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Formerly Utilized Sites Remedial Action Program (FUSRAP)

ADMINISTRATIVE RECORD

for Maywood, New Jersey

U.S. Department of Energy

0489-0613.1

Department of Energy

Oak Ridge Operations
P.O. Box 2001
Oak Ridge, Tennessee 37831—

94-336

JUN 01 1994

Honorable Philip Toronto
Mayor
One Memorial Drive
Lodi, NJ 07644

Dear Mayor Toronto:

MAYWOOD SITE - TRANSMITTAL OF 1993 ENVIRONMENTAL SURVEILLANCE REPORT

The purpose of this letter is to inform you that the 1993 environmental surveillance report for the Maywood site, located in Maywood, New Jersey, has been published and is now available. This site is managed by the U.S. Department of Energy (DOE) for the storage of radioactively contaminated soils. Enclosed is a copy of the report, along with a fact sheet summarizing results from this year's environmental surveillance efforts.

Please feel free to contact me directly with any questions that you might have on either the environmental surveillance program or any other aspect of DOE's environmental restoration activities. My number is 615-576-5724. You may also call or visit the DOE Public Information Center at 43 West Pleasant Avenue in Maywood (201-843-7466) or call DOE's toll-free access number, 1-800-253-9759, and leave a message. Someone will return your call promptly.

Sincerely,

Susan M. Cange

Susan M. Cange, Site Manager
Former Sites Restoration Division

Enclosure

DOE/OR/21949-373

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

MAYWOOD INTERIM STORAGE SITE ENVIRONMENTAL SURVEILLANCE REPORT FOR CALENDAR YEAR 1993

100 West Hunter Avenue
Maywood, New Jersey

June 1994

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DOE/OR/21949-373

MAYWOOD INTERIM STORAGE SITE

ENVIRONMENTAL SURVEILLANCE REPORT

FOR CALENDAR YEAR 1993

100 WEST HUNTER AVENUE

MAYWOOD, NEW JERSEY

JUNE 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 Maywood Interim Storage Site (MISS) during calendar year 1993. It includes an overview of site operations, the basis for radiological and nonradiological monitoring as well as summaries and results of the 1993 environmental programs at MISS. 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.

Environmental monitoring of MISS began in 1984 when the site was assigned to the U.S. Department of Energy (DOE) by Congress through the Energy and Water Development Appropriations Act and subsequently 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 and from commercial operations causing conditions that Congress has authorized DOE to remedy. In 1983, the Maywood site was added to the U.S. Environmental Protection Agency (EPA) National Priorities List (NPL).

MISS is located in the Borough of Maywood and the Township of Rochelle Park in Bergen County, New Jersey. The site occupies approximately 11.7 acres in the densely industrialized northeastern portion of the state, approximately 12 miles north-northwest of New York City and 13 miles northeast of Newark, New Jersey (Figures 1 and 2).

The scope of environmental restoration at MISS is to remediate radioactively contaminated soils and debris in the boroughs of Maywood and Lodi and the Township of Rochelle Park. This activity is being conducted in accordance with the regulatory requirements of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and applicable DOE requirements authorized by the Atomic Energy Act. CERCLA and its implementing regulations are the primary sources of federal regulatory authority for remedial action conducted at MISS. A federal facilities agreement (FFA) negotiated between DOE and EPA incorporates the procedural and documentation

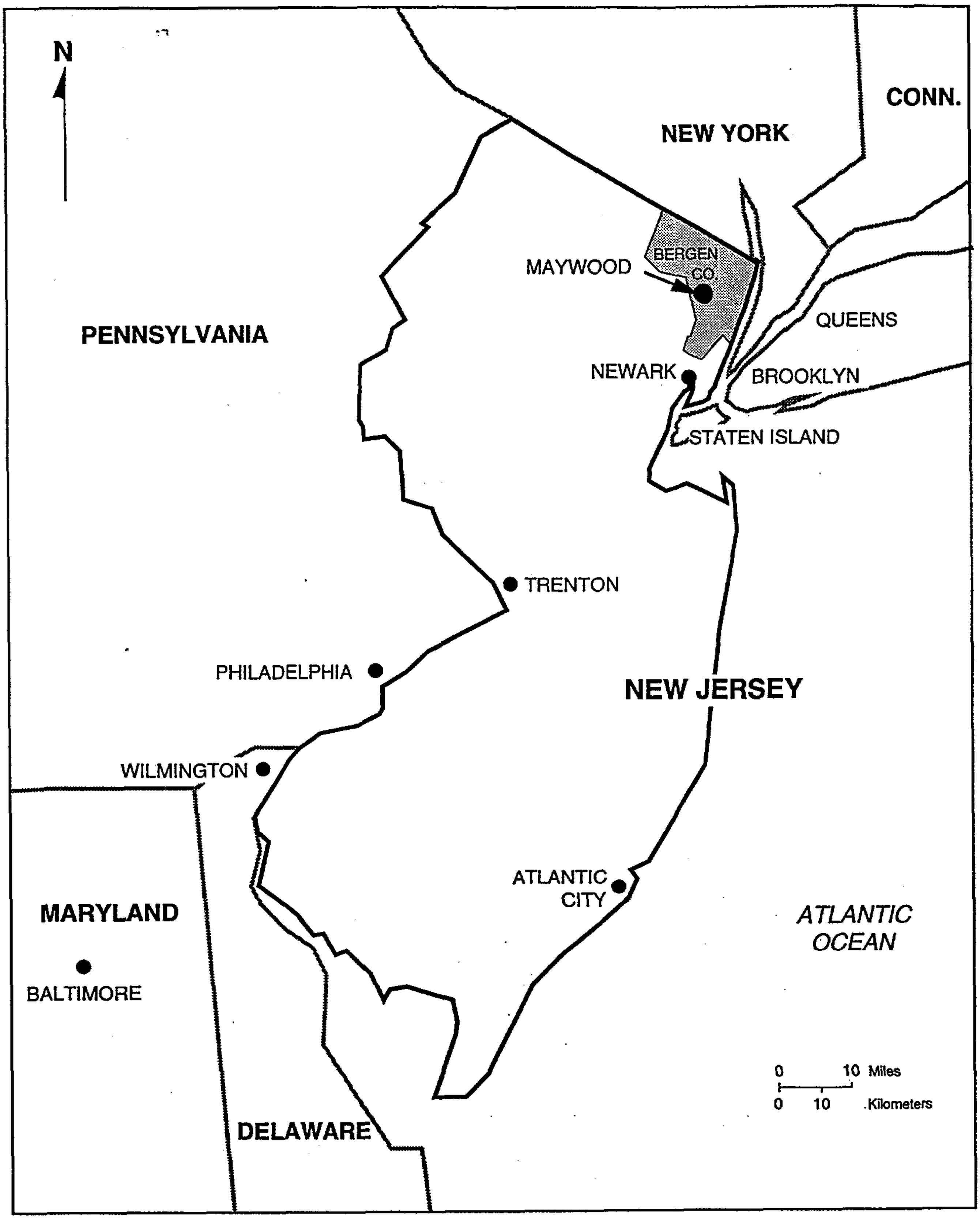

Figure 1
Location of Maywood, Bergen County, New Jersey

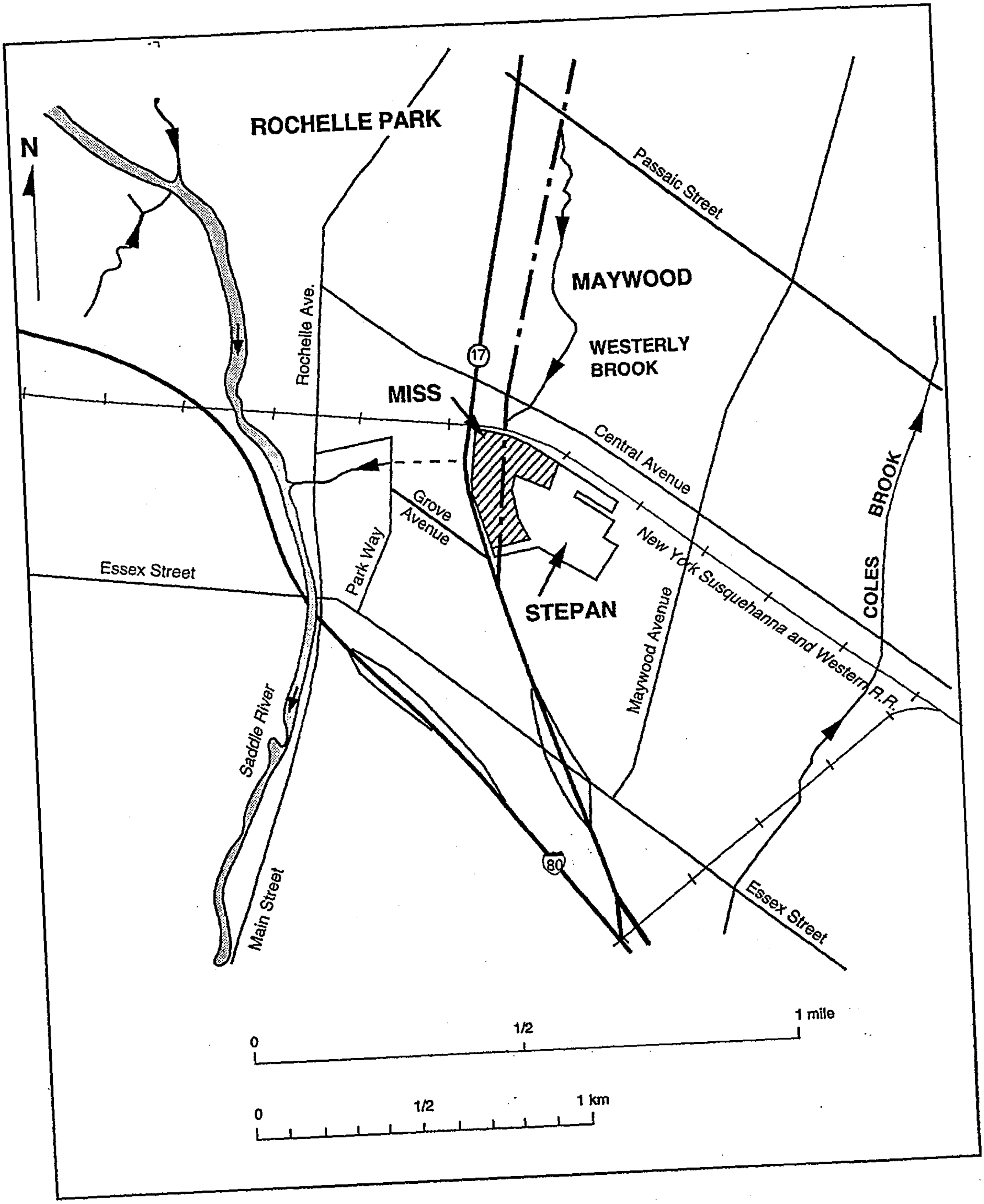

Figure 2
Location of MISS

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requirements of CERCLA and its implementing regulations and establishes the respective roles of each agency during site remediation. As required by CERCLA, the applicable or relevant and appropriate requirements of federal and State of New Jersey regulations are incorporated in the development of remediation goals for MISS.

Another primary environmental statute, the National Environmental Policy Act (NEPA), requires federal agencies to analyze the potential environmental impacts of proposed major activities, including those of environmental restoration projects such as the one being conducted at MISS. DOE policy requires the integration of NEPA requirements with the procedural and documentation requirements of CERCLA, thereby minimizing duplication of effort and the commitment of resources needed to implement both statutes separately. For MISS, the environmental impact statement required by NEPA has been integrated with the remedial investigation and feasibility study components of CERCLA. The resulting document is a remedial investigation/feasibility study-environmental impact statement.

During 1993, site activities included routine grounds and equipment maintenance and sampling for environmental surveillance. This environmental surveillance report summarizes the results of the ongoing environmental surveillance program conducted at MISS during 1993. Results for 1993 showed that concentrations of some chemical parameters were above background levels; however, these findings are not considered unusual for a facility located in an industrial area. Radiological results for 1993 showed that MISS is in compliance with all applicable DOE radionuclide release standards and guidelines and is not making a significant contribution radioactivity to the environment. Monitoring results indicated that radon levels measured at the fenceline were nearly the same as background during 1993 and far below the DOE guideline of 3.0 picocuries per liter (pCi/L). Thoron results for 1993 show fenceline levels exceeded background levels, particularly along the northeastern perimeter of the site. However, only two of the average thoron concentrations actually exceeded the DOE guideline of 3 pCi/L. Appendix A contains a discussion of the nature of radiation, the way it is measured, and common sources of it.

This report contains information about site operations, the environmental surveillance program, surveillance results, and environmental compliance activities during 1993. Copies of the report are distributed to government officials, members of Congress, environmental and civic groups, the news media, and interested individuals. The environmental surveillance report for 1993 and all previous reports may be inspected and copies obtained at the DOE Public Information Center, 43 West Pleasant Avenue, Maywood, New Jersey 07607. The telephone number is (201) 843-7466. These reports are also available in the Administrative Record file in the Maywood Public Library. 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.

HISTORY OF THE MAYWOOD INTERIM STORAGE SITE

From 1916 to 1959, the Maywood Chemical Works occupied the site now known as MISS. The company extracted thorium from monazite sands (a naturally occurring ore) to make mantles for use in gas lanterns. During this time, a thorium-contaminated slurry produced as a by-product was pumped to diked areas west of the plant. Some of this contaminated material, mixed with tea and coca leaves from other processing operations, was used by local property owners as fill or mulch, and some migrated offsite by natural mechanisms. The company continued to manufacture, process, distribute, and store radioactive material until the facility was sold to the Stepan Company in 1959.

In 1961 the Stepan Company was issued a U.S. Atomic Energy Commission license for storing radioactive materials, and the company agreed to begin cleanup of the facility. From 1966 to 1968, approximately 19,100 cubic yards of contaminated soil was removed from three offsite locations (former settling ponds separated from the site by construction of State Route 17 in 1932) and placed in three burial pits within the Stepan property boundaries.

During 1984 and 1985, approximately 34,500 cubic yards of contaminated material (predominantly soil) was removed from 18 vicinity properties in Maywood and Rochelle Park, and approximately 500 cubic yards was removed from eight vicinity properties in Lodi and Rochelle Park. These materials are stored in the interim storage pile at MISS.

Currently, the MISS property includes the interim storage pile, which is covered with a geotextile material; two railroad spurs; a wooden warehouse; and a circular concrete reservoir. This area is entirely fenced to restrict access.

THE ENVIRONMENTAL SURVEILLANCE PROGRAM AT MISS

The goals of DOE's environmental surveillance program 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 includes methods for determining exposure to radiation from both external and internal sources. Gamma radiation measurements taken along the boundary of the site are used to assess external exposure. Additionally, the 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 set up, 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 environmental surveillance program at MISS is summarized in Table 1. The radioactive contaminants at the site are thorium, radium, uranium, and their associated decay products, such as the gases [radon (radon-222) and thoron (radon-220)] they give off. The environmental surveillance program at MISS monitors for radon and thoron gas in the air and for external gamma radiation. Surface water, sediment, and groundwater are monitored for thorium-232, radium-226, and total uranium; surface water and sediment are also monitored for radium-228. In addition, certain chemicals not associated with the thorium processing operation previously conducted at the site, are also present. Under the terms of the FFA between DOE and EPA, DOE is responsible for all contaminants on the site, regardless of the source; therefore, the program also monitors for metals and organic compounds in surface water and groundwater and for metals in sediments. Figures 3, 4, and 5 show the environmental surveillance locations at MISS.

To monitor radon and external gamma radiation in air, DOE places detection devices at locations on MISS and along the fenceline at the edge of the property. Similar monitors are placed at locations well away from MISS 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, thoron, 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 environmental 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 sample the groundwater beneath the site. One well is located in an area known to be unaffected by the site. This background well measures the amount 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 contaminants at the site are affecting groundwater quality.

Table 1

MISS Environmental Surveillance Program Summary

Sample Type	Number of Sampling Locations[a]	Analyses Performed	Frequency of Sampling for Chemical Analyses	Frequency of Sampling of Detector Exchanges for Radiological Analyses
Radon and thoron	21	Radon and thoron concentrations in air	Not applicable	Quarterly
External gamma radiation	20	External gamma radiation exposure rates	Not applicable	Semiannually
Groundwater	24	Metals, volatile organic compounds, total petroleum hydrocarbons, anions, total dissolved solids, total organic carbon, total inorganic carbon	Annually	Not applicable
		Radium-226, thorium-232, total uranium	Not applicable	Annually
Surface water and sediment	3	Metals, total petroleum hydrocarbons, total organic carbons[b], total organic halides[b]	Annually	
		Radium-226, radium-228, thorium-232, total uranium	Not applicable	Semiannually

[a]Includes background and duplicate locations. Samples were not necessarily collected or available during 1993 at all sampling locations shown in Figures 3, 4, and 5.

[b]Surface water only.

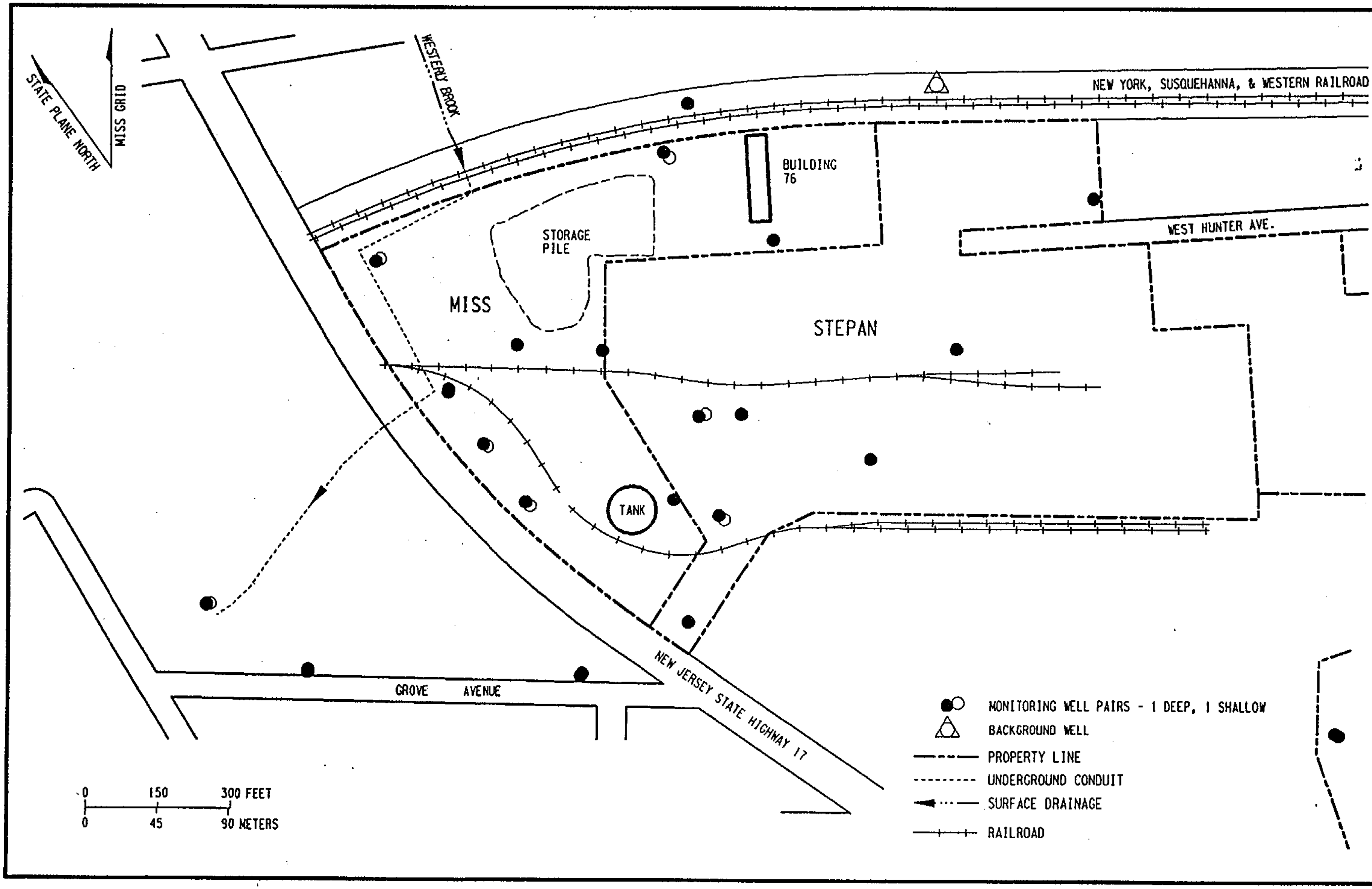

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Figure 3
Groundwater Environmental Surveillance Locations at MISS

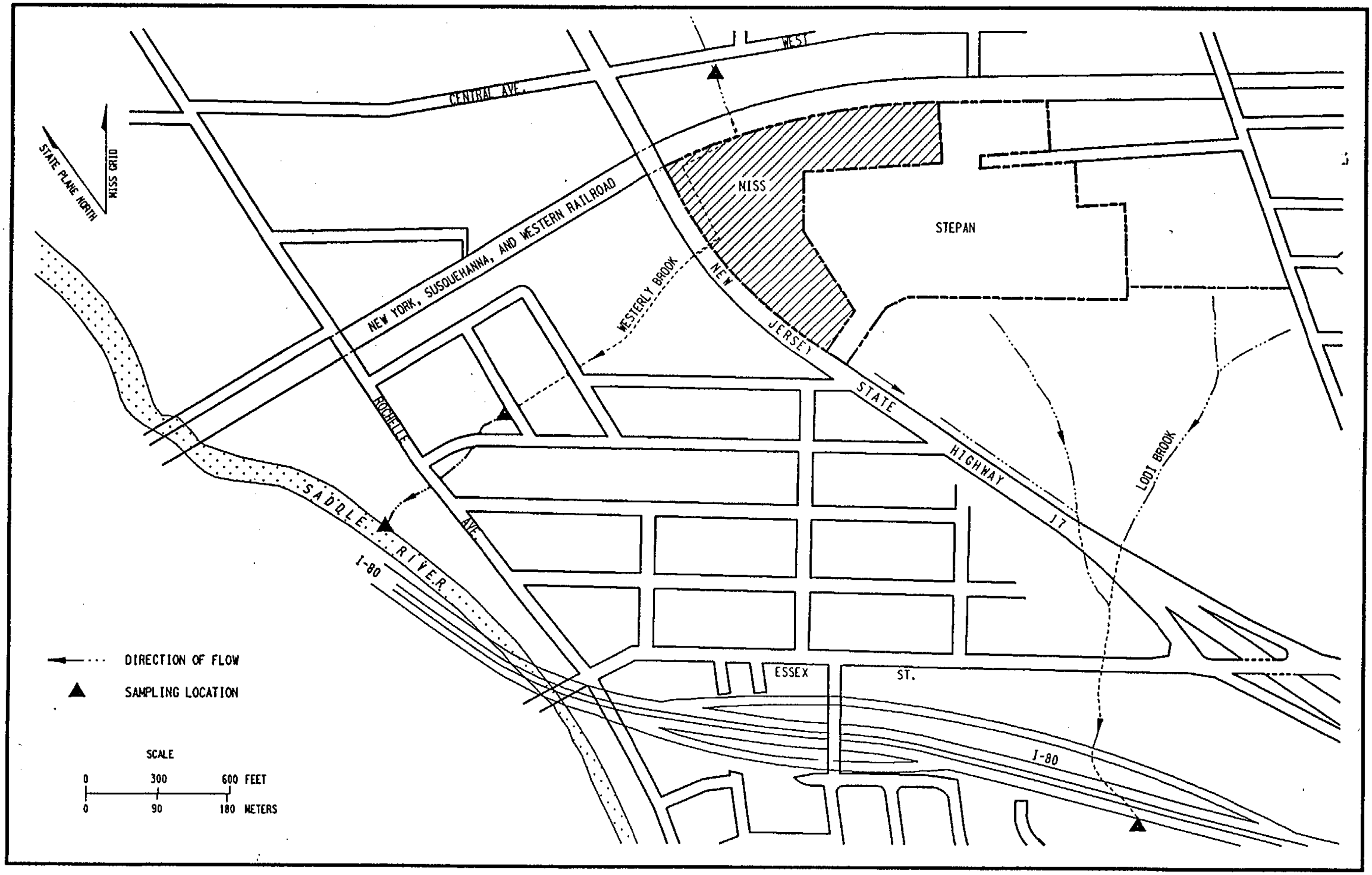

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Figure 4
Surface Water and Sediment Environmental Surveillance Locations in the Vicinity of MISS

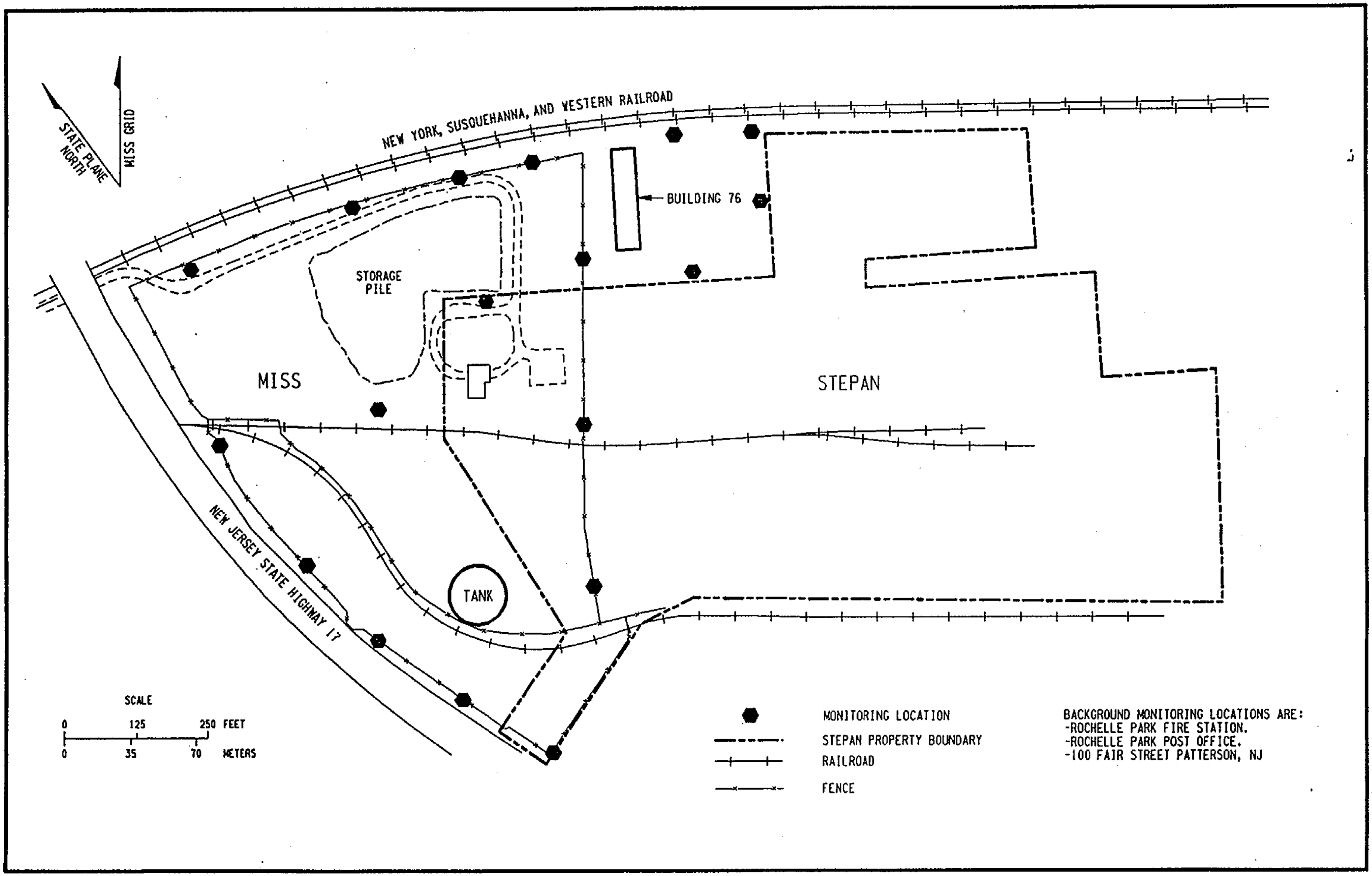

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Figure 5
Onsite Radon, Thoron, and External Gamma Radiation Monitoring Locations

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 MISS; other locations monitor the surface water and sediment in places that might be influenced by the site.

Regulatory Limits for Chemical Releases

Regulations for chemical contaminants set limits for the amounts of a substance a facility may release to the environment. These limits are determined by computer models that use data such as stream carrying capacity and aquatic toxicity studies. The regulations also stress that releases should be minimized to a degree consistent with available technology.

Surveillance Results for Chemical Parameters at MISS

In general, results of chemical surveillance for the site showed concentrations that would be expected for a facility in an industrial area. In surface water samples, the only results that were unusual for an industrial area were concentrations of lithium that were slightly above background. Sediment sampling showed levels of some metals above background levels, but this is not unusual in industrial locations.

Aluminum, arsenic, chromium, iron, lead, lithium, manganese, and tetrachloroethene were detected in groundwater in concentrations that exceeded New Jersey Class II-A groundwater quality criteria. Although organic chemicals were not used in former thorium processing operations at the site, there is evidence that chemical contaminants are present in the soil. The presence of iron, aluminum, and manganese reflects the geologic makeup of the area and is not associated with past thorium processing operations. The concentrations and distribution of arsenic, chromium, and lead are probably the result of localized sources of contaminated soil. Groundwater in the vicinity of MISS is not used as a source of drinking water.

Regulatory Limits for Radiological Releases

DOE has established total quantity limits, derived concentration guides, and dose limits for radiological 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 these releases. Conservative limits are 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 as a result of DOE operations should not exceed 100 millirem per year (mrem/yr) above background. This limit excludes medical procedures, residual fallout from past nuclear accidents and weapons tests, and consumer products. The radiation standards provided 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 6 illustrates the contribution from MISS to the dose to the public compared with the dose from background radiation and the DOE guideline of 100 mrem/yr.

Environmental surveillance results for 1993 show that MISS is in compliance with all applicable DOE radionuclide release standards and guidelines.

Surveillance Results for Radiological Parameters at MISS

Since environmental surveillance at the site began in 1984, analytical results have consistently shown that MISS is making no significant contribution to the radioactivity in the

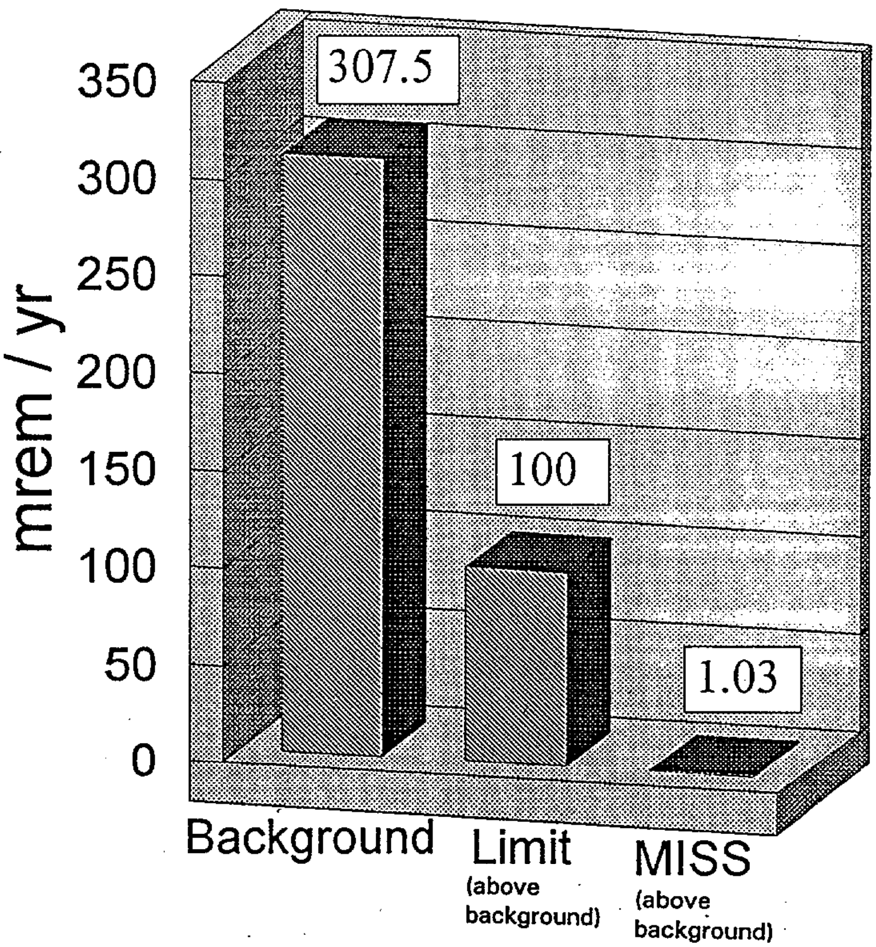

Figure 6
Comparison of Dose from the Site with Background and DOE Guideline

environment. The results of radiological surveillance for 1993 again showed this to be true. The additional radiation dose to the offsite population attributable to MISS is very close to zero. This is consistent with results from previous years.

The 1993 results for radon monitoring at MISS showed that measurements along the fenceline were about the same as background and far below the DOE guideline of 3.0 picocuries per liter (pCi/L). Monitoring results showed that thoron levels were above background at some locations but, with a couple of exceptions, far below the DOE guideline. The above-guideline results were expected because they were measured by detectors located next to an area where the thorium processing building once stood. The thoron monitoring results reflect the predominance of thorium contamination in the soil at the site. As with most gases in an open, unconfined area, radon and thoron dissipate quickly and do not affect the offsite population.

External gamma exposure monitoring results for 1993 showed, with the exception of one area of the site, an average exposure rates of 111 milliroentgens per year (mR/yr) at the site boundary. (One mR is approximately equal to one millirem.) Gamma exposure rates measured at sampling stations located in the area of the former thorium processing building ranged from 458 to 1,586 mR/yr, reflecting the localized subsurface contamination. These measurements do not include the background gamma exposure rate of 69 mR/yr. The exposure rates reported above are those that an individual could receive if that person remained at the detector location 100 percent of the time for an entire year.

The property nearest this area is an industrial facility about 150 feet northwest of MISS, occupied by employees 40 hours per week. The calculated external gamma exposure rates at the industrial facility from MISS would be much lower than those measured at the surveillance locations because of the distance between the facility and the source of radiation. The maximum dose that employees at the industrial facility could receive was calculated using conservative assumptions (which would tend to overestimate the possible dose). Hypothetically, the highest dose a person could have received from direct gamma radiation from MISS in 1993 would be equal to 0.57 mrem, a small fraction of the DOE guideline of 100 mrem/yr above background.

Results of groundwater monitoring for thorium, radium, and uranium showed that concentrations in some wells exceeded background during 1993. However, all concentrations were well below DOE guidelines and, except for one analyte from an onsite well, were within established federal and state standards for these radionuclides. The concentration of radium-226 in an onsite well was slightly higher than the current drinking water standard for radium but below the proposed revision of the drinking water standard. Overall, radionuclide concentrations measured in groundwater associated with MISS are low and have consistently been low since monitoring began.

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

Analytical results for radium-228 in surface water and sediment samples are unreliable because of procedural problems identified at the subcontracted radiological laboratory; therefore, these data are not evaluated in this document. The laboratory has corrected the problems, and there should be no difficulty with future analytical results. Historically, radium-228 concentrations in surface water and groundwater have been well below the DOE derived concentration guideline and below the FUSRAP soil concentration guideline for sediments.

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

The goal of any ALARA program is to keep radiation exposure to members of the general public and onsite workers as low as reasonably achievable. To implement the ALARA 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. The 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 MISS 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 MISS 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 may 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 site releases to the air and water, 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 MISS 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 is assumed to work within 150 feet of the site, 40 hours per week.

Table 2 presents estimates of the dose to the hypothetical maximally exposed member of the public from site 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 the site 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 the site (Figure 6).

Table 2

Comparison of Calculated Maximum Doses from MISS During 1993 with Applicable Standards and Natural Background Radiation

Exposure Pathway	Dose for Hypothetical Maximally Exposed Individual from MISS[a] (mrem/yr)	Applicable Standard[b] (mrem/yr)	Percent of Standard	Percent of Natural Background[c]
Direct gamma radiation[d]	0.57	NA[e]	NA[e]	0.19
Drinking water	NA[f]	4[f]	NA[f]	NA[f]
Airborne pathways	0.46	10[g]	4.6	0.15
All pathways	1.03	100[h]	1.0	0.34

[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]Natural background at MISS is 307.5 mrem/yr.

[d]Above natural background.

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

[f]DOE Order 5400.5 provides a standard of 4 mrem/yr from a DOE site for all drinking water sources. This limit applies to manmade beta-gamma radiation. Groundwater in the MISS vicinity is not a drinking water source.

[g]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.

[h]Exposure pathways are added to compare calculated maximum doses from MISS with the DOE "all pathways" standard.

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, FUSRAP has a quality assurance and quality control program based on state and federal guidelines. Subcontractor laboratories that provide services for MISS 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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APPENDIX A RADIATION AT A GLANCE

RADIATION AT A GLANCE

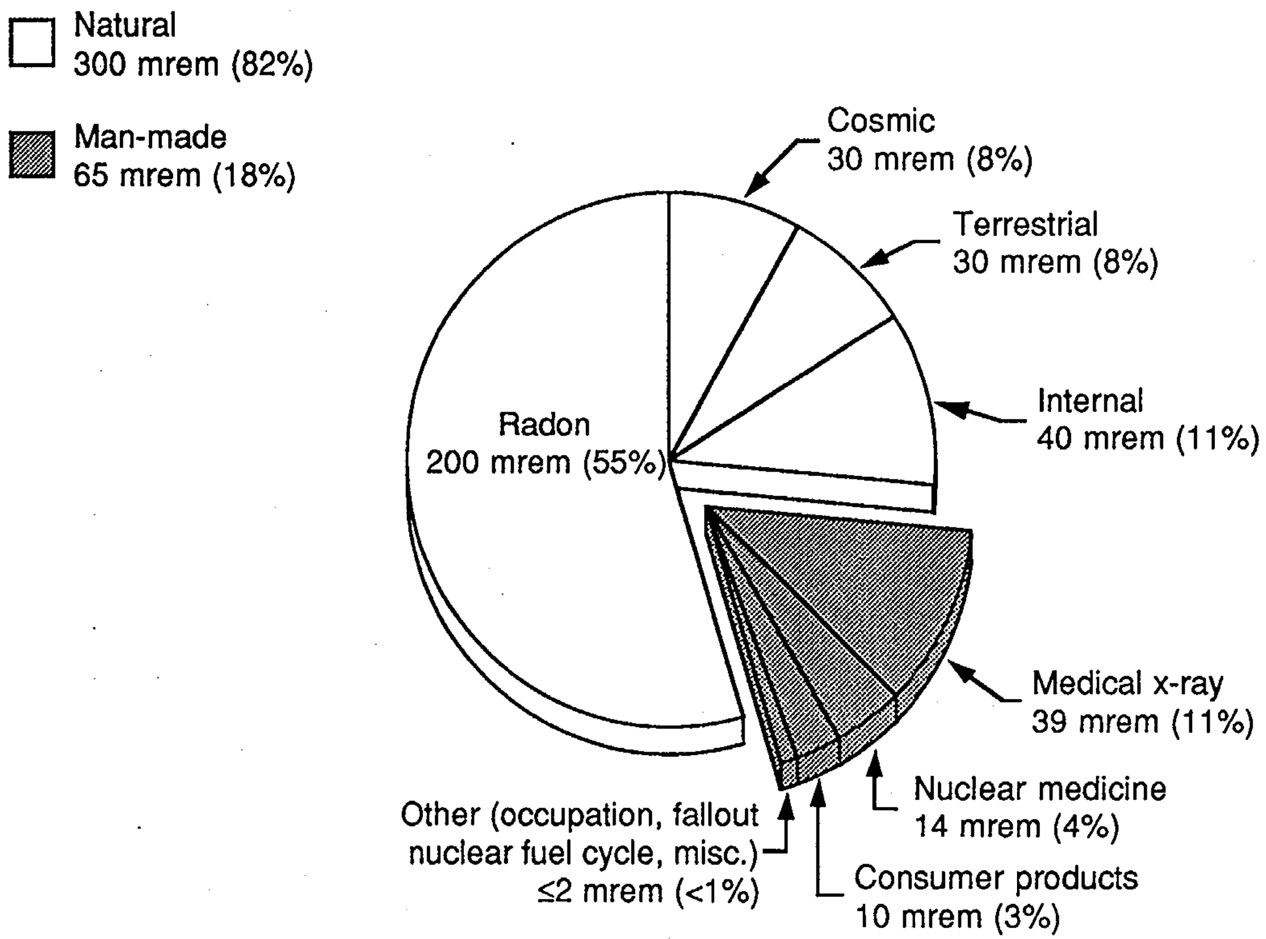
Of all activities at FUSRAP sites, those associated with radiation receive the most attention. What exactly is radiation and where does it come from? To answer these questions, it is best to start with a few basics.

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.



Source: NCRP 1987.

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

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 other sources of 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 (3.7×10^{9}) radioactive 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 (333×10^{-9}) Ci. Because the levels of radioactive contamination at most FUSRAP sites are very low, the picocurie is commonly used in reporting contaminant levels. One picocurie is equal to 1×10^{-12} curies. Contaminants in water are reported in picocuries per liter (pCi/L), and contaminants in soil are reported in picocuries per gram (pCi/g).

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 exposure.
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 1 ½ 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.