environmental Surveillance

The radioactive contaminants at NFSS are radium, uranium, and their associated decay products (such as radon gas). The environmental surveillance program at NFSS monitors for radon concentration in the air and for external gamma radiation exposure. Surface water, sediment, and groundwater are monitored for radium-226 and total uranium. The NFSS environmental surveillance program is summarized in Table 1. Figures 2 and 3 show the environmental surveillance locations at NFSS.

To monitor radon and external gamma radiation in air, DOE places radiological detection devices at locations within the NFSS property and along the fenceline at the edge of the property. Similar monitors are placed at locations well away from NFSS to measure "background" radiation. The radiological detection devices are in place 24 hours a day, year round. The fenceline locations represent the closest that a member of the public could come to the contamination on the site. The amount of radon or external gamma radiation measured at the fenceline, therefore, represents the maximum levels that could potentially be encountered by a member of the public. To receive the maximum, a person would have to stand at the fenceline 24 hours a day for an entire year. The data collected from the surveillance program are used for the assessment of doses to the public and not to onsite workers. Workers onsite participate in other monitoring programs to assess their personal exposure to radioactive material.

DOE uses a system of wells to monitor for contamination in groundwater. Several wells are used to sample the shallow groundwater beneath the perimeter of the waste containment structure. One well is used to sample the deep groundwater under the site, and one "background" well is located in an area known to be unaffected by the site. This background well measures the amounts of radioactive and chemical constituents that occur in the local environment. By comparing the samples from the background well with the samples from the other wells, DOE can determine whether materials in the waste containment structure are affecting groundwater quality.

Table 1

NFSS Environmental Surveillance Program Summary for 1993

Sample Type	Number of Sampling Locations	Analyses Performed	Frequency of Sampling for Chemical Analyses	Frequency of Sampling or Detector Exchanges for Radiological Analyses
Radon	22*	Radon concentrations in air	Not applicable	Quarterly
External gamma radiation	22**	External gamma radiation exposure rates	Not applicable	Semiannually
Groundwater	10***	Metals, total organic carbon, radium-226, total uranium (groundwater quality parameters - bicarbonate, carbonate, chloride, nitrate, sulfate, total dissolved solids)	Annually (Three wells-annually)	Annually Not applicable
Surface water and sediment	5***	Radium-226, total uranium	Not applicable	Annually

Quality Controls

* All locations have environmental duplicates.

** One location has an environmental duplicate, and one location has a matrix spike and matrix spike duplicate.

*** One location has an environmental duplicate.

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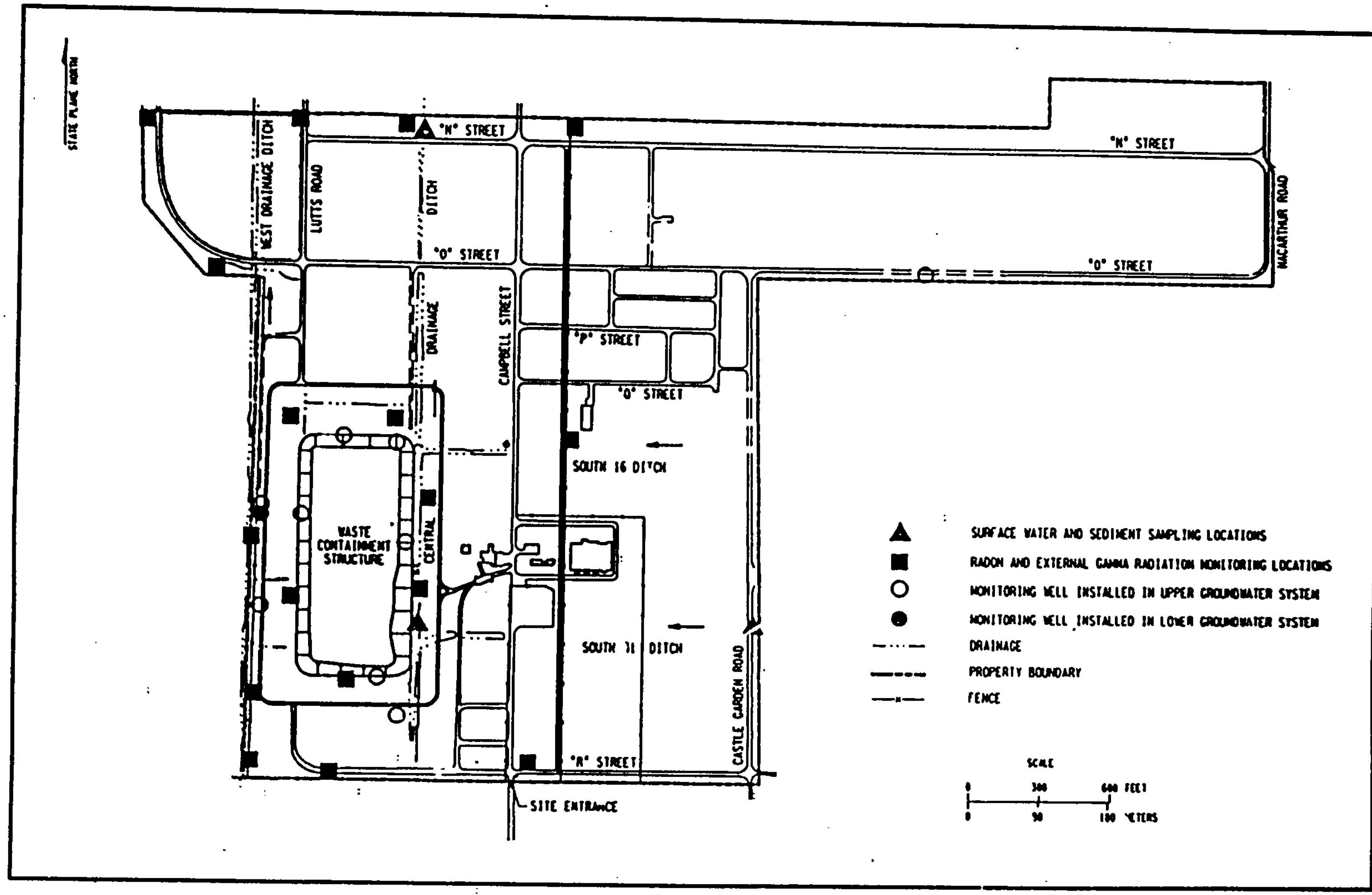

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Figure 2
Air, Surface Water, Sediment, and Groundwater Environmental Surveillance Locations at NFSS

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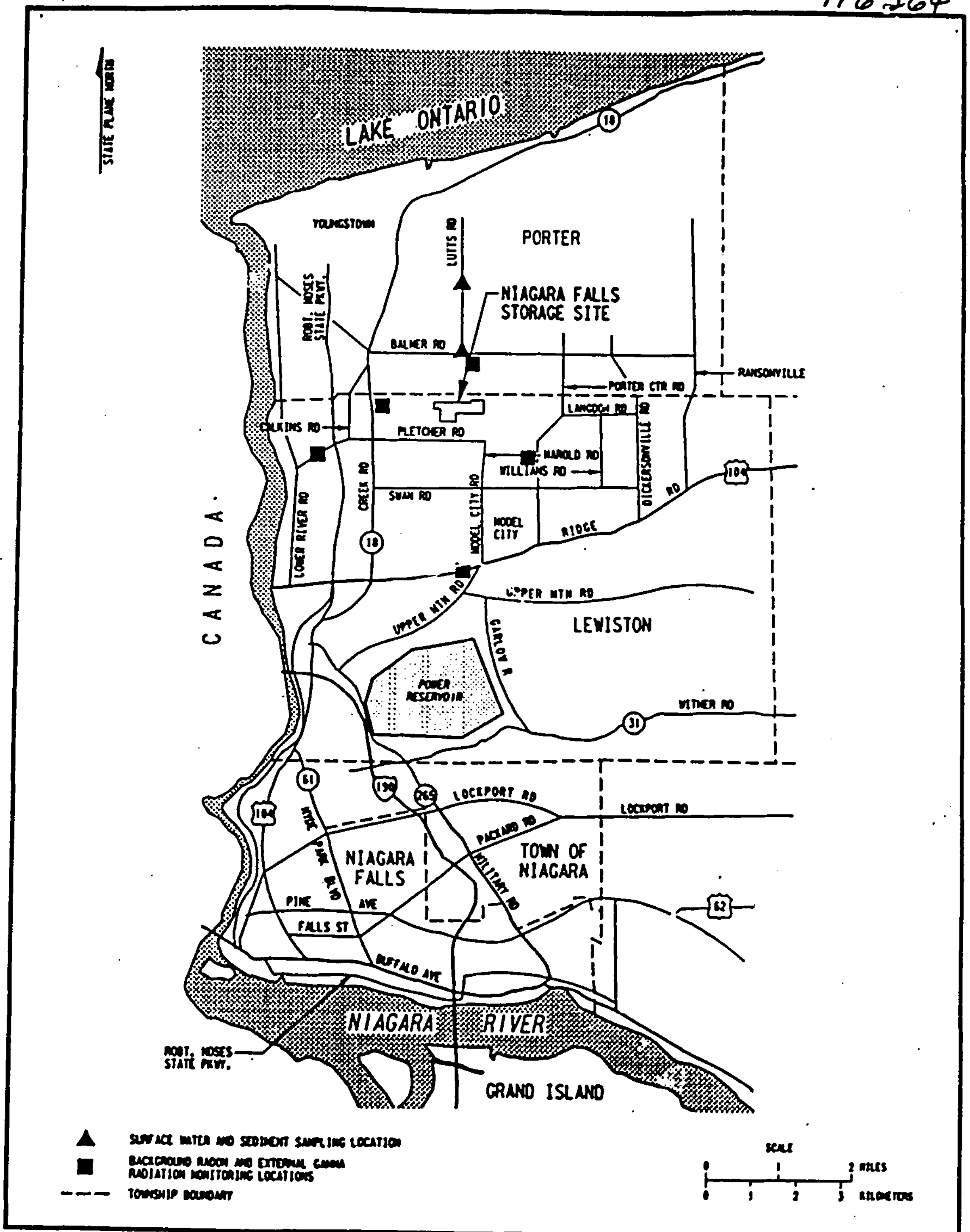

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Figure 3
Offsite Radon, External Gamma Radiation, Surface Water, and Sediment Monitoring Locations

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This same "before and after" principle is used in monitoring the effect of the site on surface water and sediment. A background sampling location monitors surface water and sediment unaffected by NFSS; other locations monitor the surface water and sediment in places that might be influenced by materials stored on the site.

Regulatory Limits for Chemical Releases

The regulations applying to chemical constituents associated with NFSS in 1993 are the Safe Drinking Water Act (SDWA) and the New York State Department of Environmental Conservation (NYSDEC) groundwater standards. The SDWA was enacted in 1974 to regulate drinking water systems, require EPA to set national standards for levels of contaminants in drinking water, and provide for protection of aquifers. Additional New York groundwater quality standards became effective in February 1993. These regulations are designed to protect ambient groundwater quality by establishing radiological and chemical constituent standards for groundwater pollutant discharges and groundwater cleanups. Environmental surveillance results from previous years showed that all constituents in groundwater at NFSS are below levels that would require remedial action. Groundwater in the NFSS vicinity is not used as a drinking water source.

Surveillance Results for Chemical Parameters at NFSS

Nonradiological surveillance at NFSS includes analyses for several metals and screening for organic contamination. Groundwater is monitored for indications of migration of the specific metals associated with wastes in the waste containment structure. Volatile organic compounds are not associated with the wastes in the waste containment structure, but as a precaution, the groundwater is also monitored for total organic carbon. Water quality parameters were measured in three of the wells.

Results of chemical surveillance at NFSS for 1993 showed that chemical constituents were consistently in compliance with applicable regulations. No concentration of metals exceeded federal or New York State guidelines.

Regulatory Limits for Radiological Releases

The primary federal statute governing air emissions is the Clean Air Act (CAA). The only potential sources of air emissions from NFSS are radon and dust-blown radionuclide emissions from the waste containment structure should the cover material be removed. The grass cover on the containment structure is routinely inspected, watered, and mowed to control erosion and dust. Radon emissions from the storage pile are regulated in the CAA under Subpart Q of NESHAPs, which limits radon-222 emissions to 20 picocuries per square meter per second (see Appendix A for explanation of units). Subpart H of NESHAPs regulates non-radon radionuclide releases to the air. The limit imposed is a calculated dose of 10 millirems per year (mrem/yr). This is a theoretical dose calculated for the sum of all airborne pathways, except for radon, from monitoring data using a standard computer model approved by both EPA and DOE.

DOE has established total quantity limits, derived concentration guides, and dose limits for radioactive releases from DOE facilities. Some regulations for radioactive contaminants set a limit on the amount or concentration of radioactivity that may be released; others set a limit on the dose a person could receive from releases. Conservative limits are also set for the dose a person could receive from all sources, from airborne releases, and from manmade beta-gamma emitters in drinking water. DOE Order 5400.5, "Radiation Protection of the Public and the Environment," sets conservative limits to which the site must adhere.

DOE Order 5400.5 specifies that the radiation dose to any member of the public resulting from routine DOE activities should not exceed 100 mrem/yr above background. This limit excludes medical procedures, residual fallout from past nuclear accidents and weapons tests, and consumer products. The radiation standards in DOE Order 5400.5 include EPA recommendations for limiting the doses from atmospheric releases and from drinking water. These recommendations state that the dose to an individual must not exceed 10 mrem/yr from releases of radioactivity to the air. The 10 mrem/yr does not include radon because radon is subject to specific DOE limits. The recommendations also state that the concentration of manmade beta-gamma radiation in drinking water must not exceed a dose of

4 mrem/yr. There is no separate limit for liquid releases alone, but these releases are included in the 100-mrem/yr limit for all pathways. Figure 4 illustrates the contribution from NFSS to the dose to the public compared with the dose from background radiation and the DOE guideline of 100 mrem/yr.

Surveillance Results for Radiological Parameters at NFSS

Environmental surveillance results for 1993 show that NFSS was in compliance with all applicable DOE radionuclide release standards and guidelines. Since environmental surveillance at the site began in 1981, analytical results consistently have shown that NFSS is making no significant contribution of radioactivity to the environment. The results of radiological surveillance for 1993 again showed this to be true. The additional radiation dose to the offsite population attributable to NFSS is very close to zero. This is consistent with results from previous years.

The 1993 results for radon monitoring at NFSS showed that fenceline measurements were about the same as background and far below the DOE guideline of 3.0 picocuries per liter (pCi/L).

External gamma exposure monitoring results for 1993 showed an average exposure rate of 0 milliroentgen per year (mR/yr) at the site fenceline. (One mR is approximately equivalent to 1 mrem.) This measurement does not include the normal background gamma exposure rate of approximately 83 mR/yr. Measurements at all of the monitoring stations, including those near the storage structure, ranged from 0 to 6 mR/yr above background. Figures 2 and 3 show the locations of fenceline and other external gamma monitoring stations.

The property nearest this area is a solid waste disposal facility (Modern Disposal) to the east and south of the site. The nearest residential areas are approximately 0.68 miles southwest of the site; the residences are primarily single-family dwellings. The nearest school is the Lewiston-Porter Central School, located 1.1 miles west of the site.

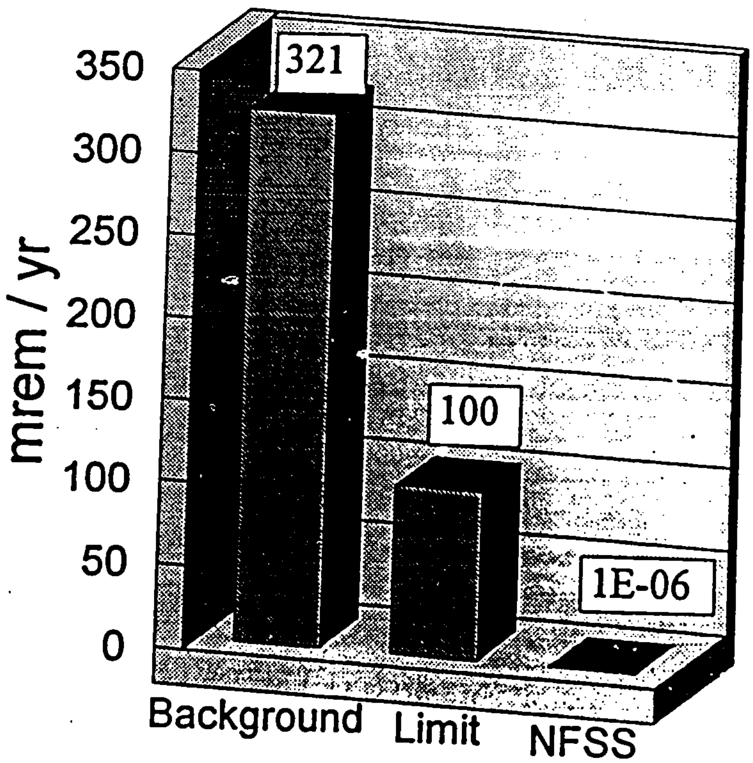

Figure 4
Comparison of Dose from the Site with Background and DOE Guideline

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Because the gamma exposure rate at the fenceline is equivalent to background, there is no reasonable scenario in which a hypothetical individual would receive any gamma radiation exposure attributable to NFSS.

Results of groundwater monitoring for radium and uranium showed that concentrations were far below DOE guidelines. Overall, radionuclide concentrations measured in groundwater associated with NFSS are low and have been consistently low since monitoring began.

Radiological sampling of surface water and sediment yielded results that were about the same as background and below guidelines and standards. These results are consistent with monitoring results from previous years.

The ALARA (As-Low-As-Reasonably-Achievable) Program

The goal of any ALARA program is to keep radiation exposure to members of the public and onsite workers as low as reasonably achievable. To implement this program at FUSRAP sites, every reasonable effort is made to maintain exposures to radiation from the sites as far as possible below the established dose limits for both worker and public exposure.

Traditionally, ALARA guides have been established to limit the amounts and concentrations of radioactive materials that could be released to the environment from nuclear facilities. Current regulations governing releases of radioactive materials emphasize minimizing the dose received from a release rather than the quantity of the release; consequently, the ALARA guidelines at all FUSRAP sites have been established to limit the total dose resulting from exposure (both internal and external) to radioactivity.

ALARA is implemented at FUSRAP sites by continuously evaluating all site activities to determine any potential increase in the risk of exposure to radiation. Dose estimates are used to identify trends to determine best management practices that should be implemented to further reduce the dose to the general public and site workers. This program has been successful in limiting dose to levels that are nearly the same as background.

Dose

As radioactive materials decay, they release energy in the form of rays and particles. When people are exposed to radioactive materials, body tissues can absorb some of the released energy, resulting in an absorbed dose. (For example, when people feel warmth from sunlight, they are actually absorbing radiant energy emitted by the sun.) However, in terms of human health, it is the effect of the absorbed dose, rather than the actual amount of radiation emitted, that is important.

The potential health effects that can result from an absorbed dose depend on the amount and type of energy absorbed and on the part of the body exposed. The effective dose (ED) is used to express dose in terms of the potential health impact. Use of the ED allows doses from different types of radiation and doses to different parts of the body to be expressed on the same basis. ED is expressed in mrem.

The amount of radioactivity measured in environmental samples does not represent the actual radiological impact of the site on the environment and offsite public. To determine the potential health effects, releases from NFSS are evaluated, and the maximum potential dose is calculated. Therefore, this report focuses on releases and maximum potential dose to explain the impact of the site on the surrounding communities.

Calculating Dose

With modern technology, very small amounts of radionuclides in environmental samples can be detected. Although all air and liquid emissions from NFSS are monitored the radionuclides at the site have such low concentrations when dispersed into the environment that they are difficult to distinguish from natural background radiation. Consequently, it is difficult to directly measure the public's exposure to some of the radioactive materials that might be released from the site. Therefore, mathematical models must be used to estimate the concentrations of radionuclides present in the environment as a result of the measured releases to air and water. Beginning with the measured releases and factoring in many other conditions (e.g., wind direction, rainfall, population distribution, and, in some cases, actual measurements from environmental samples), estimated concentrations are calculated. These estimated concentrations are used to calculate estimated doses from site releases.

When maximum doses are calculated from releases to the air and water from NFSS, the concept of a hypothetical individual who receives the maximum reasonable exposure from all pathways is used. Even though no such individual is known to exist, the concept of the maximally exposed individual is used to estimate the contribution from contaminants at NFSS to the dose of the offsite population; this ensures that the estimated dose is the highest any individual could have received as a result of site operations. For the purpose of this calculation, this hypothetical maximally exposed individual lives within 3,600 ft of the site, year round.

Table 2 presents estimates of the dose to the hypothetical maximally exposed member of the public from NFSS operations in 1993. Actual doses to any member of the public are expected to be lower than these conservative estimates. It is important to remember that the estimated dose reported by NFSS is only a part of the annual dose received by an individual; everyone is exposed to natural and man-made sources of radiation and receives a dose from that radiation regardless of exposure to radiation from NFSS (see Figure 4).

Quality Assurance and Quality Control

When releases are monitored and radiation in the environment is measured, there must be confidence that the data are reliable. To ensure that the monitoring and measurement results are accurate, NFSS has a quality assurance and quality control program based on state and federal guidelines. Subcontractor laboratories that provide services for NFSS must have established quality assurance and quality control programs and must participate in interlaboratory comparisons, evaluations, and audits of their facilities.

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Table 2

Comparison of Calculated Maximum Doses from NFSS for 1993 with Applicable Standards and Natural Background Radiation

Exposure Pathway	Dose for Hypothetical Maximally Exposed Individual from NFSS[a] (mrem/yr)	Applicable Standard[b] (mrem/yr)	Percent of Standard	Percent of Natural Background[c]
Direct gamma radiation[d]	0[e]	NA[f]	NA[f]	0[e]
Drinking water	0[g]	4[h]	NA[h]	0[g]
Airborne Pathways	1.7×10^{-6}	10[i]	1.7×10^{-5}	5.3×10^{-9}
All pathways	1.7×10^{-6}	100[j]	1.7×10^{-6}	5.3×10^{-9}

[a]Effective dose.

[b]All the limits listed are given in DOE Order 5400.5, February 8, 1990, "Radiation Protection of the Public and the Environment."

[c]The site-specific estimate of the average dose received from natural background radiation is 323 mrem/yr.

[d]Above natural background.

[e]Monitoring results for gamma radiation at the site fenceline are indistinguishable from background.

[f]There is no separate standard for direct gamma radiation alone, but it is included in the 100 mrem standard for all pathways.

[g]Exposure from this pathway is negligible. Groundwater is not a source of drinking water in the vicinity of NFSS.

[h]DOE Order 5400.5 provides a standard for dose from drinking water from manmade beta-gamma exposure. The standard excludes radium, uranium, radon, and other naturally occurring radionuclides.

[i]The standard for airborne effluents, excluding radon, applies to the sum of the doses from all airborne pathways: inhalation, exposure to radionuclides deposited on the ground surface, submersion in a plume, and consumption of foods contaminated as a result of the deposition of radionuclides.

[j]Exposure pathways are added to compare calculated maximum doses from NFSS releases with the DOE "all pathways" standard.

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APPENDIX A RADIATION AT A GLANCE

RADIATION AT A GLANCE

Of all activities at FUSRAP sites, those associated with radiation receive the most attention. What exactly is radiation and where does it come from? To answer these questions, it is best to start with a few basics.

All matter is made up of extremely small particles called atoms. Atoms contain even smaller particles called protons, neutrons, and electrons. When an atom has a stable mix of protons and neutrons, it is nonradioactive. However, when atoms have too many of either protons or neutrons, these unstable atoms can break apart, or decay, in an attempt to become stable. As atoms decay, energy is released; this released energy is called radiation.

Sources of Radiation

Radiation originates from natural events that happen all the time, but it can also be made by man. Most of the radiation people are exposed to occurs naturally. It has always been present, and every person who has ever lived has been exposed to radiation. Although modern technology may seem to have greatly increased the exposure rate, this is not necessarily the case. Exposure to man-made radiation varies greatly based on a given individual's lifestyle choices and medical treatments.

Sources of natural, or background, radiation include internal radiation from food (we all have approximately 500,000 atoms disintegrating in our bodies every minute), cosmic radiation from the sun and from outside the solar system, and terrestrial radiation from rocks, soils, and minerals (Figure A-1). People have no control over the amount of natural radiation around them, and the amount of natural radiation stays about the same over time. The natural radiation present in the environment today is not much different than it was hundreds of years ago. In general, over 80 percent of the radiation the average person is exposed to is from natural sources. Man-made radiation accounts for less than 20 percent of the total, most of it from medical procedures.

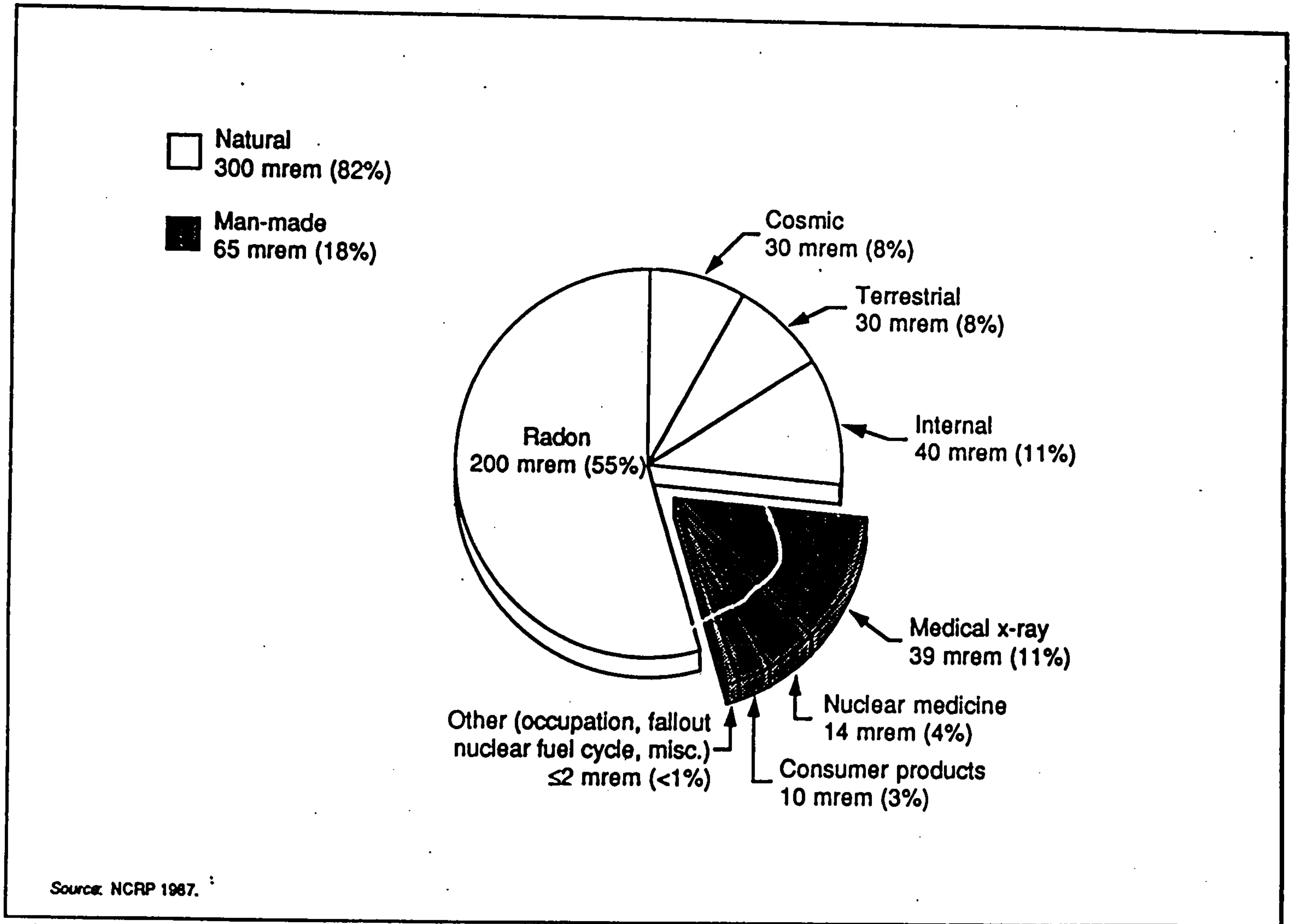

Figure A-1
Typical Annual Radiation Doses from Natural and Man-Made Sources

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Man-made sources of radiation include consumer products, medical procedures, and the nuclear industry. Some consumer products such as smoke detectors and even porcelain dentures contain radioactive elements. Probably the best-known source of man-made radiation is nuclear medicine. For example, to conduct a brain, liver, lung, or bone scan, doctors inject patients with radioactive compounds and then use radiation detectors to make a diagnosis by examining the resulting image of the organ.

Man-made radioactive materials also include cesium-137 and strontium-90, present in the environment as a result of previous nuclear weapons testing. As with background radiation, exposure to man-made radiation varies greatly depending on individual choices, such as smoking tobacco products (polonium-210) and eating certain foods (bananas contain potassium-40).

Levels of Radiation

The average dose caused by background radiation varies widely. In the United States, the average is about 300 mrem/yr; some people in other parts of the world receive a dose more than four times this amount. For example, in some areas of Brazil, doses to inhabitants can be more than 2,000 mrem/yr from background radiation. These wide variations are the result of several factors, most notably the types and amounts of radionuclides in the soil.

This diversity in background radiation is responsible for the large differences in doses. Because people live in areas with high levels of background radiation without proven harm, it is assumed by most in the scientific community that small variations in environmental radiation levels have an inconsequential, if any, effect on humans.

Measuring Radiation

To determine the possible effects of radiation on the health of the environment and people, these effects must be measured. More precisely, the potential for radiation to cause damage must be ascertained. Measurements of these potential effects are derived from the activity of each isotope and are expressed in terms of the absorbed dose to an individual and the effective dose or potential to cause biological damage.

Activity

When we measure the amount of radiation in the environment, what is actually being measured is the rate of radioactive decay, or radioactivity, of a given element. This radioactivity is expressed in a unit of measure known as a curie (Ci). A curie is a measure of radioactivity, not a set quantity of material. More specifically, one curie equals 37,000,000,000 disintegrations per second. One gram of a radioactive substance may contain the same amount of radioactivity as several tons of another radioactive substance. For example, one gram of tritium (a radioactive form of hydrogen) emits about 10,000 Ci, while one gram of uranium emits about 0.000000333 Ci.

Absorbed Dose

The total amount of energy per mass unit absorbed as a result of exposure to radiation is expressed in a unit of measure known as a rad. However, in terms of human health, it is the effect of the absorbed energy that is important, not the actual amount of energy emitted.

Effective Dose

The measure of potential biological damage caused by exposure to and subsequent absorption of radiation is expressed in a unit of measure known as a rem. One rem of any type of radiation has the same total damaging effect, regardless of the source of the radiation. Because a rem represents a fairly large dose, dose is usually expressed as a millirem (mrem), or 1/1,000 of a rem. The larger the dose, the higher the potential for damage. The dose from FUSRAP site activities is a small fraction of the dose that residents in the area surrounding the site receive from natural background radiation. Table A-1 explains the potential health effects of a range of radiation doses.

Table A-1

Comparison and Description of Various Dose Levels

Dose	Description
1 mrem	Approximate daily dose from natural background radiation, including that due to radon.
2.5 mrem	Cosmic dose to a person on a one-way airplane flight from New York to Los Angeles.
4 mrem	Annual exposure limit from manmade radiation in drinking water.
10 mrem	Typical dose from one chest X-ray using modern equipment.
10 mrem	Annual exposure limit, set by EPA, for exposures from airborne emissions (excluding radon) from operations of nuclear fuel cycle facilities, including power plants, uranium mines, and mills.
25 mrem	Annual exposure limit from low-level waste-related exposures.
65 mrem	Average yearly dose to people in the United States from man-made sources.
60-80 mrem	Average yearly dose from cosmic radiation to people in the Rocky Mountain states.
83 mrem	Estimate of the largest dose any offsite person could have received from the March 28, 1979, Three Mile Island nuclear accident.
100 mrem	Annual limit of dose from all DOE facilities to a member of the public who is not a radiation worker.
110 mrem	Average occupational dose received by United States commercial radiation workers in 1980.
170 mrem	Average yearly dose to an airline flight crew member from cosmic radiation.
300 mrem	Average yearly dose to people in the United States from all sources of natural background radiation.
900 mrem	Average dose from a lower-intestine diagnostic X-ray series.
1,000-5,000 mrem	EPA's Protective Action Guidelines state that public officials should take emergency action when the dose to a member of the public from a nuclear accident will likely reach this range.

5,000 mrem	Annual limit for occupational exposure of radiation workers set by the U.S. Nuclear Regulatory Commission and DOE.
8,000 mrem	Average yearly dose to the lungs from smoking 1½ packs of cigarettes per day.
10,000 mrem	The BEIR V report estimated that an acute dose at this level would result in a lifetime excess risk of death from cancer, caused by the radiation, of 0.8 percent.
25,000 mrem	EPA's guideline for voluntary maximum dose to emergency workers for non-lifesaving work during an emergency.
75,000 mrem	EPA's guideline for maximum dose to emergency workers volunteering for lifesaving work.
50,000-600,000 mrem	Doses in this range received over a short period of time will produce radiation sickness in varying degrees. At the lower end of this range, people are expected to recover completely, given proper medical attention. At the top of this range, most people will die within 60 days.