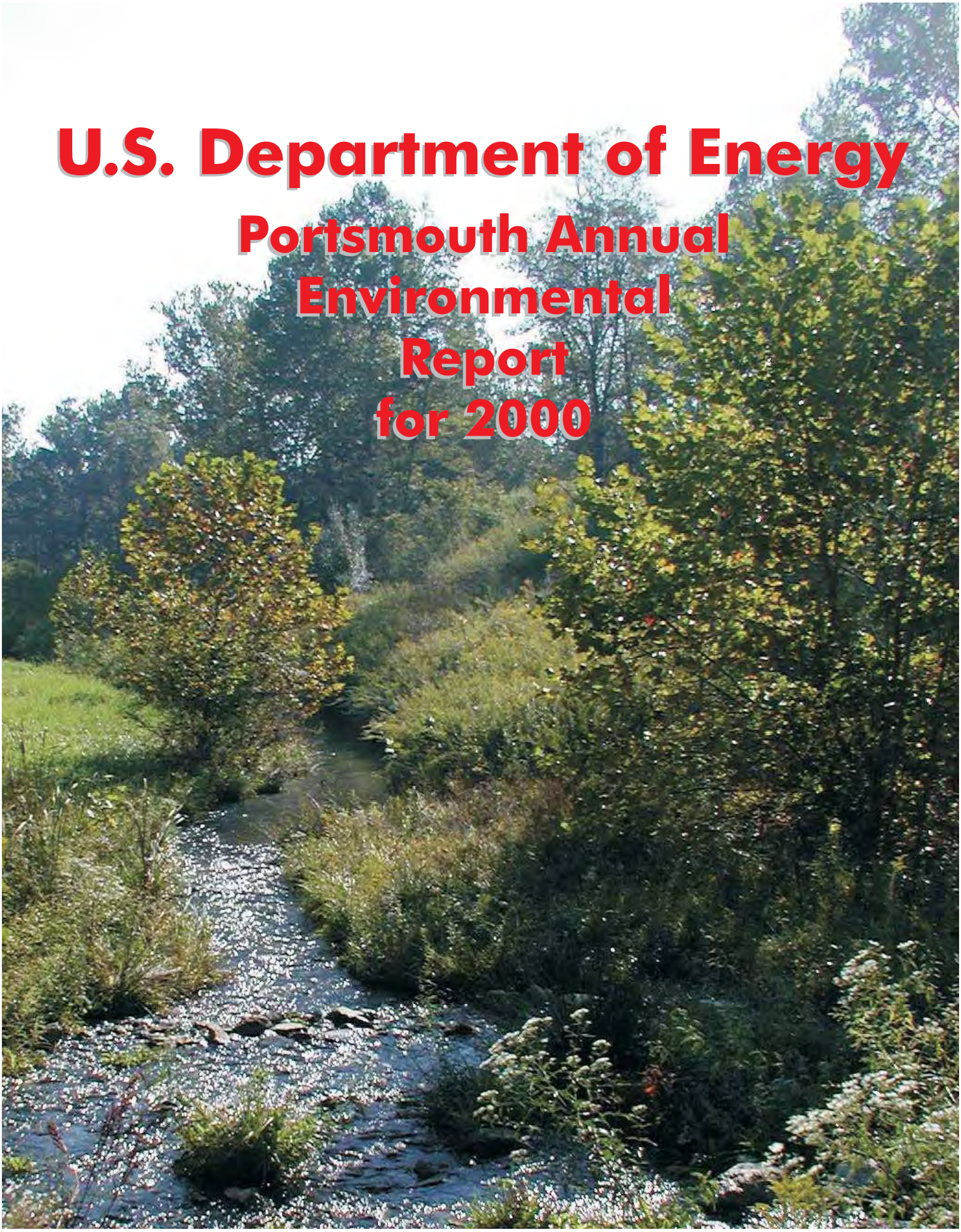
U.S. Department of Energy

Portsmouth Annual Environmental Report for 2000



Spillway from the X-230J7 pond at the Portsmouth Gaseous Diffusion Plant

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U.S. Department of Energy
Portsmouth Annual Environmental Report
for 2000
Piketon, Ohio

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managing the
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EQ Midwest, Inc.
contributed to the preparation of this document and should not be considered an eligible contractor for its review.

This document has received the appropriate reviews for release to the public.

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ACRONYMS

CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
Ci	curie
DOE	U.S. Department of Energy
DOE/PORTS	facilities operated by DOE (not leased to USEC) at the Portsmouth Gaseous Diffusion Plant
EPA	Environmental Protection Agency
HF	hydrogen fluoride
Kg	kilogram
LLW	low-level radioactive waste
mg/L	milligram per liter (equivalent to part per million)
μg/L	microgram per liter (equivalent to part per billion)
mrem	millirem
NPDES	National Pollutant Discharge Elimination System
PCB	polychlorinated biphenyl
pCi/g	picocurie per gram
pCi/L	picocurie per liter
PK	Peter Kiewit
PORTS	Portsmouth Gaseous Diffusion Plant
RCRA	Resource Conservation and Recovery Act
TLD	thermoluminescent dosimeter
USEC	United States Enrichment Corporation

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DEFINITIONS

absorption – The process by which the number and energy of particles or photons entering a body of matter are reduced by interaction with the matter.

activity – See "radioactivity."

alpha particle – A positively charged particle having the same charge and mass as that of a helium nucleus (two protons and two neutrons). Alpha particles are emitted from the nucleus of an atom during radioactive decay.

ambient air – The atmosphere around people, plants, and structures.

analyte – A constituent or parameter being analyzed.

aquifer – A geologic formation capable of yielding a significant amount of groundwater to wells or springs.

atom – Smallest particle of an element capable of entering into a chemical reaction.

background radiation – Radiation that occurs naturally in the surrounding environment.

beta particle – A negatively charged particle emitted from the nucleus of an atom during radioactive decay. It has a mass and charge equal to those of an electron.

biota – The animal and plant life of a particular region considered as a total ecological entity.

categorical exclusion – A class of actions that either individually or cumulatively would not have a significant effect on the human environment and therefore would not require preparation of an environmental assessment or environmental impact statement under the National Environmental Policy Act.

chain-of-custody – A form that documents sample collection, transport, and analysis.

closure – Control of a closed hazardous waste management facility under Resource Conservation and Recovery Act requirements.

compliance – Fulfillment of applicable regulations or requirements of a plan or schedule ordered or approved by a government authority.

concentration – The amount of a substance contained in a unit volume or mass of a sample.

contamination – Deposition of unwanted material on the surfaces of structures, areas, objects, or personnel.

cosmic radiation – Ionizing radiation with very high energies that originates outside the earth's atmosphere. Cosmic radiation is one contributor to natural background radiation.

critical habitat – Specific areas that may require special management considerations or protection and on which physical or biological features essential to the conservation of a species are found.

curie (Ci) – A unit of radioactivity. One curie is defined as 3.7×10^{10} (37 billion) disintegrations per second. Several fractions and multiples of the curie are commonly used:

kilocurie (kCi) – 10^3 Ci, one thousand curies; 3.7×10^{13} disintegrations per second.
millicurie (mCi) – 10^{-3} Ci, one-thousandth of a curie; 3.7×10^7 disintegrations per second.
microcurie (μCi) – 10^{-6} Ci, one-millionth of a curie, 3.7×10^4 disintegrations per second.
picocurie (pCi) – 10^{-12} Ci, one-trillionth of a curie; 0.037 disintegration per second.

decontamination and decommissioning – The cleanup and removal of buildings, structures, or objects contaminated with hazardous substances during past production or disposal activities.

derived concentration guide – The concentration of a radionuclide in air or water that under conditions of continuous exposure for one year by one exposure mode (i.e., ingestion of water, submersion in air, or inhalation) would result in either an effective dose equivalent of 0.1 rem or a dose equivalent of 5 rem to any tissue, including skin and the lens of the eye. The guidelines for radionuclides in air and water are provided in DOE Order 5400.5, *Radiation Protection of the Public and the Environment.*

dissolved solids – Organic or inorganic material dissolved in water. Excessive amounts of dissolved solids make water unfit to drink or to use in industrial processes.

downgradient – In the direction of groundwater flow.

downgradient well – A well installed hydraulically downgradient of a site that may be capable of detecting migration of contaminants from a site.

effluent – A liquid or gaseous waste discharge to the environment.

effluent monitoring – The collection and analysis of samples or measurement of liquid and gaseous effluents to characterize and quantify the release of contaminants, assess radiation exposures to the public, and demonstrate compliance with applicable standards.

Environmental Restoration – A DOE program that directs the assessment and cleanup of its sites (remediation) and facilities (decontamination and decommissioning) contaminated with waste as a result of nuclear-related activities.

exposure (radiation) – The incident of radiation on living or inanimate material by accident or intent. Background exposure is the exposure to natural background ionizing radiation. Occupational exposure is exposure to ionizing radiation that takes place at a person's workplace. Population exposure is the exposure to the total number of persons who inhabit an area.

external radiation – The exposure to ionizing radiation when the radiation source is located outside the body.

formation – In geologic terms, a unit of rock or a unit of material that could form a rock such as sand.

friable – The ability of a material to be pulverized, crumbled, or reduced to powder by hand pressure when dry.

gamma ray – High-energy short-wavelength electromagnetic radiation emitted from the nucleus of a charged atom. Gamma rays are identical to X-rays except for the source of the emission.

glove box – An enclosure with built-in sleeves and gloves used by a person to manipulate hazardous materials such as highly enriched uranium without directly exposing the person to the material.

groundwater – Water below the land surface in a zone where all void space between rocks, soil, etc., is filled with water.

hexavalent – A compound that has six valence electrons.

half-life, radiological – The time required for half of a given number of atoms of a specific radionuclide to decay. Each nuclide has a unique half-life.

industrial solid waste landfill – A type of landfill that exclusively disposes of solid waste generated by manufacturing or industrial operations.

in situ – In its original place; field measurements taken without removing the sample from its origin; remediation performed while the contaminated media (e.g., groundwater) remains below the surface.

interim remedial measure – Cleanup activities initiated after it has been determined that contamination or waste disposal practices pose an immediate threat to human health and/or the environment. These measures are implemented until a more permanent solution can be made.

internal radiation – Occurs when natural radionuclides enter the body by ingestion of food or water or by inhalation. Radon is the major contributor to the annual dose equivalent for internal radionuclides.

ion – An atom or compound that carries an electrical charge.

irradiation – Exposure to radiation.

isotopes – Forms of an element having the same number of protons but differing numbers of neutrons in their nuclei.

jurisdictional wetland – An area that is periodically or permanently inundated by surface or ground water, supports plants adapted to wetlands, and has soil typically found in wetlands, but is not associated with an active holding pond.

leachate – A liquid that results from water collecting contaminants as it trickles through wastes, agricultural pesticides, or fertilizers. Leachate may occur in farming areas, feed lots, and landfills and may result in hazardous substances entering surface water, groundwater, or soil.

manifest – A form required by RCRA that is used to document and track waste during transportation and disposal.

maximally exposed individual – A hypothetical individual who remains in an uncontrolled area and would, when all potential routes of exposure from a facility's operations are considered, receive the greatest possible dose equivalent.

maximum contaminant level – The maximum permissible level of a contaminant in drinking water provided by a public water system.

migration – The transfer or movement of a material through air, soil, or groundwater.

monitoring – Process whereby the quantity and quality of factors that can affect the environment or human health are measured periodically to regulate and control potential impacts.

mrem – Millirem: the dose equivalent that is one-thousandth of a rem.

natural radiation – Radiation from cosmic and other naturally occurring radionuclide sources (such as radon) in the environment.

non-jurisdictional wetland – An area that is periodically or permanently inundated by surface or ground water, supports plants adapted to wetlands, and has soil typically found in wetlands, and is associated with an active holding pond.

nuclide – An atom specified by atomic weight, atomic number, and energy state. A radionuclide is a radioactive nuclide.

outfall – The point of conveyance (e.g., drain or pipe) of wastewater or other effluents into a ditch, pond, or river.

person-rem – Collective dose to a population group. For example, a dose of 1 rem to 10 individuals results in a collective dose of 10 person-rem.

pH – A measure of the hydrogen ion concentration in an aqueous solution. Acidic solutions have a pH from 0 to 7, neutral solutions have a pH equal to 7, and basic solutions have a pH from 7 to 14.

polychlorinated biphenyl (PCB) –An industrial compound, used primarily as a lubricant, which is produced by adding chlorine to biphenyl, a colorless, crystalline compound.

preliminary remediation goal – The concentration of a constituent in environmental media (soil, groundwater, etc.) that is considered protective of human health and the environment.

quality assurance – Any action in environmental monitoring to demonstrate the reliability of monitoring and measurement data.

quality control – The routine application of procedures within environmental monitoring to obtain the required standards of performance in monitoring and measurement processes.

rad – The unit of absorbed dose deposited in a volume of material.

radioactivity – The spontaneous emission of radiation, generally alpha or beta particles or gamma rays, from the nucleus of an unstable isotope.

radioisotopes – Radioactive isotopes.

radionuclide – A radioactive nuclide capable of spontaneous transformation into other nuclides by changing its nuclear configuration or energy level. This transformation is accomplished by the emission of photons or particles.

release – Any discharge to the environment. "Environment" is broadly defined as any water, land, or ambient air.

rem – The unit of dose equivalent (absorbed dose in rads multiplied by the radiation quality factor). Dose equivalent is frequently reported in units of millirem (mrem), which is one-thousandth of a rem.

remediation – The correction or cleanup of a site contaminated with waste. See "Environmental Restoration."

reportable quantity – A release to the environment that exceeds reportable quantities as defined by the Comprehensive Environmental Response, Compensation, and Liability Act.

Resource Conservation and Recovery Act (RCRA) – Legislation that regulates the transport, treatment, and disposal of solid and hazardous wastes.

source – A point or object from which radiation or contamination emanates.

stable – Not radioactive or not easily decomposed or otherwise modified chemically.

Superfund – The program operated under the legislative authority of the Comprehensive Environmental Response, Compensation, and Liability Act and Superfund Amendments and Reauthorization Act that funds and conducts EPA emergency and long-term removal and remedial actions.

surface water – All water on the surface of the earth, as distinguished from groundwater.

suspended solids – Mixture of fine, nonsettling particles of any solid within a liquid or gas.

terrestrial radiation – Ionizing radiation emitted from radioactive materials in the earth's soils such as potassium-40, thorium, and uranium. Terrestrial radiation contributes to natural background radiation.

transuranics – Elements such as plutonium and neptunium that have atomic numbers (the number of protons in the nucleus) greater than 92. All transuranics are radioactive.

trip blank – A quality control sample of water that accompanies sample containers from the analytical laboratory, to the field sampling location where environmental samples are collected, back to the analytical laboratory to determine whether environmental samples have been contaminated during shipment.

troughing system – A system designed to collect leaking PCBs in the PORTS process buildings.

turbidity – A measure of the concentration of sediment or suspended particles in solution.

upgradient – In the opposite direction of groundwater flow.

upgradient well – A well installed hydraulically upgradient of a site to provide data to compare to a downgradient well to determine whether the site is affecting groundwater quality.

volatile organic compounds – Chemicals composed primarily of hydrogen, oxygen, and carbon that readily volatilize into the air. They include light alcohols, acetone, trichloroethene, dichloroethene, benzene, vinyl chloride, toluene, methylene chloride, and many other compounds.

wetland – A lowland area, such as a marsh or swamp, inundated or saturated by surface or groundwater sufficiently to support plants typically adapted to life in wet soils.

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EXECUTIVE SUMMARY

SITE AND OPERATIONS OVERVIEW

The Portsmouth Gaseous Diffusion Plant (PORTS) is one of two uranium enrichment facilities operating in the United States (see Fig. 1). Responsibility for implementing environmental compliance at PORTS is split between the U.S. Department of Energy (DOE), as site owner, and the United States Enrichment Corporation (USEC), a corporation formed by the Energy Policy Act of 1992 to operate the nation's uranium enrichment business. The uranium enrichment production and operations facilities at the site are leased to USEC.

Bechtel Jacobs Company LLC assumed responsibility as the management contractor for DOE on April 1, 1998. Bechtel Jacobs Company is responsible for environmental restoration, waste management, uranium programs, and operation of nonleased facilities at PORTS. With the exception of Chap. 2, Environmental Compliance, Chap. 4, Environmental Monitoring, and Chap. 5, Dose, this report does not cover USEC operations at PORTS. USEC data is included in these chapters to provide a more complete picture of the programs in place at PORTS to detect and assess potential impacts to human health and the environment resulting from PORTS activities.

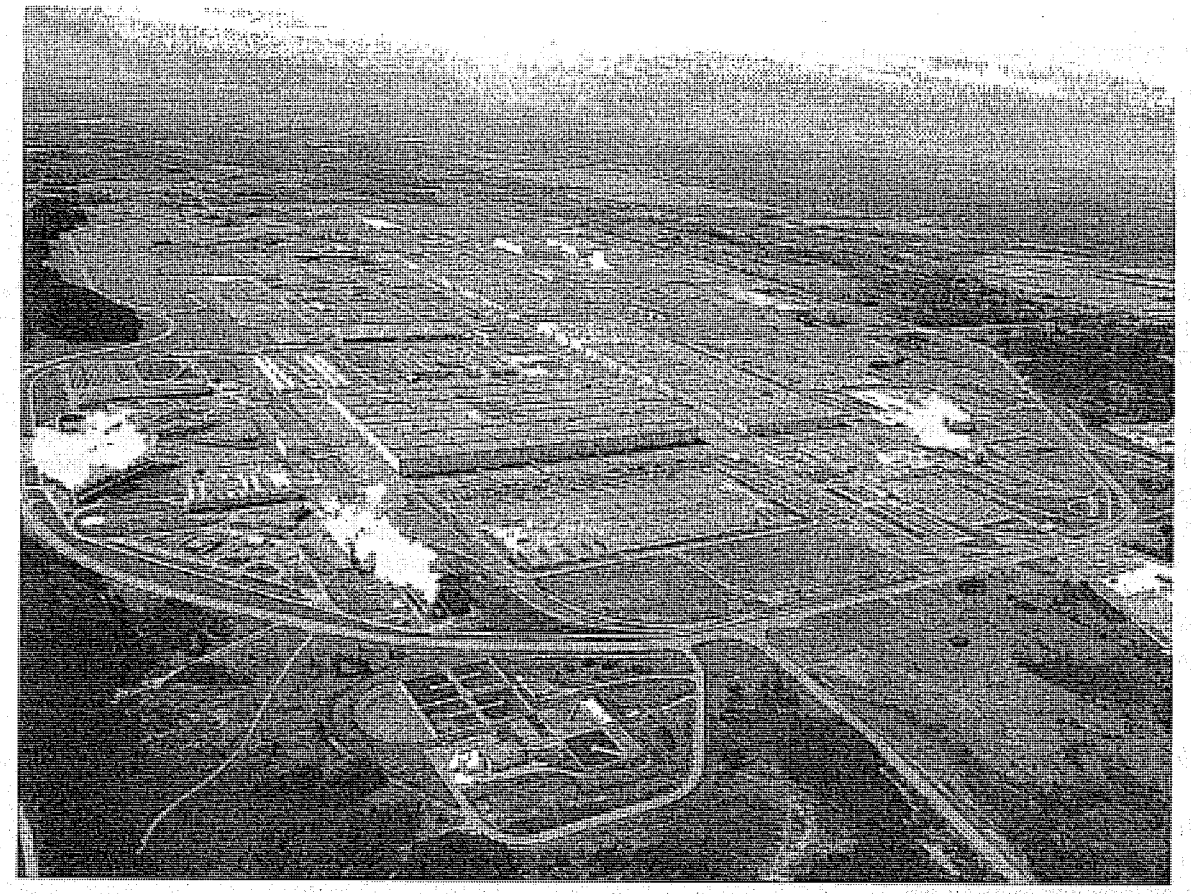

Fig. 1. The Portsmouth Gaseous Diffusion Plant.

PORTS is located on 5.8 square miles in Pike County, Ohio. The county has approximately 24,250 residents.

ENVIRONMENTAL COMPLIANCE

Responsibility for implementing environmental compliance at PORTS is divided between DOE (as the site owner) and USEC. USEC is responsible for compliance activities directly associated with the operations that are leased from DOE, including air emission permits for uranium enrichment facilities, water discharge permits for several holding ponds and water treatment facilities, and management of wastes generated by current enrichment operations.

DOE/PORTS has been issued a permit for discharge of water to surface streams, several air emission permits, and a permit for the storage of hazardous wastes. DOE is also responsible for preparing a number of reports for compliance with environmental regulations. These reports include an annual groundwater monitoring report, an annual hazardous waste report, an annual polychlorinated biphenyl (PCB) document log, an annual summary of radionuclide air emissions and the associated dose to the public from these emissions, a monthly summary of National Pollutant Discharge Elimination System (NPDES) monitoring, an annual hazardous chemical inventory, and an annual toxic chemical release inventory.

DOE/PORTS is inspected regularly by the federal, state, and local agencies responsible for enforcing environmental regulations at PORTS. From January through May 2000, the DOE Office of Oversight conducted a comprehensive investigation of historical and current environment, health, and safety activities and controls at PORTS. The investigation identified several aspects of current operations that needed improvement. DOE has implemented interim and long-term corrective actions to address the concerns raised by the investigation.

In June 2000, DOE received a Notice of Violation from Ohio EPA concerning groundwater monitoring data collected in 1999. The violation was associated with the statistical monitoring program at the X-735 and X-749A Landfills. DOE and Ohio EPA are working together to resolve the issue.

U.S. EPA, Ohio EPA, and the Ohio Department of Health conducted a multimedia inspection of PORTS in June 2000. In February 2001, DOE received a Notice of Violation concerning two minor issues identified during this inspection. One of the issues involved hazardous waste manifests that were not filled out correctly (information was not placed in the specified box on the manifest form, but was included elsewhere on the form). The manifests identified in the audit cannot be corrected; however, manifests completed since then have been completed correctly. The other issue involved labeling of a tank in one of the groundwater treatment facilities. Although the tank was labeled "trichloroethylene," Ohio EPA required additional labeling which has been completed by DOE.

ENVIRONMENTAL PROGRAMS

Environmental Restoration, Waste Management, and Public Awareness Programs are conducted at PORTS to protect and inform the local population, improve the quality of the environment, and comply with federal and state regulations.

Environmental Restoration Program

Environmental restoration is the process of cleaning up inactive waste sites and facilities to demonstrate that risks to human health and the environment are either eliminated or reduced to safe levels. DOE established the Environmental Restoration Program to find, analyze, and correct site contamination problems as quickly and inexpensively as possible. This task may be accomplished by removing, stabilizing, or treating hazardous substances. The Environmental Restoration budget for fiscal year 2000 was $29.4 million.

The Ohio Consent Decree and the U.S. EPA Administrative Consent Order require investigation and cleanup of PORTS in accordance with the RCRA Corrective Action Program. The site is divided into four quadrants to facilitate the investigation and cleanup. In June 2000, DOE received approval from Ohio EPA for the *Quadrant I Cleanup Alternative Study/Corrective Measures Study*. In November 2000, Ohio EPA issued the Preferred Plan for Quadrant I, which identified the selected remedies for the areas that require remediation. DOE submitted the *Quadrant II Cleanup Alternative Study/Corrective Measures Study* to Ohio EPA on August 15, 2000.

DOE received the decision document for Quadrant IV on October 6, 2000. The decision document identifies the remedial actions required for the quadrant. No new remedial actions are required in Quadrant IV (remedial actions have already taken place at the X-735 Landfills, X-611A Former Lime Sludge Lagoons, and the X-734 Landfill Area).

Remediation activities took place at several units in 2000. The corrective measures implementation for two units, the groundwater plume near the X-740 Waste Oil Handling Facility in Quadrant III and the X-734 Landfills in Quadrant IV, was begun in 1999 and completed in 2000. Remedial actions for two additional units, the X-231A and X-231B Biodegradation Plots in Quadrant I and X-344D Neutralization Pit in Quadrant IV, were begun and completed in 2000. Planning for remedial action at the X-701C Neutralization Pit/X-701A Lime House in Quadrant II began in 2000.

Waste Management Program

The DOE/PORTS Waste Management Program directs the safe storage, treatment, and disposal of waste generated from plant operations and from environmental restoration projects.

Waste management activities must comply with DOE Orders, Ohio EPA regulations, and U.S. EPA regulations. Waste management requirements are varied and often complex because of the variety of wastes generated by DOE/PORTS activities. The types of waste managed by DOE/PORTS include:

- *Low-level radioactive waste (LLW)* – radioactive waste not classified as high level or transuranic and that does not contain any components regulated by RCRA or the Toxic Substances Control Act.

- *Hazardous (RCRA) waste* – waste that contains one or more of the wastes listed under the Resource Conservation and Recovery Act (RCRA) or that exhibits one or more of the four RCRA hazardous characteristics: ignitability, corrosivity, reactivity, and toxicity.

- *RCRA/LLW mixed waste* – waste containing both hazardous and radioactive components. The waste is subject to RCRA, which governs the hazardous components, and to additional regulations that govern the radioactive components.

- *PCB wastes* – waste containing PCBs, a class of synthetic organic chemicals. Under Toxic Substances Control Act regulations, PCB manufacturing was prohibited after 1978. However,

continued use of PCBs is allowed, provided that the use does not pose a risk to human health or the environment. Disposal of all PCB materials is regulated under the Toxic Substances Control Act.

- *PCB/LLW mixed waste* – waste containing both PCB and radioactive components. The waste is subject to the Toxic Substances Control Act that governs PCB components, and to additional regulations that govern radioactive components.

- *Industrial sanitary waste* – waste generated by commercial operations, such as office waste.

Supplemental policies also have been implemented for waste management including minimizing waste generation; characterizing and certifying wastes before they are stored, processed, treated, or disposed; pursuing volume reduction (such as blending and bulking) as well as on-site storage in preparation for safe and compliant final treatment and/or disposal; and recycling.

Public Awareness Program

DOE provides a public Environmental Information Center to allow access to all documents used to make decisions on remedial actions being taken at PORTS. The information center is located on the plant-site just outside the E-Vehicle portal and is open 9 a.m. to 12 p.m. Monday and Tuesday, 12 p.m. to 4 p.m. Wednesday and Thursday, or by appointment (740-289-3317). Additional information is provided by the DOE Site Office (740-897-2001) and the Bechtel Jacobs Company Public Affairs Manager (740-897-2336).

Semiannual public update meetings and public workshops on specific topics are held to keep the public informed and to receive their comments and questions. Fact sheets about major projects are produced periodically for the public, and semiannual environmental bulletins are printed and distributed to more than 4,000 recipients, including those on the community relations mailing list, neighbors residing within 2 miles of PORTS, and plant employees and retirees.

ENVIRONMENTAL MONITORING

Environmental monitoring at PORTS includes air, water, soil, and biota (animals, vegetation, and crops) and includes measurement of both radiological and chemical parameters. Environmental monitoring programs may be required by regulations, permit requirements, and DOE Orders, but also may be developed to reduce public concerns about plant operations. In 2000, environmental monitoring information was collected by both DOE and USEC for the following programs:

- Airborne discharges,
- Ambient air,
- Direct radiation,
- Discharges to surface water,
- Surface water,
- Sediment,
- Soil,
- Vegetation, and
- Biota.

Evaluation of 2000 environmental monitoring data indicates that PORTS activities in 2000 had a minimal environmental impact, if any, inside or outside facility boundaries.

Five groundwater contamination plumes have been identified on site at PORTS. The primary groundwater contaminant is trichloroethene. Remediation of groundwater is being addressed under Ohio EPA's RCRA Corrective Action Program. No significant changes in the groundwater plumes were noted in 2000.

The *Integrated Groundwater Monitoring Plan* also addresses monitoring of residential water supplies near PORTS to verify that site contaminants have not migrated off site. Results of this program indicate that PORTS has not affected drinking water outside the site boundaries.

QUALITY ASSURANCE AND QUALITY CONTROL

Data reliability is of the utmost importance for monitoring releases and measuring radiation in the environment. To demonstrate that the monitoring and measurement results are accurate, DOE/PORTS has implemented a quality assurance and quality control program based on guidelines from the U.S. EPA, the American Society for Testing and Materials, and other federal and state agencies. The DOE/PORTS staff administers numerous quality control activities to verify reliability of the data on a day-to-day basis. DOE/PORTS also participates actively in quality control programs administered by agencies outside the site such as the U.S. EPA.

1. SITE AND OPERATIONS OVERVIEW

1.1 SUMMARY

The Portsmouth Gaseous Diffusion Plant (PORTS) is located on a 5.8-square-mile site in a rural area of Pike County, Ohio. U.S. Department of Energy (DOE) activities at PORTS include environmental restoration, waste management, and operation of nonleased facilities. Production facilities for the separation of uranium isotopes are leased to the United States Enrichment Corporation (USEC). USEC activities are not covered by this document, with the exception of some environmental compliance information provided in Chap. 2, the environmental monitoring programs discussed in Chap. 4, and radiological dose information in Chap. 5.

1.2 INTRODUCTION

PORTS is owned by DOE. Effective July 1, 1993, DOE leased the production facilities at the site to USEC, which was established by the Energy Policy Act of 1992. USEC became a publicly-held corporation in 1998. Lockheed Martin Utility Services managed and operated the leased facilities for USEC through May 17, 1999, at which time USEC assumed these responsibilities. Bechtel Jacobs Company LLC has managed the DOE programs at PORTS since April 1, 1998.

This report is intended to fulfill the substantive requirements of DOE Order 5400.1, *General Environmental Protection Program.* This DOE Order requires development of an Annual Site Environmental Report that includes information on regulatory compliance, environmental programs, radiological and non-radiological monitoring programs, groundwater programs, and quality assurance. This report is not intended to present all of the monitoring data at PORTS. Additional data collected for other site purposes, such as environmental restoration and waste management, are presented in other documents that have been prepared in accordance with applicable laws. These data are available through other mechanisms.

1.3 DESCRIPTION OF SITE LOCALE

DOE/PORTS is located in a rural area of Pike County, Ohio, on a 5.8-square-mile site (see Fig. 1.1). The site is 2 miles east of the Scioto River in a small valley running parallel to and approximately 120 feet above the Scioto River floodplain. Fig. 1.2 depicts the plant site and its immediate environs.

Pike County has approximately 24,250 residents. Scattered rural development is typical; however, the county contains numerous small villages such as Piketon, Wakefield, and Jasper that lie within a few miles of the plant. The county's largest community, Waverly, is about 10 miles north of the plant and has a population of about 4,500 residents. The nearest

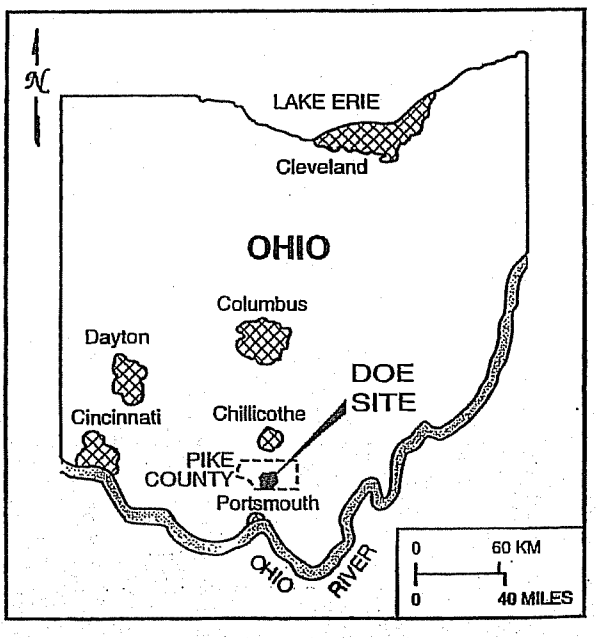

Fig. 1.1. Location of PORTS within the State of Ohio.

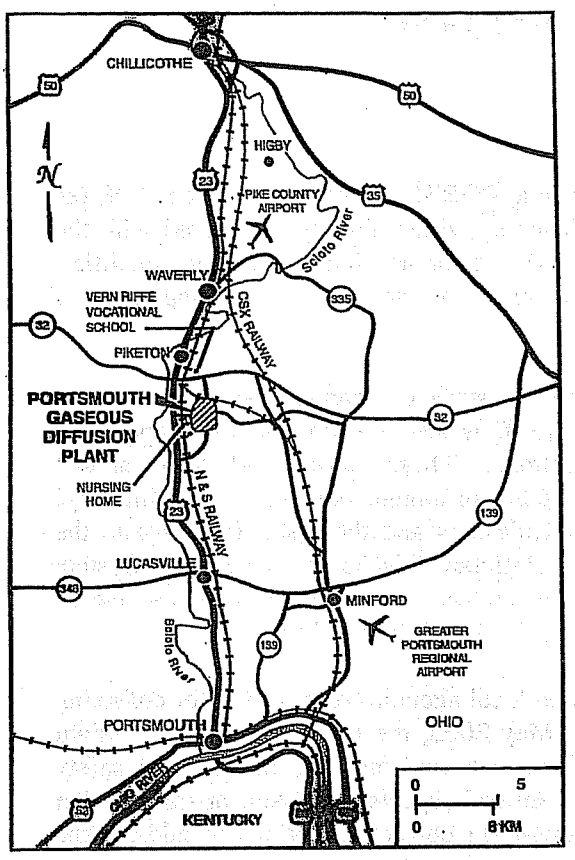

Fig. 1.2. Location of PORTS in relation to the geographic region.

residential center in this area is Piketon, which is about 5 miles north of the plant on U.S. Route 23; its population is about 1,700. Several residences are adjacent to the southern half of the eastern boundary and along Wakefield Mound Road (old U.S. 23), directly west of the plant. One nursing home, with a capacity of 36 persons, is located along Wakefield Mound Road.

Additional population centers within 50 miles of the plant are Portsmouth (population 22,249), 27 miles south; Chillicothe (population 21,923), 27 miles north; and Jackson (population 6,144), 18 miles east. The total population within 50 miles of the plant is approximately 600,000 persons (1990 U.S. Census).

1.4 DESCRIPTION OF SITE OPERATIONS

DOE, through its managing contractor Bechtel Jacobs Company LLC, operates the Environmental Restoration, Waste Management, and Uranium Programs at the plant, as well as other nonleased DOE property. The Environmental Restoration Program performs remedial investigations to define the nature and extent of contamination, evaluate the risk to public health and the environment, and determine the available alternatives from feasibility studies of potential remedial actions for sites under investigation. The goal of the Environmental Restoration Program is to verify that releases from past operations and waste management at DOE/PORTS are thoroughly investigated and that remedial action is taken to protect human health and the environment.

The Waste Management Program is responsible for managing wastes generated at the site. Wastes must be identified and stored in accordance with all environmental regulations. The Waste Management Program also arranges transportation and off-site disposal of wastes. The goal of the Waste Management Program is to manage waste from the time it is generated to its ultimate treatment, recycling, or disposal in accordance with all applicable regulations.

The Uranium Program is responsible for the cost-effective management of PORTS facilities and real property retained by DOE. Responsibilities include managing contracts between DOE/PORTS and other subcontractors for such services as maintenance, utilities, chemical operations, uranium material handling, and laboratory analysis. The Uranium Program also oversees the management and coordination of the PORTS Depleted Uranium Hexafluoride and Lithium Management and Storage Programs and warehousing of uranium materials.

2. ENVIRONMENTAL COMPLIANCE

2.1 SUMMARY

Responsibility for implementing environmental compliance at PORTS is divided between DOE (as the site owner) and USEC. USEC is responsible for compliance activities directly associated with the operations that are leased from DOE, including air emission permits for uranium enrichment facilities, water discharge permits for several holding ponds and water treatment facilities, and management of wastes generated by current enrichment operations.

DOE/PORTS has been issued a permit for discharge of water to surface streams, several air emission permits, and a permit for the storage of hazardous wastes. DOE is also responsible for preparing a number of reports for compliance with environmental regulations. These reports include an annual groundwater monitoring report, an annual hazardous waste report, an annual polychlorinated biphenyl (PCB) document log, an annual summary of radionuclide air emissions and the associated dose to the public from these emissions, a monthly summary of National Pollutant Discharge Elimination System (NPDES) monitoring, an annual hazardous chemical inventory, and an annual toxic chemical release inventory. Additional information on each of these reports is provided within this chapter.

DOE/PORTS is inspected regularly by the federal, state, and local agencies responsible for enforcing environmental regulations at PORTS. From January through May 2000, the DOE Office of Oversight conducted a comprehensive investigation of historical and current environment, health, and safety activities and controls at PORTS. The investigation identified several aspects of current operations that needed improvement. DOE has implemented interim and long-term corrective actions to address the concerns raised by the investigation.

2.2 INTRODUCTION

Responsibility for implementing environmental compliance at PORTS is divided between DOE (as the site owner) and USEC. USEC is responsible for compliance activities directly associated with the operations that are leased from DOE, including air emission permits for uranium enrichment facilities and water discharge permits for several holding ponds and water treatment facilities. USEC is also responsible for the management of wastes generated by current enrichment operations. DOE retains responsibility for "legacy" wastes, which contain constituents such as asbestos and PCBs that were used in DOE operations and became prohibited from use by law prior to the lease agreement. DOE is also responsible for the Environmental Restoration Program, Waste Management Program, and operation of all nonleased facilities.

DOE/PORTS has been issued an NPDES permit for discharge of water to surface streams, several air emission permits, and a Resource Conservation and Recovery Act (RCRA) Part B permit for the storage of hazardous wastes. Appendix B lists the active DOE/PORTS environmental permits for 2000.

Several federal, state, and local agencies are responsible for enforcing environmental regulations at DOE/PORTS. Primary regulatory agencies are the U.S. Environmental Protection Agency (EPA), Ohio EPA, Ohio Department of Health, and Ohio State Fire Marshal's Office. These agencies issue permits, review compliance reports, conduct joint monitoring programs, inspect facilities and operations, and oversee compliance with applicable regulations.

DOE/PORTS conducts self-assessments to identify environmental issues and consults the regulatory agencies to identify the appropriate actions necessary to achieve and maintain compliance.

2.3 COMPLIANCE PROGRAMS

2.3.1 Ohio Consent Decree and U.S. EPA Administrative Consent Order

A Consent Decree with the State of Ohio, issued on August 29, 1989, and an Administrative Consent Order with the U.S. EPA, issued on September 29, 1989 (amended in 1994 and 1997), require the investigation and cleanup of surface water and air releases, groundwater contamination plumes, and solid waste management units. PORTS was divided into four quadrants based on groundwater flow patterns to facilitate the expedient cleanup of contaminated sites in accordance with RCRA corrective action and closure requirements. The Environmental Restoration Program at PORTS addresses requirements of the Ohio Consent Decree and U.S. EPA Administrative Consent Order. Chap. 3, Sect. 3.2, provides additional information on the Environmental Restoration Program.

2.3.2 Resource Conservation and Recovery Act

RCRA regulates the generation, accumulation, storage, transportation, and disposal of wastes. Wastes are designated as hazardous by the EPA because of various chemical properties, including ignitibility, corrosivity, reactivity, and toxicity.

2.3.2.1 Hazardous waste

DOE/PORTS is permitted by Ohio EPA to store hazardous waste in the X-7725 and X-326 facilities. The permit, often called a Part B Permit, was issued to DOE/PORTS in 1995. A permit renewal application was submitted to Ohio EPA in 2000 and the permit was renewed by Ohio EPA on March 15, 2001. The permit governs the storage of hazardous waste and includes requirements for waste identification, inspections of storage areas and emergency equipment, emergency procedures, training requirements, and other information required by Ohio EPA.

Facilities that generate or store hazardous waste are required to submit an annual report to Ohio EPA. This annual report contains the name and address of each facility that waste was shipped to during the previous calendar year, the name and address of the transporter for each waste shipment, the description and quantity of each waste shipped off site, and a description of waste minimization efforts. PORTS submitted the report for calendar year 2000 to Ohio EPA on February 23, 2001. Chap. 3, Sect. 3.3, Waste Management Program, provides additional information on wastes from PORTS that were recycled, treated, or disposed in 2000.

RCRA also requires closure of areas formerly used to store hazardous waste. Of the 19 areas at PORTS that were formerly used to store hazardous waste, 14 have been closed in accordance with Ohio EPA requirements. The five remaining areas are being remediated as part of the RCRA Corrective Action Program at PORTS.

RCRA may also require groundwater monitoring at hazardous waste units. As discussed in Chap. 6, groundwater monitoring requirements at PORTS have been integrated into one document, the *Integrated Groundwater Monitoring Plan*. Hazardous waste units included in the *Integrated Groundwater Monitoring Plan* are the X-231B Southwest Oil Biodegradation Plot, X-616 Chromium Sludge Surface Impoundments, X-701B Holding Pond, X-701C Neutralization Pit, X-735 RCRA Landfill (northern

portion), and X-749 Contaminated Materials Storage Yard (northern portion). Chap. 6 discusses the groundwater monitoring requirements for these units.

2.3.2.2 Solid waste

Closure of the X-734 Landfill Area began in 1999 and was completed in 2000. This area, which was used for disposal of solid wastes such as construction debris, trash, and garbage, was closed in the 1980s in accordance with regulations at the time. As part of the PORTS RCRA Corrective Action Program, however, contamination consisting primarily of volatile organic compounds was identified in this area. Therefore, a landfill cap was constructed over the area. Chap. 3, Sect. 3.2.2.2, provides additional information about the X-734 Landfill Area closure.

Groundwater monitoring may be required at closed solid waste facilities. Groundwater monitoring requirements for the closed X-735 Industrial Solid Waste Landfill and X-749A Classified Materials Disposal Facility are included in the *Integrated Groundwater Monitoring Plan*. Chap. 6 discusses the groundwater monitoring programs for these units. Groundwater monitoring at the X-734 Landfill Area began in the second quarter 2001.

2.3.3 Federal Facility Compliance Act

DOE/PORTS currently stores waste that is a mixture of RCRA hazardous waste and low-level radioactive waste. RCRA hazardous waste is subject to Land Disposal Restrictions, which do not allow the storage of hazardous waste for longer than one year. The Federal Facility Compliance Act, enacted by Congress in October 1992, allows for the storage of mixed hazardous/low-level radioactive waste for longer than one year because treatment for this type of waste is not readily available. The Act also requires federal facilities to develop and submit site treatment plans for treatment of mixed wastes. On October 4, 1995, Ohio EPA issued Director's Final Findings and Orders to implement the Federal Facility Compliance Act. This Act allows the storage of mixed waste beyond one year and gave approval of the DOE/PORTS Proposed Site Treatment Plan. An annual update to the Site Treatment Plan is required by these Director's Final Findings and Orders. This annual update for fiscal year 2000 was submitted to Ohio EPA in December 2000.

2.3.4 Comprehensive Environmental Response, Compensation, and Liability Act

DOE/PORTS is not on the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) National Priorities List of sites requiring cleanup, but is regulated under the provisions of CERCLA by the U.S. EPA Administrative Consent Order. U.S. EPA and Ohio EPA have chosen to oversee environmental remediation activities at DOE/PORTS under the RCRA Corrective Action Program.

Section 103 of CERCLA requires notification to the National Response Center if hazardous substances are released to the environment in amounts greater than or equal to the reportable quantity. Reportable quantities are listed in the Act and vary depending on the type of hazardous substance released. During 2000, DOE/PORTS had no reportable quantity releases of hazardous substances subject to Section 103 notification requirements.

2.3.5 Toxic Substances Control Act

The Toxic Substances Control Act regulates the use, storage, and disposal of PCBs. The electrical power system at PORTS, which is leased by USEC, uses oil-based circuit breaker transformers and large high-voltage capacitors, both containing PCB oil, to supply electricity to the enrichment cascade. The

2000 PCB Annual Document Log identifies 147 PCB transformers and 11,099 large PCB capacitors either in service or stored for reuse at PORTS.

In February 1992, a Federal Facilities Compliance Agreement between DOE and U.S. EPA addressing PCB issues became effective and resolved several compliance issues. These issues included the use of PCBs in systems that are not totally enclosed, storage of wastes containing both PCBs and radionuclides in accordance with nuclear criticality safety requirements, and storage of wastes containing both PCBs and radionuclides for longer than one year. The agreement required installation of troughs under motor exhaust duct gaskets located in production facilities to collect PCB oil leaks. When leaks or spills of PCBs occur, they are managed in accordance with the Federal Facilities Compliance Agreement. Annual and quarterly reports of progress made toward milestones specified in the Federal Facilities Compliance Agreement are submitted to the U.S. EPA. In addition, DOE and U.S. EPA representatives meet to resolve any unanticipated issues or uncertainties regarding the terms of the agreement. As of the end of 2000, DOE/PORTS was in compliance with the requirements and milestones of this Federal Facilities Compliance Agreement.

DOE/PORTS operates a number of storage areas for PCB wastes. The storage areas meet all applicable requirements of the federal regulations and the DOE Federal Facilities Compliance Agreement. Much of PORTS PCB waste is in long-term storage because of the lack of commercial disposal facilities authorized to dispose of wastes containing both PCBs and radionuclides.

An annual document log is prepared to meet regulatory requirements. The document log provides an inventory of PCB items in use, in storage as waste, and shipping/disposal information for PCB items disposed in 2000. The *2000 PCB Annual Document Log* was prepared in June 2001. Chap. 3, Sect. 3.3, Waste Management Program, provides additional information on PORTS PCB wastes treated or disposed in 2000.

Other sections of the Toxic Substances Control Act have little or no impact on DOE/PORTS. Although friable asbestos, which deteriorates into airborne fibers, is regulated under the Act, the specific regulations applicable to PORTS are duplications of other state and federal regulations such as the National Emission Standards for Hazardous Air Pollutants. DOE/PORTS also responds to U.S. EPA requests for health and safety data, but such responses indicate that DOE/PORTS neither imports chemicals nor manufactures, processes, or distributes chemical substances for commercial purposes.

2.3.6 Clean Air Act

DOE/PORTS had four permitted and nine registered air emission sources at the end of 2000 (see Appendix B). The air permit obtained in 1999 for emissions of particulates, or dust, from unpaved roadways and soil storage piles during closure of the X-734 Landfill Area was cancelled in August 2000 after the project was completed.

2.3.6.1 Clean Air Act, Title VI, Stratospheric Ozone Protection

As part of the Stratospheric Ozone Protection Plan, DOE has instituted a record-keeping system consisting of forms and labels to comply with the Title VI record-keeping and labeling requirements. These requirements affect all areas that use ozone-depleting substances in units or devices. The appliance service record and retrofit or retirement plan forms apply to units with a capacity of more than 50 pounds. The refrigeration equipment disposal log and associated appliance disposal label are used by all units regardless of capacity. Maintenance and service of air conditioning/refrigeration units and motor vehicle air-conditioning units under DOE control are conducted under contract with USEC. The contractor technicians who service the equipment have been trained in accordance with U.S. EPA requirements.

USEC uses an ozone-depleting substance, specifically dichlorotetrafluoroethane, as a coolant in the cascade system used to produce enriched uranium. In 2000, USEC estimated that 430,000 pounds of dichlorotetrafluoroethane were released to the air.

2.3.6.2 National Emission Standards for Hazardous Air Pollutants

The National Emission Standards for Hazardous Air Pollutants require PORTS to submit an annual estimate of radiological emissions from DOE/PORTS sources. In the first quarter 2001, air emissions testing at two of the DOE/PORTS groundwater treatment facilities indicated that these facilities emit small quantities of radionuclides to the air. Based on these results, air emissions from the two groundwater treatment facilities in 2000 were estimated and added to emissions from the two DOE/PORTS glove boxes that emit radionuclides (the X-326 L-cage Glove Box and the X-744G Glove Box). A glove box is an enclosure with built-in sleeves and gloves that is used by a person to repackage or transfer hazardous material without directly exposing the person to the material.

In 2000, the X-744G Glove Box was not used; therefore, radiological emissions from DOE/PORTS in 2000 are based on emissions from the X-326 L-cage Glove Box, the X-623 Groundwater Treatment Facility, and the X-624 Groundwater Treatment Facility. Gaseous radiological emissions from these sources are calculated by using standard engineering procedures. For example, emissions from the glove box are based on the amount and type of material handled in the glove box and the amount of material removed from emissions by pollution control equipment installed on the glove box. Emissions from the groundwater treatment facilities were conservatively estimated based on the assumption that the highest emissions recorded during the first quarter 2001 testing were emitted continuously throughout 2000.

Radiological air emissions from the X-326 L-cage Glove Box, the X-623 Groundwater Treatment Facility, and the X-624 Groundwater Treatment Facility in 2000 were 0.00063 curie (Ci). Chap. 5, Dose, provides the radiological dose calculations to members of the public from these emissions.

2.3.7 Clean Water Act

The DOE/PORTS NPDES permit, issued in 1995 and modified in 1996 and 1997, encompasses six monitored outfalls. Three of the outfalls are classified as point-source discharges to waters of the state, and the other three outfalls are internal outfalls classified as effluents. Water from these three internal outfalls is treated in the USEC Sewage Treatment Plant before reaching waters of the state. Chap. 4 provides additional information on the DOE/PORTS NPDES outfalls. U.S. EPA and Ohio EPA conducted the annual inspection of all DOE/PORTS outfalls during the multimedia environmental inspection conducted in June 2000. No problems were noted during the inspection.

The DOE/PORTS NPDES permit expired on March 31, 1999. DOE submitted a permit renewal application to Ohio EPA in September 1998 in accordance with Ohio EPA requirements. The old permit will remain in effect until Ohio EPA issues a new permit. This old permit was in effect throughout 2000.

One of the NPDES permit limitations was exceeded during 2000. The sample collected from Outfall 013 (X-2230N Holding Pond) in February 2000 exceeded the permit limitation for total suspended solids. The permit limitation was 45 milligrams per liter (mg/L) and the sample result was 70.8 mg/L. Ohio EPA was notified of the permit exceedence. No other NPDES permit limitations were exceeded during 2000. The overall DOE NPDES compliance rate for 2000 was 99.8%. The compliance rate is calculated by dividing the number of measurements that did not exceed the applicable permit limits by the total number of measurements made.

2.3.8 Underground Storage Tank Regulations

The Underground Storage Tank Program is managed in accordance with the Ohio State Fire Marshal's Bureau of Underground Storage Tank Regulations. DOE/PORTS renewed the registration of eight tanks in June 2000. DOE leases all of these underground storage tanks to USEC.

2.3.9 Emergency Planning and Community Right-To-Know Act

The Emergency Planning and Community Right-To-Know Act of 1986, also referred to as the Superfund Amendments and Reauthorization Act Title III, requires reporting of emergency planning information, hazardous chemical inventories, and releases to the environment. Emergency Planning and Community Right-To-Know Act reports are submitted to federal, state, and local authorities.

Section 304 of the Emergency Planning and Community Right-To-Know Act requires reporting of off-site reportable quantity releases to state and local authorities. During 2000, DOE/PORTS had no reportable quantity releases.

The Hazardous Chemical Inventory Report, which includes the identity, location, storage information, and hazards of the chemicals that exceeded threshold planning quantities, is submitted annually to state and local authorities. Twenty materials stored by DOE/PORTS exceeded the threshold planning quantities for the entire site (including USEC) in 2000: 1,1,1-trichloroethane, aluminum oxide, argon, asbestos, diesel fuel, ethylene glycol, gasoline, kerosene, lithium hydroxide monohydrate, methanol, oxygen, PCBs, sodium chloride, sodium fluoride, triuranium octaoxide, uranium dioxide, uranium hexafluoride, uranium metal, uranium tetrafluoride, and uranium trioxide.

The Toxic Chemical Release Inventory is sent annually to U.S. EPA and Ohio EPA. This report details releases to the environment of specified chemicals when they are manufactured, processed, or otherwise used by the entire site (including USEC) in amounts that exceed threshold quantities specified by U.S. EPA. In 2000, DOE/PORTS was required to report the off-site transfer of 2 lbs. of mercury compounds and 2 lbs. of methanol to permitted treatment/disposal facilities. USEC reported the release and/or on-site treatment of seven chemicals: chlorine, dichlorotetrafluoroethane, methanol, nitrate compounds, nitric acid, sulfuric acid, and mercury compounds.

2.3.10 National Environmental Policy Act

The National Environmental Policy Act requires evaluation of the environmental impacts of activities at federal facilities and of activities funded with federal dollars. Reviews are required for all projects to determine the potential for environmental impacts to the following:

- property (e.g., sites, buildings, structures, and objects) of historical, archaeological, or architectural significance, as officially designated by federal, state, or local governments, including properties eligible for listing on the *National Register of Historic Places*;
- potential habitat (including critical habitat) of federally listed endangered, threatened, proposed, or candidate species or of state-listed endangered and threatened species;
- floodplains and wetlands;
- natural areas such as federally and state-designed wilderness areas, national parks, national natural landmarks, wild and scenic rivers, coastal zones, state and federal wildlife refuges, and marine sanctuaries;

- prime agricultural lands; and
- special sources of water (such as sole-source aquifers, wellhead protection areas, and other water sources that are vital to a region).

Reviews also consider impacts to air, surface water, groundwater, biota, socioeconomics, environmental justice, and worker safety and health.

DOE/PORTS has a formal program dedicated to compliance pursuant to DOE Order 451.1, *National Environmental Policy Act Compliance Program*. Restoration actions, waste management, enrichment facilities maintenance, and other activities are evaluated to determine the appropriate level of documentation. Documents are evaluated and approved internally. Environmental impact statements, however, must be produced by an independent organization. Routine operation and maintenance activities are also evaluated to assess potential environmental impacts. Most activities at PORTS qualified for a categorical exclusion as defined in the regulations. These activities were judged to be routine and had no significant individual or cumulative environmental impacts.

In 2000, 19 record reports and 5 categorical exclusions were generated for DOE/PORTS project activities. These projects were part of the Waste Management, Environmental Restoration, and Uranium Programs. Examples of projects addressed by the reports or exclusions include X-611 Lime Slurry Pipeline Removal, Removal of the X-344D Hydrogen Fluoride Neutralization Pit, and Perimeter Road Repaving.

2.3.11 Federal Insecticide, Fungicide, and Rodenticide Act

Plant personnel apply general-use pesticides according to product labeling, and all product warnings and cautions are strictly obeyed. When application of a restricted-use pesticide is required, a certified contractor is employed. No restricted-use pesticides were applied at DOE/PORTS in 2000.

2.4 OTHER ENVIRONMENTAL ACTS AND FEDERAL REGULATIONS

2.4.1 Endangered Species Act

The Endangered Species Act of 1973, as amended, provides for the designation and protection of endangered and threatened wildlife and plants, and the habitat on which such species depend. When appropriate, formal consultations are made with the U.S. Fish and Wildlife Service and the Ohio Department of Natural Resources. A sitewide threatened and endangered species habitat survey and an Indiana bat (*Byosis sodalis*) survey were completed in August 1996. No Indiana bats were found at PORTS. Few potential critical habitats were identified, and a report of the survey activities and results was provided to the Ohio Department of Natural Resources as required by the Federal Fish and Wildlife permit obtained to conduct the survey. No additional activities were completed in 2000.

2.4.2 National Historic Preservation Act

The National Historic Preservation Act of 1966 is the primary law governing the protection of cultural resources (archaeological and historical properties). Cultural resource reviews are conducted on a case-by-case basis, and consultations with the Ohio State Historic Preservation Officer are made as required by Section 106 of the Act. A draft programmatic agreement among DOE, the Ohio State Historic Preservation Officer, and the Advisory Council on Historic Preservation concerning the

management of historical and cultural properties at DOE/PORTS was submitted to the State Historic Preservation Officer for review and comment in 1997.

Phase I of the historical/archaeological survey was completed in September 1996. Fieldwork for Phase II of the project was completed in May 1997. Artifacts from the 1940s and 1950s were uncovered as well as remains from former dwellings that were present prior to construction of PORTS. Results from the survey will be coordinated with the State of Ohio Historic Preservation Office, and a Cultural Resources Management Plan will be developed.

In 2000, a letter of notification regarding the demolition of the X-701A Lime House Facility and the removal of the X-701C Neutralization Pit was submitted to the State Historical Preservation Officer.

2.4.3 Archaeological and Historic Preservation Act and Archaeological Resources Protection Act

The Archaeological and Historic Preservation Act and the Archaeological Resources Protection Act require the Secretary of the Department of Interior to report to Congress on various federal archaeological activities. The Archaeological Resources Protection Act requires federal land managers to provide archaeology program information to the Secretary of the Interior for this report. *The Department of the Interior Questionnaire on Fiscal Year 1999 Federal Archaeological Activities at the Portsmouth Gaseous Diffusion Plant* was completed and submitted to DOE Headquarters and forwarded to the Department of Interior in 2000 to satisfy this requirement.

2.4.4 Farmland Protection Policy Act

The Farmland Protection Policy Act of 1981 requires federal agencies to consider the effects of their proposed actions on prime farmland. Prime farmland is generally defined as land that has the best combination of physical and chemical characteristics for producing crops of statewide or local importance. When required, prime farmland surveys are conducted, and consultations with the U.S. Department of Agriculture's Natural Resources Conservation Service are made. No prime farmland surveys have been conducted at DOE/PORTS.

2.4.5 Title 10 Code of Federal Regulations Part 1022, "Compliance with Floodplain/Wetlands Environmental Review Requirements"

Part 1022 of Title 10 of the Code of Federal Regulations establishes policy and procedures for compliance with Executive Order 11988, Floodplain Management, and Executive Order 11990, Protection of Wetlands. The regulatory authority for wetlands is the United States Army Corps of Engineers. Activities (other than routine maintenance) proposed within 100-year and 500-year floodplains or in wetlands require publication of a notice of involvement in the Federal Register. For floodplains, a floodplain statement of findings summarizing the floodplain assessment is also required by DOE and must be published in the Federal Register for public comment at least 15 days prior to the start of the project. An assessment is also required for activity in a wetland prior to authorization to determine all effects of the proposed project. Many activities have been previously authorized by nationwide or regional permits and only require notification. Other activities qualify for abbreviated permit processing, whereby permission is granted via correspondence from the Corps of Engineers.

The sitewide wetland survey report was completed and submitted to the Corps of Engineers in 1996. There are 41 jurisdictional wetlands and four non-jurisdictional wetlands totaling 34.361 acres at PORTS. Activities in jurisdictional wetlands require a Clean Water Act Section 404 permit from the Corps of Engineers. No DOE activities required a Clean Water Act Section 404 permit during 2000.

2.5 DOE ORDERS

2.5.1 DOE Order 5400.1, General Environmental Protection Program

DOE Order 5400.1 establishes environmental protection program requirements, authorities, and responsibilities for DOE operations for compliance with applicable U.S. EPA, state, and local environmental regulations, Executive Orders, and internal DOE policies. The order specifically defines the mandatory environmental protection standards (including those imposed by federal and state law), establishes reporting of environmental occurrences and periodic routine reporting of significant environmental protection information, and provides requirements and guidance for environmental monitoring programs. DOE Order 5400.1 requires the development and periodic update of several environmental reports and programs. Examples of these reports include an annual site environmental report, environmental protection implementation plan, and waste minimization program plan.

DOE Order 5400.1 also requires an environmental monitoring program that defines environmental monitoring activities for PORTS. The program assesses pathways by which humans and/or the environment could be exposed to radionuclides and other chemicals released by PORTS activities. Chap. 4 discusses the results of environmental monitoring (with the exception of groundwater) at PORTS. Groundwater monitoring is discussed in Chap. 6.

2.5.2 DOE Order 5400.5, Radiation Protection of the Public and the Environment

DOE Order 5400.5 provides guidance and establishes radiation protection standards and control practices designed to protect the public and the environment from undue radiological risk from operations of DOE and DOE contractors. The order requires that off-site radiation doses do not exceed 100 mrem/year above background for all exposure pathways. Chap. 5 provides the dose calculations for compliance with this DOE Order.

2.6 ENVIRONMENTAL PROGRAM INSPECTIONS

During 2000, four inspections of the DOE/PORTS programs were conducted by federal, state, or local agencies. Table 2.1 lists these inspections.

Table 2.1. Environmental inspections at DOE/PORTS for 2000

Date	Agency	Type	Findings
January-May	DOE Environment and Health Team	Assessment of historical and current environment, safety, and health activities and controls	See Sect. 2.6.1
April 4	Ohio Department of Health	Inspection of closed solid waste facilities: X-749A, X-749, and X-735 (solid waste portion)	None
June 19-28	U.S. EPA, Ohio EPA, Ohio Department of Health	Multimedia environmental compliance	See Sect. 2.6.1
September 15	Federal Energy Regulatory Commission	Inspection of dams and impoundments	None

2.6.1 Inspection Findings

The DOE Office of Oversight conducted an investigation of PORTS from January through May 2000. The purposes of the investigation were (1) determine whether historical environmental, safety, and

health activities and controls associated with uranium enrichment and supporting operations were in accordance with the knowledge, standards, and local requirements applicable at that time; (2) identify any additional past environmental, health, and safety concerns that had not been documented; and (3) determine whether current work practices for DOE-controlled areas of the site adequately protect workers, the public, and the environment. The investigation determined that although current operations in the DOE-controlled areas of PORTS did not present an immediate risk to workers or the public, improvements were needed in several areas. The investigation identified 17 significant issues that required corrective action in the areas of environmental monitoring, radiation protection, and integrated safety management.

Following the investigation, DOE/PORTS implemented a number of interim and long-term corrective actions. The actions included:

- Verification of radiological postings in all DOE areas
- Enhancement of radiological programs and staff
- Development of additional quality control programs
- Additional staff and training for safety and environmental staff
- Enhanced ambient air monitoring
- Monitoring of environmental media for additional radionuclides
- Additional funding for removal of scrap metal from DOE storage yards
- Removal of containerized chromium sludge waste from PORTS
- Installation of additional groundwater wells to verify containment of the X-749 groundwater plume

U.S. EPA, Ohio EPA, and the Ohio Department of Health conducted a multimedia inspection of PORTS in June 2000. In February 2001, DOE received a Notice of Violation concerning two minor issues identified during this inspection. One of the issues involved hazardous waste manifests that were not filled out correctly (information was not placed in the specified box on the manifest form, but was included elsewhere on the form). The manifests identified in the audit cannot be corrected; however, manifests completed since then have been completed correctly. The other issue involved labeling of a tank in one of the groundwater treatment facilities. Although the tank was labeled "trichloroethylene," Ohio EPA required additional labeling which has been completed by DOE.

2.6.2 Other Notices of Violation

In June 2000, DOE received a Notice of Violation from Ohio EPA. The violation was associated with the statistical monitoring program at the X-735 and X-749A Landfills. The concentrations of several parameters detected at three of the monitoring wells at the X-735 Landfills and one parameter in one well at the X-749A Landfill in 1999 were higher than background concentrations. DOE had not reported the differences because the concentrations of these parameters in the wells had not shown a statistically significant increase in downgradient concentrations for many years and appear to result from natural variation rather than a release of hazardous constituents from the landfill. DOE initiated an assessment monitoring program at the landfills in August 2000, which includes collecting information to support the assertion that the exceedences at the wells were due to natural variation. Chap. 6, Groundwater Monitoring, provides additional information.

3. ENVIRONMENTAL PROGRAMS

3.1 SUMMARY

Environmental Restoration activities in 2000 include construction of caps on the X-734 Landfills and the X-231A and X-231B Biodegradation Plots, removal of the X-344D Neutralization Pit, maintenance of the X-740 phytoremediation project, and development of various work plans, sampling plans, and other documents required by Ohio EPA.

In 2000, the Waste Management Program directed the treatment and/or disposal of over 8 million lbs of wastes (primarily at off-site locations), characterized 10 waste streams, and recycled more than 33,000 lbs of paper, cardboard, and aluminum cans.

Activities undertaken by the Waste Minimization, Pollution Prevention, Training, Information Exchanges, and Public Awareness programs are also discussed in this chapter.

3.2 ENVIRONMENTAL RESTORATION PROGRAM

DOE established the Environmental Restoration Program in 1989 to identify and correct site contamination areas as quickly and cost-effectively as possible. The Environmental Restoration Program was granted an initial budget of $13.8 million. The Environmental Restoration Program budget for fiscal year 2000 was $29.4 million.

The Environmental Restoration Program addresses inactive sites through remedial action and deals with active facilities through eventual decontamination and decommissioning. Options for correcting or mitigating the contaminated sites and facilities include removal, containment, and treatment of contaminants. Because PORTS is a large facility, it is divided into four quadrants (Quadrant I, II, III, and IV) to facilitate the cleanup process.

The Environmental Restoration Program was established to fulfill the cleanup requirements of the Ohio Consent Decree and U.S. EPA Administrative Consent Order, both issued in 1989. As required by these enforcement actions, DOE/PORTS Environmental Restoration Program activities are conducted in accordance with the RCRA corrective action process, which consists of the following:

- *Description of current conditions* – to provide knowledge of the groundwater, surface water, soil, and air.
- *RCRA facility assessment* – to identify releases of contaminants and determine the need for further investigation.
- *RCRA facility investigation* – to determine the nature and extent of any contamination.
- *Cleanup alternatives study/corrective measures study* – to evaluate and select a remediation alternative.
- *Corrective measures implementation* – to implement the selected remediation measure.

- *Interim remedial measures* – to implement quick remediation or mitigation measures prior to permanent action.

DOE/PORTS has completed the description of current conditions, RCRA facility assessment, and RCRA facility investigation. No interim remedial measures were undertaken in 2000. Cleanup alternatives study/corrective measures study activities, corrective measures implementations, and technology applications are described in the following sections.

3.2.1 Cleanup Alternatives Study/Corrective Measures Study

As required by the Consent Decree and the Administrative Consent Order, the cleanup alternatives studies/corrective measures studies identify the solid waste management units and explore the remedial alternatives within Quadrants I through IV. Following the approval of the final cleanup alternative studies/corrective measure studies, Ohio EPA selects the remedial alternatives that will undergo further review for determining the final remedial actions (the Preferred Plan). Upon concurrence from the U.S. EPA and completion of the public review and comment period, the U.S. EPA and Ohio EPA select the final remedial actions for each quadrant. Ohio EPA issues a decision document to notify DOE/PORTS of the final remedial actions chosen for the site. DOE/PORTS is required to submit a corrective measures implementation plan that details the implementation of the final remedial actions listed in the decision document.

The *Quadrant I Cleanup Alternative Study/Corrective Measures Study* was approved by Ohio EPA on June 12, 2000. In November 2000, Ohio EPA issued the Preferred Plan for Quadrant I, which identified the selected remedies for the areas that require remediation. The remedial actions identified for Quadrant I are (1) installation of multimedia caps over the X-231A and X-231B Biodegradation Plots (see Sect. 3.2.2.3), (2) installation of 11 additional groundwater extraction wells in the Quadrant I Groundwater Investigative Area to extract contaminated groundwater for treatment in the X-622 Groundwater Treatment Facility, and (3) for the X-749/X-120/PK Landfill Area groundwater plume, phytoremediation of 27.5 acres of the plume, installation of a barrier wall at the south end of the X-749 groundwater plume, deed restrictions, continued operation of the groundwater collection trenches installed in the area, and continued groundwater monitoring.

The *Quadrant II Cleanup Alternative Study/Corrective Measures Study* was submitted to Ohio EPA on August 15, 2000. Ohio EPA provided comments to DOE on October 17, 2000. Meetings were held to discuss the comments, and the revised document was expected to be submitted to Ohio EPA in 2001.

The *Quadrant III Cleanup Alternative Study/Corrective Measures Study* was approved by Ohio EPA in 1998. The decision document for Quadrant III required remediation of the groundwater plume near the X-740 Waste Oil Handling Facility. Sect. 3.2.2.1 provides information on the corrective measures implementation for this area.

The *Quadrant IV Cleanup Alternative Study/Corrective Measures Study* was approved by Ohio EPA in 1998. In 1999, Ohio EPA issued the decision document for the X-734 Landfill Area (part of Quadrant IV). A summary of the corrective measures for the X-734 Landfills is discussed in Sect. 3.2.2.2. Ohio EPA also required removal of the X-344D Neutralization Pit prior to issuing the decision document for all of Quadrant IV; this area was removed in 2000 (see Sect 3.2.2.4). DOE received the decision document for the remainder of Quadrant IV on October 6, 2000. No new remedial actions are required in Quadrant IV (remedial actions have already taken place at the X-735 Landfills, X-611A Former Lime Sludge Lagoons, and the X-734 Landfill Area).

3.2.2 Corrective Measures Implementation

The corrective measures implementations for two units, the groundwater plume near the X-740 Waste Oil Handling Facility and the X-734 Landfills, were begun in 1999 and completed in 2000. Remedial actions for two additional units, the X-231A and X-231B Biodegradation Plots and X-344D Neutralization Pit, were begun and completed in 2000. Planning for removal of the X-701C Neutralization Pit/X-701A Lime House in Quadrant II began in 2000. The following subsections provide summaries of each of these projects.

3.2.2.1 Groundwater plume near the X-740 Waste Oil Handling Facility

The X-740 Waste Oil Handling Facility was used as a drum-staging area of non-radionuclide contaminated waste oils and solvents generated by various plant site activities from 1982 to 1992. This facility underwent RCRA closure in 1993 including decontamination of the floor and walls of the facility and removal of a tank/sump and surrounding contaminated soil. The remaining groundwater contamination (consisting mainly of trichloroethene) near this facility is the basis for the remedial action recommended by Ohio EPA in its decision document.

Ohio EPA's preferred cleanup alternative involves institutional controls and the use of *in situ* (in place) phytoremediation for the X-740 groundwater plume. Phytoremediation is considered an emerging technology that uses plants to remove, degrade, or contain contaminants in soil and groundwater. Although phytoremediation is an emerging technology, it has been shown to remediate trichloroethene at several Department of Defense and Superfund Sites. Mature trees can consume more than 3,000 gallons of groundwater per day per acre. Organic compounds are expected to be removed from the groundwater, captured in the trees' root systems, and then degraded by ultraviolet light as they are transpired along with the water vapor through the leaves of the trees.

Over 700 hybrid poplar trees were planted on a 2.6-acre area above the X-740 groundwater plume in 1999. In 2000, dead trees in the area were replaced and settled areas around the trees were filled. DOE/PORTS also developed on-going monitoring requirements for the area, which include (1) installation of 4 new monitoring wells within the groundwater plume, and (2) monitoring water levels around the trees beginning in 2001 to determine the amount of water consumed by the trees. Chap. 6 provides information about the groundwater monitoring completed for this area in 2000.

PORTS will realize an estimated cost savings of more than $31 million by implementing this phytoremediation technology rather than a standard groundwater pump-and-treat facility. It cost $500,000 to plant the trees for this project, whereas a treatment facility would cost $2 million to build and $1 million a year for 30 years to operate.

3.2.2.2 X-734 Landfill Area

The X-734 Landfill Area consists of the X-734 Old Sanitary Landfill, the X-734A Construction Spoils Landfill, and the X-734B Construction Spoils Landfill. The decision document for the X-734 Landfill Area, issued in 1999, requires (1) a multimedia cap at the X-734/X-734A Landfills, (2) a soil cap at the X-734B Landfill, and (3) phytoremediation downgradient of the X-734B Landfill to capture and remediate any groundwater that could potentially migrate from the landfill.

Phase I of the project, completed in 1999, consisted of the installation of an 18-inch soil cap on the X-734B Landfill and planting of the poplar trees for phytoremediation. The soil cap consists of compacted clay and is covered with a 6-inch vegetative soil layer (topsoil) and planted with grass seed.

Phase II consisted of the installation of a multimedia cap on the northern portion of the landfill (X-734/X-734A). Construction of the multimedia cap at X-734/X-734A (Phase II) was initiated in November 1999 and suspended for the winter. Installation of the cap resumed in May 2000 and was completed in July 2000. A closure certification report was expected to be submitted to Ohio EPA in 2001.

Groundwater monitoring requirements for the area were approved by Ohio EPA and were scheduled to begin in the second quarter 2001.

3.2.2.3 X-231A and X-231B Oil Biodegradation Plots

The X-231A and X-231B Oil Biodegradation Plots were used in the 1970s through 1983 for disposal of waste oils. Waste oil contaminated with solvents, radionuclides, metals, and PCBs was applied to the ground. The areas were periodically fertilized and plowed to introduce oxygen and nutrients to the soil and encourage biological activity to break down the oil. This disposal practice was commonly practiced in the 1970s. However, the waste oil disposal resulted in contamination of the soil and groundwater in this area and is one of the sources of the Quadrant I Groundwater Investigative Area groundwater plume (see Chap. 6).

Remedial actions identified in the Preferred Plan for Quadrant I (see Sect. 3.2.1) include installation of caps on the X-231A and X-231B Oil Biodegradation Plots to minimize infiltration of water (rainfall and other precipitation). Minimizing water infiltration into the area helps control the spread of contaminants. In 2000, a multilayered cap was installed over the former plots. Installation of the cap was begun on September 20, 2000 and completed by the end of October 2000.

3.2.2.4 X-344D Neutralization Pit removal

Ohio EPA required removal of the X-344D Neutralization Pit as part of the remedial activities for Quadrant IV. The pit was a reinforced concrete retention basin lined with asphalt that was designed to contain and neutralize releases of hydrogen fluoride (HF) from the X-344C HF Tank Storage Facility; however, historical records of plant operations do not cite any events involving the release of hydrogen fluoride to the pit. The X-344C HF Tank Storage Facility had not been used for many years, with the result that rainwater and sediment accumulated in the neutralization pit.

A work plan for removal of the pit was approved by Ohio EPA on July 27, 2000. Work began and was completed in September 2000. The following activities were completed:

- Water and sediment were removed from the pit.
- All structures (a concrete sidewalk, slab, and the pit) were removed.
- The excavation was backfilled with clean fill material to match the surrounding area.
- Grass was established over the excavation.

3.2.2.5 X-701C Neutralization Pit/X-701A Lime House work plan

In Quadrant II, Ohio EPA required removal of the X-701C Neutralization Pit/X-701A Lime House and associated facilities. This pit received process water and wastewater from the basement sump in the X-700 Chemical Cleaning Facility for over 30 years and is one of the sources of groundwater contamination in the Quadrant II Groundwater Investigative Area (see Chap. 6).

A work plan for removal of the X-701C Neutralization Pit/X-701A Lime House was submitted to Ohio EPA in November 2000.

3.2.3 Additional Cleanup Alternatives Study/Corrective Measures Study Activities

3.2.3.1 Quadrant III and Quadrant IV confirmatory sampling

In an effort to determine final disposition of solid waste management units within Quadrant III and Quadrant IV, DOE met with Ohio EPA and agreed to perform additional confirmatory sampling in these quadrants. A sampling plan was approved by Ohio EPA in 1999 and sampling was completed in February 2000. Sampling results were submitted to Ohio EPA in April 2000. The solid waste management units were either (1) determined to require no further action or (2) deferred to the decontamination and decommissioning program (the units will be remediated, if necessary, when they are no longer used for their original purpose or when the entire plant is no longer in operation).

3.2.4 Technology Applications

The DOE/PORTS Technology Applications Program was established in 1993 to facilitate the introduction of innovative or experimental environmental technology into the DOE/PORTS Environmental Restoration Program. The primary function of the technology program is to identify, evaluate, and test/demonstrate innovative advancements in environmental characterization and cleanup. The goal is to incorporate the most practical, cost-effective cleanup approaches as they are evolving for full-scale application at the plant. By combining conventional research and development with cleanup efforts, technology demonstrations enable the site to solve real problems using innovative methods. The Technology Applications Program utilizes a team of DOE contractors, national laboratory scientists, university researchers, private industries, site engineers, and technical staff.

3.2.4.1 X-701B *in situ* chemical oxidation

Oxidation is a type of chemical reaction. *In situ* (in place) chemical oxidation is used to remediate volatile organic compounds such as trichloroethene in groundwater. With this technique, chemical oxidants are injected into the ground, a chemical reaction takes place, and the trichloroethene is changed into nontoxic chemical compounds. Laboratory experiments have demonstrated that potassium permanganate, sodium permanganate, and hydrogen peroxide can effectively oxidize trichloroethene.

The X-701B Holding Pond area was chosen for this technology demonstration because of the existing horizontal and vertical groundwater wells and the extensive site characterization data for the area. In 1998, groundwater was extracted from one horizontal well, pumped to an existing groundwater treatment facility, mixed with potassium permanganate, and reinjected into a parallel horizontal well approximately 90 ft away. The results of this test indicated that *in situ* chemical oxidation through recirculation effectively oxidized trichloroethene in groundwater in the area affected by the wells. Where the oxidant was found, trichloroethene was no longer detectable.

In 1999, another demonstration was conducted using sodium permanganate injected through vertical wells. The system was shut down because the sodium permanganate was moving from below ground, where it had been injected, to the ground surface. Following a series of tests to identify and correct the problem, the demonstration was restarted in 2000; however, activities were restricted to injection of the sodium permanganate to the soil above the contaminated groundwater, because of problems with the injection well used to deliver the oxidant solution to the groundwater. Injection of the soil began in July 2000; however, an accident occurred on August 22, 2000, which involved a serious injury to a worker caused by a chemical reaction. The project was shut down for the remainder of 2000.

3.3 WASTE MANAGEMENT PROGRAM

The DOE/PORTS Waste Management Program directs the safe storage, treatment, and disposal of waste generated by past and present operations and from current Environmental Restoration projects. DOE/PORTS also stores USEC-generated waste in the RCRA Part B permitted storage areas. Waste managed under the program is divided into the following six categories, which are defined below:

- *Low-level radioactive waste (LLW)* – radioactive waste not classified as high level or transuranic and that does not contain any components regulated by RCRA or the Toxic Substances Control Act.

- *Hazardous (RCRA) waste* – waste that contains one or more of the wastes listed under RCRA or that exhibits one or more of the four RCRA hazardous characteristics: ignitability, corrosivity, reactivity, and toxicity.

- *RCRA/LLW mixed waste* – waste containing both hazardous and radioactive components. The waste is subject to RCRA, which governs the hazardous components, and to additional regulations that govern the radioactive components.

- *PCB wastes* – waste containing PCBs, a class of synthetic organic chemicals. Under Toxic Substances Control Act regulations, PCB manufacturing was prohibited after 1978. However, continued use of PCBs is allowed, provided that the use does not pose a risk to human health or the environment. Disposal of all PCB materials is regulated under the Toxic Substances Control Act.

- *PCB/LLW mixed waste* – waste containing both PCB and radioactive components. The waste is subject to the Toxic Substances Control Act that governs PCB components, and to additional regulations that govern radioactive components.

- *Industrial sanitary waste* – waste generated by commercial operations, such as office waste.

During 2000, over 8 million lbs of waste from PORTS were recycled, treated, or disposed (Table 3.1). Future waste management projects include the shipment for disposal of low-level radioactive waste and mixed waste, and the treatment of mixed and PCB/mixed waste at off-site commercial facilities.

Waste management requirements are varied and are sometimes complex because of the variety of waste streams generated by DOE/PORTS activities. DOE Orders, Ohio EPA regulations, and U.S. EPA regulations must be satisfied to demonstrate compliance for waste management activities. Additional policies have been implemented for management of radioactive, hazardous, and mixed wastes. These policies include the following:

- minimizing waste generation;

- characterizing and certifying wastes before they are stored, processed, treated, or disposed;

- pursuing volume reduction (such as blending and bulking) as well as on-site storage in preparation for safe and compliant final treatment and/or disposal; and

- recycling.

Table 3.1. Waste Management Program treatment, disposal, and recycling accomplishments for 2000

Waste stream	Quantity	Treated, disposed, or recycled	Treatment, disposal, or recycling facility
Waste streams characterized	10 waste streams (3317 drums)	Not applicable	Not applicable
Ion exchange resin	1 drum / 177 lbs	Disposed	Envirocare
X-701B PCB sludge	125 B-25 boxes / 620,818 lbs	Disposed	Envirocare
X-616 waste	1443 B-25 boxes / 7,376,993 lbs	Disposed	Envirocare
X-720 Neutralization Pit soils	32 B-25 boxes / 191,812 lbs	Disposed	Envirocare
X-749 soils	18 drums / 9175 lbs	Treated and disposed	Safety-Kleen
Wastewater	20,144 lbs	Treated	On-site treatment facilities
PCB mineral oil	2 tankers / 48,900 lbs	Trial burn	TSCA Incinerator
PCB mineral oil	16 drums / 7084 lbs	Treated and disposed	Safety-Kleen
Compressed gas cylinders	18 cylinders	Treated and disposed	Safety-Kleen
Lab packs	13 drums / 1363 lbs	Disposed	Waste Control Specialists LLC
Fluorescent light bulbs	2050 lbs	Recycled	Superior Special Services, Inc.
Aluminum cans	1677 lbs	Recycled	Star, Inc.
Cardboard	6953 lbs	Recycled	Star, Inc.
Mixed office paper	24,670 lbs	Recycled	Rumpke

3.4 WASTE MINIMIZATION AND POLLUTION PREVENTION PROGRAM

DOE/PORTS has combined its waste minimization and pollution prevention efforts to consolidate related activities. The objectives of the DOE/PORTS Waste Minimization and Pollution Prevention Program include the following:

- fostering a philosophy to conserve resources and create a minimum of waste and pollution;
- promoting the use of nonhazardous materials in DOE/PORTS operations to minimize potential risks to human health and the environment;
- reducing or eliminating the generation of wastes through material substitution, product reformulation, process modification, improved housekeeping, and on-site recycling; and
- complying with federal and state regulations and DOE policies and requirements for waste minimization.

The DOE/PORTS Waste Minimization and Pollution Prevention Program continues activities to achieve the waste minimization objectives. Typical projects include the following:

- maintaining a comprehensive waste tracking and reporting system;
- evaluating DOE/PORTS processes and activities to identify waste minimization opportunities;
- maintaining an effective DOE/PORTS waste minimization training program;
- maintaining a waste minimization and pollution prevention awareness promotional campaign; and
- providing a waste minimization and pollution prevention information exchange network.

The Pollution Prevention Awareness Program consists of (1) pollution prevention awareness through Earth Day events, newsletters, bulletins, and memoranda; (2) awards, recognition for employees, and performance indicators; (3) information exchange; and (4) training. Other recognized pollution prevention measures are the *Best Management Practices Plan* and the *Portsmouth Spill Prevention, Control, and Countermeasures Plan.*

Highlights of the Waste Minimization and Pollution Prevention Program in 2000 include the following:

- reused excess computer equipment by donating it to public schools through the Southern Ohio Diversification Initiative;

- sponsored a science-related field trip for approximately 2000 students from southern Ohio and northern Kentucky to the Center of Science and Industry in Columbus, Ohio;

- recharacterized (through sampling and analysis) over 170,000 lbs of waste resulting in reduced hazards associated with storage of the waste;

- recycled more than 33,000 lbs of sanitary waste including office paper, corrugated cardboard, and aluminum cans; and

- maintained 100% procurement of post-consumer recycled office paper and significantly increased the purchase of other products containing recycled material.

Activities planned for 2001 include initiating a comprehensive training program for Environmental Restoration activities to support the goals established in Executive Order 13101, continuing the scrap metal recycling program, and conducting a Pollution Prevention Opportunity Assessment on volume reduction of wood products (pallets) contaminated with radioactivity.

3.5 ENVIRONMENTAL TRAINING PROGRAM

DOE/PORTS provides environmental training to increase employee awareness of environmental activities and to enhance the knowledge and qualifications of personnel performing tasks associated with environmental assessment, planning, and restoration. The program includes on- and off-site classroom instruction, on-the-job training, seminars, and specialized workshops and courses. Environmental training conducted or prepared by DOE/PORTS includes hazardous waste training required by RCRA and numerous Occupational Safety and Health Administration training requirements.

3.6 INFORMATION EXCHANGE PROGRAM

To improve and update its environmental monitoring and research programs, DOE/PORTS exchanges information within the site and with other DOE facilities and other sources of information.

DOE/PORTS representatives attend both DOE-sponsored and independent technical information exchange workshops, such as the annual DOE Model Conference and other professional conferences.

3.7 PUBLIC AWARENESS PROGRAM

A comprehensive community relations and public participation program has been in place since early 1990. The purpose of the program is to foster a spirit of openness and credibility between PORTS officials and local citizens, elected officials, business, media, and various segments of the public. The program also provides the public with opportunities to become involved in the decisions affecting environmental issues at the plant.

DOE/PORTS opened a public Environmental Information Center in February 1993 to provide public access to all documents used to make decisions on remedial actions being taken at the plant. The information center is on the plant site in a modular unit outside the E-Vehicle portal. The mailing address for the Information Center is U.S. DOE Environmental Information Center, P.O. Box 693, Piketon, Ohio 45661. The street address is 3930 U.S. Route 23 South, Perimeter Road West, Piketon, Ohio 45661. Hours for the Information Center are 9 a.m. to 12 p.m. Monday and Tuesday, 12 p.m. to 4 p.m. Wednesday and Thursday, or by appointment (740-289-3317).

A group of approximately 45 key stakeholders, composed of elected officials, community leaders, environmentalists, and other individuals who have expressed an interest in the Environmental Restoration and Waste Management Programs, is targeted for information and input on current activities and actions under consideration at the plant. Semiannual public update meetings and public workshops on specific topics are also held to keep the public informed and to receive their comments and questions. Periodically, fact sheets about major projects are written for the public. Semiannual environmental bulletins are printed and distributed to more than 4,000 recipients, including those on the community relations mailing list, neighbors within 2 miles of the plant, and plant employees and retirees.

Points of contact have been established for the public to obtain information or direct questions regarding the Environmental Restoration and Waste Management Programs. The DOE Site Office may be contacted at 740-897-2001. The Bechtel Jacobs Company Public Affairs Manager (740-897-2336) also provides information on the programs.

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4. ENVIRONMENTAL MONITORING

4.1 SUMMARY

Environmental monitoring at PORTS includes air, water, soil, sediment, and biota (animals, vegetation, and crops) and includes measurement of both radiological and chemical parameters. Environmental monitoring programs are required by state and federal regulations, permit requirements, and DOE Orders, but also are developed to reduce public concerns about plant operations. In 2000, environmental monitoring information was collected by both DOE and USEC. Unlike other chapters of this report that focus on DOE activities at PORTS, this chapter includes monitoring information collected by USEC. Environmental monitoring data collected in 2000 indicate that PORTS operations in 2000 did not have a significant environmental impact inside or outside the reservation boundaries.

4.2 INTRODUCTION

Environmental monitoring programs at PORTS are designed to detect the effects (if any) of PORTS operations on human health and the environment. Multiple samples are collected throughout the year and are analyzed for radionuclides and chemicals that could be present from PORTS activities. The results of these monitoring programs are used to gauge the environmental impacts of PORTS operations and to set priorities for environmental improvements.

Environmental regulations, permit requirements, DOE Orders, and public concerns are all considered in developing environmental monitoring programs. State and federal regulations drive some of the monitoring conducted at DOE/PORTS such as limitations on discharges to air and water. DOE Orders 5400.1, *General Environmental Protection Program*, and 5400.5, *Radiation Protection of the Public and the Environment,* also address environmental monitoring requirements. Specific radionuclides monitored at PORTS are selected based on the materials handled at PORTS and on historic sampling data.

Environmental monitoring data is collected by both DOE and USEC. Because USEC data is important in developing a complete picture of environmental monitoring at PORTS, it is included in this report. USEC information is provided for informational purposes only; DOE cannot certify the accuracy of USEC data.

Data from the following environmental monitoring programs are included in this chapter:

- Airborne discharges,
- Ambient air,
- Direct radiation,
- Discharges to surface water,
- Surface water,
- Sediment,
- Soil,
- Vegetation, and
- Biota.

DOE also conducts an extensive groundwater monitoring program at PORTS. Chap. 6 provides information for the groundwater monitoring program, associated surface water monitoring, and residential water supply monitoring.

4.3 AIR

Air monitoring at PORTS includes monitoring of both radiological and chemical discharges from permitted air emission sources and ambient air monitoring within the DOE reservation and in the surrounding area. Direct radiation measurements are also discussed in this section.

4.3.1 Airborne Discharges

4.3.1.1 Radiological airborne discharges

Airborne discharges of radionuclides from PORTS are regulated under the Clean Air Act National Emission Standards for Hazardous Air Pollutants. Releases of radionuclides are used to calculate a dose to members of the public. Chap. 5 discusses the results of this dose calculation.

Because USEC operates the uranium enrichment process at PORTS, USEC is responsible for most of the sources that emit radionuclides. In 2000, USEC reported emissions of 0.09 curie (a measure of radioactivity) from its radionuclide emission sources.

DOE/PORTS is responsible for four radiological emission sources: the X-326 L-cage Glove Box, X-744G Glove Box, X-623 Groundwater Treatment Facility, and X-624 Groundwater Treatment Facility. The glove boxes are used to repackage wastes or other materials that contain radionuclides, and the groundwater treatment facilities treat groundwater contaminated with radionuclides. Emissions from the glove boxes are based on waste analysis data, and emissions from the treatment facilities are based on emission tests completed in the first quarter 2001. Radiological emissions from these DOE sources were estimated at 0.00063 curie in 2000.

4.3.1.2 Nonradiological airborne discharges

DOE/PORTS operates numerous small sources of conventional air pollutants such as nitrogen oxides, sulfur dioxide, and particulate matter. These emissions are estimated every two years for the Ohio EPA's biennial emission fee statement.

Emissions of nonradiological air pollutants at DOE/PORTS are estimated using various U.S. EPA-approved procedures. In calculating air emissions, DOE assumes that each source emits the maximum allowable amount of each pollutant as provided in the permit or registration for the source. Under this worst-case scenario, DOE/PORTS estimated emissions of sulfur dioxide, nitrogen oxides, organic compounds, and particulate matter in 1999 to be 13 tons per year. Emissions for 2000 are not calculated until 2002, but are expected to be similar to 1999. Most of these worst-case emissions resulted from particulate (dust) emissions from the X-734 Landfill Area closure. Worst-case air emissions excluding this source are no more than 1.5 tons per year.

Another potential air pollutant present at DOE/PORTS is asbestos released by renovation or demolition of plant facilities. Asbestos emissions are controlled by a system of work practices. The amount of asbestos removed and disposed is reported to the Ohio EPA. No asbestos was removed or disposed by DOE in 2000.

In 2000, USEC reported the following emissions of nonradiological air pollutants for the Ohio EPA Fee Assessment of Air Pollution Emissions: 61.77 tons of particulate matter, 1.59 tons of organic compounds, 2945.08 tons of sulfur dioxide, and 374.4 tons of nitrogen oxides. These emissions are associated with the boilers at the X-600 Steam Plant, which provide steam for the PORTS reservation, a boiler at the X-611 Water Treatment Plant, an emergency generator, and a trash pump.

4.3.2 Ambient Air Monitoring

The ambient air monitoring stations measure fluoride and radionuclides released from (1) DOE and USEC point sources (the sources discussed in Sect. 4.3.1.1), (2) fugitive air emissions (emissions from PORTS that are not associated with a stack or pipe such as remediation sites or normal building ventilation), and (3) background concentrations of radionuclides (radionuclides that occur naturally, such as uranium). DOE upgraded ambient air monitoring stations and took over the ambient air monitoring program from USEC in October 2000. Samples collected by USEC (samples collected from January through September 2000) were analyzed for alpha activity, beta activity, and fluoride. Samples collected by DOE (samples collected October through December 2000) were analyzed for fluoride and specific radionuclides that could be present in ambient air due to PORTS activities. These radionuclides are isotopic uranium (uranium-233/234, uranium-235, uranium-236, and uranium-238), technetium-99, and selected transuranic radionuclides (americium-241, neptunium-237, plutonium-238, and plutonium-239/240).

In 2000, samples were collected from 16 ambient air monitoring stations in and around PORTS (see Figs. 4.1 and 4.2). A background ambient air monitoring station is located approximately 13 miles southwest of the plant. The analytical results from air sampling stations closer to the plant are compared to these background measurements. In 2000, concentrations of radionuclides and fluoride at sampling stations around PORTS appear to be similar to background, with the possible exception of technetium-99 detected at stations A10 and A29 in December 2000.

The detections of technetium-99 may result from the inherent level of error associated with laboratory measurements. Technetium-99 was not detected at either of these monitoring stations in the first quarter 2001. To confirm that air emissions from PORTS are within regulatory requirements and are not harmful to human health, this ambient air monitoring data was used to calculate a dose to a hypothetical person living at the monitoring station. The net dose calculation for stations A10 and A29, which includes the detections of technetium-99, is 0.0019 millirem (mrem)/year, which is well below the 10 mrem/year limit applicable to PORTS. Chap. 5, Sect. 5.3.2.2, provides additional information about this dose calculation.

Transuranic radionuclides (americium-241, neptunium-237, plutonium-238, and plutonium-239/240) were not detected in ambient air samples collected by DOE.

4.3.3 Direct Radiation

Direct radiation, or gamma radiation, is also measured by USEC and DOE at monitoring stations in and around PORTS (see Figs. 4.1 and 4.2). Direct radiation measurements collected by USEC indicate that the level of gamma radiation in and around PORTS is similar to background, with the exception of the X-745C Depleted Uranium Hexafluoride Cylinder Storage Yard. DOE measurements confirm that cylinders in the storage yard emit higher than background levels of gamma radiation. Chap. 5 includes the direct radiation measurements made by DOE and the resulting potential dose to the public. Public access to radiation from these cylinder yards is controlled as described in Chap. 5.

4.4 WATER

Surface water and groundwater are monitored at PORTS. Groundwater monitoring is discussed in Chap. 6. Surface water monitoring consists of sampling (1) water discharges associated with both DOE and USEC NPDES-permitted outfalls, (2) surface water runoff from the DOE depleted uranium cylinder storage yards, and (3) local rivers and creeks including the Scioto River, Big Run Creek, Big Beaver

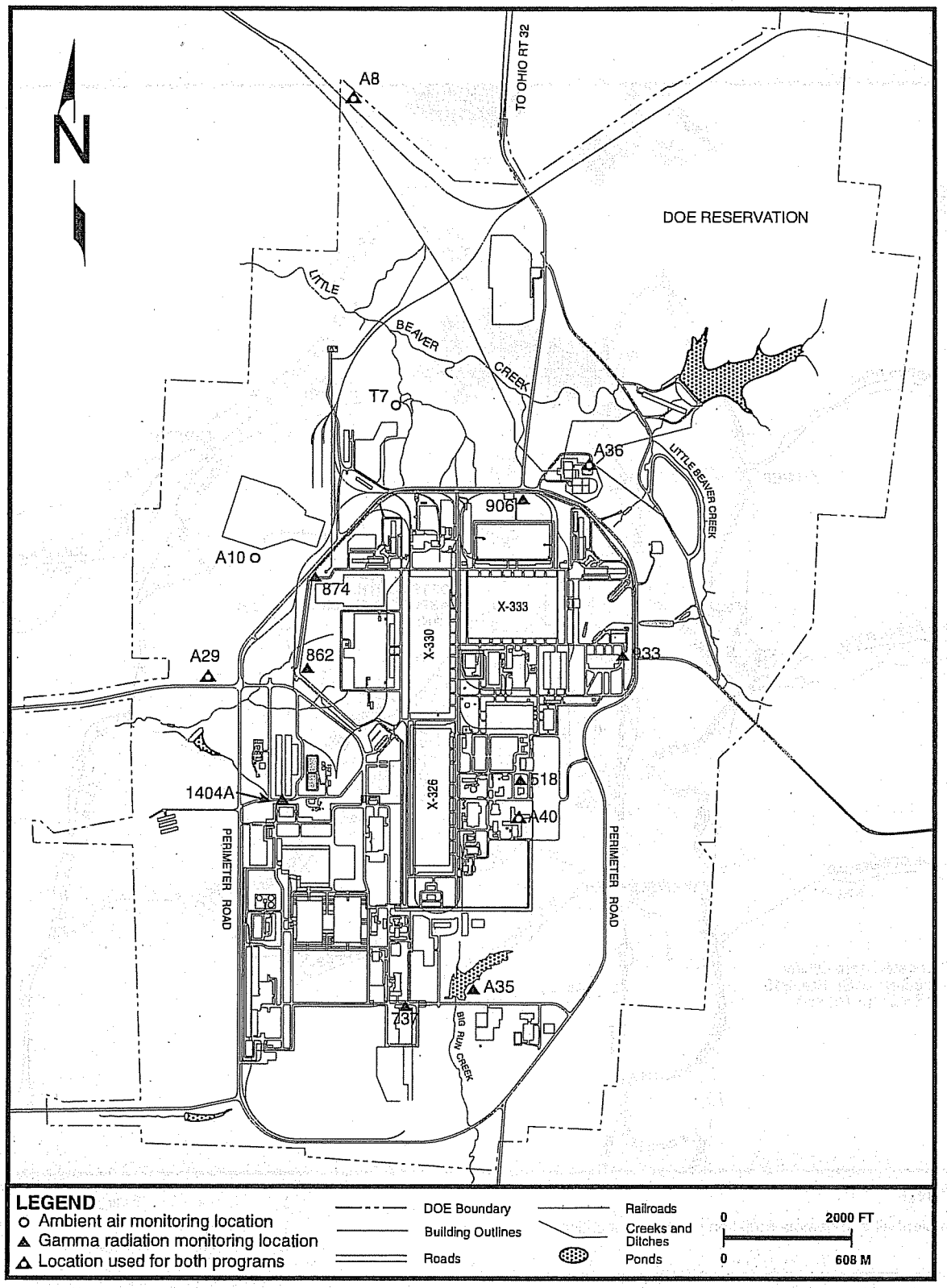

Fig. 4.1. On-site monitoring locations for the DOE and USEC ambient air and USEC gamma radiation monitoring programs.

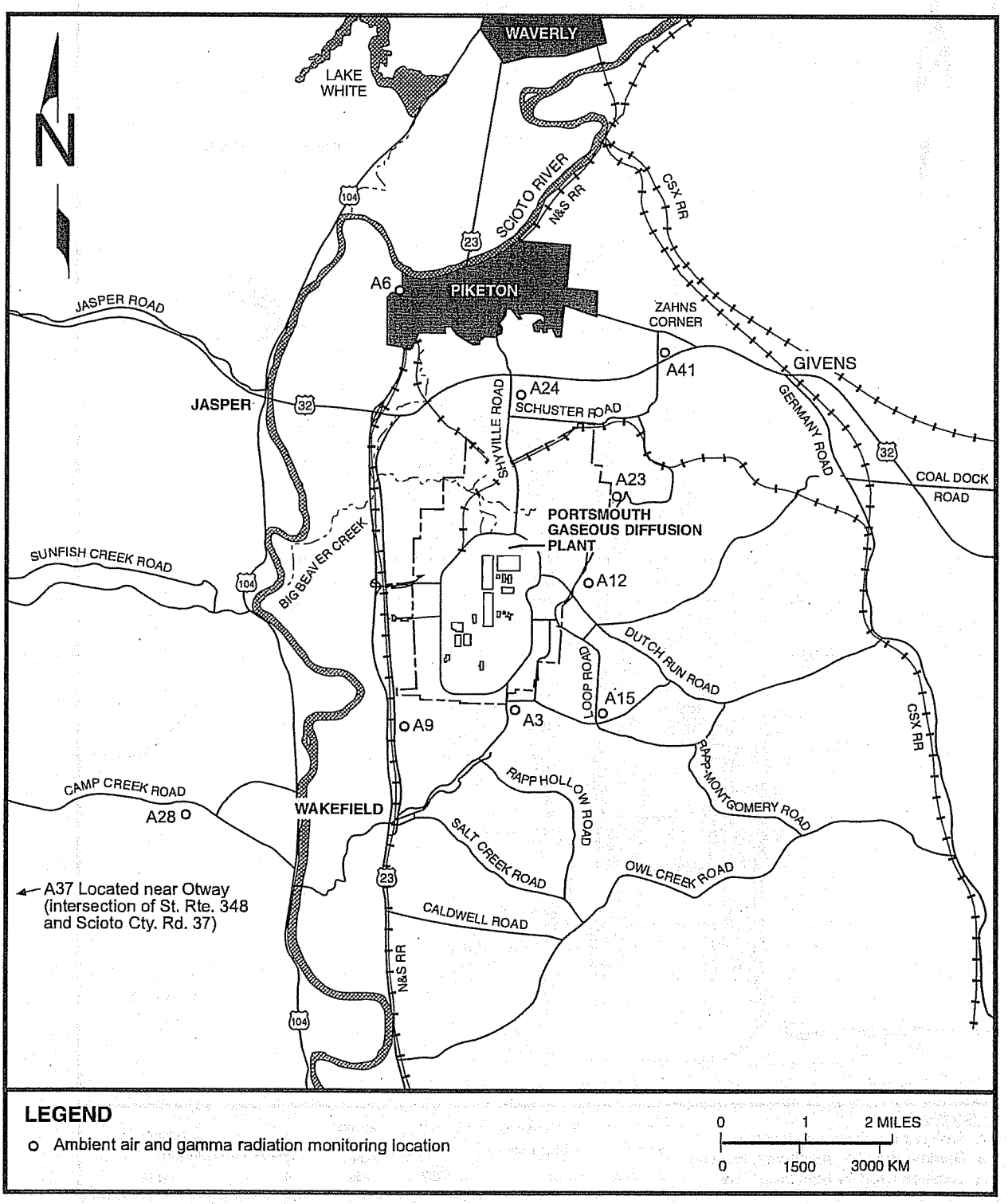

Fig. 4.2. Off-site monitoring locations for the DOE and USEC ambient air and USEC gamma radiation monitoring programs.

Creek, and Little Beaver Creek. DOE also collects surface water samples as part of the groundwater monitoring program at PORTS (see Chap. 6).

4.4.1 Water Discharges (NPDES Outfalls)

DOE/PORTS has six discharge points, or outfalls, through which water is discharged from the site (see Fig. 4.3). Three outfalls discharge directly to surface water, and three discharge to the USEC X-6619 Sewage Treatment Plant before leaving the site through USEC NPDES Outfall 003 to the Scioto River. A brief description of each DOE outfall at PORTS follows.

DOE NPDES Outfall 012 (X-2230M Holding Pond) – The X-2230M Holding Pond accumulates precipitation runoff, non-contact cooling water, and steam condensate from the southern portion of the PORTS reservation. The pond provides an area where solids can settle, chlorine can dissipate, and oil can be separated from the water prior to its release to an unnamed stream that flows to the Scioto River.

DOE NPDES Outfall 013 (X-2230N Holding Pond) – The X-2230N Holding Pond accumulates precipitation runoff, non-contact cooling water, and steam condensate from the southwestern portion of the PORTS reservation. The pond provides an area where solids can settle, chlorine can dissipate, and oil can be separated from the water prior to its release to the West Ditch, which flows to the Scioto River.

DOE NPDES Outfall 015 (X-624 Groundwater Treatment Facility) – This facility removes volatile organic compounds from contaminated groundwater originating from the X-701B plume interceptor trenches. These groundwater interceptor trenches were constructed to control the migration of volatile organic compound-contaminated groundwater toward Little Beaver Creek. Treated water is released to a ditch that flows to Little Beaver Creek.

DOE NPDES Outfall 608 (X-622 Groundwater Treatment Facility) – This facility removes volatile organic compounds from contaminated groundwater originating from site remediation activities in the southern portion of the site. Treated water is discharged to the sanitary sewer and then through USEC NPDES Outfall 003.

DOE NPDES Outfall 610 (X-623 Groundwater Treatment Facility) – This facility removes volatile organic compounds from contaminated groundwater originating from site remediation activities and from miscellaneous well development and purge waters. Treated water is discharged to the sanitary sewer and then through USEC NPDES Outfall 003.

DOE NPDES Outfall 611 (X-622T Groundwater Treatment Facility) – This facility removes volatile organic compounds from groundwater collecting in sumps located in the basements of the X-705 and the X-700 buildings. Treated water is discharged to the sanitary sewer and then through USEC NPDES Outfall 003.

USEC is responsible for 11 NPDES outfalls through which water is discharged from the site (see Fig. 4.3). Eight outfalls discharge directly to surface water, and three discharge to another USEC NPDES outfall before leaving the site. A brief description of each USEC NPDES outfall follows.

USEC NPDES Outfall 001 (X-230J7 East Holding Pond) – The X-230J7 East Holding Pond receives non-contact cooling water, steam condensate, foundation drainage, storm runoff, hydro-testing water from cylinders, and sanitary water for eyewash/shower station testing and flushing. The pond provides an area where materials suspended in the influent can settle, chlorine can dissipate, and oil can be diverted and contained. Water from this holding pond is discharged to a ditch that flows to Little Beaver Creek.

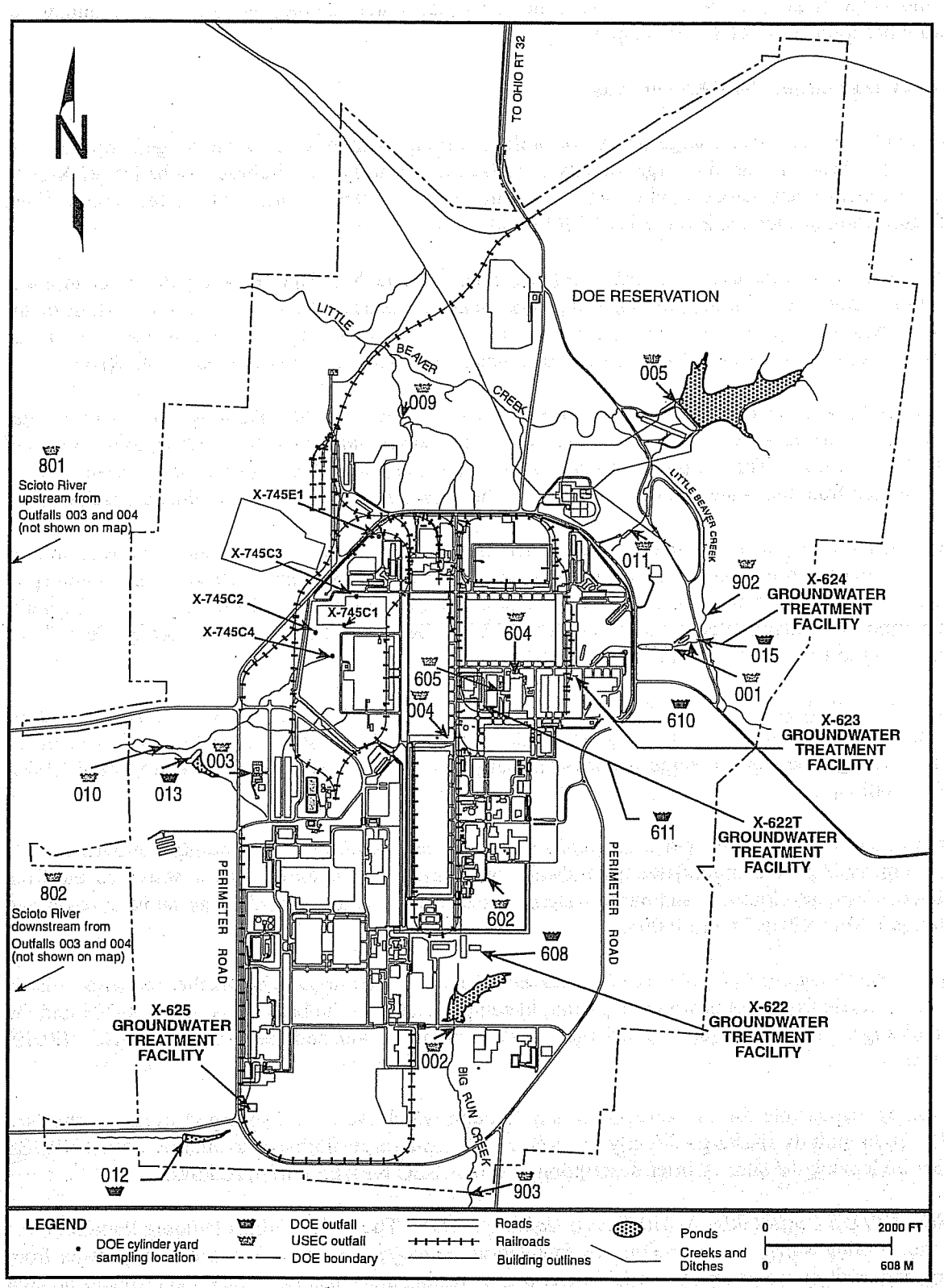

Fig. 4.3. DOE and USEC NPDES outfalls, DOE groundwater treatment facilities, and DOE cylinder storage yard surface water sampling locations.

USEC NPDES Outfall 002 (X-230K South Holding Pond) – The X-230K South Holding Pond receives non-contact cooling water, steam condensate, foundation drainage, treated coal pile runoff, storm runoff, fire-fighting training and fire suppression system water, and sanitary water for eyewash/shower station testing and flushing. The pond provides an area where materials suspended in the influent can settle, chlorine can dissipate, oil can be contained, and pH can be adjusted. Water from this holding pond is discharged to Big Run Creek.

USEC NPDES Outfall 003 (X-6619 Sewage Treatment Plant) – The X-6619 Sewage Treatment Plant treats PORTS sewage as well as water discharged from DOE groundwater treatment facilities, the X-700 Biodenitrification Facility, the X-705 Decontamination Microfiltration System, and miscellaneous waste streams. The X-6619 Sewage Treatment Plant uses screening, aeration, clarification, and filtering followed by chlorination to treat wastewater prior to release to the Scioto River.

USEC NPDES Outfall 004 (Cooling Tower Blowdown) – This outfall was relocated in 2000 to the junction of Pike Avenue and 15th Avenue at PORTS. It monitors blowdown water from various cooling towers on site prior to discharge to the Scioto River.

USEC NPDES Outfall 005 (X-611B Lime Sludge Lagoon) – The X-611B Lime Sludge Lagoon is used to settle lime sludge used in a water-softening process. The X-611B also receives rainwater runoff. Water from this facility is generally returned to the X-611 Water Treatment Plant for treatment. Direct discharges from this facility occur only during periods of excessive rainfall. During such rare events, the lagoon discharges to Little Beaver Creek.

USEC NPDES Outfall 009 (X-230L North Holding Pond) – The X-230L North Holding Pond receives non-contact cooling water, steam condensate, storm runoff, fire suppression system water, and sanitary water for eyewash/shower station testing and flushing. The pond provides an area where materials suspended in the influent can settle, chlorine can dissipate, and oil can be contained. Water from this holding pond is discharged to an unnamed stream that flows to Little Beaver Creek.

USEC NPDES Outfall 010 (X-230J5 Northwest Holding Pond) – The X-230J5 Northwest Holding Pond receives non-contact cooling water, steam condensate, storm runoff, fire-fighting training and fire suppression system water, and sanitary water for eyewash/shower station testing and flushing. The pond provides an area where materials suspended in the influent can settle, chlorine can dissipate, and oil can be diverted and contained. Water from this holding pond is discharged to the West Ditch, which flows to the Scioto River.

USEC NPDES Outfall 011 (X-230J6 Northeast Holding Pond) – The X-230J6 Northeast Holding Pond receives non-contact cooling water, steam condensate, storm runoff, fire suppression system water, and sanitary water for eyewash/shower station testing and flushing. The pond provides an area where materials suspended in the influent can settle, chlorine can dissipate, and oil can be diverted and contained. Water from this holding pond is discharged to an unnamed stream that flows to Little Beaver Creek.

USEC NPDES Outfall 602 (X-621 Coal Pile Runoff Treatment Facility) – The X-621 Coal Pile Runoff Treatment Facility treats storm water runoff from the coal pile at the X-600 Steam Plant. The treated water is discharged to the X-230K South Holding Pond (USEC NPDES Outfall 002).

USEC NPDES Outfall 604 (X-700 Biodenitrification Facility) – The X-700 Biodenitrification Facility receives solutions from plant operations that are high in nitrate. At the X-700, these solutions are diluted and treated biologically using bacteria prior to being discharged to the X-6619 Sewage Treatment Plant (USEC NPDES Outfall 003).

USEC NPDES Outfall 605 (X-705 Decontamination Microfiltration System) – The X-705 Decontamination Microfiltration System treats process wastewater using microfiltration and pressure filtration technology. The treated water is discharged to the X-6619 Sewage Treatment Plant (USEC NPDES Outfall 003).

The USEC NPDES Permit also identifies four additional outfalls that are monitoring points only as opposed to the discharge points described in the previous paragraphs. USEC NPDES Outfall 801 is a background monitoring location on the Scioto River upstream from USEC NPDES Outfalls 003 and 004. USEC NPDES Outfall 901 is a monitoring location on the Scioto River downstream from Outfall 003 and 004 and located in the discharge plume from these two outfalls. USEC NPDES Outfall 902 is a monitoring location on Little Beaver Creek downstream from USEC NPDES Outfall 001, and USEC NPDES Outfall 903 is a monitoring location on Big Run Creek downstream from USEC NPDES Outfall 002.

4.4.1.1 Radiological liquid discharges

Both DOE and USEC monitor NPDES outfalls for radiological discharges by collecting water samples and analyzing the samples for radionuclides. Samples collected by DOE were analyzed for alpha activity, beta activity, technetium-99, total uranium, uranium isotopes (uranium-233/234, uranium-235, uranium-236, and uranium-238), and transuranic radionuclides (americium-241, neptunium-237, plutonium-238, and plutonium-239/240).

Discharges of radionuclides in liquids through DOE NPDES outfalls have no significant impact on public health and the environment. Uranium discharges from DOE NPDES outfalls in 2000 were estimated at 1.1 kilograms. This value was calculated using monthly monitoring data from the DOE NPDES outfalls. Alpha activity and beta activity measurements at the DOE NPDES outfalls indicated that 0.0041 curie of radioactivity was discharged through these outfalls during 2000.

Data collected by USEC and provided to DOE showed that USEC released 16.8 kilograms of uranium through its NPDES outfalls in 2000. Total radioactivity released was 0.0314 curie of uranium and 0.0625 curie of technetium-99. Analytical results below the detection limit were assigned a value of zero in the calculations to determine the quantities of uranium and radiation discharged through the DOE and USEC NPDES outfalls.

Chap. 5 provides dose calculations based on discharges of radionuclides from both DOE and USEC NPDES outfalls.

4.4.1.2 Radiological monitoring results for surface water from DOE cylinder storage yards

Ohio EPA requires monthly collection of surface water samples from two locations (X-745C1 and X-745E1) at the X-745C and X-745E Depleted Uranium Hexafluoride Cylinder Storage Yards, and DOE voluntarily collects samples at three additional locations (X-745C2, X-745C3, and X-745C4). Monitoring location X-745C4 was added to the program in May 2000. Fig. 4.3 shows the sampling locations. Samples collected during 2000 were analyzed for alpha activity, beta activity, total uranium, uranium isotopes (uranium-233/234, uranium-235, uranium-236, and uranium-238), total PCBs, and transuranic radionuclides (americium-241, neptunium-237, plutonium-238, and plutonium-239/240).

During 2000, alpha activity ranged from 0 to 15 picocuries per liter (pCi/L), beta activity ranged from less than 2 pCi/L to 44.7 pCi/L, and total uranium ranged from 0 to 12 micrograms per liter (μg/L). Maximum detections for technetium-99 and uranium isotopes are as follows: technetium-99 at 16 pCi/L, uranium-233/234 at 6 pCi/L, uranium-235 at 0.19 pCi/L, uranium-236 at 0.13 pCi/L, and uranium-238 at

2.7 pCi/L. Total PCBs, americium-241, neptunium-237, plutonium-238, and plutonium-239/240 were not detected in any of the samples collected in 2000.

4.4.1.3 Nonradiological liquid discharges

Nonradiological discharges from DOE NPDES outfalls are regulated by the DOE NPDES permit. The permit was issued to DOE/PORTS on September 1, 1995 and modified on December 1, 1996, and May 1, 1997. Sampling of nonradioactive constituents is regulated under the DOE/PORTS NPDES permit, and analyses are performed in accordance with applicable regulations. In 2000, the overall DOE NPDES compliance rate was 99.8%. Compliance rates for individual parameters at each outfall were 100%, with the exception of total suspended solids at DOE NPDES Outfall 013 (95.8%).

The daily concentration discharge limitation for total suspended solids (45 mg/L) was exceeded at this outfall in February 2000; the sample result was 70.8 mg/L. The exceedence was most likely caused by a project to replace the pipes that discharge water from the outfall. The project was completed in February 2000 and the discharge limitation for total suspended solids was not exceeded for the remainder of the year. The public was not harmed as a result of this exceedence.

Nonradiological discharges from USEC NPDES outfalls are regulated by the USEC NPDES permit. USEC was issued a new NPDES permit on January 20, 2000, which became effective on March 1, 2000. In 2000, the overall USEC NPDES compliance rate was 99.7%. During 2000, USEC experienced the following exceedences of its NPDES permit limits:

- The daily (maximum) loading discharge limitation for total copper [0.12 kilogram per day (Kg/day)] was exceeded at USEC NPDES Outfall 002 in January 2000. The applicable daily effluent loading was determined to be 0.151 Kg/day, which was the result of an increase in the discharge volume due to storm runoff.

- The daily (maximum) concentration discharge limitation for total oil and grease (10 mg/L) was exceeded at USEC NPDES Outfall 002 in February 2000; the sample result was 11.3 mg/L.

- An upset condition occurred in February 2000 when untreated runoff overflowed the X-621 Coal Pile Runoff Lagoon (USEC NPDES Outfall 602) and entered the X-230K South Holding Pond (USEC NPDES Outfall 002); however, no adverse environmental conditions were noted in the pond. The incident was caused by a significant rainfall event.

- A temporary noncompliance with the "free from" general effluent limitation occurred in March 2000 when effluent from the X-230L North Holding Pond (USEC NPDES Outfall 009) containing an iridescent sheen entered a tributary to Little Beaver Creek. Samples were collected at the outfall and analyzed for total oil and grease and total PCBs; sample results were 20.7 mg/L and less than 1 μg/L, respectively. No detectable concentrations were noted for either parameter in a sample collected downstream near the confluence of Little Beaver Creek and the drainage tributary. The impoundment's water level and discharge volume increased because of storm runoff, thereby resulting in the discharge of a sheen from the holding pond.

- The monthly (average) temperature limitation (16.7 degrees Celsius) was exceeded at USEC NPDES Outfall 902 in November 2000; the measured temperature was 17.4 degrees Celsius.

- The daily (maximum) loading discharge limitation for total suspended solids (96 Kg/day) was exceeded at USEC NPDES Outfall 002 in December 2000. The applicable daily effluent loading was determined to be 110 Kg/day.

4.4.2 Surface Water Monitoring

In 2000, USEC collected water samples at locations upstream and downstream from the PORTS reservation. These samples were taken from the Scioto River, Little Beaver Creek, Big Beaver Creek, and Big Run Creek (see Fig. 4.4). As background measurements, samples were also collected from local streams approximately 10 miles north, south, east, and west of PORTS. Samples were collected weekly from the Scioto River and monthly from the other streams, with the exception of one of the downstream locations on Little Beaver Creek (RW-8), which was sampled weekly.

Each sample was analyzed for alpha activity, beta activity, total uranium, and technetium-99. Samples from the Scioto River were also analyzed for total phosphate as phosphorus, fluoride, 29 metals, and PCBs (metals and PCBs were analyzed quarterly). Each of these measurements, with the exception of technetium-99 and PCBs, will detect naturally-occurring constituents and radionuclides in the environment; therefore, measurements from upstream locations are compared to downstream locations to assess whether PORTS activities have affected the river or stream. Natural variation and manmade activities not related to PORTS can also cause sample variation.

No significant differences were noted in nonradiological parameters (fluoride, total phosphate as phosphorus, metals, and total PCBs) monitored at the upstream and downstream Scioto River sampling locations. PCBs were not detected in any of the quarterly samples collected in 2000. Concentrations of alpha activity, beta activity, and total uranium detected in the samples collected at upstream and downstream locations were usually similar.

In 2000, technetium-99 was occasionally detected in samples collected from downstream monitoring locations on the Scioto River (RW-1), Little Beaver Creek (RW-7 and RW-8), and Big Run Creek (RW-3) at a maximum concentration of 32 pCi/L at sampling point RW-7. The detections are well below the DOE derived concentration guide of 100,000 pCi/L for technetium-99 in ingested water.

4.5 SEDIMENT

In 2000, USEC collected sediment samples at the same locations upstream and downstream from the PORTS reservation where surface water samples are collected and at the NPDES outfalls on the east and west sides of the reservation (see Fig. 4.4). Samples were collected in the spring and fall and were analyzed for 21 metals, PCBs, alpha activity, beta activity, total uranium, and technetium-99. Metals, uranium, alpha activity, and beta activity occur naturally in the environment; therefore, these constituents detected in the samples may not result from activities at PORTS. The results of sampling conducted in 2000 appear to indicate that there are no appreciable differences in the levels of these constituents found in the samples taken upstream and downstream from PORTS.

Historically, PORTS sediment sampling has detected low levels of PCB contamination in the Little Beaver Creek east of PORTS. This contamination was caused by discharges of treated process water before 1988. PCBs were not detected in the sediment samples collected in 2000. Technetium-99 is also usually detected in sediment samples collected in locations downstream from PORTS. In 2000, technetium-99 was detected in one or both of the samples collected from downstream sampling locations on the Scioto River (RM-1) and Little Beaver Creek (RM-7 and RM-8). Technetium-99 was detected in both the upstream and downstream samples collected on Big Beaver Creek (RM-5 and RM-13) and Big Run Creek (RM-33, RM-2, and RM-3). Technetium-99 was also detected in the sediment samples collected at USEC NPDES Outfalls 001 and 010 (RM-10 and RM-11).

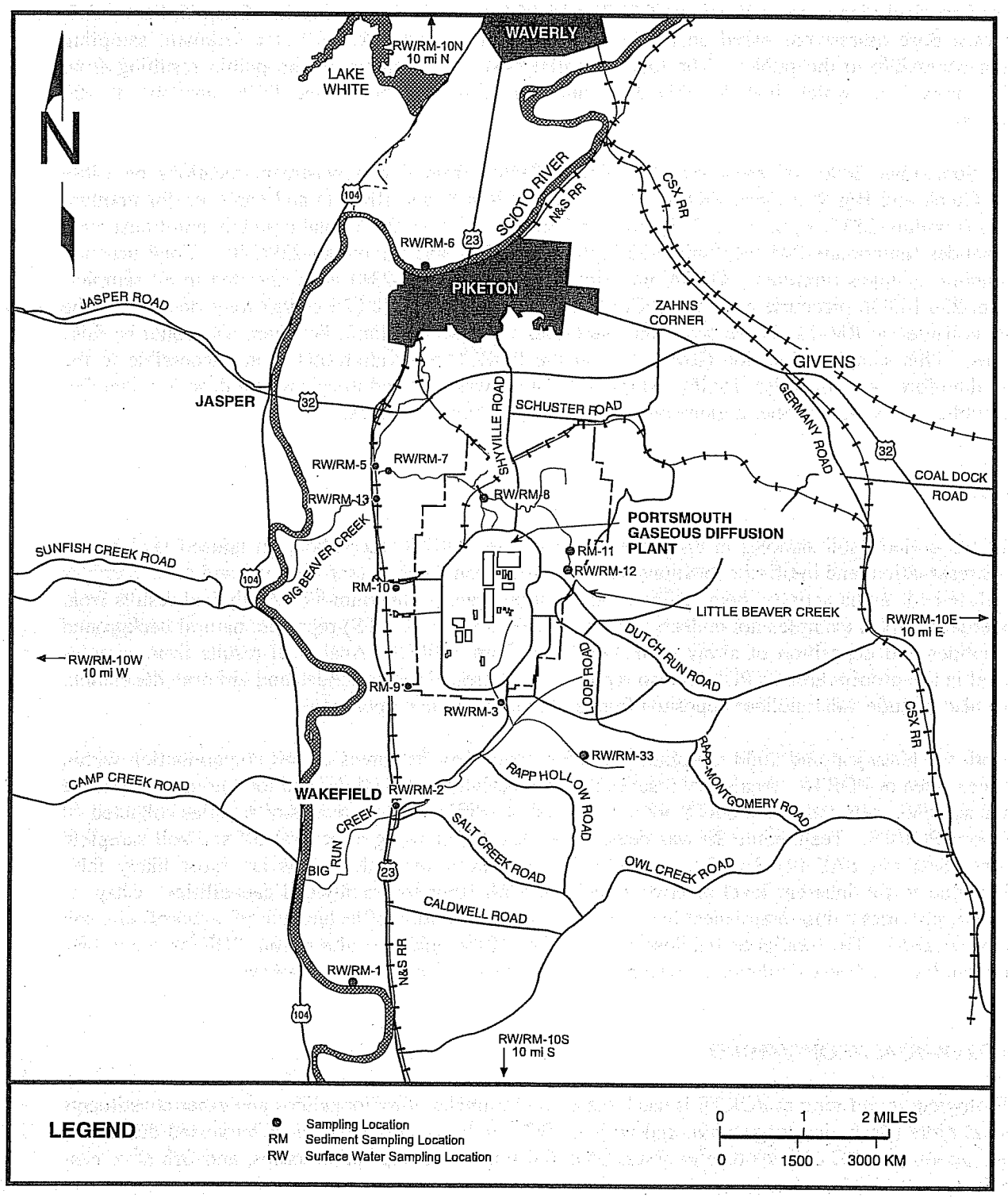

Fig. 4.4. USEC surface water and sediment monitoring locations.

Many of the detections of technetium-99 were at or close to the detection limit for the analytical method and may be false positives due to the inherent level of error associated with laboratory analytical capabilities. In general, levels of technetium-99 detected in sediment are consistent with results from 1999 and are declining at some locations (RM-7 and RM-8 on Little Beaver Creek). Chap. 5, Sect. 5.3.5, provides a dose assessment based on the highest detection of technetium-99 at a sediment sampling location accessible to the public. The total potential dose to a member of the public resulting from PORTS operations, which includes this dose calculation, is well below the DOE standard of 100 mrem/year.

In September 2000, sediment samples were collected from five downstream locations on Little Beaver Creek and Big Run Creek (RM-2, RM-3, RM-7, RM-8, and RM-11) and analyzed for uranium isotopes (uranium-233/234, uranium-235, uranium-236, and uranium-238), total uranium, and transuranic radionuclides (americium-241, neptunium-237, plutonium-238, and plutonium-239/240). Total uranium and uranium isotopes (uranium 233/234, uranium-235, and uranium-238) were detected in all samples. Uranium-236 [0.036 picocurie per gram (pCi/g)] and neptunium-237 (0.028 pCi/g) were detected in the sample collected at RM-11. These detections were near the detection limit, however, and could be false positives. This sampling location (RM-11) is on the PORTS reservation and is not accessible to the public; therefore, analytical data for this sampling location was not used to calculate a dose to a member of the public. None of the other radionuclides were detected in the samples.

4.6 SOIL

USEC collects soil samples in the process area of the PORTS reservation, on unused land on the PORTS reservation, and in off-site locations up to 10 miles from PORTS (see Figs. 4.5 and 4.6). Samples are analyzed for alpha activity, beta activity, total uranium, and technetium-99. Analytical results from the external samples (samples not collected in the process area of PORTS) represent natural background radionuclides and deposition of airborne radionuclides from PORTS. Analytical results from samples collected in the process area of PORTS also represent background radionuclides and airborne deposition, but can also include radionuclides deposited from spills or other plant operations.

Both the historical and 2000 sampling programs have identified areas of soil contamination within the process area of PORTS. Analytical results for alpha activity, beta activity and total uranium from the external samples collected near PORTS are not appreciably different from results of samples collected 10 miles from PORTS. Technetium-99 was detected at less than 1 pCi/g at several off-site soil sampling locations (SAS-13, SAS-14, SAS-25, and SAS-26); however, these detections are most likely false positives due to the inherent level of error associated with laboratory analytical capabilities. Chap. 5, Sect. 5.3.5, provides a dose assessment based on the highest detection of technetium-99 at an off-site soil sampling location. The total potential dose to a member of the public resulting from PORTS operations, which includes this dose calculation, is well below the DOE standard of 100 mrem/year.

4.7 BIOLOGICAL MONITORING

Biological monitoring at PORTS is used to assess the uptake of radionuclides and other constituents into local biota (deer, fish, vegetation, and crops). DOE collects samples of deer harvested during the hunting season. USEC collects data to assess potential impacts to vegetation, crops, and fish at or near PORTS.

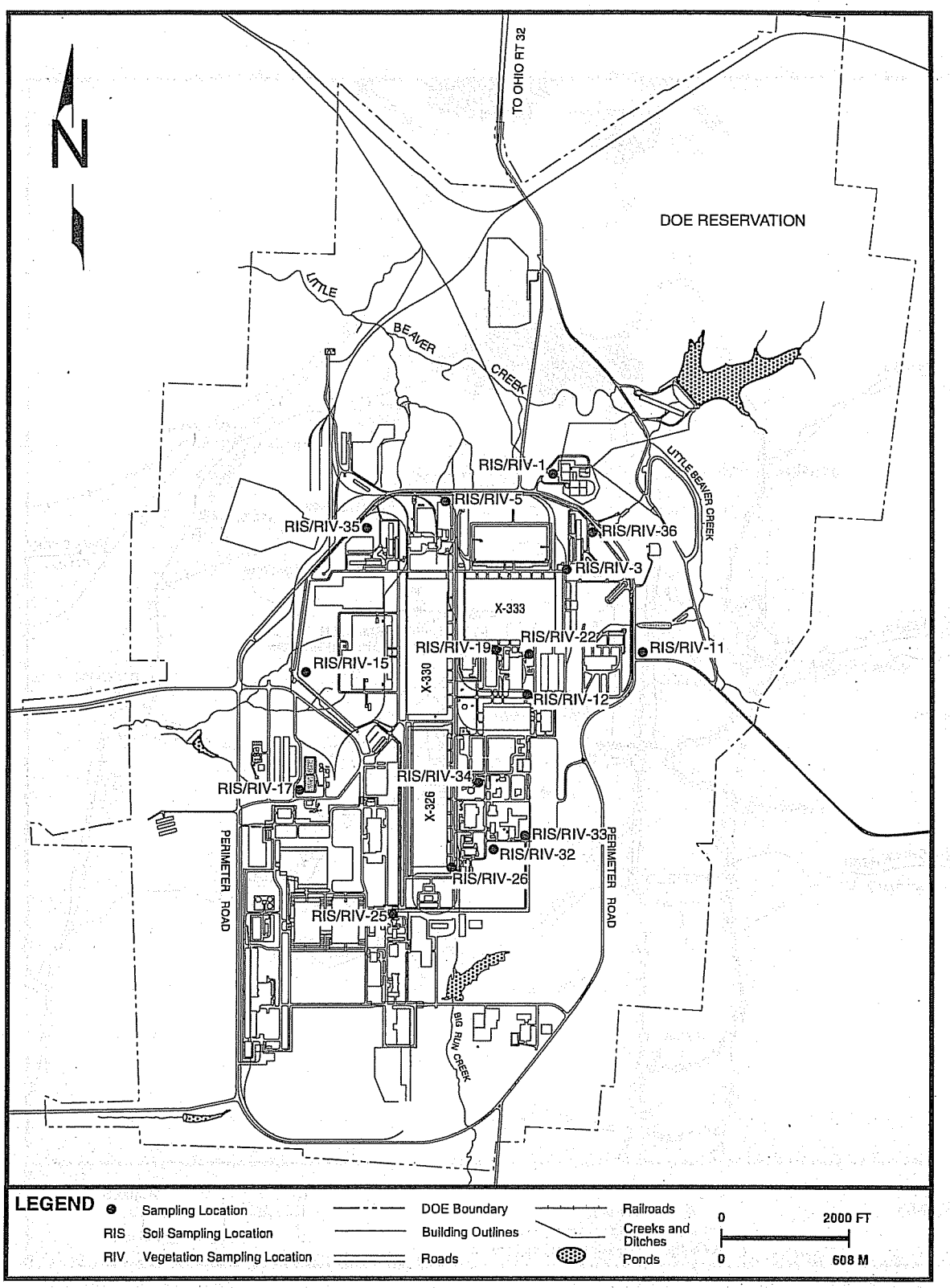

Fig. 4.5. Internal monitoring locations for the USEC soil and vegetation monitoring programs.

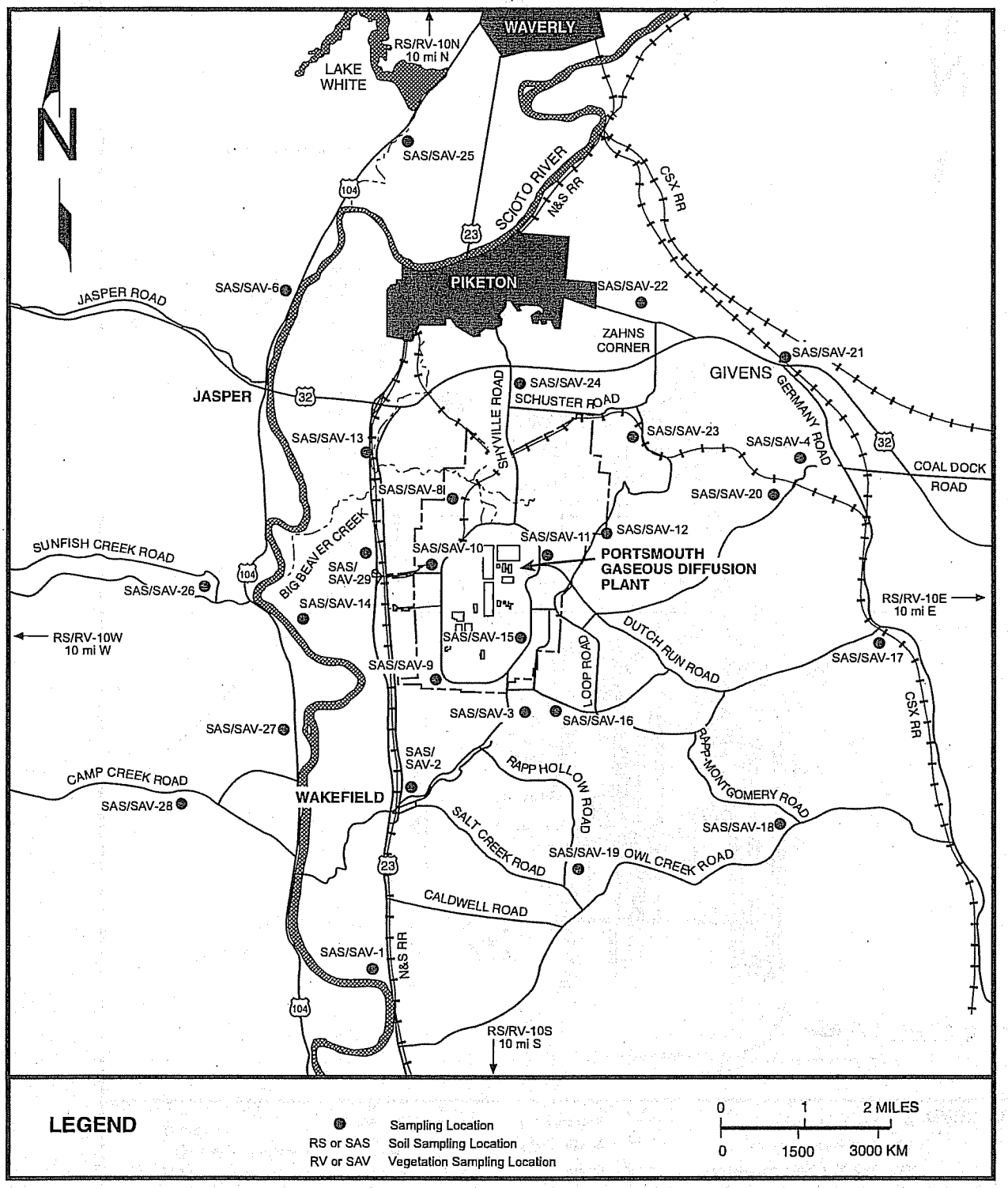

Fig. 4.6. External monitoring locations for the USEC soil and vegetation monitoring programs.

4.7.1 Deer

Kidney and liver samples were collected from five deer harvested at PORTS during the 2000-2001 hunting season (December 2000 through January 2001). The kidneys and liver were collected from each deer for analysis because these organs concentrate any radiological constituents ingested by the deer. Each kidney and liver sample was analyzed for americium-241, neptunium-237, plutonium-238, plutonium-239/240, technetium-99, total uranium, uranium-233/234, uranium-235/236, and uranium-238.

The kidney sample from one deer contained americium-241 at 0.0405 pCi/g and the liver from the same deer contained plutonium-238 at 0.0567 pCi/g, uranium isotopes at concentrations ranging from 0.0255 to 0.0512 pCi/g, and total uranium at 0.0667 pCi/g. The liver from another deer contained americium-241 at 0.0458 pCi/g. Uranium and uranium isotopes occur naturally and may be present due to exposure to naturally-occurring uranium. The detections of americium-241 and plutonium-238 are considered suspect because of the very low detection limits for these samples and the inherent level of error associated with laboratory analytical capabilities. Chap. 5, Sect. 5.3.5, provides a dose assessment based on a member of the public consuming two deer livers containing radionuclides. The total potential dose to a member of the public resulting from PORTS operations, which includes this dose calculation, is well below the DOE standard of 100 mrem/year. None of the other radionuclides listed above were present above detection limits in any of the other samples.

4.7.2 Fish

In 2000, USEC collected fish from the Little Beaver Creek and Scioto River. Fish samples were analyzed for chromium, PCBs, alpha activity, beta activity, technetium-99, and total uranium. Selected samples were also analyzed for uranium isotopes (uranium-233/234, uranium-235, uranium-236, and uranium-238). PCBs were detected in 5 of 12 fish samples. PCBs, a widespread environmental contaminant, are often detected in fish and may or may not be present as a result of PORTS activities. Chromium was detected in 6 of 12 fish samples. Chromium occurs naturally in soil and is often present in surface water. Chromium was not detected at any of the DOE or USEC NPDES outfalls in 2000; therefore, the chromium detected in these fish is most likely due to naturally-occurring chromium.

Alpha activity, beta activity, and uranium occur naturally in the environment and were detected in some of the samples at low concentrations that are most likely indicative of background levels. Technetium-99 was detected at an estimated concentration of 0.02 pCi/g in a large mouth bass from Little Beaver Creek and at 0.1 pCi/g in a catfish from the Scioto River at USEC NPDES Outfall 003. These detections may be due to the inherent level of error associated with laboratory analytical capabilities. Chap. 5, Sect. 5.3.5, provides a dose assessment based on a member of the public consuming catfish containing radionuclides. The total potential dose to a member of the public resulting from PORTS operations, which includes this dose calculation, is well below the DOE standard of 100 mrem/year.

4.7.3 Vegetation

To assess the uptake of radionuclides into plant material, USEC collects vegetation samples in the same areas where soil samples are collected (see Figs. 4.5 and 4.6). Vegetation is analyzed for fluoride, technetium-99, and total uranium. Some vegetation samples collected in 2000 within the process area of PORTS contained detectable concentrations of fluorides and technetium-99 that are higher than the concentrations present in samples collected off site. No uranium was detected in the vegetation collected within the process area in 2000.

Vegetation samples collected at two of four background locations contained technetium-99 at 0.3 to 0.4 pCi/g in 2000. Technetium-99 was also detected at similar concentrations at several other off-site

sampling locations. These detection are most likely false positives due to the inherent level of error associated with laboratory analytical capabilities. Chap. 5, Sect. 5.3.5, provides a dose assessment based on a member of the public consuming beef cattle that have grazed on vegetation containing technetium-99. The total potential dose to a member of the public resulting from PORTS operations, which includes this dose calculation, is well below the DOE standard of 100 mrem/year. One sample contained uranium at the detection limit. Fluorides were present in samples collected at off-site sampling locations at concentrations that are most likely indicative of background levels.

4.7.4 Crops

In addition to vegetation samples, USEC also collects crop samples to assess the uptake of radionuclides into crops. In 2000, 25 samples were collected from seven residential locations near PORTS. Crops collected from locations near PORTS included apples, corn, green peppers, squash, tomatoes, green beans, cucumbers, and watermelon. Each sample was analyzed for technetium-99 and total uranium. Neither constituent was detected in any of the samples collected in 2000.

A pawpaw was also collected near surface water sampling location RW-7 (see Fig. 4.4) and analyzed for alpha activity, beta activity, total PCBs, technetium-99, total uranium, uranium-233/234, uranium-235, uranium-236, and uranium-238. The following parameters were detected in the sample: technetium-99 at 0.2 pCi/g, uranium-233/234 at 0.23 pCi/g, and uranium-238 at 0.21 pCi/g. The uranium isotopes detected in the sample may be due to naturally-occurring uranium; the detections of uranium isotopes may also be false positives due to the inherent level of error associated with laboratory analytical capabilities. The detection of technetium-99 is most likely due to the inherent level of error associated with laboratory analytical capabilities. Chap. 5, Sect. 5.3.5, provides a dose assessment based on a member of the public consuming pawpaws containing radionuclides. The total potential dose to a member of the public resulting from PORTS operations, which includes this dose calculation, is well below the DOE standard of 100 mrem/year.

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5. DOSE

5.1 SUMMARY

Environmental monitoring data collected at PORTS is used to assess potential impacts to human health and the environment from radionuclides released by PORTS operations. This impact, called a dose, can be caused by radionuclides released to air and/or water, or radiation emanating directly from buildings or other objects at PORTS. The U.S. EPA sets a 10 mrem/year limit for dose from radionuclides released to the air and the DOE sets a 100 mrem/year limit for dose from radionuclides from all potential pathways. A person living in southern Ohio receives a dose of approximately 300 mrem/year from natural sources of radiation. This chapter includes radiological dose calculations for the dose to the public from radionuclides released to the air and surface water, from direct radiation, and from radionuclides detected by environmental monitoring programs for sediment, soil, vegetation, and biota (deer, crops, and fish). The maximum dose a member of the public could receive from radiation released by PORTS in 2000 or detected by environmental monitoring programs in 2000 is 2.9 mrem. Table 5.1 summarizes this dose information.

Table 5.1. Summary of potential doses to the public from PORTS in 2000

Source of dose	Dose (mrem)
Airborne radionuclides	0.047
Radionuclides released to the Scioto River	0.042
Direct radiation from depleted uranium cylinder storage yards	1.15
Radionuclides detected by environmental monitoring programs [sediment, soil, vegetation, and biota (deer, fish, and crops)]	1.62
Total	2.9

5.2 INTRODUCTION

As discussed in this chapter, dose is a measure of the potential biological damage that could be caused by exposure to and subsequent absorption of radiation to the body. Because there are many natural sources of radiation, a person living in the Portsmouth area receives a dose of approximately 300 mrem/year from sources of natural radiation. Appendix A provides additional information on radiation and dose.

Releases of radionuclides such as uranium from PORTS activities can cause a dose to a member of the public in addition to the dose received from natural sources of radiation. PORTS activities that release radionuclides are regulated by the U.S. EPA and DOE. Airborne releases of radionuclides from DOE facilities are regulated by the U.S. EPA under the Clean Air Act and the National Emission Standards for Hazardous Air Pollutants. These regulations set an annual dose limit of 10 mrem/year to any member of the public as a result of airborne radiological releases. Airborne radionuclide discharges may also be regulated, along with all other atmospheric pollutants, under the State of Ohio Permit to Operate requirements for sources of air emissions.

DOE also regulates radionuclide emissions to all environmental media through DOE Orders 5400.1, *General Environmental Protection Program,* and 5400.5, *Radiation Protection of the Public and the Environment.* DOE Order 5400.5 sets an annual dose limit of 100 mrem/year to any member of the

public from all radionuclide releases from a facility, unlike the National Emission Standards for Hazardous Air Pollutants, which apply to only airborne radiological releases.

Small quantities of radionuclides were released to the environment from DOE/PORTS operations during 2000. This chapter describes the methods used to estimate the potential doses that could result from radionuclides released from PORTS operations. In addition, this chapter assesses the potential doses that could result from radionuclides historically released by PORTS and detected in 2000 by USEC environmental monitoring programs.

5.3 RADIOLOGICAL DOSE CALCULATION

Exposure to radioactive materials can occur from releases to the atmosphere, surface water, or groundwater. In addition, a dose could be received through direct external irradiation by radiation emanating from buildings and other objects located within PORTS boundaries. For 2000, doses are estimated for exposure to atmospheric releases, releases to surface water, and direct radiation. Doses are also estimated for exposure to radionuclides from PORTS operations that were detected in 2000 as part of the USEC monitoring programs for sediment, soil, vegetation, and biota (deer, crops, and fish). Exposure to radionuclides from groundwater is not included because contaminated groundwater at PORTS is contained on site and is not a source of drinking water.

In addition, DOE Order 5400.5 sets an absorbed dose rate of 1 rad per day to native aquatic organisms. This chapter contains the dose calculations required to demonstrate compliance with this requirement.

DOE/PORTS workers and visitors who may be exposed to radiation are also monitored. These results are discussed at the end of this chapter.

5.3.1 Terminology

Most consequences associated with radionuclides released to the environment are caused by interactions between human tissue and various types of radiation emitted by the radionuclides. These interactions involve the transfer of energy from radiation to tissue, possibly resulting in tissue damage. Radiation may come from radionuclides outside the body (in or on environmental media or objects) or from radionuclides deposited inside the body (by inhalation, ingestion, and, in a few cases, absorption through the skin). Exposures to radiation from radionuclides outside the body are called external exposures, and exposures to radiation from radionuclides inside the body are called internal exposures. This distinction is important because external exposure occurs only as long as a person is near the external radionuclide; simply leaving the area of the source will stop the exposure. Internal exposure continues as long as the radionuclide remains inside the body.

The three natural uranium isotopes (uranium-234, uranium-235, and uranium-238) and technetium-99 are the most commonly detected radionuclides in environmental media samples collected around PORTS. Other radioactive isotopes are also part of the radioactive dose received from PORTS operations.

A number of specialized measurement units have been defined for characterizing exposures to ionizing radiation. Because the damage associated with exposure to radiation results primarily from the deposition of radiant energy in tissue, the units are defined in terms of the amount of radiant energy absorbed by human (or animal) tissue and in terms of the biological consequences of the absorbed energy. These units include the following:

- *Absorbed dose* – a physical quantity that defines the amount of incident radiant energy absorbed per unit mass of an irradiated material; its unit of measure is the rad. The absorbed dose depends on the type and energy of the incident radiation and on the atomic number of the absorbing material.

- *Dose equivalent* – a quantity that expresses the biological effectiveness of an absorbed dose in a specified human organ or tissue; its unit of measure is the rem. The dose equivalent is numerically equal to the absorbed dose multiplied by modifying factors that relate the absorbed dose to biological effects.

- *Effective dose equivalent* – a weighted sum of dose equivalents to specified organs that can be used to estimate health-effect risk to exposed persons. In this report, the term "effective dose equivalent" is often shortened to "dose."

- *Committed (effective) dose equivalent* – the total (effective) dose equivalent that will be received over a specified time period (in this document, calculations are based on a 50-year period) because of radionuclides taken into the body during the current year.

- *Collective dose equivalent* – the sum of committed (effective) dose equivalents to all individuals in an exposed population. The unit of measure is the person-rem. The collective dose is also frequently called the "population dose."

5.3.2 Dose Calculation for Atmospheric Releases

5.3.2.1 Dose calculation based on point source emissions

A dose calculation for atmospheric, or airborne, radionuclides is required by the U.S. EPA under the program called the National Emission Standards for Hazardous Air Pollutants. The effect of radionuclides released to the atmosphere by DOE/PORTS during 2000 was characterized by calculating effective dose equivalents to the maximally exposed person (the individual who resides at the most exposed point near the plant) and to the entire population (approximately 600,000 residents) within 50 miles of the plant. Dose calculations were made using a computer program called CAP88 (Beres 1990), which was developed under sponsorship of the U.S. EPA for use in demonstrating compliance with the National Emission Standards for Hazardous Air Pollutants for radionuclides. The program uses models to calculate concentrations of radionuclides in the air and on the ground and in foodstuffs (e.g., vegetables, meat, and milk) and subsequent intakes by individuals. The program also uses meteorological data collected at PORTS such as wind direction, wind speed, atmospheric stability, rainfall, and average air temperature.

Radionuclide release data were modeled for the three DOE/PORTS radionuclide sources discussed in Sect. 2.3.6.2: the X-326 L-cage Glove Box, X-623 Groundwater Treatment Facility, and the X-624 Groundwater Treatment Facility. The dose calculations assumed that each person remained unprotected, resided at home (actually outside the house) during the entire year, and obtained food according to the rural pattern defined in the National Emission Standards for Hazardous Air Pollutants background documents. This pattern specifies that 70% of the vegetables and produce, 44% of the meat, and 40% of the milk consumed by each person are produced in the local area (e.g., in a home garden). The remaining portion of each food is assumed to be produced within 50 miles of DOE/PORTS. These assumptions most likely result in an overestimate of the dose received by a member of the public, since it is unlikely that a person spends the entire year outside at home and consumes food from the local area as described above.

The maximum potential dose to an off-site individual from radiological releases from DOE air emission sources at PORTS in 2000 was 0.01 mrem/year. This dose has increased from the dose calculated by DOE in 1999 (0.00048 mrem/year) as a result of additional air emission monitoring completed at the X-623 and X-624 Groundwater Treatment Facilities (see Sect. 2.3.6.2).

USEC also completes the dose calculations described above for the air emission sources leased to USEC (e.g., the uranium enrichment facilities and other sources). The combined dose from USEC and DOE sources is 0.047 mrem/year, well below the 10-mrem/year limit applicable to PORTS and the approximate 300-mrem/year dose that the average individual in the United States receives from natural sources of radiation.

The collective dose equivalent (or population dose) to the entire population within 50 miles of PORTS was 0.167 person-rem/year, based on USEC calculations of 0.15 person-rem/year from USEC sources and 0.017 person-rem/year from DOE sources. The population dose to the nearest community, Piketon, was calculated to be 0.03 person-rem/year, based on USEC calculations of 0.029 person-rem/year from USEC sources and 0.0019 person-rem/year from DOE sources. These dose calculations have also increased from the doses calculated in 1999 as a result of the additional monitoring completed at the X-623 and X-634 Groundwater Treatment Facilities.

5.3.2.2 Dose calculation based on ambient air monitoring

DOE upgraded ambient air monitoring stations and took over the ambient air monitoring program from USEC in October 2000. Samples were collected from 14 ambient air monitoring stations from October through December 2000 and analyzed for the radionuclides that could be present in ambient air due to PORTS activities. These radionuclides are isotopic uranium (uranium-233/234, uranium-235, uranium-236, and uranium-238), technetium-99, and selected transuranic radionuclides (americium-241, neptunium-237, plutonium-238, and plutonium-239/240). The ambient air monitoring stations measure radionuclides released from the DOE and USEC point sources (the sources described in the previous section), fugitive air emissions (emission that are not associated with a specific release point, such as a stack), and background concentrations of radionuclides (radionuclides that occur naturally in the environment and are not associated with PORTS operations).

The CAP88 model generates a dose conversion factor that was used to calculate a dose for a given concentration of each radionuclide in air. The following assumptions were made to calculate the dose at each station: (1) the highest concentration of each radionuclide detected in October through December 2000 was assumed to be present for the entire year; or (2) if a radionuclide was not detected, the radionuclide was assumed to be present at half the detection limit for the analytical method.

The dose associated with each radionuclide at each ambient air monitoring station was added to obtain the gross dose for each station. The net dose for each station was obtained by subtracting the dose measured at the background station (A37). The net dose ranged from zero (at stations with a gross dose less than the background station) to 0.0019 mrem/year at stations A10 and A29. Fig. 5.1 shows the gross and net dose calculated at each DOE ambient air monitoring station that monitored radionuclides in 2000.

The highest net dose measured at the ambient air monitoring stations is approximately 4% of the dose calculated from the combined DOE and USEC point source emissions (0.047 mrem/year). These results indicate that fugitive emissions of radionuclides from the PORTS reservation do not cause a significant unmeasured dose to individuals near the site and further demonstrate that emissions of radionuclides from PORTS are within NESHAP limits.

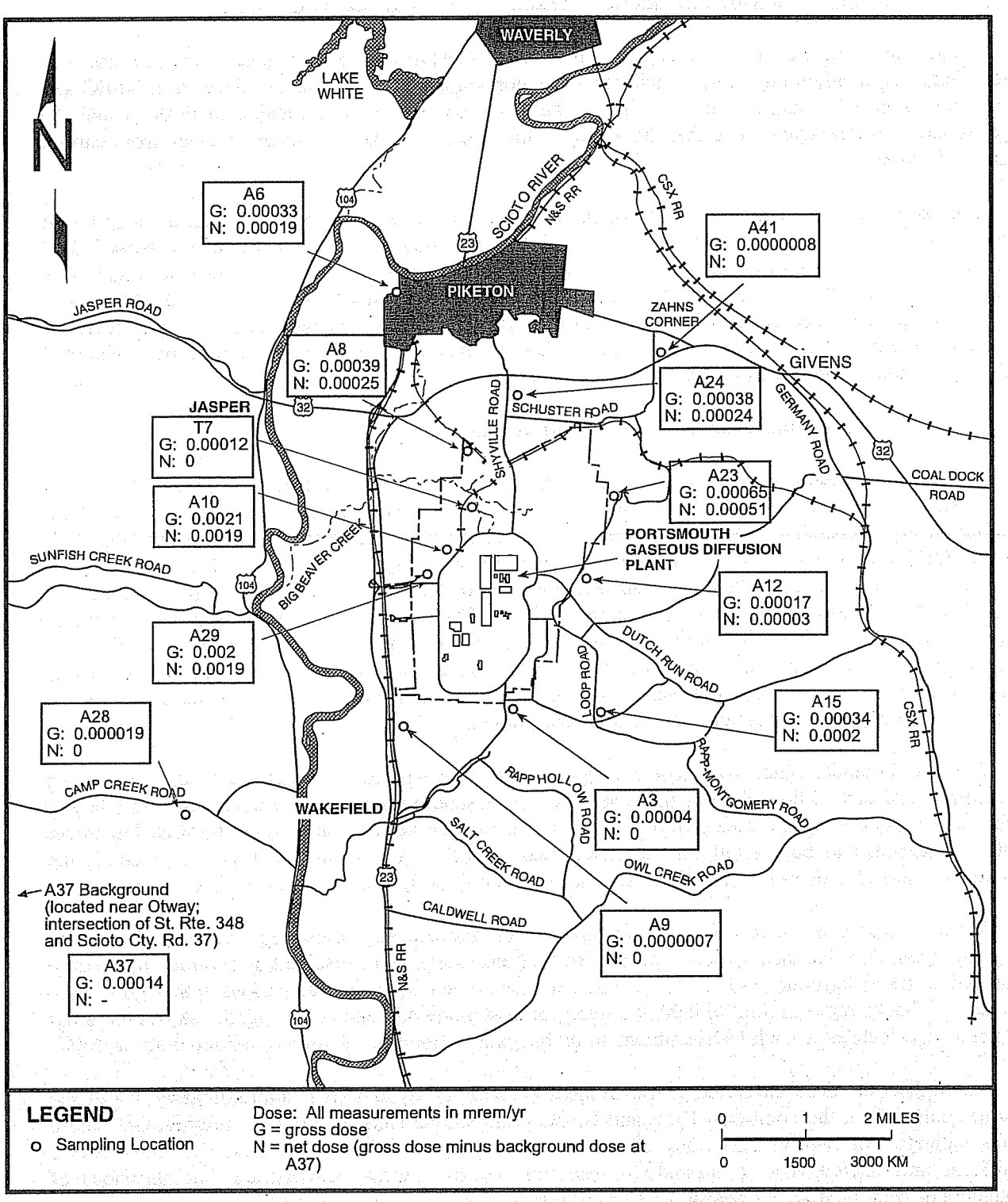


Fig. 5.1. Doses calculated at DOE ambient air monitoring stations.

5.3.3 Dose Calculation for Releases to Surface Water

Radionuclides are measured at the DOE and USEC NPDES external outfalls (three DOE outfalls and eight USEC outfalls). Water from these external outfalls is either directly discharged to the Scioto River or eventually flows into the Scioto River from the Little Beaver Creek, Big Run Creek, or unnamed tributaries to these water bodies. A hypothetical dose to a member of the public was calculated using the measured radiological discharges and the average annual flow rate of the Scioto River.

Total uranium mass (in μg/L) and activity (in pCi/L) for americium-241, neptunium-237, plutonium-238, plutonium-239/240, technetium-99, and thorium-230 (DOE NPDES Outfall 015 only) were measured in the water discharged from the DOE or USEC outfalls. Total uranium was assumed to be 94% uranium-235, 5.2% uranium-238, and 0.8% uranium-234. The maximum individual dose was calculated using the above-mentioned measured radionuclide discharges from the plant outfalls and the average annual flow rate of the Scioto River. All discharge radioactivity levels were expressed in total activity per year (Ci/year) and used along with the average river flow to calculate radioactivity per volume.

The dose calculations were derived from the procedures developed for a similar DOE facility: *LADTAPXL: An Improved Electronic Spreadsheet Version of LADTAP II* (Hamby 1991). Environmental pathways considered were ingestion of water, ingestion of fish, swimming, boating, and shoreline activities. The assumption was made that a person eats 21 kilograms (46 lbs) of fish caught in the Scioto River, drinks 730 liters (190 gal) of river water, swims for 27 hours, boats for 105 hours, and occupies the shoreline for 69 hours during the year. Based on the calculations across all isotopes found in the outfalls, this individual could receive an annual dose of about 0.042 mrem. This is a very conservative exposure scenario because the Scioto River is not used for drinking water downstream of PORTS (about 90% of the hypothetical dose from liquid effluents is from drinking water) and it is unlikely that a person would eat 46 lbs of fish from the river. This dose has decreased slightly from the dose calculated in 1999 because the amount of uranium discharged from PORTS in 2000 (17.9 kilograms – see Sect. 4.4.1.1) decreased slightly from 1999 (21.73 kilograms).

5.3.4 Radiological Dose Calculation for Direct Radiation

The DOE/PORTS Radiological Protection Organization monitors direct radiation levels in active DOE/PORTS facilities on a continual basis. This radiation monitoring assists in determining the radiation levels that workers are exposed to and in identifying changes in radiation levels. These measurements provide (1) information for worker protection, (2) a means to trend radiological exposure data for specified facilities, and (3) a means to estimate potential public exposure to radiation from DOE/PORTS activities.

Thermoluminescent dosimeters (TLDs) are used to measure beta, gamma, and neutron radiation. The TLD consists of four crystals that store radiation as potential energy. When the TLD crystals are heated, this stored energy is released as light. This light is quantifiable and correlates directly to the amount of ionizing radiation to which the TLD was exposed. The TLD can differentiate exposure to beta, gamma, and neutron radiation as well as shallow and deep radiation. Shallow radiation penetrates only the outer portion of the skin. Deep radiation penetrates the entire body (similar to an x-ray).

Five major DOE/PORTS facilities are monitored for direct radiation exposure levels: the X-7725 Waste Storage Facility, X-326 Process Building, X-345 SNM Storage Building, X-744G Bulk Storage Building, and the X-745C and X-745E Depleted Uranium Hexafluoride Cylinder Storage Yards.

None of these facilities are readily accessible to the public; however, Perimeter Road passes close to the edge of the cylinder yards. Therefore, data from direct radiation monitoring at the cylinder yards are used to assess potential exposure to the public from passing traffic on Perimeter Road.

The radiological exposure data provided from the TLDs at each facility are based on exposure to ionizing radiation for an entire year (i.e., 24 hours/day, 7 days/week, 52 weeks/year - 8,736 hours/year). The radiological exposure to members of the general public is estimated as the time that a person drives on Perimeter Road past the cylinder yards. Tests estimate that a car traveling slightly under the posted speed limit passes by the cylinder yards in 20 to 30 seconds. Potential public exposure to radiation from the cylinder yards is calculated as follows:

Assumptions:

- A person driving to and from work (2 exposures/day) is the most conservative plausible scenario.
- The driver will pass by the cylinder yards within 1 minute.

Calculation:

1. Subtract natural background radiation – 78 mrem/year from the committed effective dose equivalent. Natural background radiation consists of 50 mrem/year cosmic radiation and 28 mrem/year terrestrial radiation (see Appendix A).

2. Divide this dose measurement by 8736 hours to determine the exposure per hour.

3. Multiply this exposure by 8.7 hours/year (1 minute/trip x 2 trips/day x 5 work-days/week x 52 weeks/year).

The committed effective dose equivalent reported in Table 5.2 represents the gross exposure levels at each facility. These levels include ionizing radiation from PORTS activities in those areas and natural background radiation (i.e., terrestrial and cosmic radiation). The final column provides the potential dose to the public from each area.

Table 5.2. Direct radiation doses at DOE/PORTS facilities – 2000

Facility	Committed effective dose equivalent (deep dose) (mrem/year)	Estimated public dose (mrem/year) 8.7 hours exposure
X-7725	61	NA[a]
X-326	0	NA[a]
X-345	0	NA[a]
X-744G	1240	NA[a]
X-745C	531	0.45
X-745E	776	0.7

[a]Not applicable - no public exposure to radiation from these buildings.

Based on the assumptions and calculations provided, exposure to the public from radiation from the cylinder yards is approximately 1.15 mrem/year. This dose has increased from the dose reported in 1999 (0.59 mrem/year) due to the construction of two new storage areas at the cylinder yards and the resulting increase in cylinders stored in the yards. The average yearly dose to a person in the United States is approximately 366 mrem: 300 mrem from natural radiation sources and 66 mrem from manmade radiation sources (see Appendix A). The potential estimated dose from the cylinder yards to a member of

the public is less than 0.3 percent of the average yearly radiation exposure for a person in the United States.

5.3.5 Radiological Dose Calculations for Environmental Monitoring Data

Environmental monitoring at PORTS includes collecting samples at off-site locations around the PORTS reservation and analyzing the samples for radionuclides that could be present due to PORTS operations. Samples are analyzed for uranium, technetium-99, and/or selected transuranics (americium-241, neptunium-237, plutonium-238, and plutonium-239/240). Uranium occurs naturally in the environment; therefore, detections of uranium usually cannot be attributed to PORTS operations. Detections of technetium-99 and transuranics most likely result from activities at PORTS, although detections of radionuclides near the detection limit for the analytical method can be false positives (due to the inherent level of error associated with laboratory analytical capabilities).

DOE sets a limit of 100 mrem/year for a potential dose to a member of the public via exposure to all radionuclide releases from a DOE facility. To ensure that PORTS meets this standard, dose calculations were completed for detections of radionuclides in sediment, soil, vegetation, and biota (deer, fish, and crops) at off-site sampling locations. Detections of radionuclides on the DOE reservation were not used to assess risk because the public does not have access to the facility.

The following paragraphs provide brief descriptions of the dose calculations for each monitoring program. Methodologies used to complete each risk calculation are based on information developed and approved by U.S. EPA. Table 5.3 summarizes the results of each dose calculation.

Table 5.3. Summary of potential doses to the public from radionuclides detected by PORTS environmental monitoring programs in 2000

Source of dose	Dose (mrem)
Sediment	0.042
Soil	0.0038
Vegetation	0.0014
Biota (deer)	0.757
Biota (fish)	0.645
Biota (crops)	0.169
Total	1.62

The dose calculation for sediment is based on the detection of 3.8 pCi/g of technetium-99 in the sediment collected from monitoring location RM-13, an off-site sampling location on Big Beaver Creek (see Chap. 4, Fig. 4.4 for a sampling location diagram). Based on ingestion rates and methodologies approved by U.S. EPA, the dose received by an individual is 0.042 mrem/year.

The dose calculation for soil is based on the detection of 0.4 pCi/g of technetium-99 at sampling location SAS-13, which is northwest of the PORTS reservation (see Chap. 4, Fig. 4.6 for a sampling location diagram). Based on ingestion rates and methodologies approved by U.S. EPA, the dose received by an individual is 0.0038 mrem/year.

The dose calculation for vegetation is based on the detection of 0.4 pCi/g of technetium-99 at sampling location RV-10N, which is a background sampling location 10 miles north of the PORTS

reservation (see Chap. 4, Fig. 4.6 for a sampling location diagram). The dose calculation of 0.0014 mrem/year is based on human consumption of beef cattle that ate this vegetation.

The dose calculation for consumption of deer is based on the detection of radionuclides in two of the five deer livers collected at PORTS during the 2000-2001 hunting season and assumes a limit of two deer per hunter for the hunting season. If the hunter ate both of these deer livers - one liver containing americium-241 at 0.0458 pCi/g, and the second liver containing plutonium-239 at 0.0567 pCi/g, uranium-233/234 at 0.034 pCi/g, uranium-235/236 at 0.0512 pCi/g, and uranium-238 at 0.0255 pCi/g - the hunter would receive a dose of 0.757 mrem.

The dose calculation for fish is based on the detection of 0.1 pCi/g of technetium-99, 0.021 pCi/g of uranium-233/234, and 0.012 pCi/g of uranium-236 in a catfish caught in the Scioto River near USEC NPDES Outfall 003. Based on consumption rates and methodologies approved by U.S. EPA, the dose received by an individual is 0.645 mrem/year.

The dose calculation for crops is based on the detection of 0.2 pCi/g of technetium-99, 0.23 pCi/g of uranium-233/234, and 0.21 pCi/g of uranium-238 in a pawpaw collected near surface water sampling location RW-7 on Little Beaver Creek (see Chap. 4, Fig. 4.4 for a sampling location diagram). Based on consumption rates and methodologies approved by U.S. EPA, the dose received by an individual is 0.169 mrem/year.

5.3.6 Radiological Dose Calculation for Aquatic Biota

DOE Order 5400.5 sets an absorbed dose rate of 1 rad/day to native aquatic organisms. To demonstrate compliance with this limit, absorbed dose rates to primary organisms such as crustacea, mollusks, and fish were calculated using the CRITR2 ingestion methodology (Baker and Soldat 1992) and average annual radionuclide concentrations in the Scioto River. The average annual radionuclide concentrations in the Scioto River are based on total activity released from DOE and USEC external NPDES outfalls and the annual average Scioto River flow. The CRITR2 model estimates dose rates from internally deposited radionuclides, from immersion in water, and from sediment irradiation. Internal and external dose rates were also calculated for secondary aquatic biota, namely, muskrats, raccoons, herons, and ducks.

Modeling results indicate that the aquatic biota in the Scioto River did not receive an absorbed dose of more than 1 rad/day in 2000. Table 5.4 lists the total dose rates (including internal and external doses) for native aquatic biota. These dose rates are comparable to the dose rates calculated in 1999.

Table 5.4. Dose rates for native aquatic biota

Animal	Total dose rate (rad/day)
Fish	0.000003
Crustacea and mollusks	0.000005
Muskrat	0.00003
Raccoon	0.000007
Heron	0.000004
Duck	0.00003

5.3.7 Radiological Dose Results for DOE/PORTS Workers and Visitors

The Radiation Exposure Information Reporting System report is an electronic file created annually to comply with DOE Order 231.1. This report contains exposure results for all monitored individuals at DOE/PORTS, including visitors, with a positive exposure during the previous calendar year. The 2000

6. GROUNDWATER PROGRAMS

6.1 SUMMARY

Groundwater monitoring at DOE/PORTS is required by legal agreements with Ohio EPA and U.S. EPA and DOE Orders. More than 400 monitoring wells are used to track the flow of groundwater and to identify and measure groundwater contaminants. Groundwater programs also include on-site surface water monitoring and residential water supply monitoring. The contaminated groundwater plumes present at PORTS did not change significantly in 2000.

6.2 INTRODUCTION

The PORTS reservation is the largest industrial user of water in the vicinity and obtains its water from three water supply well fields that are next to the Scioto River south of Piketon. The wells tap the Scioto River Valley buried aquifer. In 2000, total groundwater production from the water supply well fields averaged 11.8 million gallons per day for the entire site, including USEC activities. Groundwater directly beneath PORTS is not used as a domestic, municipal, or industrial water supply, and contaminants in the groundwater beneath PORTS do not affect the quality of the water in the Scioto River Valley buried aquifer.

Groundwater monitoring at PORTS includes several activities. Monitoring wells are used to obtain information about groundwater. When the level of water, or groundwater elevation, is measured in a number of wells over a short period of time, the groundwater elevations, combined with information about the subsurface soil, can be used to estimate the rate and direction of groundwater flow. The rate and direction of groundwater flow can be used to predict the movement of contaminants in the groundwater and to develop ways to control or remediate groundwater contamination. Samples of water are also collected from groundwater monitoring wells and analyzed to obtain information about contaminants and naturally-occurring compounds in the groundwater.

6.3 GROUNDWATER MONITORING AT DOE/PORTS

Groundwater monitoring at PORTS was initiated in the 1980s. Groundwater monitoring has been conducted in response to state and/or federal regulations, regulatory documents prepared by DOE/PORTS, legal agreements between DOE and Ohio EPA or U.S. EPA, and DOE Orders.

In 2000, groundwater monitoring at PORTS was performed in accordance with the *Integrated Groundwater Monitoring Plan*. This plan, developed by DOE/PORTS, was implemented in April 1999 and establishes all groundwater monitoring requirements for PORTS. The plan has been reviewed and approved by Ohio EPA.

Groundwater monitoring is also completed to meet DOE Order requirements. Exit pathway monitoring assesses the effect of PORTS on regional groundwater quality and quantity. Baseline monitoring is conducted to establish background data for use in assessing the effect of PORTS operations on the groundwater. DOE Orders are also the basis for the radiological monitoring of groundwater at PORTS.

Two water-bearing zones are present beneath PORTS: the Gallia and Berea formations. The Gallia is the uppermost water-bearing zone and contains most of the groundwater contamination at PORTS. The Berea is deeper than the Gallia and is usually separated from the Gallia by the Sunbury shale, which is a barrier to groundwater flow between the Gallia and Berea formations.

Several areas of groundwater contamination have been identified at PORTS. Groundwater contamination consists of volatile organic compounds, primarily trichloroethene, and radionuclides such as uranium and technetium-99. In general, groundwater monitoring results for 2000 indicate that:

- Groundwater flow directions and rates of flow were generally similar to those recorded in 1999.
- Groundwater contamination is contained within the reservation's boundaries.
- The concentration of contaminants and the lateral extent of plume boundaries did not significantly increase in 2000.

The *2000 Groundwater Monitoring Report for the Portsmouth Gaseous Diffusion Plant* provides further details on the groundwater plumes at PORTS, specific monitoring well identifications, and analytical results for monitoring wells.

This chapter also includes information on the groundwater treatment facilities at PORTS. These facilities receive contaminated groundwater from the groundwater monitoring areas and treat the water prior to discharge through the DOE/PORTS permitted NPDES outfalls.

6.4 GROUNDWATER MONITORING AREAS

The *Integrated Groundwater Monitoring Plan* requires groundwater monitoring of eight areas within the four quadrants of the site designated by the RCRA Corrective Action Program. These areas (see Fig. 6.1) are:

- X-749/X-120/Peter Kiewit (PK) Landfill,
- Quadrant I Groundwater Investigative Area/X-749A Classified Materials Disposal Facility,
- Quadrant II Groundwater Investigative Area,
- X-701B Holding Pond,
- X-616 Chromium Sludge Surface Impoundments,
- X-740 Waste Oil Handling Facility,
- X-611A Former Lime Sludge Lagoons, and
- X-735 Landfills.

The *Integrated Groundwater Monitoring Plan* also contains requirements for (1) surface water monitoring in creeks and drainage ditches at PORTS that receive groundwater discharge, and (2) residential water supply monitoring.

In general, samples are collected from wells (or surface water locations) at each area listed above and are analyzed for metals, volatile organic compounds, and radiological constituents. Table 6.1 lists the analytical requirements for each groundwater monitoring area and other monitoring programs described in this chapter. DOE/PORTS then compares constituents detected in the groundwater to standards called preliminary remediation goals to assess the potential for each constituent to affect human health and the environment. The preliminary remediation goals have been determined as part of the RCRA Corrective

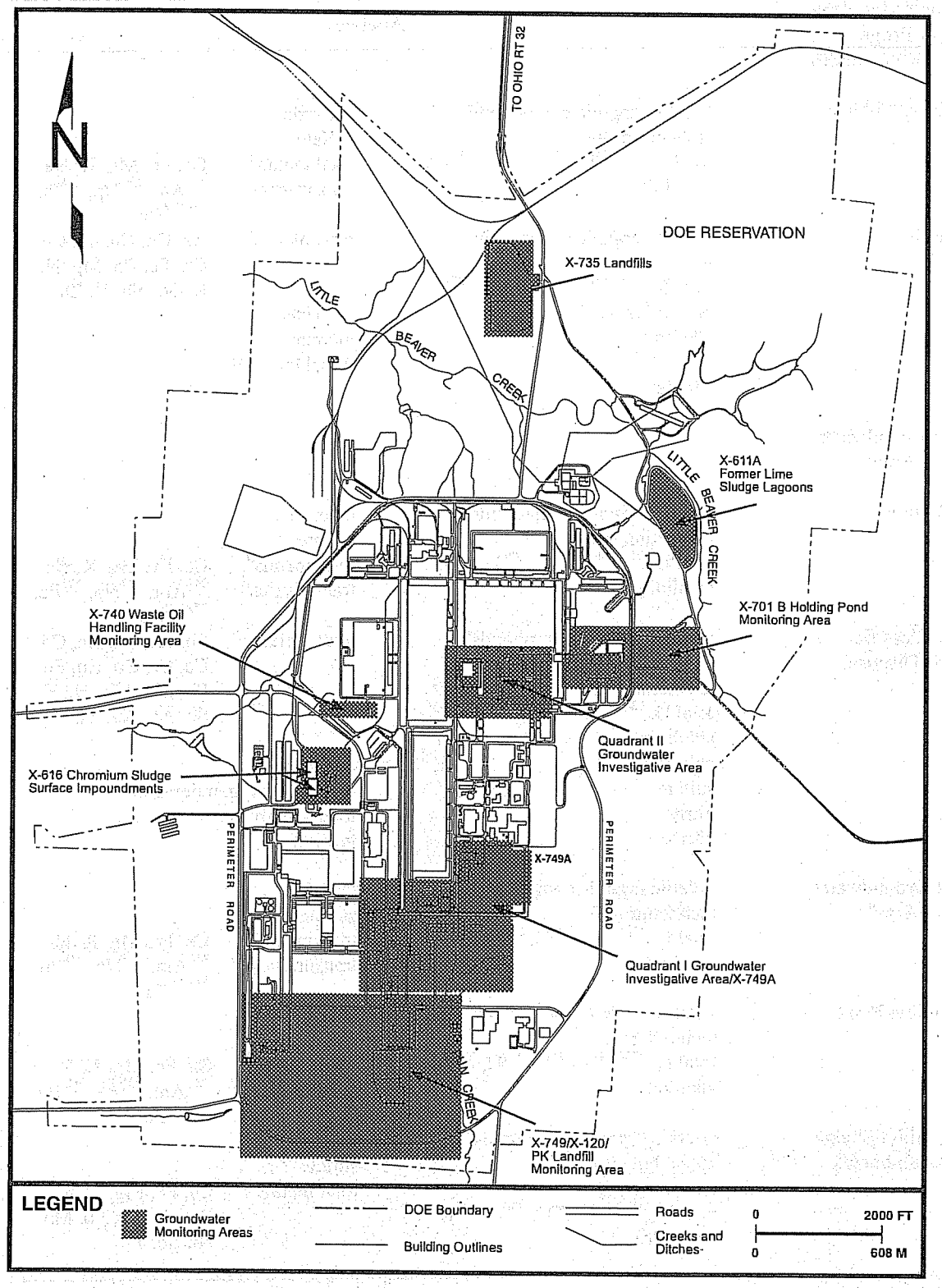


Fig. 6.1. Groundwater monitoring areas at PORTS.

Table 6.1. Analytical parameters for monitoring areas and programs at PORTS

Monitoring Area or Program	Analytes	
X-749/X-120/PK Landfill[a]		
X-749/X-120 plume	volatile organic compounds[b] technetium-99 total U, $^{233/234}U$, ^{235}U, ^{236}U, ^{238}U[d] alkalinity	chloride sulfate total metals[d]: Ca, Fe, Mg, K, Na transuranics[d, e]: ^{241}Am, ^{237}Np, ^{238}Pu, $^{239/240}Pu$
PK Landfill	volatile organic compounds[b] technetium-99 total U, $^{233/234}U$, ^{235}U, ^{236}U, ^{238}U[d] % uranium-235 alkalinity chloride sulfate	total metals[d]: As, Cd, Ca, Cr, Co, Cu, Fe, Pb, Mg, Ni, K, Se, Na, V, Zn fluoride mercury Arochlor-1260
Quadrant I Groundwater Investigative Area[a]		
X-231B plume	volatile organic compounds[b] technetium-99 total U, $^{233/234}U$, ^{235}U, ^{236}U, ^{238}U[d] alkalinity	chloride sulfate total metals[d]: Ca, Fe, Mg, K, Na transuranics[d, e]: ^{241}Am, ^{237}Np, ^{238}Pu, $^{239/240}Pu$
X-749A Classified Materials Disposal Facility	volatile organic compounds[c] alpha, beta activity technetium-99 total U, $^{233/234}U$, ^{235}U, ^{236}U, ^{238}U[d] alkalinity chloride sulfate nitrite nitrate	total metals[d]: Sb, As, Ba, Be, Cd, Ca, Cr, Co, Cu, Fe, Pb, Mg, Mn, Ni, K, Se, Ag, Na, Tl, V, Zn ammonia chemical oxygen demand total dissolved solids turbidity
Quadrant II Groundwater Investigative Area[a]	volatile organic compounds[b] technetium-99 total U, $^{233/234}U$, ^{235}U, ^{236}U, ^{238}U[d] alkalinity	chloride sulfate total metals[d]: Ca, Fe, Mg, K, Na transuranics[d, e]: ^{241}Am, ^{237}Np, ^{238}Pu, $^{239/240}Pu$
X-701B Holding Pond[a]	volatile organic compounds[b] technetium-99 total U, $^{233/234}U$, ^{235}U, ^{236}U, ^{238}U[d] alkalinity	chloride sulfate total metals[d]: Ca, Fe, Mg, K, Na transuranics[d, e]: ^{241}Am, ^{237}Np, ^{238}Pu, $^{239/240}Pu$
X-616 Chromium Sludge Surface Impoundments	volatile organic compounds[b] alpha, beta activity technetium-99 total U, $^{233/234}U$, ^{235}U, ^{236}U, ^{238}U[d] alkalinity	chloride sulfate total metals[d]: Ca, Fe, Mg, K, Na, Ba, Cd, Cr, Pb, Mn, Ni, Sb, Tl

Table 6.1. Analytical parameters for monitoring areas and programs at PORTS (continued)

Monitoring Area or Program	Analytes		
X-740 Waste Oil Handling Facility[a]	volatile organic compounds[b] technetium-99 total U, $^{233/234}U$, ^{235}U, ^{236}U, ^{238}U[d] alkalinity	chloride sulfate total metals[d]:	 Ca, Fe, Mg, K, Na
X-611A Former Lime Sludge Lagoons	total metals[d]: Be, Cr total U, $^{233/234}U$, ^{235}U, ^{236}U, ^{238}U[d]		
X-735 Landfills	volatile organic compounds[c] alpha, beta activity technetium-99 total U, $^{233/234}U$, ^{235}U, ^{236}U, ^{238}U[d] alkalinity chloride sulfate nitrite nitrate	total metals[d]: ammonia chemical oxygen demand total dissolved solids turbidity	Sb, As, Ba, Be, Cd, Ca, Cr, Co, Cu, Fe, Pb, Mg, Mn, Ni, K, Se, Ag, Na, Tl, V, Zn
Surface Water	volatile organic compounds[b] technetium-99 total U, $^{233/234}U$, ^{235}U, ^{236}U, ^{238}U[d] alkalinity	chloride sulfate total metals[d]: transuranics[d]:	 Ca, Fe, Mg, K, Na ^{241}Am, ^{237}Np, ^{238}Pu, $^{239/240}Pu$
Residential Water Supply	volatile organic compounds[b] technetium-99 total U, $^{233/234}U$, ^{235}U, ^{236}U, ^{238}U[d] alkalinity	chloride sulfate total metals[d]: transuranics[d]:	 Ca, Fe, Mg, K, Na ^{241}Am, ^{237}Np, ^{238}Pu, $^{239/240}Pu$
Exit Pathway and Baseline	volatile organic compounds[b] technetium-99 total U, $^{233/234}U$, ^{235}U, ^{236}U, ^{238}U[d] alkalinity	chloride sulfate total metals[d]: transuranics[d, e]: $^{239/240}Pu$	 Ca, Fe, Mg, K, Na ^{241}Am, ^{237}Np, ^{238}Pu,

[a] Selected well(s) in this area are sampled once every two years for a comprehensive list of over 200 potential contaminants (Title 40, Code of Federal Regulations, Part 264 Appendix IX – Appendix to Ohio Administrative Code Rule 3745-54-98).

[b] Acetone, benzene, bromodichloromethane, bromoform, carbon disulfide, carbon tetrachloride, chlorobenzene, chloroethane, chloroform, dibromochloromethane, 1,2-dichlorobenzene, 1,4-dichlorobenzene, 1,1-dichloroethane, 1,2-dichloroethane, 1,1-dichloroethene, cis-1,2-dichloroethene, trans-1,2-dichloroethene, ethylbenzene, bromomethane, chloromethane, methylene chloride, 2-butanone (methyl ethyl ketone), 4-methyl-2-pentanone (methyl isobutyl ketone), 1,1,2,2-tetrachloroethane, tetrachloroethene, toluene, 1,1,1-trichloroethane, 1,1,2-trichloroethane, trichloroethene, trichlorofluoromethane (CFC-11), vinyl chloride, xylenes (M+P xylenes).

[c] Volatile organic compounds listed in footnote b plus: acrylonitrile, bromochloromethane, 1,2-dibromo-3-chloropropane, 1,2-dibromoethane, trans-1,4-dichloro-2-butene, 1,2-dichloropropane, cis-1,3-dichloropropene, trans-1,3-dichloropropene, 2-hexanone (methyl butyl ketone), dibromomethane, iodomethane, styrene, 1,1,1,2-tetrachloroethane, 1,2,3-trichloropropane, and vinyl acetate.

[d] Appendix C lists the symbols for metals and transuranic radionuclides.

[e] Samples from selected wells at this area are analyzed for these parameters.

Action Program at PORTS. Preliminary remediation goals are based on naturally occurring concentrations of some constituents or on risk-based numbers calculated by the EPA, or are determined through a site-specific risk assessment. Data for the X-749A Classified Materials Disposal Facility (part of the Quadrant I Groundwater Investigative Area) and the X-735 Landfills are also statistically evaluated to determine whether the areas have impacted groundwater.

6.4.1 X-749 Contaminated Materials Storage Facility/X-120 Old Training Facility/PK Landfill

In the southernmost portion of PORTS, groundwater concerns focus on three contaminant sources: the X-749 Contaminated Materials Disposal Facility, the X-120 Old Training Facility, and the PK Landfill.

6.4.1.1 X-749 Contaminated Materials Disposal Facility

The X-749 Contaminated Materials Disposal Facility is a landfill located in the south-central section of the facility. The landfill covers approximately 7.5 acres and was built in an area of highest elevation within the southern half of PORTS. The landfill operated from 1955 to 1990, during which time buried wastes were generally contained in metal drums or other containers that were compatible with the waste.

The northern portion (approximately 200,000 square ft) contains waste contaminated with industrial solvents, waste oils from plant compressors and pumps, sludges that were classified as hazardous, and low-level radioactive materials. The southern portion (approximately 130,000 square ft) contains non-hazardous, low-level radioactive scrap materials.

Closure of the X-749 landfill included installation of (1) a multimedia cap, (2) a slurry wall along the north side and northwest corner of X-749, and (3) subsurface groundwater drains on the northern half of the east side and the southwest corner, including one groundwater extraction well within each of the groundwater drains. The slurry wall and subsurface drains extend down to bedrock. Groundwater from the subsurface drains is treated on site and discharged in accordance with the DOE/PORTS NPDES permit.

The leading edge of the contaminated groundwater plume emanating from the X-749 landfill has been approaching the southern boundary of the PORTS reservation. In 1995, a subsurface diversion wall was completed across a portion of this southern boundary. The diversion wall is designed to inhibit migration of the plume off plant property prior to the implementation of a final remedial measure.

Three wells monitor the subsurface diversion wall at the leading edge of the groundwater plume and are sampled quarterly. In 2000, six new wells were installed to monitor the area between the diversion wall and the DOE property boundary; these wells are sampled semiannually. Twenty-one other wells (19 monitoring wells and 2 extraction wells) are sampled semiannually to monitor the X-749 plume. Twenty additional wells are sampled annually or biennially to monitor both the X-749 and the X-120 plumes. Table 6.1 lists the analytical parameters for the wells in this area.

6.4.1.2 X-120 Old Training Facility

The X-120 Old Training Facility covered an area of approximately 11.5 acres near the present-day XT-847 building. The X-120 facility, which no longer exists, included a machine shop, metal shop, paint shop, and several warehouses used during the construction of PORTS in the 1950s. The shops may have used solvents and various other materials; disposal practices of these solvents are unknown.

Groundwater in the vicinity of this facility contains primarily trichloroethene. The upgradient (northern) portion of the X-120 plume co-mingles with a portion of the X-749 plume; however, downgradient the X-120 plume migrates independently to the southwest. In 1996, a horizontal well was installed along the approximate axis of the X-120 plume. Contaminated groundwater flows from this well to the X-625 Groundwater Treatment Facility.

Three wells are sampled semiannually to monitor the plume associated with the X-120 area. Twenty additional wells are sampled annually or biennially to monitor both the X-749 and the X-120 plumes. Table 6.1 lists the analytical parameters for the wells in this area.

6.4.1.3 PK Landfill

The PK Landfill is located west of Big Run Creek just south of the X-230K Holding Pond. The landfill, which began operations in 1952, was used as a salvage yard, burn pit, and trash area during the construction of PORTS. After the initial construction, the disposal site was operated as a sanitary landfill until 1968, when soil was graded over the site and the area was seeded with native grasses. No records exist that characterize the material in the landfill.

During site investigations, intermittent seeps were observed emanating from the PK Landfill into Big Run Creek. In 1993, sampling was conducted at three of the seeps and at Big Run Creek approximately 40 ft downstream of the seeps. Sample results indicated that the seeps contained vinyl chloride; however, no vinyl chloride was detected in Big Run Creek.

In 1994, a portion of Big Run Creek was relocated approximately 50 ft to the east. A groundwater collection system was installed in the old creek channel to capture the seeps emanating from the landfill. A second collection system was constructed on the southeastern boundary to contain the groundwater plume migrating toward Big Run Creek from the southern portion of the PK landfill in 1997. A cap was constructed over the landfill in 1998.

Ten wells were sampled semiannually and two sumps that collect groundwater from the plume are sampled quarterly. Table 6.1 lists the analytical parameters for the wells and sumps in this area.

6.4.1.4 Monitoring results for the X-749/X-120/PK Landfill in 2000

Contaminated groundwater plumes are associated with the X-749/X-120/PK Landfill groundwater monitoring area (see Fig. 6.2). The most extensive and most concentrated constituents associated with the X-749/X-120 plume are volatile organic compounds, particularly trichloroethene. In 2000, no significant changes to the perimeter of the plume (defined as 5 μg/L of trichloroethene) were noted. Volatile organic compounds were not detected in samples collected from the six new wells installed between the diversion wall and the DOE property boundary, indicating that contamination from the groundwater plume has not migrated off site in this area.

In addition to volatile organic compounds, inorganics (metals) and radiological constituents (uranium and technetium-99) have also been detected in the groundwater beneath the X-749 area. Remediation of groundwater is being completed in accordance with the RCRA Corrective Action Program.

Samples from selected wells (X749-07G, X749-08G, X749-10G, and X749-WPW) were also analyzed for americium-241, neptunium-237, plutonium-238, and plutonium-239/240. These analytes were not detected in the samples.

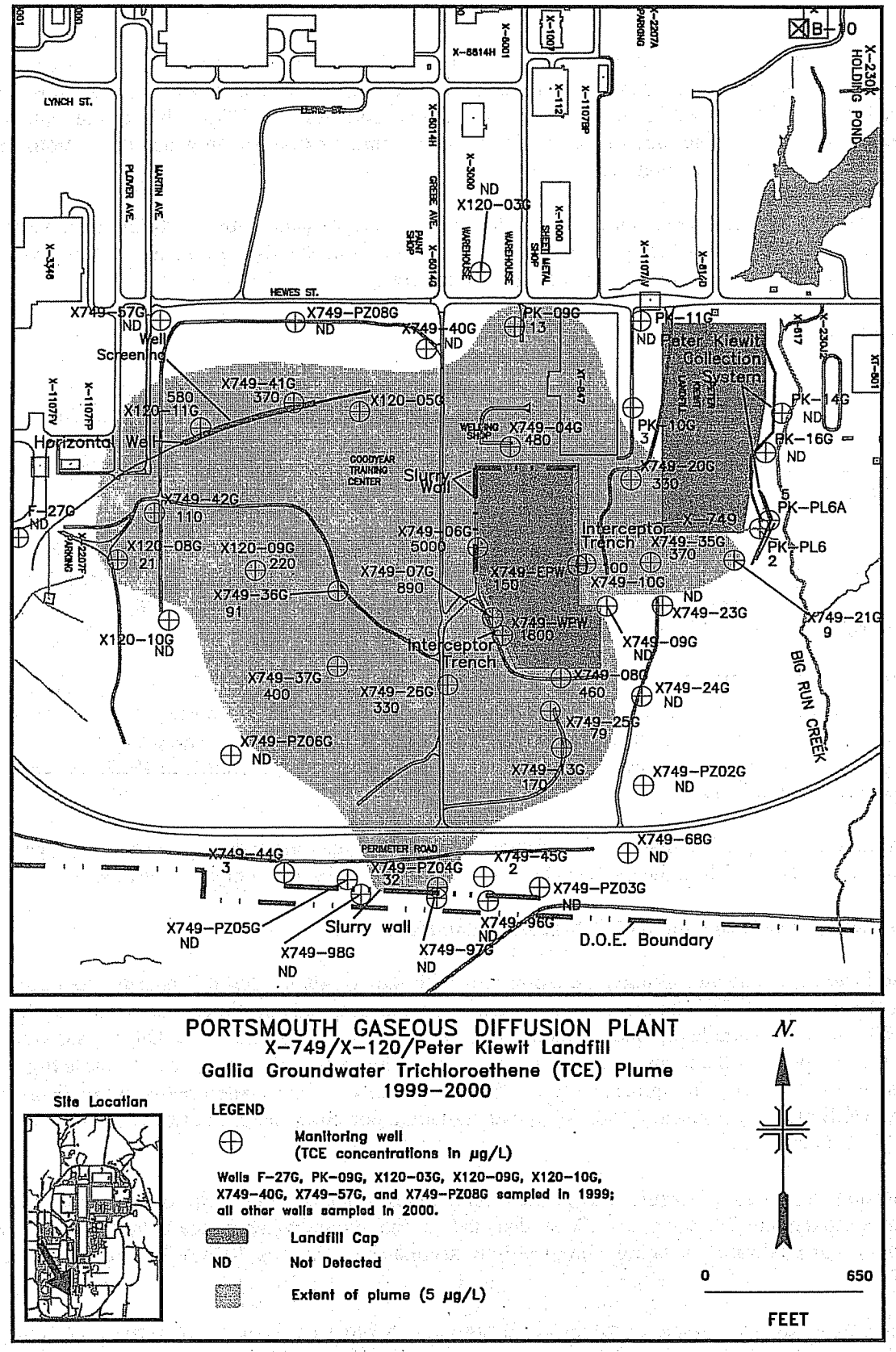


Fig. 6.2. Trichloroethene-contaminated Gallia groundwater plume at the X-749/X-120/PK Landfill (1999-2000).

Some of the wells associated with the PK Landfill also appear to be contaminated with low levels of volatile organic compounds, but usually at concentrations below preliminary remediation goals. However, vinyl chloride was detected in two wells in 2000 above its preliminary remediation goal. Remediation of groundwater is being completed in accordance with the RCRA Corrective Action Program.

6.4.2 Quadrant I Groundwater Investigative Area/X-749A Classified Materials Disposal Facility

In the northern portion of Quadrant I, groundwater concerns focus on two areas: the Quadrant I Groundwater Investigative Area and the X-749A Classified Materials Disposal Facility. The X-231B Southwest Oil Biodegradation Plot is a part of the Quadrant I Groundwater Investigative Area and was monitored prior to implementation of the *Integrated Groundwater Monitoring Plan*. The X-749A was also monitored prior to implementation of the *Integrated Groundwater Monitoring Plan* under requirements for solid waste landfills.

6.4.2.1 X-231B Southwest Oil Biodegradation Plot

The X-231B Southwest Oil Biodegradation Plot was used from 1976 to 1983 for land application of contaminated oil/solvent mixtures generated from the enrichment process and maintenance activities. The X-231B area is located west of the X-600 Steam Plant, and consisted of two disposal plots, each surrounded by an elevated soil berm, which were periodically fertilized and plowed to enhance aeration and promote biological degradation of waste oil.

Three groundwater extraction wells were installed in the Gallia in 1991 as part of the X-231B interim remedial measure. These wells have a cumulative pumping rate of about 9 gal/minute. The wells are located south (downgradient) of the X-231B area. The extracted groundwater is treated at the X-622 Groundwater Treatment Facility. In 1994, soils above the groundwater were treated using *in situ* thermal enhanced vapor extraction to remove volatile organic compounds. Approximately 80% of the volatile organic compounds present in the soils were removed by this treatment. In 2000, a multimedia landfill cap was installed over this area to minimize water infiltration and control the spread of contamination. Sect. 3.2.2.3 provides additional information on this project.

Fifteen wells are sampled semiannually as part of the monitoring program for the Quadrant I Groundwater Investigative Area. An additional 20 wells are sampled annually or biennially. Table 6.1 lists the analytical parameters for the wells in this area.

6.4.2.2 X-749A Classified Materials Disposal Facility

The 6-acre X-749A Classified Materials Disposal Facility operated from 1953 through 1988 for the disposal of wastes classified under the Atomic Energy Act. Potential contaminants include PCBs, asbestos, radionuclides, and industrial waste. Closure of the landfill, completed in 1994, included the construction of a multilayer cap and the installation of a drainage system to collect surface water runoff. The drainage system discharges via a USEC NPDES-permitted outfall.

Eight wells are sampled semiannually as part of the monitoring program for the X-749A landfill. Table 6.1 lists the analytical parameters for the wells in this area.

6.4.2.3 Monitoring results for the Quadrant I Groundwater Investigative Area/X-749A in 2000

A contaminated groundwater plume consisting primarily of trichloroethene is associated with the Quadrant I Groundwater Investigative Area (see Fig. 6.3). Other volatile organic compounds are also

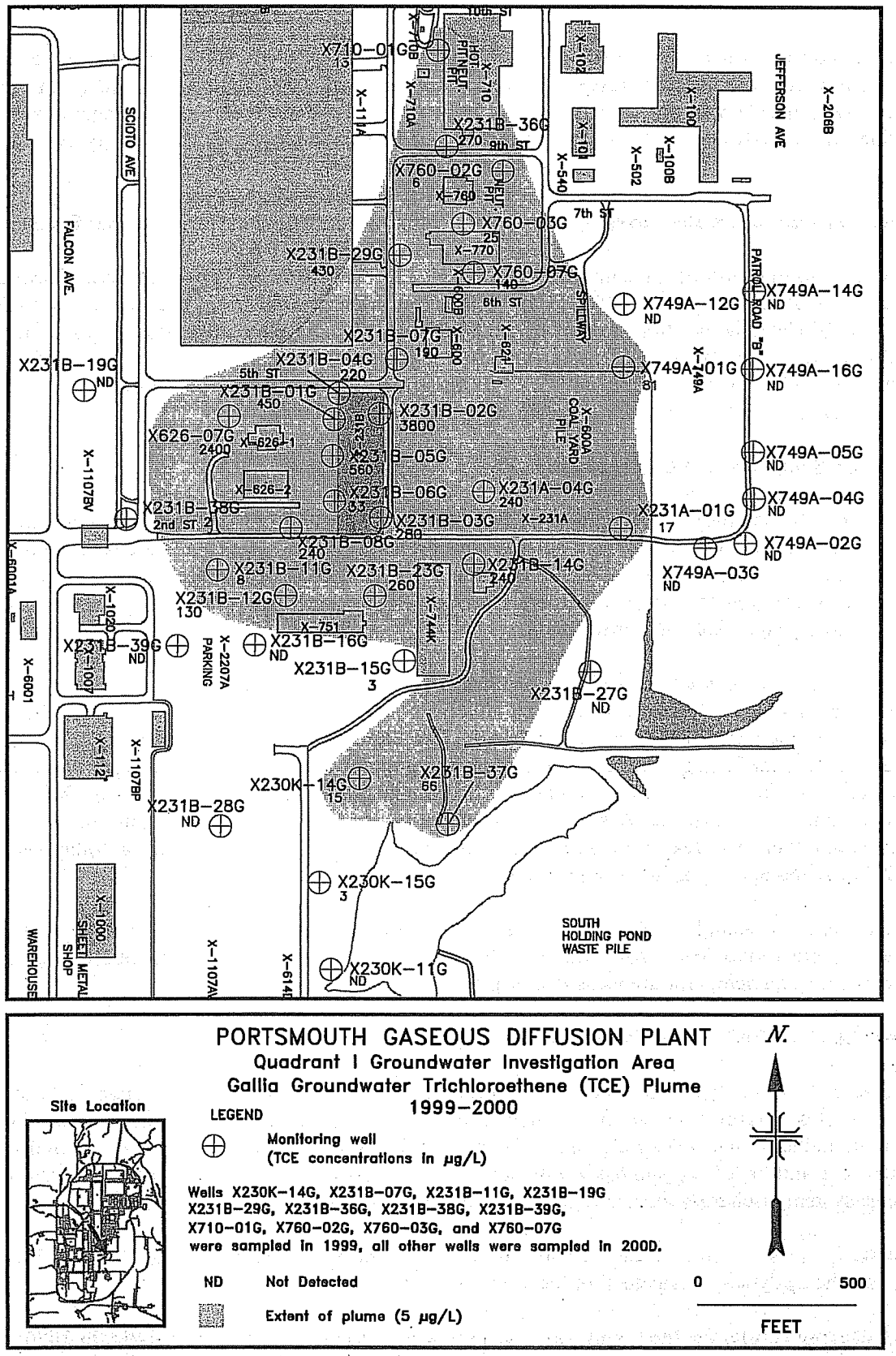


Fig. 6.3. Trichloroethene-contaminated Gallia groundwater plume at the Quadrant I Groundwater Investigative Area (1999-2000).

present in the plume. The plume shrank somewhat in 2000 because trichloroethene was not detected above 5 μg/L in well X230K-15G, which was the southernmost extent of the plume. Inorganics (metals), uranium, and technetium-99 have also been detected in the groundwater beneath the area. Remediation of groundwater is being completed in accordance with the RCRA Corrective Action Program.

Samples from selected wells (wells X231B-03G, X231B-06G, and X231B-14G) were also analyzed for transuranic radionuclides (americium-241, neptunium-237, plutonium-238, and plutonium-239/240) in the third quarter of 2000. While americium-241 was detected in the sample collected from well X231B-06G at 0.16 pCi/L, a large error (75%) is associated with this result. Additionally, no other transuranics were detected in this sample and no transuranics (including americium-241) were detected in the sample collected in this well in 1999. Therefore, the detection of americium-241 in the sample collected from well X231B-06G is considered suspect. No other transuranic radionuclides were present above detection limits.

In June 2000, DOE received a Notice of Violation from Ohio EPA concerning groundwater monitoring data collected at the X-749A landfill in 1999. The violation was associated with the statistical monitoring program at the landfill. The concentration of alkalinity detected at one of the monitoring wells in 1999 was higher than the background concentration (based on concentrations of alkalinity measured at background monitoring wells). DOE had not reported the difference because the concentration of alkalinity in this well had not shown a statistically significant increase when compared to historic data from this well and appears to result from natural variation rather than a release of hazardous constituents from the landfill. The difference became apparent only when the well became a part of the statistical monitoring program for the X-749A landfill in the second quarter of 1999 (upon implementation of the *Integrated Groundwater Monitoring Plan).*

DOE initiated an assessment monitoring program at the landfill in August 2000, which includes collecting information to support the assertion that the exceedence at this well was due to natural variation. Monitoring data collected at the X-749A landfill in 2000 were consistent with historical data.

6.4.3 Quadrant II Groundwater Investigative Area

The Quadrant II Groundwater Investigative Area consists of an area of groundwater contamination with several potential sources. One of these sources, the X-701C Neutralization Pit, was monitored prior to implementation of the *Integrated Groundwater Monitoring Plan.* The X-701C Neutralization Pit is an open-topped neutralization pit that received process effluents and basement sump wastewater such as acid and alkali solutions and rinse water contaminated with trichloroethene and/or trichloroethane from metal cleaning operations. The X-701C Neutralization Pit is located within a trichloroethene plume centered around the X-700 and X-705 buildings.

The natural groundwater flow direction in this area is to the east toward Little Beaver Creek. However, the groundwater flow pattern has been changed in this area by using sump pumps in the basement of the X-705 building. The use of the sump pumps means that the groundwater plume in this area does not spread but flows toward the sumps where it is collected and then treated at the X-622T Groundwater Treatment Facility.

Eight wells are sampled annually as part of the monitoring program for this area. An additional 16 wells are sampled biennially. Table 6.1 lists the analytical parameters for the wells in this area.

6.4.3.1 Monitoring results for the Quadrant II Groundwater Investigative Area in 2000

A contaminated groundwater plume consisting primarily of trichloroethene is associated with the Quadrant II Groundwater Investigative Area (see Fig. 6.4). The extent of this groundwater plume did not change between 1999 and 2000. Numerous other volatile organics were also detected within the plume. Inorganics (metals), uranium, and technetium-99 were also detected in 2000. Remediation of groundwater is being completed in accordance with the RCRA Corrective Action Program.

Samples from selected wells (X701-70G, X705-01G, X705-07G, and X720-01G) were also analyzed for transuranic radionuclides (americium-241, neptunium-237, plutonium-238, and plutonium-239/240). None of these radionuclides were present above detection limits.

6.4.4 X-701B Holding Pond

In the eastern portion of Quadrant II, groundwater concerns focus on three areas: the X-701B Holding Pond, the X-230J7 Holding Pond, and the X-744Y Waste Storage Yard.

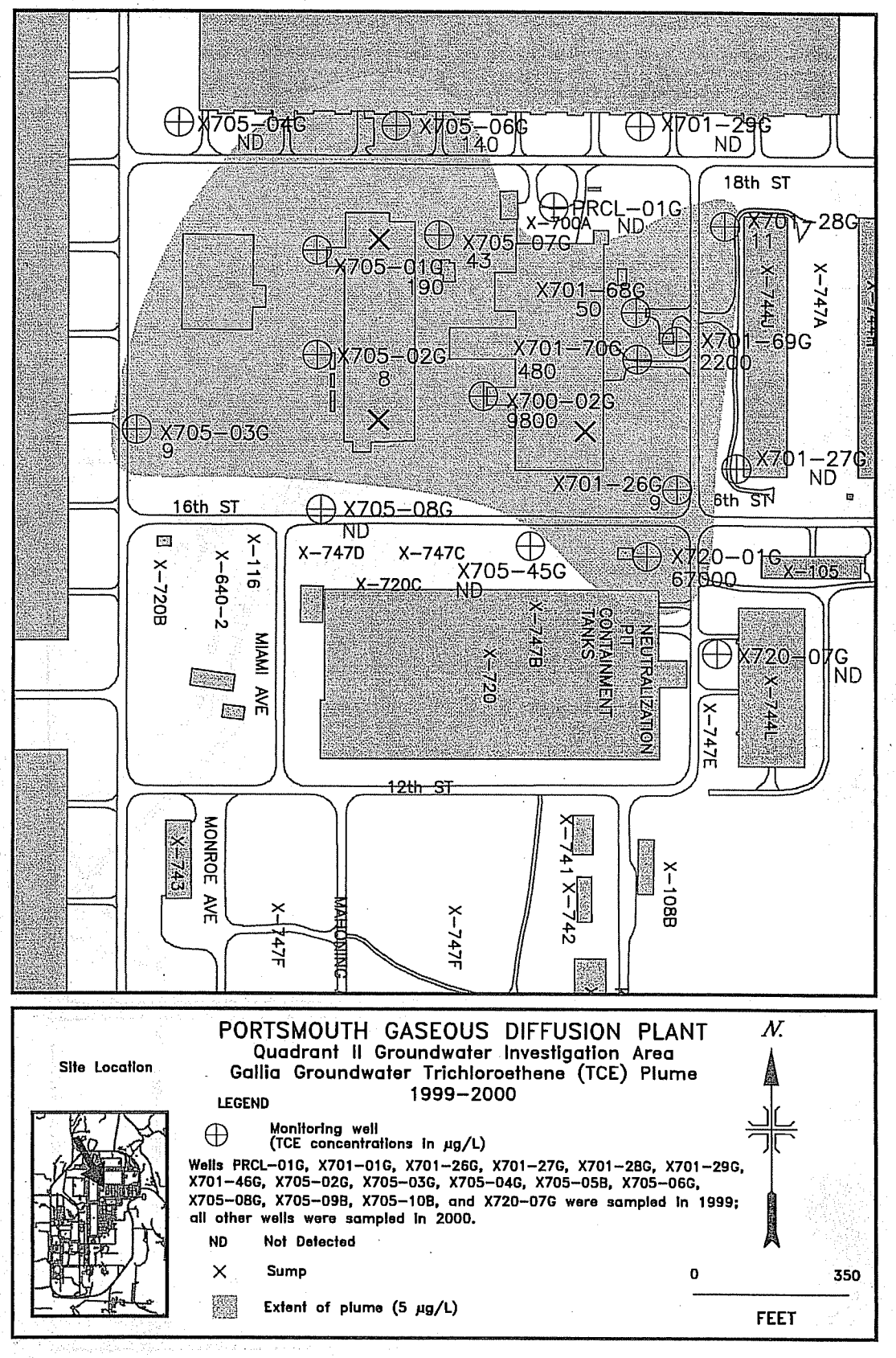
The X-701B Holding Pond was used from the beginning of plant operations in 1954 until November 1988. The pond was designed for neutralization and settlement of acid waste from several sources. Trichloroethane and trichloroethene were also discharged to the pond. Two sludge retention basins were located west of the holding pond. The X-230J7 Holding Ponds received wastewater from the X-701B Holding Pond. The X-744Y Waste Storage Yard is south of the X-701B Holding Pond. The yard is approximately 15 acres and surrounds the X-744G Bulk Storage Building. RCRA hazardous waste was managed in this area.

A contaminated groundwater plume extends from the X-701B Holding Pond to Little Beaver Creek. Three groundwater extraction wells were installed southeast of X-701B as part of the ongoing RCRA closure of the unit. These wells were designed to intercept contaminated groundwater emanating from the holding pond area before it could join the existing groundwater contaminant plume. Extracted groundwater is processed at the X-623 Groundwater Treatment Facility. This facility also processes water recovered from a shallow sump in the bottom of the X-701B Holding Pond. Two groundwater interceptor trenches (French drains) are used to intercept trichloroethene-contaminated groundwater emanating from X-701B. The X-237 Groundwater Collection System has significantly reduced trichloroethene migration into Little Beaver Creek. The 660-foot-long primary trench has two extraction wells completed in the backfill, and a 440-foot-long secondary trench intersects the primary trench. The extracted groundwater is treated at the X-624 Groundwater Treatment Facility.

Fifteen wells are sampled semiannually as part of the monitoring program for this area. An additional 17 wells are sampled annually or biennially. Table 6.1 lists the analytical parameters for the wells in this area.

6.4.4.1 Monitoring results for the X-701B Holding Pond in 2000

The trichloroethene plume at this groundwater monitoring area contains the highest concentrations of trichloroethene measured in groundwater at PORTS. Numerous other volatile organics are also detected in samples collected from the monitoring wells in this area. The plume perimeter did not change significantly from 1999 to 2000 (see Fig. 6.5).



PORTSMOUTH GASEOUS DIFFUSION PLANT
Quadrant II Groundwater Investigation Area
Gallia Groundwater Trichloroethene (TCE) Plume
1999–2000

Site Location

LEGEND

⊕ Monitoring well (TCE concentrations in µg/L)

Wells PRCL–01G, X701–01G, X701–26G, X701–27G, X701–28G, X701–29G, X701–46G, X705–02G, X705–03G, X705–04G, X705–05B, X705–06G, X705–08G, X705–09B, X705–10B, and X720–07G were sampled in 1999; all other wells were sampled in 2000.

ND Not Detected

× Sump

Extent of plume (5 µg/L)

N.

0 350

FEET

Fig. 6.4. Trichloroethene-contaminated Gallia groundwater plume at the Quadrant II Groundwater Investigative Area (1999-2000).

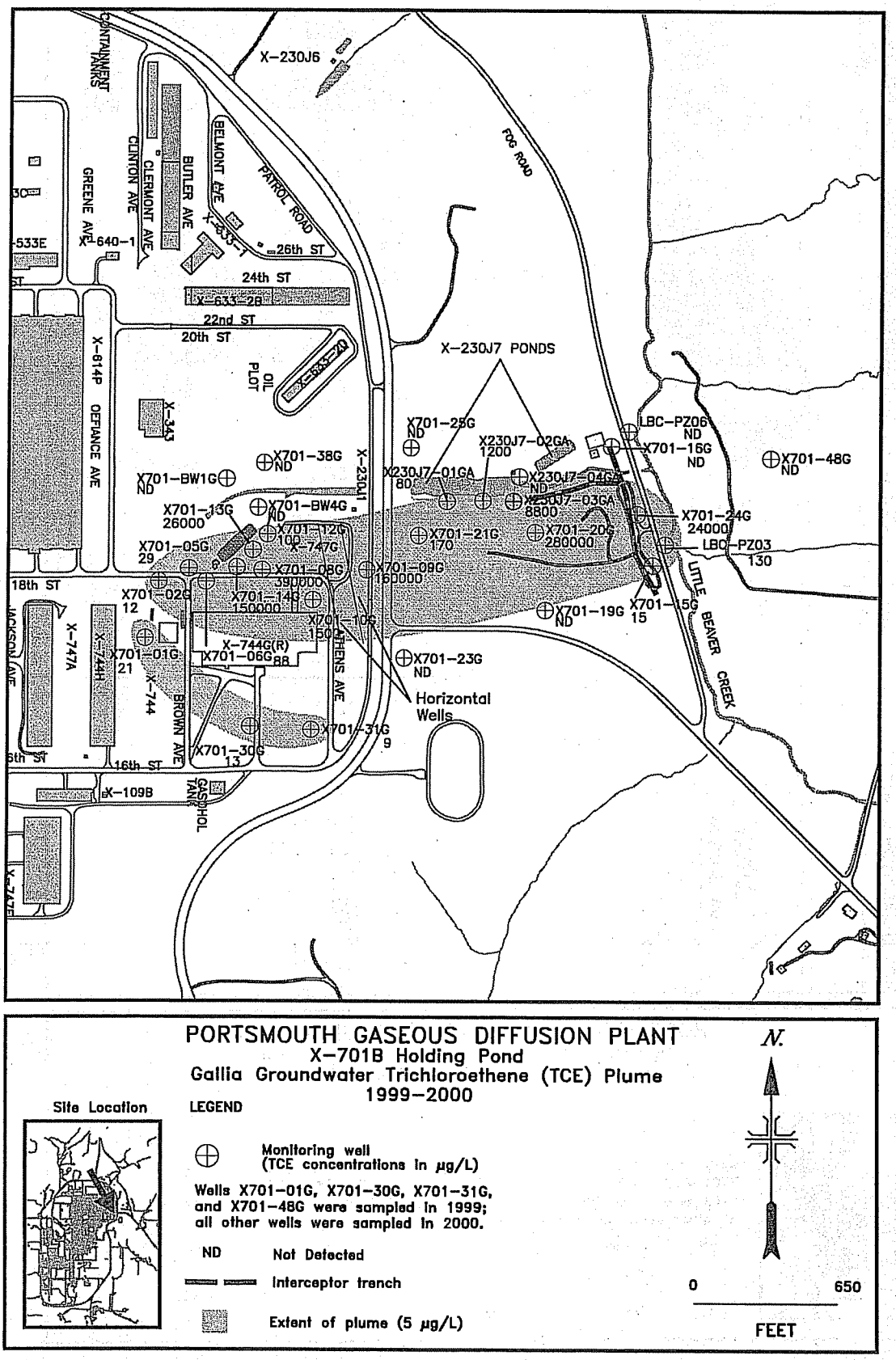


Fig. 6.5. Trichloroethene-contaminated Gallia groundwater plume at the X-701B Holding Pond (1999-2000).

A second trichloroethene plume at the X-701B monitoring area was identified in 1998 and continued to be detected in 2000 in the X-744Y Waste Storage Yard area. This apparently isolated and crescent-shaped plume is believed to be separate from and unrelated to the X-701B Holding Pond plume. Flow data for this new plume indicate the flow direction is to the northeast, or toward the main X-701B plume. This flow data and historical sampling data support the theory that this new plume is unrelated to the primary X-701B plume. Inorganics (metals) and radiological constituents (uranium and technetium-99) are also detected in the groundwater in this area. Remediation of groundwater is being completed in accordance with the RCRA Corrective Action Program.

Samples from selected wells (X701-13G, X701-14G, X701-16G, X701-24G, and X701-BW4G) were also analyzed for americium-241, neptunium-237, plutonium-238, and plutonium-239/240 in the third quarter of 2000. None of these radionuclides were present above detection limits.

6.4.5 X-616 Chromium Sludge Surface Impoundments

The X-616 Chromium Sludge Surface Impoundments are two unlined surface impoundments used from 1976 to 1985 for storage of sludge generated by the treatment of water from the PORTS process cooling system. A corrosion inhibitor containing chromium was used in the cooling water system. Sludge containing chromium was produced by the water treatment system and was pumped into and stored in the X-616 impoundments. The sludge was removed from the impoundments and remediated as an interim action in 1990 and 1991. The unit was certified closed in 1993. Six wells are sampled annually and 10 wells are sampled biennially as part of the monitoring program for this area. Table 6.1 lists the analytical parameters for the wells in this area.

6.4.5.1 Monitoring results for the X-616 Chromium Sludge Surface Impoundments in 2000

Chromium is of special concern at the X-616 because of the previous use of the area. Chromium was detected in one of the six wells sampled in 2000: well X616-05G at 3360 μg/L, which exceeded the preliminary remediation goal for chromium of 100 μg/L. Concentrations of chromium detected in this well have exceeded the preliminary remediation goal in previous years as well. Fig. 6.6 shows the concentrations of chromium in wells at the X-616.

Volatile organic compounds were detected at low levels in samples collected from three wells at this area. The only volatile organic detected above its preliminary remediation goal was trichloroethene. Remediation of groundwater is being completed in accordance with the RCRA Corrective Action Program.

6.4.6 X-740 Waste Oil Handling Facility

The X-740 Waste Oil Handling Facility, which is located on the western half of PORTS south of the X-530A Switchyard, consists of two hazardous waste management units: the X-740 Waste Storage Facility and the X-740 Hazardous Waste Storage Tank (sump) located within the building. The X-740 Waste Oil Handling Facility operated from 1983 until 1991; the tank/sump was only operated until 1990. The units were initially identified as hazardous waste management units in 1991. The unit underwent closure, and closure certification was approved by Ohio EPA in 1998.

Constructed in 1982, the facility consists of a diked concrete pad, a roof, corrugated steel siding on three sides, and a plastic windbreak on the fourth side. The unit is approximately 120-ft by 50-ft. During its period of operation, the facility was used as an inventory and staging facility for waste oil and waste

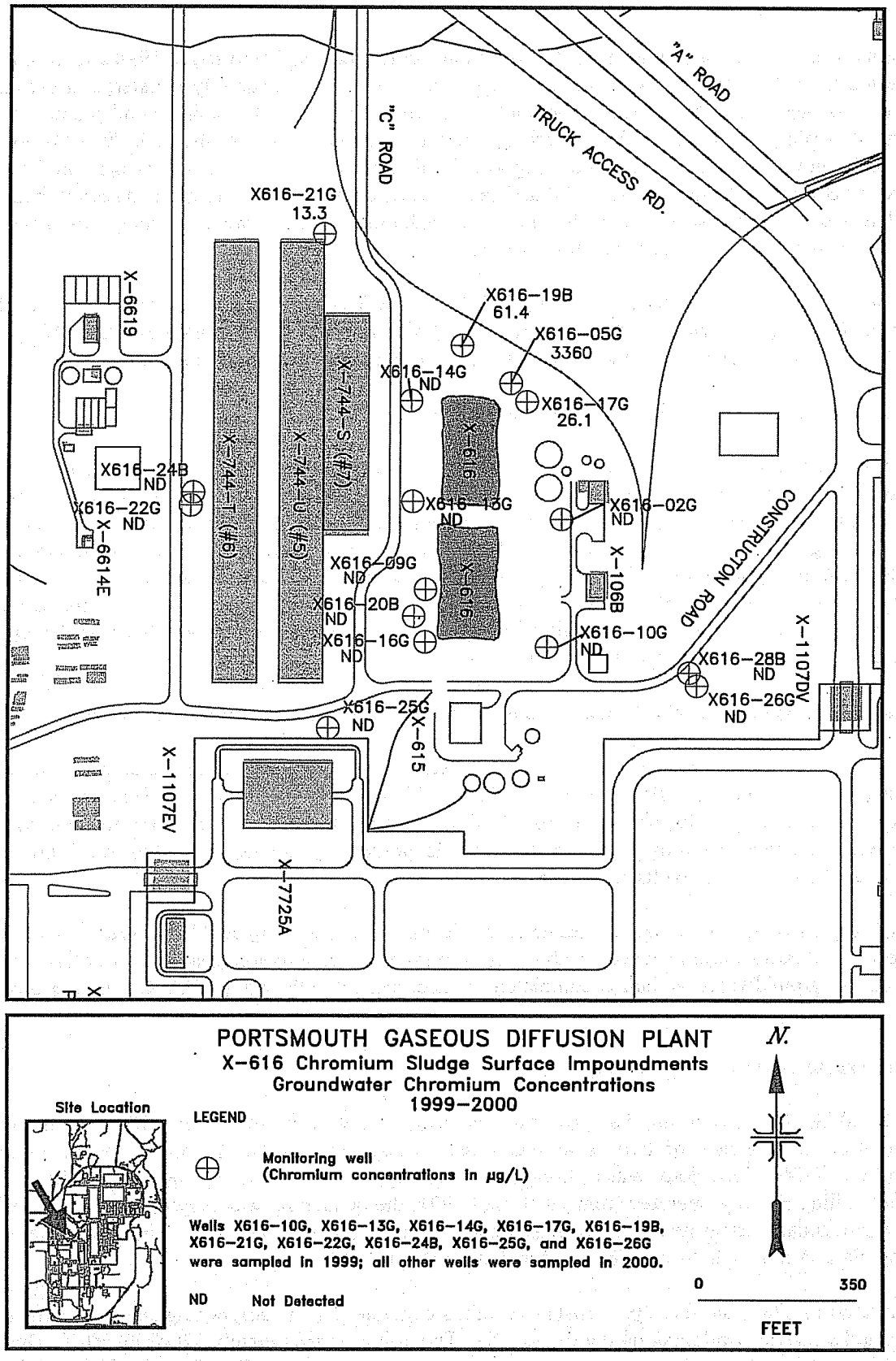


Fig. 6.6. Chromium concentrations in groundwater at the X-616 Chromium Sludge Surface Impoundments (1999-2000).

solvents that were generated from various plant operational and maintenance activities. The drums were staged at the facility pending analysis of their contents and subsequent final disposition. Empty drums, resulting from combining partially full drums, were crushed in a hydraulic drum crusher located in the X-740 Waste Oil Handling Facility. The tank/sump was installed in 1986 and was used to collect residual waste oil and waste solvents from the drum crushing operation. No drainage system was associated with the tank/sump area.

In 1999, poplar trees were planted in the area of the groundwater plume near the X-740 Waste Oil Handling Facility. This remediation technique, called phytoremediation, uses plants to remove or degrade contaminants in soil and groundwater. Sect. 3.2.2.1 provides additional information on this project.

Fifteen wells are part of the monitoring program for this area, including four new wells that were added to the program in the fourth quarter of 2000. Table 6.1 lists the analytical parameters for the wells in this area.

6.4.6.1 Monitoring results for the X-740 Waste Oil Handling Facility in 2000

A contaminated groundwater plume consisting primarily of trichloroethene is associated with the X-740 Waste Oil Handling Facility (see Fig. 6.7). The volatile organic compounds detected in 2000 were restricted to the previously defined plume perimeter. Remediation of these constituents is proceeding as part of the RCRA Corrective Action Program. Chap. 3, Sect. 3.2.2.1, describes the phytoremediation project at the X-740 area.

Several metals and uranium were also detected in samples collected in 2000, but the concentrations of these constituents are below the established preliminary remediation goals.

6.4.7 X-611A Former Lime Sludge Lagoons

The X-611A Former Lime Sludge Lagoons are three adjacent unlined sludge retention lagoons constructed in 1954 and used for disposal of lime sludge waste from the site water treatment plant from 1954 to 1960. The lagoons, which had a capacity of approximately 295,000 cubic yards, cover a surface area of approximately 18 acres. The lagoons were constructed in a low-lying area that included Little Beaver Creek. As a result, approximately 1500 feet of Little Beaver Creek was relocated to a channel just east of the lagoons.

As part of the RCRA Corrective Action Program, a prairie habitat has been developed at this area by placing a soil cover over the north, middle, and south lagoons. A soil berm was also constructed outside the northern boundary of the north lagoon to facilitate shallow accumulation of water in this low-lying area. Six wells are sampled semiannually as part of the monitoring program for this area. Table 6.1 lists the analytical parameters for the wells in this area.

6.4.7.1 Monitoring results for the X-611A Former Lime Sludge Lagoons in 2000

The six monitoring wells at X-611A (see Fig. 6.8) are sampled and analyzed for beryllium and chromium. Chromium was detected in one well (F-07G) in 2000 at concentrations less than the preliminary remediation goal. Beryllium was detected in samples collected from three of the X-611A monitoring wells in 2000.

Samples collected from the wells in the third quarter of 2000 were also analyzed for total uranium and uranium isotopes (uranium-233/234, uranium-235, uranium-236, and uranium-238).

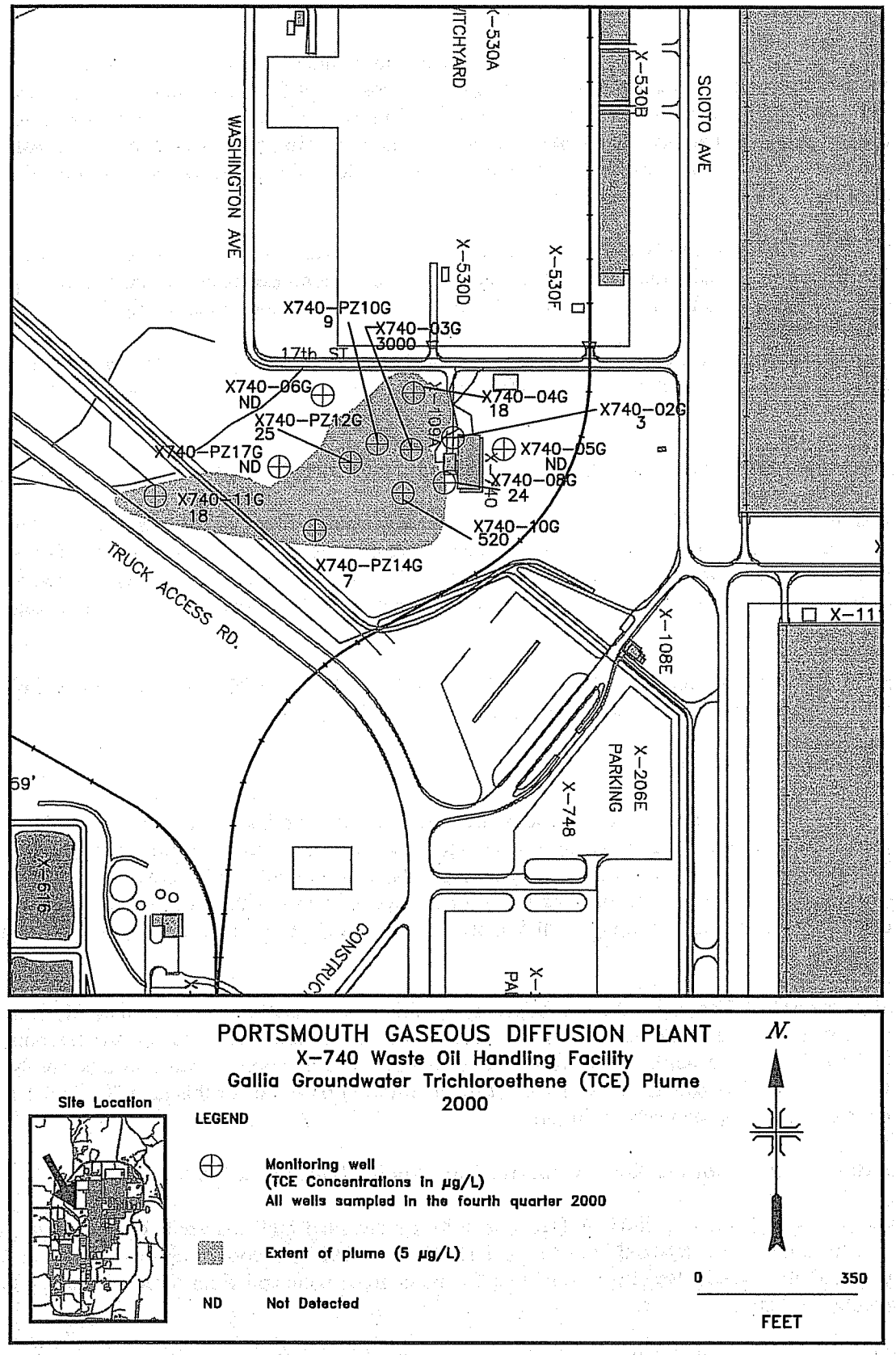


Fig. 6.7. Trichloroethene-contaminated Gallia groundwater plume near the X-740 Waste Oil Handling Facility (2000).

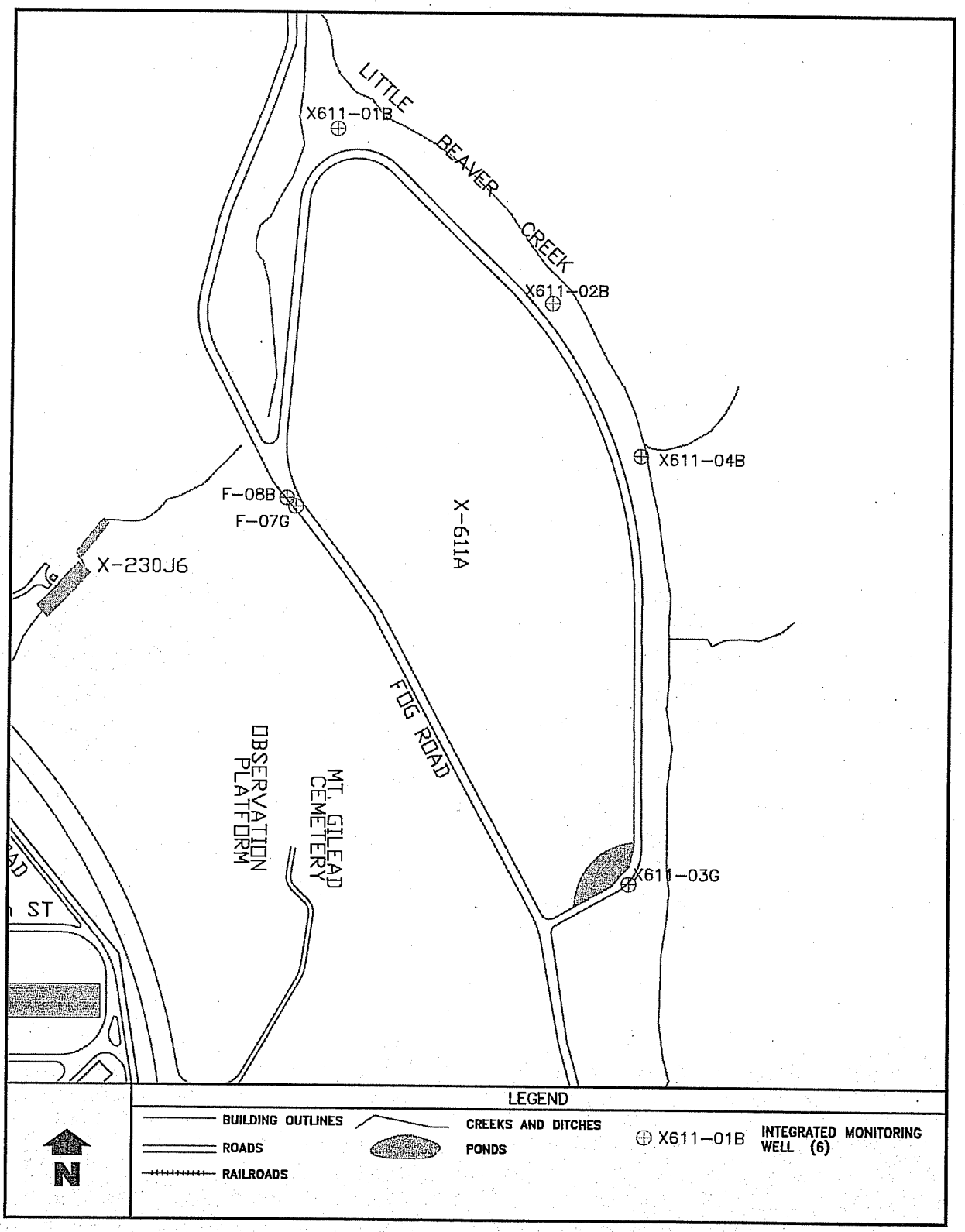


Fig. 6.8. Monitoring wells at the X-611A Former Lime Sludge Lagoons.

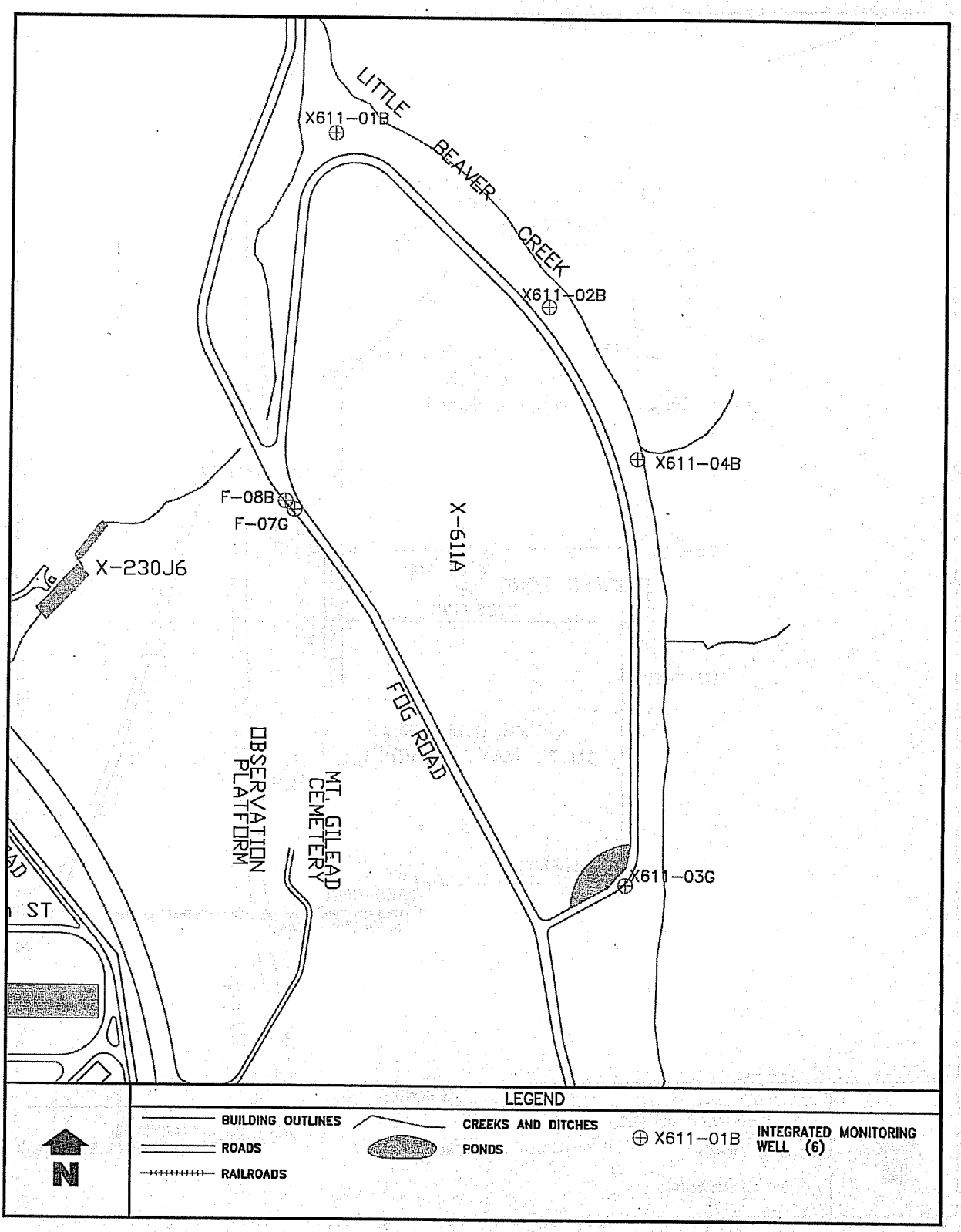


Fig. 6.8. Monitoring wells at the X-611A Former Lime Sludge Lagoons.

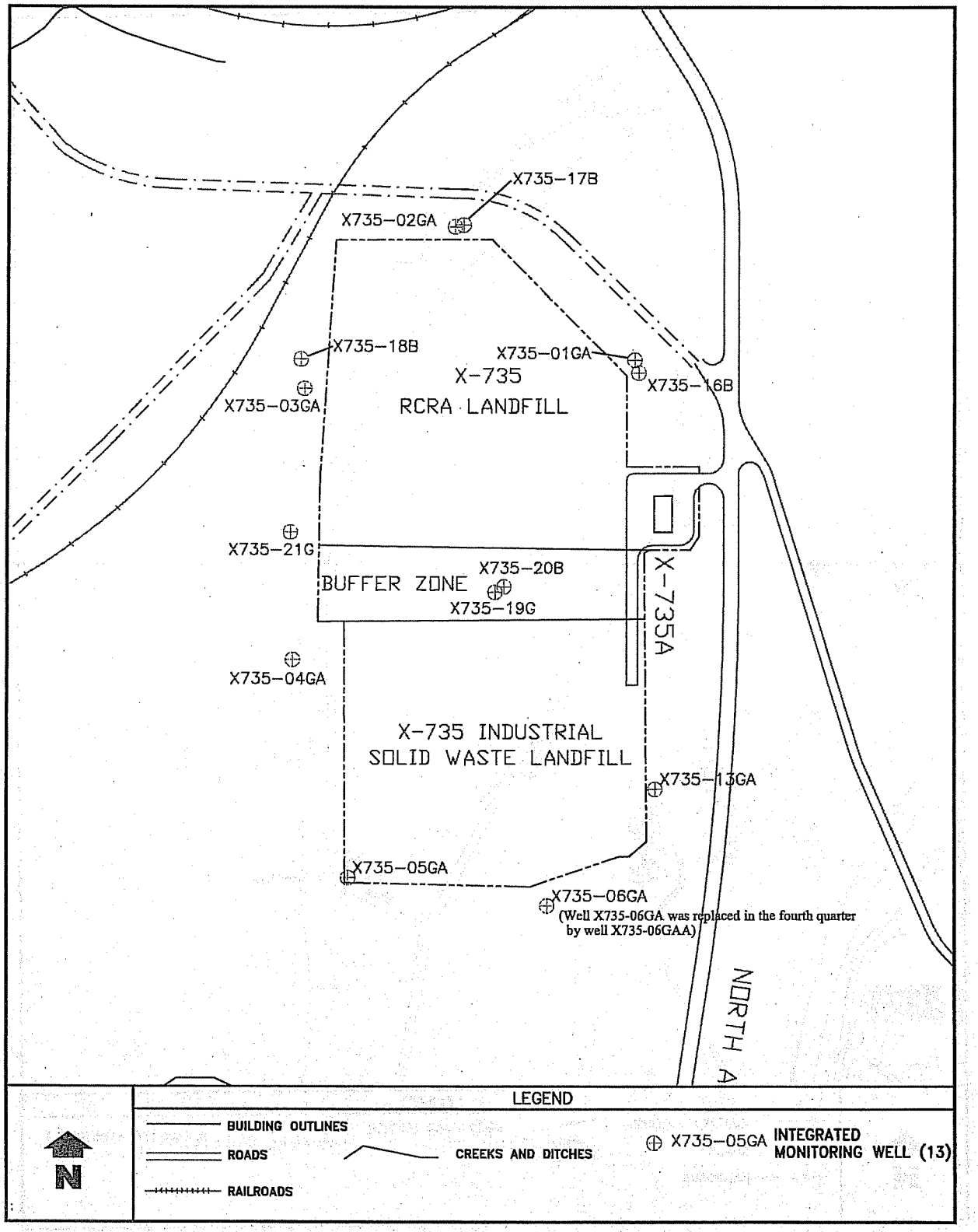


Fig. 6.9. Monitoring wells at the X-735 Landfills.

Industrial Solid Waste Landfill were combined under the *Integrated Groundwater Monitoring Plan* in the second quarter of 1999.

DOE initiated an assessment monitoring program at the landfill in August 2000, which includes collecting information to support the assertion that the exceedences at the wells were due to natural variation. Monitoring data collected at the X-735 Landfills in 2000 were consistent with historical data.

6.4.9 Surface Water Monitoring

Surface water monitoring is conducted in conjunction with groundwater assessment monitoring to determine if contaminants present in groundwater are detected in surface water samples. Surface water is collected quarterly from 13 locations (see Fig. 6.10). The purpose for each surface water monitoring location is listed below:

- Little Beaver Creek and East Drainage Ditch sample locations LBC-SW01, LBC-SW02, and EDD-SW01 assess possible X-701B area plume groundwater discharges.

- Little Beaver Creek sample location LBC-SW03 assesses potential contamination from the X-611A Lime Sludge Lagoons.

- Big Run Creek sample locations BRC-SW01 and BRC-SW02 monitor for potential groundwater discharges related to the X-231B Southwest Oil Biodegradation Plot, the Quadrant I Groundwater Investigative Area plume, and the X-749/X-120/PK Landfill area plume, all of which discharge into the X-230K Holding Pond and Big Run Creek.

- The unnamed Southwestern Drainage Ditch is sampled at two locations, UND-SW01 and UND-SW02, to assess potential groundwater releases to this creek and the X-2230M Holding Pond from the X-749/X-120/PK Landfill area plume.

- The North Holding Pond sample locations NHP-SW01 and LBC-SW04 assess potential groundwater discharges from any unknown Quadrant IV sources.

- The West Drainage Ditch sample locations WDD-SW01, WDD-SW02, and WDD-SW03 assess potential groundwater discharges from the X-616 area to the West Drainage Ditch and the X-2230N Holding Pond.

Table 6.1 lists the analytical parameters for the surface water sampling locations.

6.4.9.1 Monitoring results for surface water in 2000

No volatile organic compounds were detected at the surface water sampling locations in Big Run Creek, Little Beaver Creek, East Drainage Ditch, or North Holding Pond during 2000, with the exception of small amounts of chloroform and other trihalomethanes that are common residuals in treated chlorinated drinking water. These streams receive discharges that contain treated drinking water from the PORTS NPDES outfalls. Trichloroethene has been detected regularly in samples collected from the unnamed Southwestern Drainage Ditch (UND-SW01, located inside the perimeter road) at low levels since 1990 and was detected in 2000 at 2 - 4 μg/L. Trichloroethene was not detected at the sampling location downstream from UND-SW01 (UND-SW02), however, which indicates that trichloroethene is not present in the surface water exiting the PORTS site.

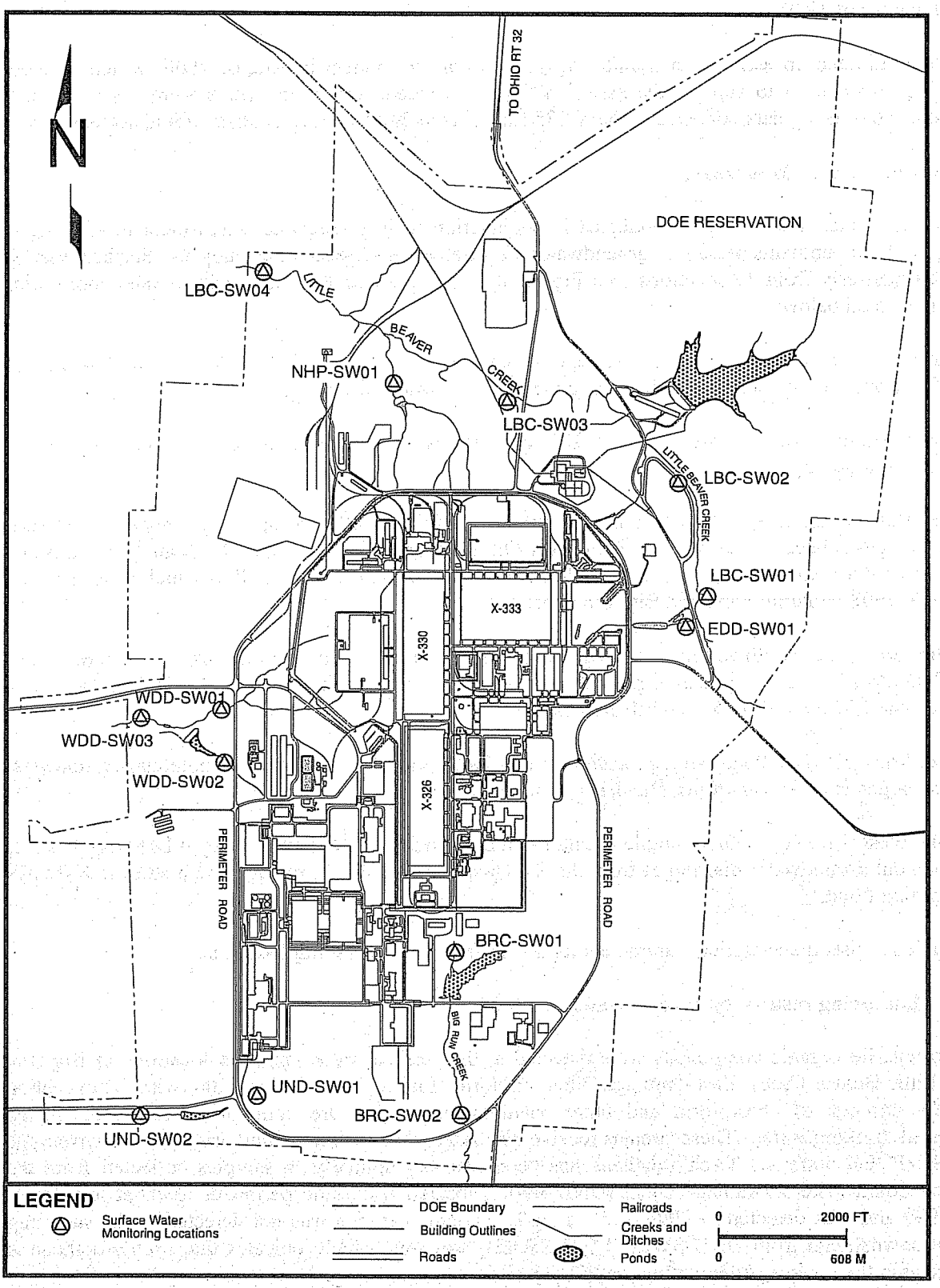


Fig. 6.10. Surface water monitoring locations.

Uranium occurs naturally in rocks and soil, which may account for the low uranium concentrations that were detected below preliminary remediation goals at many surface water sampling locations in 2000. Technetium-99 was detected at 13 pCi/L in the sample collected from the North Holding Pond (NHP-SW01) in the fourth quarter of 2000, but was not detected at this location or any other locations in any other quarter in 2000. Additional radiological analyses for americium-241, neptunium-237, plutonium-238, and plutonium-239/240 were performed on each sample collected in the second quarter and fourth quarter of 2000. These radionuclides were not detected in the samples.

6.4.10 Residential Water Supply Monitoring

Routine monitoring of residential drinking water sources is completed at PORTS in accordance with the requirements of Section VIII of the September 1989 Consent Decree between the State of Ohio and DOE and the Residential Groundwater Monitoring Requirements contained in the *Integrated Groundwater Monitoring Plan.*

The purpose of the program is to determine whether residential drinking water sources have been adversely affected by plant operations. Although this program may provide an indication of contaminant transport off site, it should not be interpreted as an extension of the on-site groundwater monitoring program, which bears the responsibility for detection of contaminants and determining the rate and extent of contaminant movement. Data from this program will not be used in environmental investigations due to the lack of knowledge of how residential wells were constructed and due to the presence of various types of pumps (which may not be ideal equipment for sampling).

Four residential drinking water sources participating in the program (see Fig. 6.11) are sampled semiannually for the parameters listed in Table 6.1. The PORTS water supply is also sampled as part of this program. Sampling locations may be added or deleted as resident requests and program requirements dictate. Typically, sampling locations are deleted when a resident obtains a public water supply. One residential drinking water supply was deleted from the program in 2000 because the resident obtained a public water supply. Sampling locations are added upon request if there is a probable hydrogeologic connection between PORTS and the resident's water supply.

Sampling results for 2000 indicate that DOE/PORTS operations have not affected the PORTS water supply or residential water supplies sampled as part of this monitoring program. Volatile organic compounds were not detected in any of the water supply samples. Metals detected in the water supply samples were within naturally-occurring concentrations found in the area. Low levels of uranium and uranium isotopes detected in some of the wells are consistent both with naturally-occurring concentrations found in common geologic materials and the inherent level of error associated with laboratory analytical capabilities. Americium-241, neptunium-237, plutonium-238, plutonium-239/240, and technetium-99 were not detected in any of the water supply samples.

6.5 DOE ORDER MONITORING PROGRAMS

The surveillance monitoring program at DOE/PORTS consists of exit pathway monitoring and baseline monitoring. Exit pathway monitoring assesses the effect of the facility on regional groundwater quality and quantity. Baseline monitoring is conducted to establish baseline data.

6.5.1 Exit Pathway Monitoring

Selected locations on local streams and drainage channels near the reservation boundary are sampling points of the exit pathway monitoring program because groundwater discharges to these surface

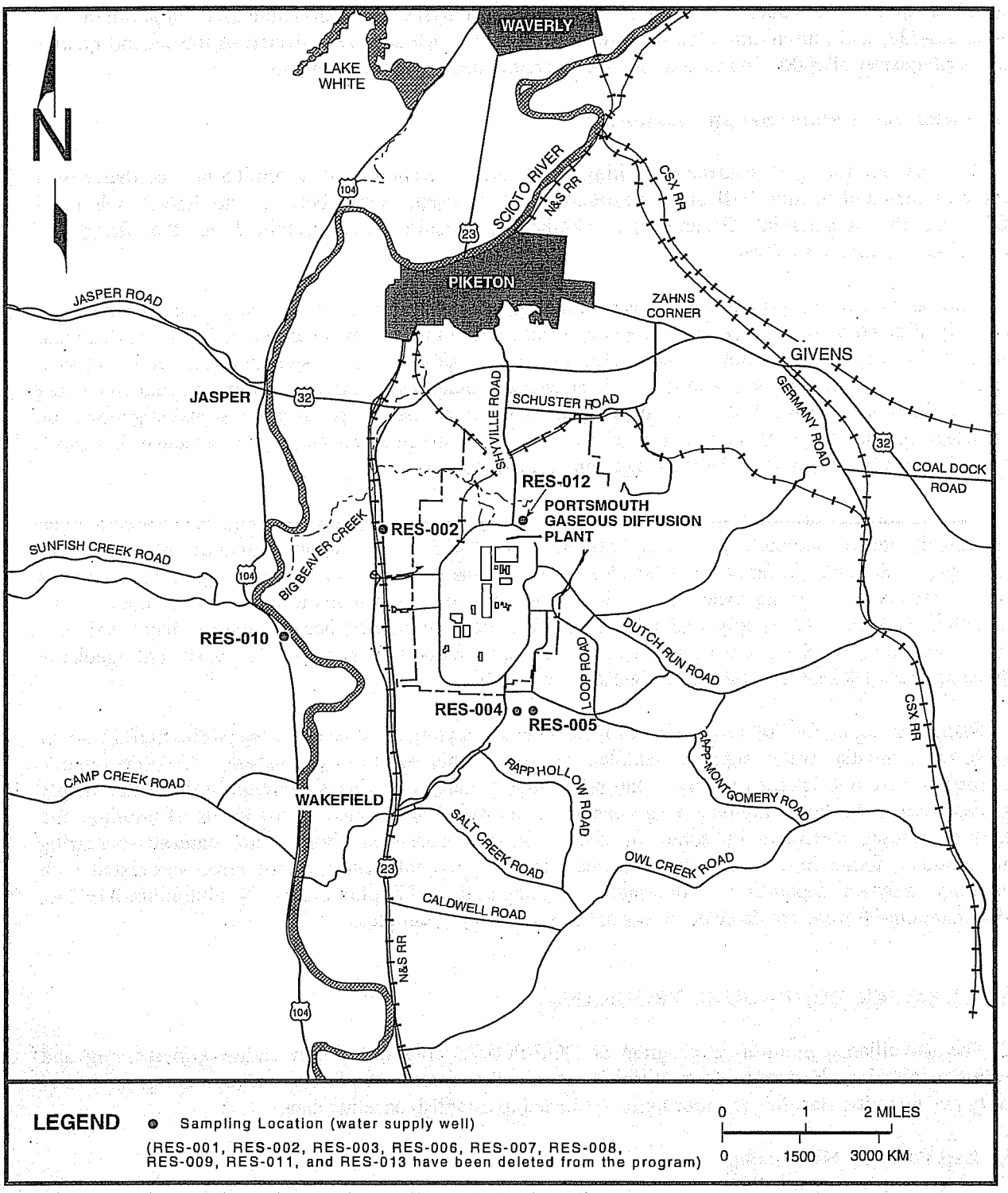


Fig. 6.11. Residential water supply monitoring locations.

waters. Monitoring wells near the reservation boundary are also used in the exit pathway monitoring program. In 2000, six new wells were installed at the southern boundary of the PORTS reservation in the X-749/X-120/PK Landfill groundwater monitoring area to monitor the DOE property boundary. These new wells are also considered part of the exit pathway monitoring program. Fig. 6.12 shows the sampling locations for exit pathway monitoring.

Four surface water sampling points (BRC-SW01, LBC-SW01, UND-SW02, and WDD-SW03) are part of the exit pathway monitoring program. No volatile organic compounds, technetium-99, or transuranics were detected in the samples collected from these points. Metals, including uranium, were detected at concentrations consistent with background concentrations for these parameters.

In 2000, trichloroethene was detected in two of the exit pathway groundwater monitoring wells (X749-44G and X749-45G) at concentrations of 2-3 μg/L, which is below the preliminary remediation goal of 5 μg/L. Trichloroethene was not detected in the samples collected from any of the six new monitoring wells installed by the DOE property boundary, which indicates that the trichloroethene plume has not moved off site. Technetium-99 was not detected in any of the exit pathway groundwater monitoring wells. Samples from the six new wells were also analyzed from transuranic radionuclides americium-241, neptunium-237, plutonium-238, and plutonium-238, and plutonium-239/240. These radionuclides were not detected in the samples.

6.5.2 Baseline Monitoring

Four well clusters, each composed of one well completed in the Gallia and one well completed in the Berea, are sampled annually to determine baseline water quality (Fig. 6.12). Sampling is conducted to provide a comparison between on-site wells and wells that represent background water quality.

6.6 GROUNDWATER TREATMENT FACILITIES

In 2000, a combined total of approximately 20.7 million gallons of contaminated water was treated at the X-622, X-622T, X-623, X-624, and X-625 Groundwater Treatment Facilities. Approximately 129 gallons of trichloroethene were removed from the groundwater. All processed water is discharged through NPDES outfalls before exiting PORTS. Less water was treated in 2000 than in 1999 (24.7 million gallons) due to variations in groundwater recovery. Facility information is summarized in Table 6.2.

Table 6.2. Summary of trichloroethene removed by DOE/PORTS groundwater treatment facilities in 2000

Facility	Gallons of water treated	Gallons of trichloroethene removed
X-622	5,985,360	1
X-622T	10,416,060	11
X-623	1,641,454	85
X-624	2,615,096	32
X-625	38,663	0.003

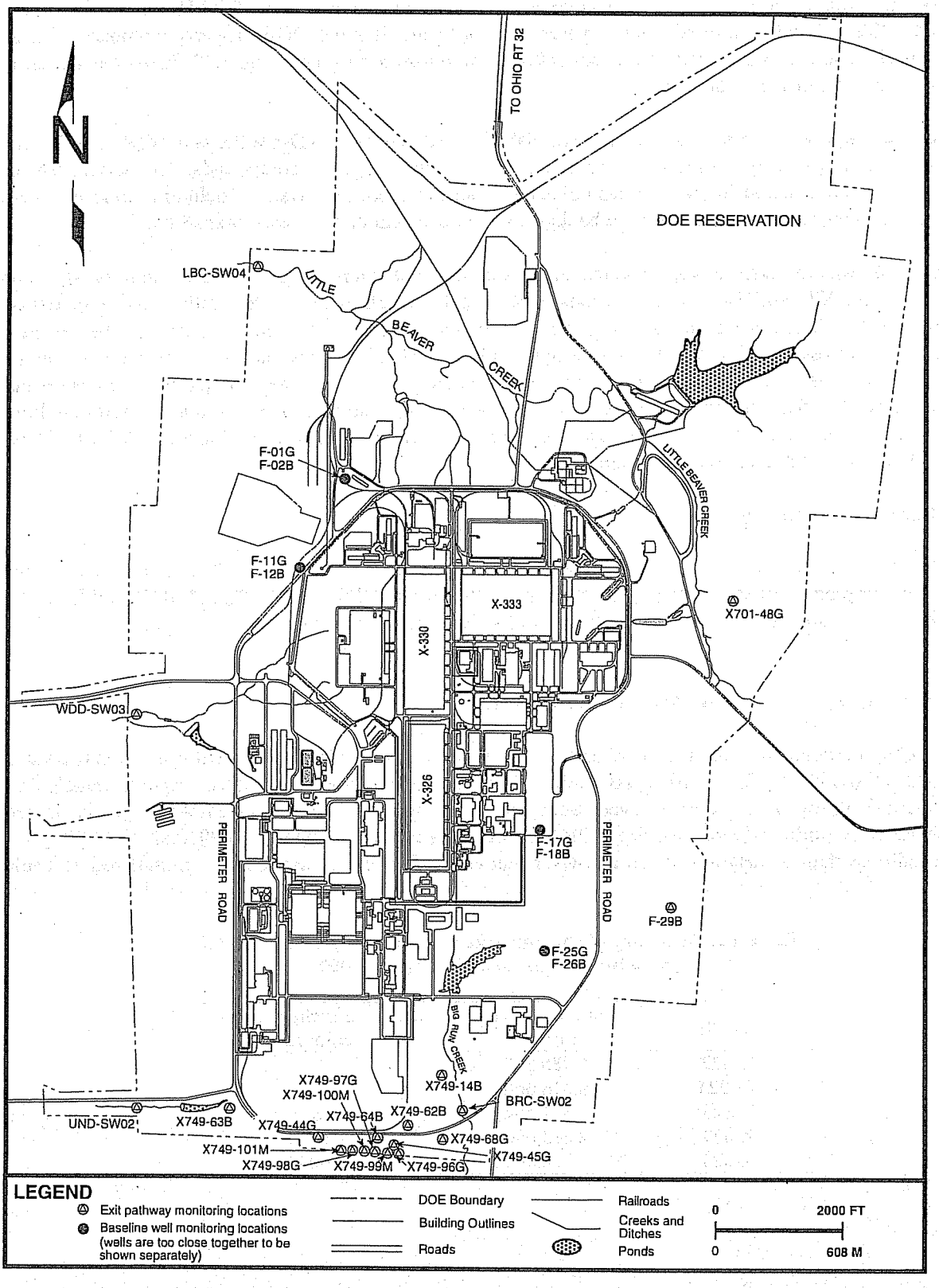


Fig. 6.12. Exit pathway and baseline monitoring locations.

6.6.1 X-622 Groundwater Treatment Facility

Activated carbon and green sand filtration are used to treat water at the X-622 Groundwater Treatment Facility. This facility processes groundwater from the Quadrant I Groundwater Investigative Area and the X-749 Contaminated Materials Disposal Facility/X-120 Old Training Facility/PK Landfill groundwater collection systems and releases the treated water through DOE/PORTS NPDES Outfall 608. In 2000, the unit processed almost 6 million gallons of groundwater, removing 1 gallon of trichloroethene from the water.

6.6.2 X-622T Groundwater Treatment Facility

At the X-622T Groundwater Treatment Facility, activated carbon is used to treat contaminated groundwater from the X-700 and X-705 buildings. These buildings are located above the Quadrant II Groundwater Investigative Area plume, and contaminated groundwater is extracted from sumps located in the basement of each building. The treated water is released through DOE/PORTS NPDES Outfall 611. In 2000, approximately 10.4 million gallons of groundwater were processed, thereby removing 11 gallons of trichloroethene from the water.

6.6.3 X-623 Groundwater Treatment Facility

The X-623 Groundwater Treatment Facility consists of an air stripper with offgas activated carbon filtration and aqueous-phase activated carbon filtration. The X-623 Groundwater Treatment Facility treats trichloroethene-contaminated groundwater from the X-701B Holding Pond and groundwater extraction wells in the X-701B plume area and releases the treated water through DOE/PORTS NPDES Outfall 610. The facility treated approximately 1.6 million gallons of water in 2000, thereby removing 85 gallons of trichloroethene from the water.

6.6.4 X-624 Groundwater Treatment Facility

At the X-624 Groundwater Treatment Facility, groundwater is treated via an air stripper with offgas activated carbon filtration and aqueous-phase activated carbon filtration. This facility processes trichloroethene-contaminated groundwater from the X-237 interceptor trench associated with the X-701B plume and releases the treated water through DOE/PORTS NPDES Outfall 015. The facility treated approximately 2.6 million gallons of water in 2000, thereby removing 32 gallons of trichloroethene from the water.

6.6.5 X-625 Groundwater Treatment Facility

Groundwater is gravity-fed from a horizontal well associated with the X-749/X-120 groundwater plume to the X-625 Groundwater Treatment Facility. As part of an ongoing technology demonstration, water at this facility has been treated with various passive media such as iron filings. The water is further treated by being passed through activated carbon filtration prior to being discharged from the facility, combined with other wastewaters, and released through DOE/PORTS NPDES Outfall 012. In 2000, approximately 39,000 gallons of groundwater were treated, thereby removing 0.003 gallon of trichloroethene.

7. QUALITY ASSURANCE

7.1 SUMMARY

Quality assurance and quality control are essential components of environmental monitoring at DOE/PORTS. Quality is integrated into sample preservation, field data and sample collection, sample transportation, and sample analysis. Numerous program assessment activities in the field and within the facilities are conducted at regular intervals to demonstrate that quality is built into and maintained in all DOE/PORTS programs.

7.2 INTRODUCTION

Quality assurance, an integral part of environmental monitoring, requires systematic control of the processes involved in sampling the environment and in analyzing the samples. To demonstrate accurate results, DOE/PORTS uses the following planned and systematic controls:

- implementation of standard operating procedures for sample collection and analysis;
- training and qualification of surveyors and analysts;
- implementation of sample tracking and chain-of-custody procedures to demonstrate traceability and integrity of samples and data;
- participation in external quality control programs;
- frequent calibration and routine maintenance of measuring and test equipment;
- maintenance of internal quality control programs;
- implementation of good measurement techniques and good laboratory practices; and
- frequent assessments of field sampling, measurement activities, and laboratory processes.

Environmental sampling is conducted at DOE/PORTS in accordance with state and federal regulations. Sampling plans and procedures are prepared, and appropriate sampling instruments or devices are selected in accordance with practices recommended by the U.S. EPA, the American Society for Testing and Materials, or other authorities. Chain-of-custody documentation is prepared from the point of sampling. The samples remain in the custody of the sampling group until they are transferred to the sample custodian at the chosen laboratory.

The analytical data are reviewed to determine compliance with applicable regulations and permits. The data are used to identify locations and concentrations of contaminants of concern, to evaluate the rate and extent of contamination at the site, and to help determine the need for remedial action. Adequate and complete documentation generated as a result of these efforts support the quality standards established at DOE/PORTS.

7.3 FIELD SAMPLING AND MONITORING

Personnel involved in field sampling and monitoring are properly trained. Procedures are developed from guidelines and regulations created by DOE or other regulatory agencies that have authority over DOE/PORTS activities. These procedures specify sampling protocol, sampling devices, and containers and preservatives to be used. Chain-of-custody procedures (used with all samples) are documented, and samples are controlled and protected from the point of collection to the generation of analytical results.

Data generated from field sampling can be greatly influenced by the methods used to collect and transport the samples. A quality assurance program provides the procedures for proper sample collection so that the samples represent the conditions that exist in the environment at the time of sampling. The DOE/PORTS quality assurance program mandates compliance with written sampling procedures, use of clean sampling devices and containers, use of approved sample preservation techniques, and collection of field blanks, trip blanks, and duplicate samples. Chain-of-custody procedures are strictly followed to maintain sample integrity. In order to maintain sample integrity, samples are delivered to the laboratory as soon as practicable after collection.

7.4 ANALYTICAL QUALITY ASSURANCE

DOE/PORTS only uses analytical laboratories that demonstrate compliance in the following areas through participation in independent audits and surveillance programs:

- compliance with federal waste disposal regulations,
- data quality,
- materials management,
- sample control,
- data management,
- electronic data management,
- implementation of a laboratory quality assurance plan, and
- review of external and internal performance evaluation program.

After it is received by DOE/PORTS, analytical laboratory data is independently evaluated using a systematic process that compares the data to established quality assurance/quality control criteria. An independent data validator checks documentation produced by the analytical laboratory to verify that the laboratory has provided data that meets established criteria.

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APPENDIX A

RADIATION

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This appendix presents basic facts concerning radiation. The information is intended as a basis for understanding the dose associated with releases from DOE/PORTS, not as a comprehensive discussion of radiation and its effects on the environment and biological systems. *The McGraw-Hill Dictionary of Scientific and Technical Terms* defines radiation and radioactivity as follows.

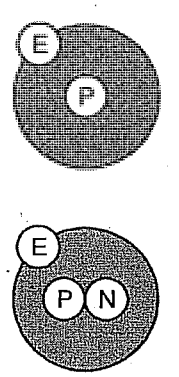
> *radiation* — (1) The emission and propagation of waves transmitting energy through space or through some medium; for example, the emission and propagation of electromagnetic, sound, or elastic waves. (2) The energy transmitted through space or some medium; when unqualified, usually refers to electromagnetic radiation. Also known as radiant energy. (3) A stream of particles, such as electrons, neutrons, protons, alpha particles, or high-energy photons, or a mixture of these (McGraw-Hill 1989).

> *radioactivity*—A particular type of radiation emitted by a radioactive substance, such as alpha radioactivity (McGraw-Hill 1989).

Radiation occurs naturally; it was not invented but discovered. People are constantly exposed to radiation. For example, radon in air, potassium in food and water, and uranium, thorium, and radium in the earth's crust are all sources of radiation. The following discussion describes important aspects of radiation, including atoms and isotopes; types, sources, and pathways of radiation; radiation measurement; and dose information.

A.1 ATOMS AND ISOTOPES

All matter is made up of atoms. An atom is "a unit of measure consisting of a single nucleus surrounded by a number of electrons equal to the number of protons in the nucleus" (American Nuclear Society 1986). The number of protons in the nucleus determines an element's atomic number, or chemical identity. With the exception of hydrogen, the nucleus of each type of atom also contains at least one neutron. Unlike protons, the number of neutrons may vary among atoms of the same element. The number of neutrons and protons determines the atomic weight. Atoms of the same element with a different number of neutrons are called isotopes. In other words, isotopes have the same chemical properties but different atomic weights. Fig. A.1 depicts isotopes of the element hydrogen. Another example is the element uranium, which has 92 protons; all isotopes of uranium, therefore, have 92 protons. However, each uranium isotope has a different number of neutrons. Uranium-238 (also denoted ^{238}U) has 92 protons and 146 neutrons; uranium-235 has 92 protons and 143 neutrons; uranium-240 has 92 protons and 148 neutrons.



	PROTONS	NEUTRONS
HYDROGEN	1	0
DEUTERIUM	1	1

Fig. A.1. Isotopes of the element hydrogen.

Some isotopes are stable, or nonradioactive; some are radioactive. Radioactive isotopes are called radioisotopes, or radionuclides. In an attempt to become stable, radionuclides "throw away," or emit, rays or particles. This emission of rays and particles is known as radioactive decay.

A.2 RADIATION

Radiation, or radiant energy, is energy in the form of waves or particles moving through space. Visible light, heat, radio waves, and alpha particles are examples of radiation. When people feel warmth from the sunlight, they are actually absorbing the radiant energy emitted by the sun.

Electromagnetic radiation is radiation in the form of electromagnetic waves; examples include gamma rays, ultraviolet light, and radio waves. Particulate radiation is radiation in the form of particles; examples include alpha and beta particles. Radiation also is characterized by the way in which it interacts with matter.

A.2.1 Ionizing Radiation

Normally, an atom has an equal number of protons and electrons; however, atoms can lose or gain electrons in a process known as ionization. Some form of radiation can ionize atoms by "knocking" electrons off atoms. Examples of ionizing radiation include alpha, beta, and gamma radiation. Ionizing radiation is capable of changing the chemical state of matter and subsequently causing biological damage and thus is potentially harmful to human health. Fig. A.2 shows the penetrating potential of different types of ionizing radiation.

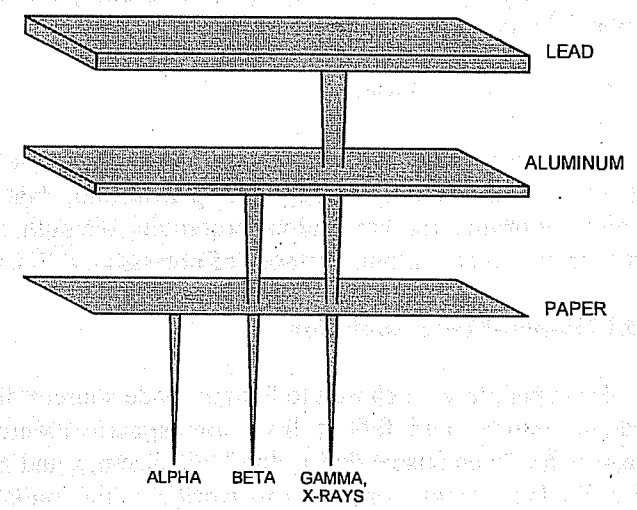


Fig. A.2. Penetrating power of radiation.

A.2.2 Nonionizing Radiation

Nonionizing radiation bounces off or passes through matter without displacing electrons. Examples include visible light and radio waves. Currently, it is unclear whether nonionizing radiation is harmful to human health. In the discussion that follows, the term radiation is used to describe ionizing radiation.

A.3 SOURCES OF RADIATION

Radiation is everywhere. Most occurs naturally, but a small percentage is human-made. Naturally occurring radiation is known as background radiation.

A.3.1 Background Radiation

Many materials are naturally radioactive. In fact, this naturally occurring radiation is the major source of radiation in the environment. Although people have little control over the amount of background radiation to which they are exposed, this exposure must be put into perspective. Background radiation remains relatively constant over time; background radiation present in the environment today is much the same as it was hundreds of years ago.

Sources of background radiation include uranium in the earth, radon in the air, and potassium in food. Background radiation is categorized as cosmic, terrestrial, or internal, depending on its origin.

A.3.1.1 Cosmic radiation

Energetically charged particles from outer space continuously hit the earth's atmosphere. These particles and the secondary particles and photons they create are called cosmic radiation. Because the atmosphere provides some shielding against cosmic radiation, the intensity of this radiation increases with altitude above sea level. For example, a person in Denver, Colorado, is exposed to more cosmic radiation than a person in Death Valley, California.

A.3.1.2 Terrestrial radiation

Terrestrial radiation refers to radiation emitted from radioactive materials in the earth's rocks, soils, and minerals. Radon (Rn); radon progeny, the relatively short-lived decay products of radium-235 (^{235}Ra); potassium (^{40}K); isotopes of thorium (Th); and isotopes of uranium (U) are the elements responsible for most terrestrial radiation.

A.3.1.3 Internal radiation

Radioactive material in the environment enters the body through the air people breathe and the food they eat; it also can enter through an open wound. Natural radionuclides in the body include isotopes of uranium, thorium, radium, radon, polonium, bismuth, and lead in the ^{238}U and ^{232}Th decay series. In addition, the body contains isotopes of potassium (^{40}K), rubidium (^{87}Rb), and carbon (^{14}C).

A.3.2 Human-Made Radiation

Most people are exposed to human-made sources of radiation. Examples include consumer products, medical sources, and fallout from atmospheric atomic bomb tests. (Atmospheric testing of atomic weapons has been suspended in the United States and most parts of the world.) Also, about one-half of 1% of the U.S. population performs work in which radiation in some form is present.

A.3.2.1 Consumer products

Some consumer products are sources of radiation. In some of these products, such as smoke detectors and airport X-ray baggage inspection systems, radiation is essential to the performance of the device. In other products, such as television and tobacco products, the radiation occurs incidentally to the product function.

A.3.2.2 Medical sources

Radiation is an important tool of diagnostic medicine and treatment, and, in this use, is the main source of exposure to human-made radiation. Exposure is deliberate and directly beneficial to the patients exposed. Generally, medical exposures from diagnostic or therapeutic X-rays result from beams directed to specific areas of the body. Thus, all body organs generally are not irradiated uniformly. Radiation and radio-active materials are also used in a wide variety of pharmaceuticals and in the preparation of medical instruments, including the sterilization of heat-sensitive products such as plastic heart valves. Nuclear medicine examinations and treatment involve the internal administration of radioactive compounds, or radiopharmaceuticals, by injection, inhalation, consumption, or insertion. Even then, radionuclides are not distributed uniformly throughout the body.

A.3.2.3 Other sources

Other sources of radiation include fallout from atmospheric atomic bomb tests; emissions of radioactive materials from nuclear facilities such as uranium mines, fuel processing plants, and nuclear power plants; emissions from mineral extraction facilities; and the transportation of radioactive materials.

Transuranic materials are man-made radiological elements. They are created as a reaction in a reactor where uranium fuel is used. These elements are a group of isotopes that are all alpha emitting. They emit alpha particles similar to uranium alpha particles and are monitored by Health Physics at PORTS in the same manner as uranium. Some of the transuranic isotopes that are detectable at PORTS are americium-241, plutonium-238, and plutonium-239/240.

A.4 PATHWAYS OF RADIATION

Radiation and radioactive materials in the environment can reach people through many routes. Potential routes for radiation are referred to as pathways. For example, radioactive material in the air could fall on a pasture. The grass could then be eaten by cows, and the radioactive material on the grass would be present in the cow's milk. People drinking the milk would thus be exposed to this radiation. Or people could simply inhale the radioactive material in the air. The same events could occur with radioactive material in water. Fish living in the water would be exposed; people eating the fish would then be exposed to the radiation in the fish. Or people swimming in the water would be exposed (see Fig. A.3.).

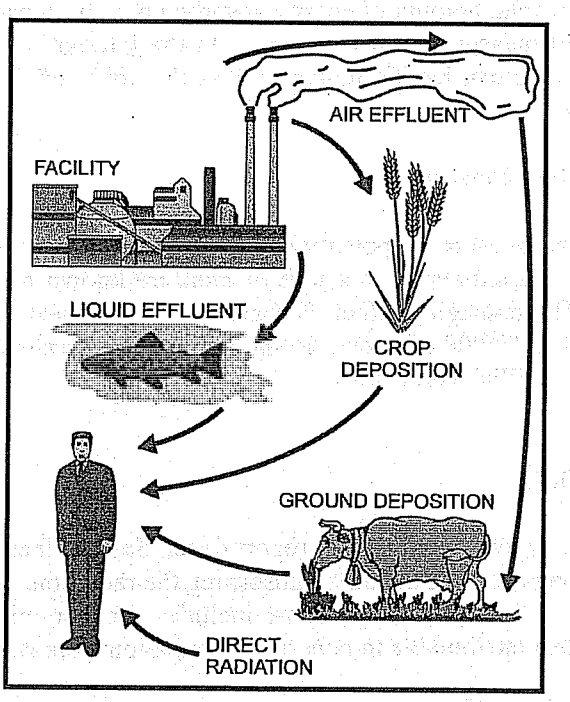


Fig. A.3. Possible radiation pathways.

A.5 MEASURING RADIATION

To determine the possible effects of radiation on the environment and the health of people, the radiation must be measured. More precisely, its potential to cause damage must be determined.

A.5.1 Activity

When measuring the amount of radiation in the environment, what is actually being measured is the rate of radioactive decay, or activity. The rate of decay varies widely among the various radioisotopes. For that reason, 1 gram of a radioactive substance may contain the same amount of activity as several tons of another material. This activity is expressed in a unit of measure known as a curie (Ci). More specifically, 1 Ci = 3.75E+10 (37,000,000,000) atom disintegrations per second (dps). In the international system of units, 1 dps = 1 becquerel (Bq). Table A.1 provides units of radiation measure and applicable conversions.

Table A.1. Units of radiation measures

Current System	International System	Conversion
curie (Ci)	Becquerel (Bq)	1 Ci = 3.7×10^{10} Bq
rad (radiation absorbed dose)	Gray (Gy)	1 rad = 0.01 Gy
rem (roentgen equivalent man)	Sievert (Sv)	1 rem = 0.01 Sv

A.5.2 Absorbed Dose

The total amount of energy absorbed per unit mass as a result of exposure to radiation is expressed in a unit of measure known as a rad. In the international system of units, 100 rad equals 1 gray (Gy). In terms of human health, however, it is the effect of the absorbed energy that is important, not the actual amount.

A.5.3 Dose Equivalent

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. Because a rem represents a fairly large dose, dose is expressed as a millirem (mrem) or 1/1000 of a rem. In the international system of units, 100 rem equals 1 sievert (Sv); 100 mrem equals 1 millisievert (mSv).

A.6 DOSE

Many terms are used to report dose. Several factors are taken into account, including the amount of radiation absorbed, the organ absorbing the radiation, and the effect of the radiation over a 50-year period. The term "dose" in this report includes the committed effective dose equivalent and effective dose equivalent attributable to penetrating radiation from sources external to the body.

Determining dose is an involved process using complex mathematical equations based on several factors, including the type of radiation, the rate of exposure, weather conditions, and typical diet. Basically, radiant energy is generated from radioactive decay, or activity. People absorb some of the energy to which they are exposed. This absorbed energy is calculated as part of an individual's dose. Whether radiation is natural or human-made, its effects on people are the same.

A.6.1 Comparison of Dose Levels

A scale of dose levels is presented in Table A.2. Included is an example of the type of exposure that may cause such a dose or the special significance of such a dose. This information is intended to familiarize the reader with the type of doses individuals may receive.

A.6.1.1 Dose from cosmic radiation

The average annual dose received by residents of the United States from cosmic radiation is about 27 mrem (0.27 mSv) (National Council on Radiation Protection 1987). The average annual dose from cosmic radiation received by residents in the Portsmouth area is about 50 mrem (0.50 mSv).

Table A.2. Comparison and description of various dose levels

Dose level	Description
1 mrem (0.01 mSv)	Approximate daily dose from natural background radiation, including radon
2.5 mrem (0.025 mSv)	Cosmic dose to a person on a one-way airplane flight from New York to Los Angeles
10 mrem (0.10 mSv)	Annual exposure limit, set up by the U.S. EPA, for exposures from airborne emissions from operations of nuclear fuel cycle facilities, including power plants and uranium mines and mills
46 mrem (0.46 mSv)	Estimate of the largest dose any off-site person could have received from the March 28, 1979, Three Mile Island nuclear power plant accident
50 mrem (0.50 mSv)	Average yearly dose from cosmic radiation received by people in the Portsmouth area
66 mrem (0.66 mSv)	Average yearly dose to people in the United States from human-made sources
100 mrem (1.00 mSv)	Annual limit of dose from all DOE facilities to a member of the public who is not a radiation worker
110 mrem (1.10 mSv)	Average occupational dose received by U.S. commercial radiation workers in 1980
244 mrem (2.44 mSv)	Average dose from an upper gastrointestinal diagnostic X-ray series
300 mrem (3.00 mSv)	Average yearly dose to people in the United States from all sources of natural background radiation
1-5 rem (0.01-0.05 Sv)	U.S. EPA protective action guideline calling for public officials to take emergency action when the dose to a member of the public from a nuclear accident will likely reach this range
5 rem (0.05 Sv)	Annual limit for occupational exposure of radiation workers set by the Nuclear Regulatory Commission and DOE
10 rem (0.10 Sv)	The Biological Effects of Ionizing Radiations V report estimated that an acute dose at this level would result in a lifetime excess risk of death from cancer of 0.8% (Biological Effects of Ionizing Radiation 1990)
25 rem (0.25 Sv)	U.S. EPA guideline for voluntary maximum dose to emergency workers for non-lifesaving work during an emergency
75 rem (0.75 Sv)	U.S. EPA guideline for maximum dose to emergency workers volunteering for lifesaving work
50-600 rem (0.50-6.00 Sv)	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 would die within 60 days

Adapted from Savannah River Site Environmental Report for 1993, Summary Pamphlet, WSRC-TR-94-076, Westinghouse Savannah River Company, 1994.

A.6.1.2 Dose from terrestrial radiation

The average annual dose received from terrestrial gamma radiation is about 28 mrem (0.28 mSv) in the United States. This dose varies geographically across the country (National Council on Radiation Protection 1987); typical reported values are 16 mrem (0.16 mSv) at the Atlantic and Gulf coastal plains and 63 mrem (0.63 mSv) at the eastern slopes of the Rocky Mountains.

A.6.1.3 Dose from internal radiation

Short-lived decay products of radon are the major contributors to the annual dose equivalent for internal radionuclides (mostly ^{222}Rn). They contribute an average dose of about 200 mrem (2.00 mSv) per year. This dose estimate is based on an average radon concentration of about 1 pCi/L (0.037 Bq/L) (National Council on Radiation Protection 1987).

The average dose from other internal radionuclides is about 39 mrem (0.39 mSv) per year, most of which can be attributed to the naturally occurring isotope of potassium, ^{40}K. The concentration of radioactive potassium in human tissues is similar in all parts of the world (National Council on Radiation Protection 1987).

A.6.1.4 Dose from consumer products

The U.S. average annual dose received by an individual from consumer products is about 10 mrem (0.10 mSv) (National Council on Radiation Protection 1987).

A.6.1.5 Dose from medical sources

Nuclear medicine examinations, which involve the internal administration of radiopharmaceuticals, generally account for the largest portion of the dose received from human-made sources. The radionuclides used in specific tests, however, are not distributed uniformly throughout the body. In these cases, comparisons are made using the concept of effective dose equivalent, which relates exposure of organs or body parts to one effective whole-body dose. The average annual effective dose equivalent from medical examinations is 53 mrem (0.53 mSv), including 39 mrem (0.39 mSv) for diagnostic X-rays and 14 mrem (0.14 mSv) for nuclear medicine procedures (National Council on Radiation Protection 1989). The actual doses received by individuals who complete such medical exams are much higher than these values, but not everyone receives such exams each year (National Council on Radiation Protection 1989).

A.6.1.6 Doses from other sources

Small doses received by individuals occur as a result of radioactive fallout from atmospheric atomic bomb tests, emissions of radioactive materials from nuclear facilities, emissions from certain mineral extraction facilities, and transportation of radioactive materials. The combination of these sources contributes less than 1 mrem (0.01 mSv) per year to the average dose to an individual (National Council on Radiation Protection 1987).

A comprehensive U.S. EPA report of 1984 projected the average occupational dose to monitored radiation workers in medicine, industry, the nuclear fuel cycle, government, and miscellaneous industries to be 105 mrem (1.05 mSv) per year for 1985, down slightly from 110 mrem (1.10 mSv) per year in 1980 (Kumazawa et al. 1984).

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APPENDIX B

ENVIRONMENTAL PERMITS

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Table B.1. DOE/PORTS environmental permits and registrations

Permit/registered source	Source no.	Issue date	Expiration date	Status
	Clean Air Act Permits			
Permit to Install X-734 Landfill Unpaved Road and Storage Piles	F010	10/6/99	Cancelled in August 2000; project completed.	Cancelled
Permit to Operate X-326 L-cage Glove Box	P022	5/5/95	PTO renewal submitted 4/27/98	Active
Permit to Operate X-624 Groundwater Treatment Facility	P019		PTO renewal submitted 11/4/98; PTO under appeal	Active
Permit to Operate X-735 Landfill Cap and Venting System (northern portion)	P023	5/26/95	PTO renewal submitted 4/27/98	Active
Permit to Operate X-744G Glove Box	P007		PTO renewal submitted 11/4/98; PTO under appeal	Active
Registered Source X-345 Emergency Generator	B005		None	Active
Registered Source X-345 Security Fuel Oil Tank	T005		None	Active
Registered Source X-623 Groundwater Treatment Facility	P018		None	Active
Registered Source X-7725 Fluorescent Bulb Crusher	P028		None	Active
Registered Source X-744G Oil-fired Furnace	B006		None	Active
Registered Source X-749 Contaminated Materials Disposal Facility	P027		None	Active
Registered source X-744G Fuel Oil Tank (south)	T008		None	Source no longer operating
Registered Source X-744G Alumina Melter	P020		None	Source no longer operating
Registered Source X-735 Landfill Storage Piles	F006		None	Source no longer operating
	Clean Water Act Permits			
NPDES Permit DOE	0IO00000*GD	8/5/95	3/31/99[a]	Active
Permit to Install X-622 Groundwater Treatment Facility	06-2951	11/20/90	None	Active
Permit to Install X-622T Groundwater Treatment Facility	06-3520	11/24/92	None	Active
Permit to Install X-623 Groundwater Treatment Facility	06-3528	1/9/96	None	Active
Permit to Install X-624 Groundwater Treatment Facility	06-3556	10/28/92	None	Active
U.S. Army Corps of Engineers-Section 404, Nationwide Permit No.6, Radiological Survey		4/30/97		

Table B.1. DOE/PORTS environmental permits and registrations (continued)

Permit/registered source	Source no.	Issue date	Expiration date	Status
	Hazardous Waste Permit			
RCRA Part B Permit	Ohio Permit No. 04-66-0680	3/15/01	3/15/06	Active
	Registrations			
Underground Storage Tank Registration	6651067		Renewed annually	Active

[a]Permit will remain active until renewal application is acted upon by Ohio EPA. The NPDES Permit Renewal Application was submitted to the Ohio EPA on September 23, 1998.

APPENDIX C

RADIONUCLIDE AND CHEMICAL NOMENCLATURE

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Table C.1. Nomenclature and half-life for radionuclides

Radionuclide	Symbol	Half-life
Actinium-228	^{228}Ac	6.2 hours
Americium-241	^{241}Am	458 years
Beryllium-7	^{7}Be	53.3 days
Bismuth-210	^{210}Bi	5.01 days
Bismuth-214	^{214}Bi	19.7 minutes
Lead-206	^{206}Pb	Stable
Lead-210	^{210}Pb	22.3 years
Lead-212	^{212}Pb	10.6 hours
Lead-214	^{214}Pb	26.8 minutes
Neptunium-237	^{237}Np	2,140,000 years
Plutonium-238	^{238}Pu	86.4 years
Plutonium-239	^{239}Pu	24,390 years
Plutonium-240	^{240}Pu	6,580 years
Plutonium-241	^{241}Pu	13.2 years
Plutonium-242	^{242}Pu	379,000 years
Plutonium-244	^{244}Pu	76,000,000 years
Polonium-210	^{210}Po	138.9 days
Polonium-214	^{214}Po	164 microseconds
Polonium-218	^{218}Po	3.05 minutes
Potassium-40	^{40}K	1,260,000,000 years
Protactinium-233	^{233}Pa	27.0 days
Protactinium-234	^{234}Pa	6.7 hours
Protactinium-234m	^{234m}Pa	1.17 minutes
Radium-224	^{224}Ra	3.7 days
Radium-226	^{226}Ra	1,602 years
Radium-228	^{228}Ra	5.8 years
Radon-222	^{222}Rn	3.821 days
Technetium-99	^{99}Tc	212,000 years
Thallium-208	^{208}Tl	3.1 minutes
Thorium-228	^{228}Th	1.9 years
Thorium-230	^{230}Th	75,400 years
Thorium-231	^{231}Th	25.5 hours
Thorium-232	^{232}Th	14,000,000,000 years
Thorium-234	^{234}Th	24.1 days
Uranium-234	^{234}U	247,000 years
Uranium-235	^{235}U	710,000,000 years
Uranium-236	^{236}U	23,900,000 years
Uranium-238	^{238}U	4,510,000,000 years

Table C.2. Nomenclature for elements and chemical constituents

Constituent	Symbol
Aluminum	Al
Ammonia	NH_3
Antimony	Sb
Arsenic	As
Barium	Ba
Beryllium	Be
Cadmium	Cd
Calcium	Ca
Calcium carbonate	$CaCO_3$
Carbon	C
Chlorine	Cl
Chromium	Cr
Cobalt	Co
Copper	Cu
Fluorine	F
Hydrogen fluoride	HF
Iron	Fe
Lead	Pb
Lithium	Li
Magnesium	Mg
Manganese	Mn
Mercury	Hg
Nickel	Ni
Nitrogen	N
Nitrate	NO_3
Nitrite	NO_2
Oxygen	O
Ozone	O_3
Phosphorus	P
Phosphate	PO_4
Potassium	K
Radium	Ra
Radon	Rn
Selenium	Se
Silver	Ag
Sodium	Na
Sulfate	SO_4
Sulfur dioxide	SO_2
Thorium	Th
Thallium	Tl
Uranium	U
Vanadium	V
Zinc	Zn

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